Southampton NHS
University Hospitals NHS Trust

Wessex Neurological Centre

Neuro-anatomy & Physiology Workbook

Sarah Irwin, Senior Sister NICU, SUHT &

Rachel Palmer, Lecturer Practitioner Neurosciences (SUHT & School of Health Professionals, University of Southampton

2008

Index:

INTRODUCTION

This Neuroanatomy and physiology workbook is designed to guide and develop your understanding in relation to the neuroscience patient and hence expand your underpinning knowledge base, which is essential to manage the variety of neurological conditions that you will see. This workbook is intended for use by both pre and post-qualified staff. The workbook will lead you through the variety of neurology subsystems. At various points through the book there are questions to answer and diagrams to label. Marieb (2007) is the core anatomy and physiology text used, which corresponds to local undergraduate pre-registration and learning beyond registration curriculum's at the University of Southampton. A recommended reading list is provided.

1. Cells Of The Nervous System

There are two main types of cells in the nervous system: **Neuroglia** and **Neurons.**

1.1 Neuroglia cells

The function of neuroglia cells is to ensure structural support, nourishment and neuron protection. There are six types of Neuroglia cells: -

- Oligodendrocytes
- Astrocytes
- Ependyma
- Microglia
- Schwann

What is the role of each of these neuroglia cells? (write in the space above)

They are a major source of tumours due to their ability to divide by mitosis.

1.2 Neurons

Neurons (see Fig 1.1) are the fundamental functional units of the nervous system. They have several roles: -

- React to chemical and sensory stimuli
- Conduct the impulses
- Emit specific chemical regulators.

The Neuron is composed of: -

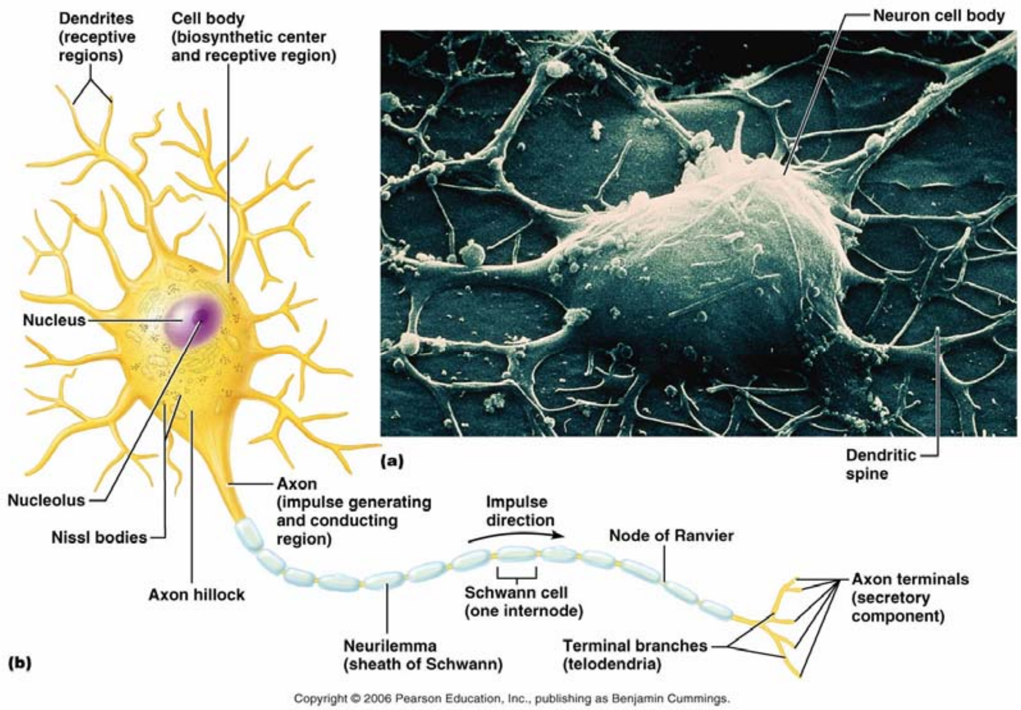
The cell body: It is composed of the nucleus (containing DNA and RNA) and the cell membrane (which controls the movement of molecules between the cell and the surrounding environment). It also contains cytoplasm, endoplasmic reticulum, nissl bodies, Golgi apparatus, mitochondria, lysosomes and neurotubules.

The cell processes are composed of the dendrites and cell axon. The dendrites carry impulses from another neuron to the cell body and impulses then travel down the axon.

Axons can either be myelinated (an insulating sheath that aids impulse conduction) or unmyelinated. Schwann cells form the myelin sheath.

What other structures are located on the axon?

Figure 1.1 : A Myelinated Neuron (from Marieb 2007 pp 392)



The junctions between one neuron and the next where impulses are transmitted consist of a pre-synaptic terminal, synaptic cleft and the postsynaptic membrane

1.3 Nerve Impulse Generation

The neuron undergoes a variety of changes in order to transmit an impulse. The **resting potential** of the neuron is a state where no impulse is being initiated. The membrane has different levels of potassium and sodium on either side which results in a charge difference of -70mV. The membrane is semi permeable. The interstitial space (outside the cell) has higher levels of sodium and chloride. Within the cell greater levels of potassium occur. Both these voltage gates are shut in the resting state. A pump mechanism moves the ions from high to low concentrations.

The **Action potential** of the neuron allows the transmission of an impulse. A stimulus changes the cell permeability to ions and this results in a change in the membrane potential. An impulse is conducted and an action potential is generated. There are three phases:

Describe what occurs during these three phases.

- Depolarizing Phase:

- Repolarizing Phase:

- Hyperpolarization Phase

The action potential is then propagated along the axon.

1.4 Synapses

Synapses (see Fig 1.2) are junctions that allow information to be transferred from one neuron to another (Marieb 2007). There are electrical and chemical synapses, which the latter is the most common. A presynaptic neuron sends impulses towards a synapse and the post synaptic (effector) neuron carries the impulse away from it.

The important structures, which allow impulses to be transmitted, are the presynaptic terminals, the synaptic cleft and the post synaptic membrane.

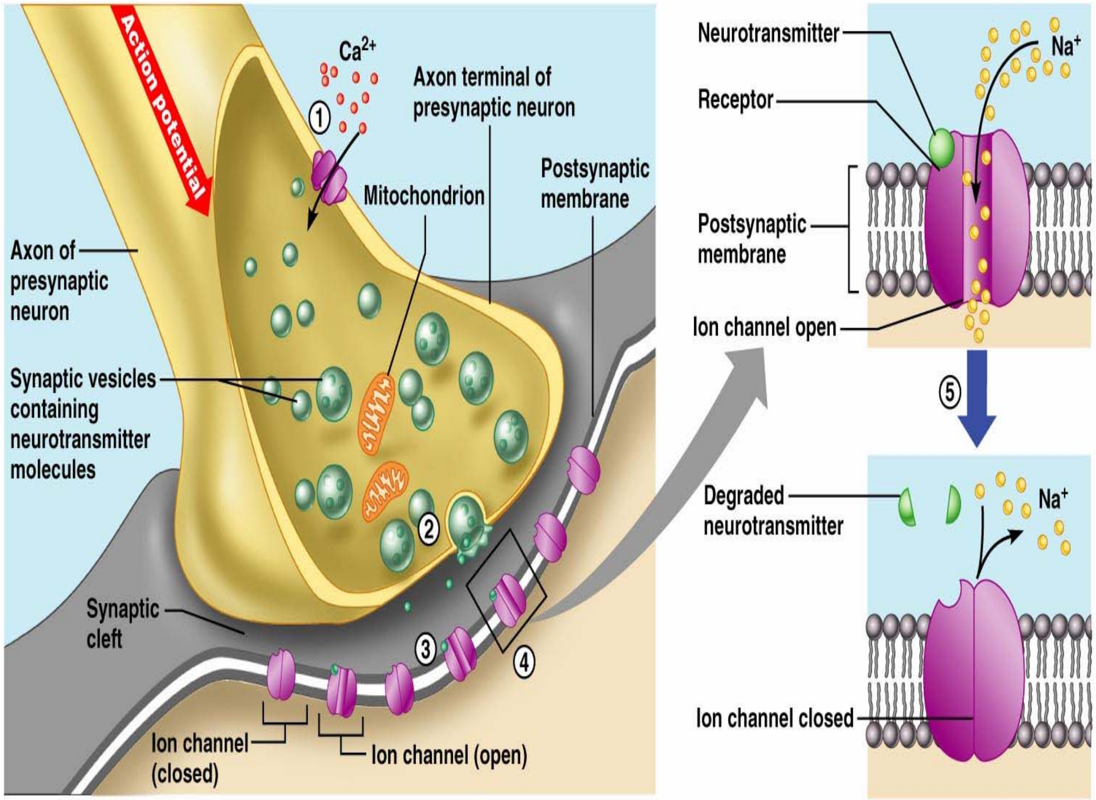
Presynaptic terminals can be described as excitatory or inhibitory. An excitatory presynaptic terminal ‘secretes an excitatory substance into the synaptic cleft, which excites the effector neuron’ (Hickey 1997 pg 38), where as an inhibitory presynaptic terminal ‘secretes an inhibitory substance into the synaptic cleft it will inhibit the effector neuron’. (Hickey 1997 pg 39). These substances are called **neurotransmitters,** which are held in synaptic vesicles in the presynaptic axon terminal.

Name the four main neurotransmitters.

The synaptic cleft is a fluid filled space between the presynaptic terminal and the postsynaptic membrane of the effector neuron.

The impulses are received at the axon terminal where the membrane depolarises and triggers a neurotransmitter release. The neurotransmitter crosses the synaptic cleft and binds with the receptors on the postsynaptic membrane. The chemical neurotransmitter signals are then reverted back to impulses, which are then transmitted away from the synapse down the neuron.

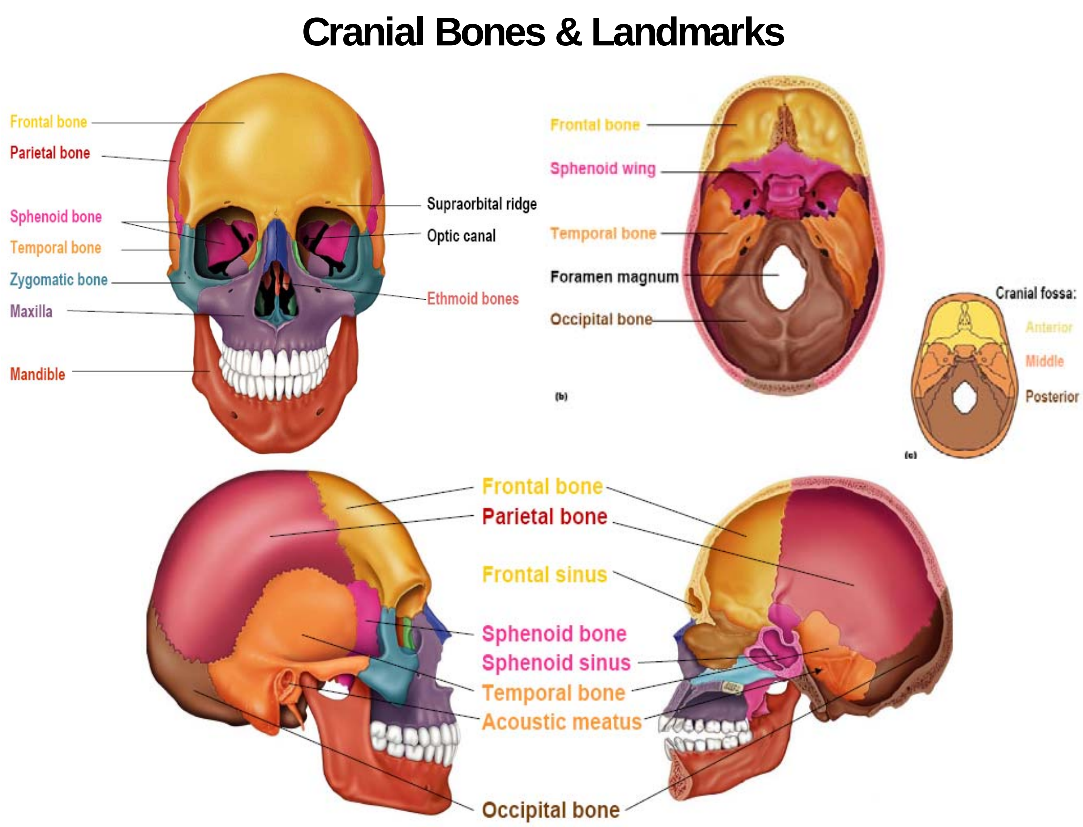
Figure 1.2: A Synapse (From Marieb 2007 pp 410)



2. Cranial Bones

The skull's role is to protect the brain. The skull is made up of 8 cranial bones and 14 facial bones. The cranium is formed of the following bones: - Frontal, occipital, sphenoid, ethmoid, temporal, squamous, mastoid, petrous and parietal. The skull bones are united by four major **sutures**: Sagittal, coronal, lamboidal and basilar.

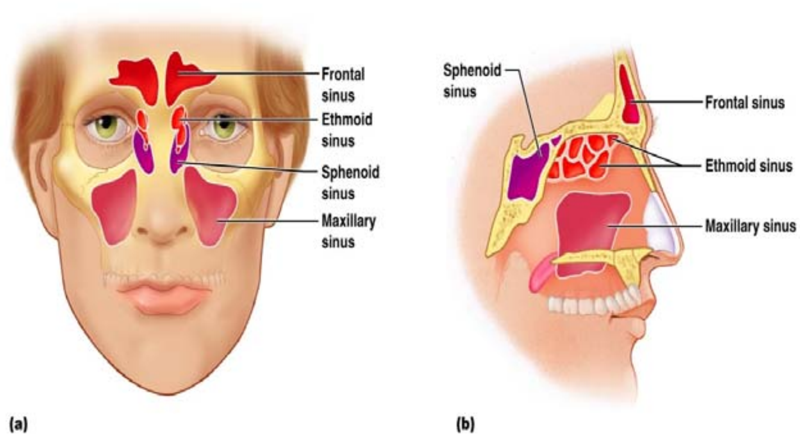
Figure 2.1 The Cranial Bones (From Marieb 2007 pp 205-206)



Adapted from Marieb (2007) (CD rom – 2006 Pearson Education, Inc, published as Benjamin Cummings)

The skull also contains **Paranasal sinuses** (see Figure 2.2). There role is to lighten the skull.

Figure 2.2 The Sinuses (From Marieb 2007 pp 218)



3. The Meninges

The Meninges (see Figure 3.1) are 3 fine membranes covering the brain and spinal cord. They are called the **Dura, Arachnoid** and the **Pia Mater**.

3.1 The Dura

The dura has two layers; the outer layer fuses with the periosteum, the inner layer forms compartments throughout the skull. It is fibrous and inelastic in nature. The inner layer of the cerebral dura continues to form the spinal dura. It has a protective function (Martin 2003).

What space lies between the skull and outermost layer of the dura?

3.2 The Arachnoid

The arachnoid is the middle layer. It is a thin and fragile layer, which surrounds the brain.

Between the dura and arachnoid lies what space?

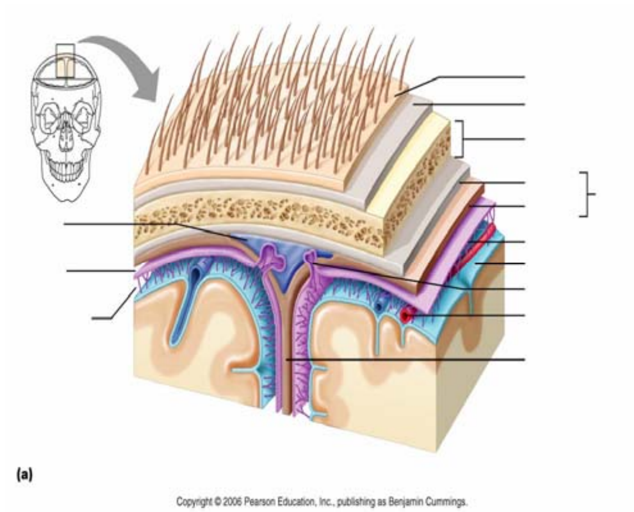
The **subarachnoid space** is an area where there is no actual defined space due to the presence of soft connective tissue sitting between the arachnoid and Pia. A network of blood vessels occurs within this. There is a flow of cerebro spinal fluid within the subarachnoid space

3.3 The Pia Mater

The Pia is the final and innermost layer is the final layer. It is a 'mesh like, vascular membrane which derives its blood supply from the internal carotid and vertebral arteries (Hickey 1997 pg 45). It follows the convolutions of the cerebral surface.

Label the diagram below

Figure 3.1 The Meninges (From Marieb 2007 pp 464)



4. The Ventricular System

The ventricular system is a 'closed system' (Hickey 1997 pg 47) that is composed of the **Ventricles** and contains **Cerebro Spinal Fluid (CSF)**.

There are two **Lateral** ventricles which connect to a **Third** ventricle. This in turns connects to the **Fourth** ventricle, which is bordered by the pons and cerebellar peduncles.

Within the ventricles flows CSF. It is a clear, colourless fluid filling the ventricles and subarachnoid space.

What is the role of CSF?

It is composed of water, protein, oxygen, carbon dioxide, sodium, potassium, chloride and glucose. It has a specific gravity of 1.007.

What is the volume of circulating CSF in mls?

CSF is formed by active transport and diffusion. It is produced by three sources. The first is by the **Choroid Plexus** lining the ventricles (FitzGerald & Folan-Curran 2002). The second source is the **ependymal** cells, which occur in the ventricles and meningeal blood vessels; and the final source are the blood vessels of the brain and spinal cord (Hickey 1997).

How much CSF is produced a day in mls.

CSF absorption occurs by the **arachnoid villi**, which are small projections into the venous sinuses of the brain from the subarachnoid space. They are unidirectional valves (Martin 2003). When CSF pressure exceeds the venous pressure CSF flows through the villi and drains into the Superior Sagittal sinus until the pressure is equalized.

Fill in the missing words.

The CSF flow is a closed system. CSF is formed in the lateral ventricles flows into the third ventricle via the ______________________ The 3rd and 4th ventricles are connected by the ____________________________ After which it flows through the _____________________ and the ____________________________ to the cisternal space into the subarachnoid space. The Foramen of Magendie directs the CSF flow around the ___________________ and the Foramen of Luschka directs CSF around the brain.

Label the diagram below:

Figure 4.1 The Ventricular system (From Marieb 2007 pp 434)

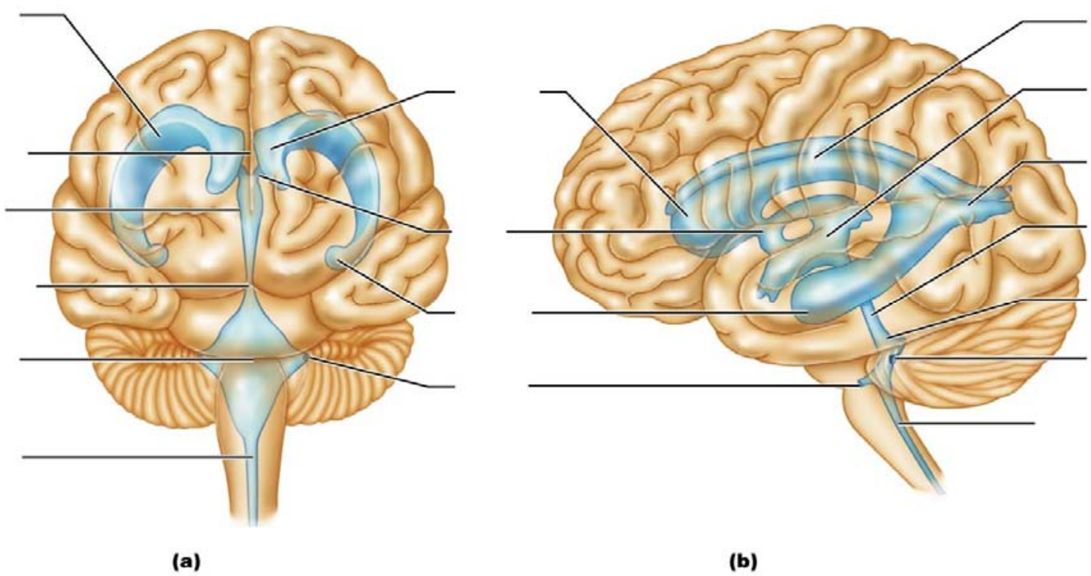
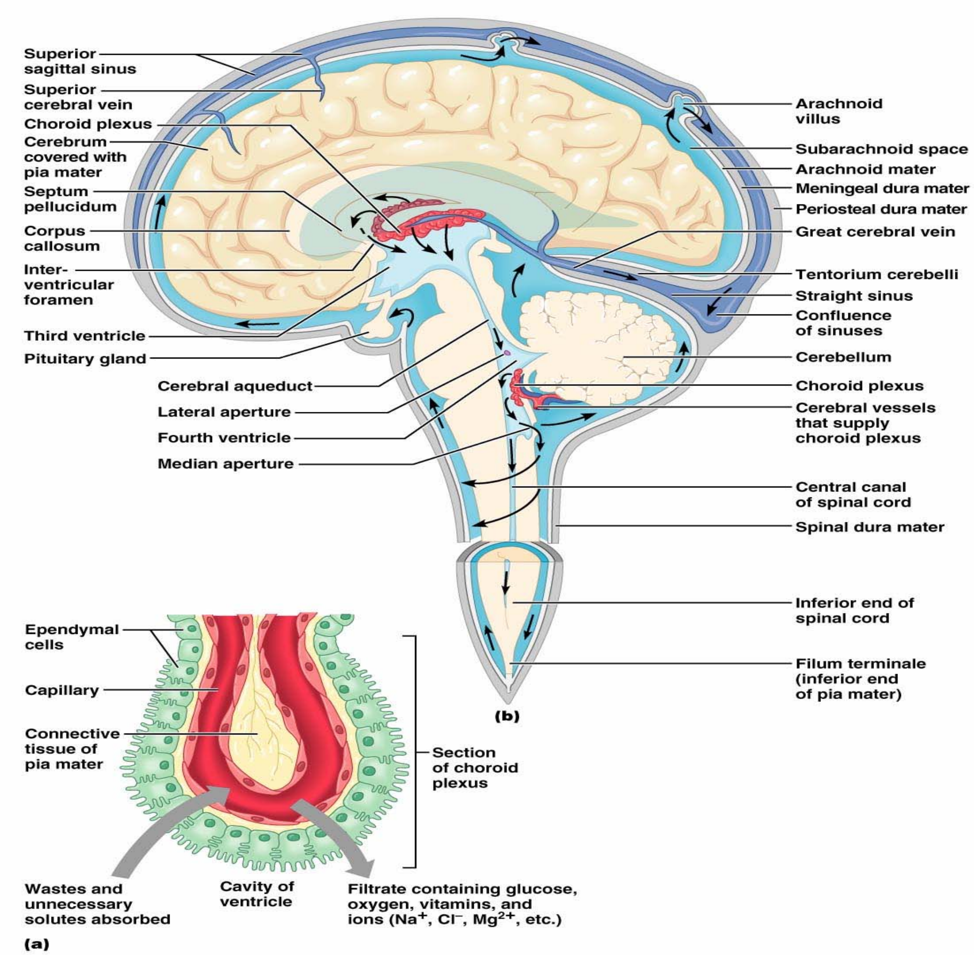


Figure 4.2 The CSF Circulation (From Marieb 2007 pp 466)



5. The Cerebral Circulation

Brain metabolism requires glucose, which cannot be stored in the brain. If the brain receives no oxygen for more than three minutes ischaemia and infarction can follow.

How many mls of blood does the brain receive per minute?

5.1 The Cerebral Arterial Circulation.

The cerebral arterial circulation is called the Circle of Willis.

Fill in the missing words.

Two Vertebral and two Internal carotid arteries supply the brain.

The **Vertebral arteries** which supply the 'cerebellum, brain stem, occipital lobes, inferior surface of the temporal lobes, diencephalons and spinal cord' (Hickey 1997 pg 49) stem from the subclavian arteries and join at the level of the pons to form the _____________ artery.

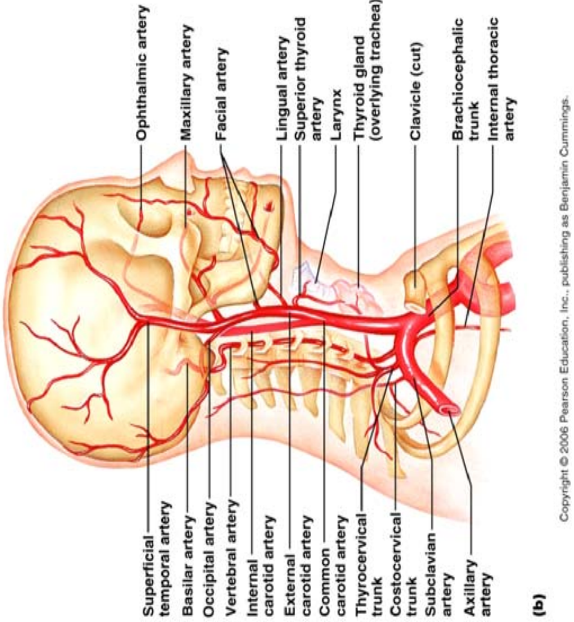
The ______________________________ arteries stem from the vertebral arteries. The basilar then divides to form the _______________________ arteries (supplying the cerebellum). The _________________________ arteries connect the posterior circulation to the anterior circulation.

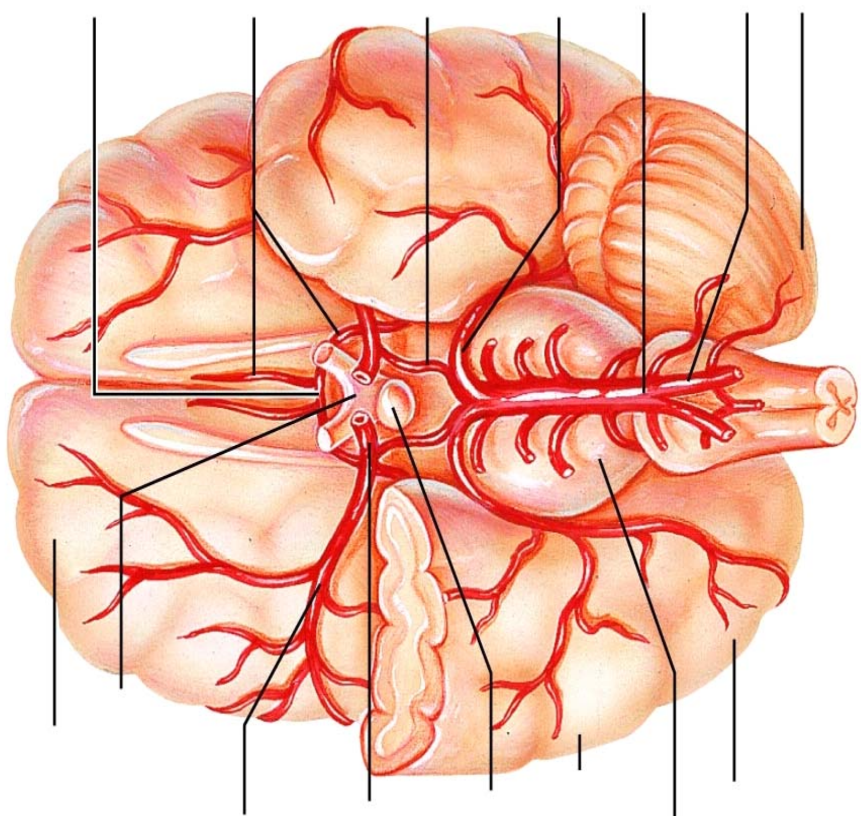
The ____________________ arteries supply the anterior circulation. The Middle Cerebral arteries feed off laterally and the circulation continues with **Anterior Cerebral** arteries, which are connected together by the ______________________________.

The Internal Carotid arteries supply the majority of the hemispheres (apart from the occipital lobes), the basal ganglia and part of the diencephalon.

Label the diagram of Circle of Willis on the next page

Figure 5.1 The Circle of Willis (From Marieb 2007 pp 749)





Each artery serves specific parts of the brain. The table below shows which artery serves which cerebral area.

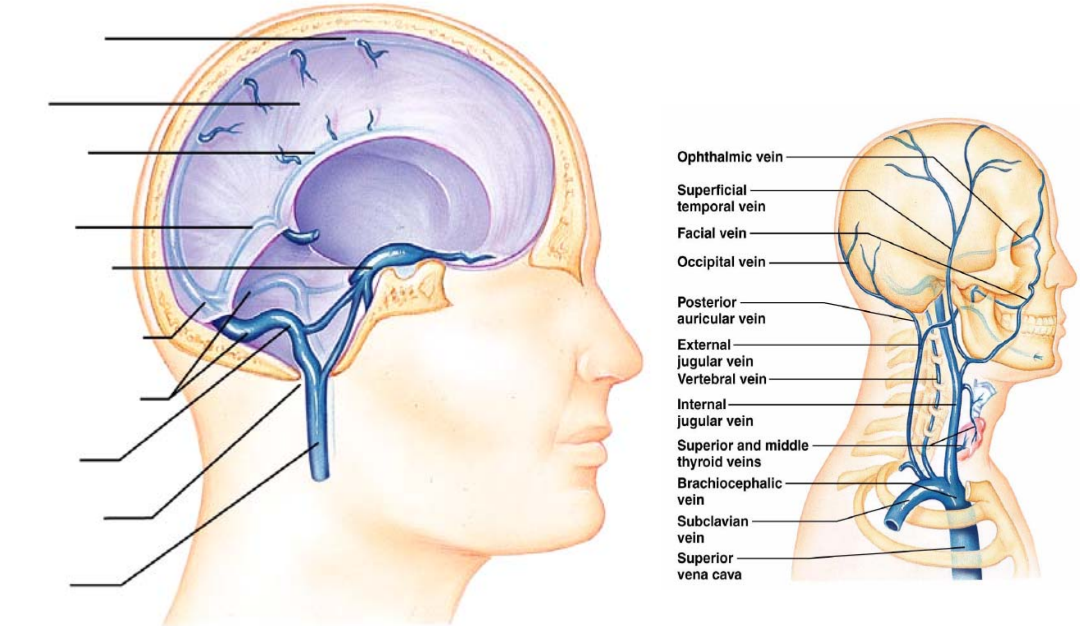
Table of Cerebral Territories:	
Artery	**Territory Served**
Anterior circulation:	
Internal Carotid	Arises from the external carotids to supply the anterior circulation
Opthalmic	Optic nerves and orbits
Anterior Cerebral (ACA)	Frontal and Parietal lobes – branches supply the leg area of the motor cortex.
Anterior Communicating (ACoA)	Joins the ACAs together and supplies the basal ganglia and internal capsule.
Middle Cerebral (MCA)	Lateral surface of hemispheres. Occlusion may lead to face and arm deficits and dysphasia.
Anterior choroidal	Supplies the choroids plexus and the hippocampus.
Posterior Communicating (PCoA)	Connects the MCAs & PCAs hence joining the anterior (carotid) and posterior (vertebrobasilar) circulations together.
Posterior circulation:	
Posterior Cerebral (PCA)	Occipital and temporal lobe, midbrain and choroid plexus (3rd ventricle). Signs of occlusion may present with visual deficits, amnesia or language problems.
Basilar (BA)	Arises from the vertebral arteries to supply the posterior circulation. Vessels from the basilar supply the cerebellum and pons.
Superior Cerebellar	Cerebellum and midbrain
Pontine	Pons
Anterior Inferior Cerebellar (AiCA)	Cerebellum and pons
Posterior Inferior Cerebral (PiCA)	Choroid Plexus (4th ventricle). Cerebellum medulla

5.2 The Cerebral Venous Circulation

Vascular channels control cerebral venous drainage. These are ‘created by two dural layers called **Dural Sinuses’** (Hickey 1997 pg 50). Extra cranial veins connect to the venous sinuses by **Emissary veins.** The brain and dural sinuses are connected by **Bridging veins**. The cerebral veins drain into the dural sinuses and then into the jugular veins.

Label the cranial venous sinuses

Figure 5.2 The Cranial venous sinuses (From Marieb 2007 pp 761)

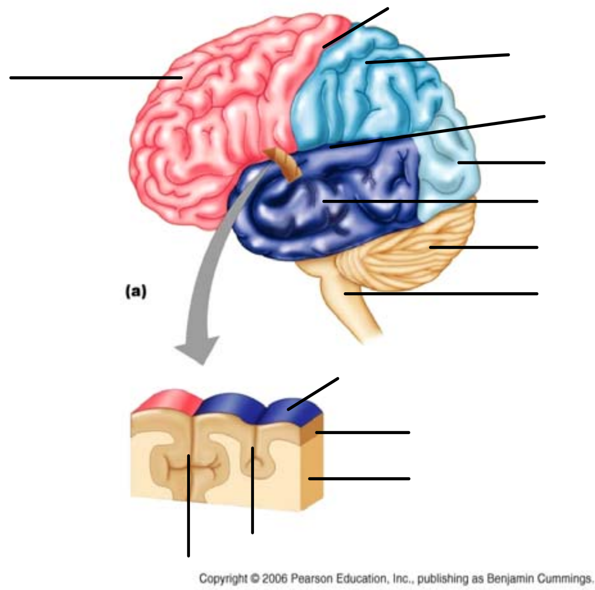


The **Blood Brain barrier** provides protection by ensuring the nervous system is isolated from the rest of the body. This ensures the environment is optimal for neuronal function. Movement of substances across the barrier is dependant on 'particle size, lipid solubility, chemical dissociation and protein binding potential of the drug' (Hickey 1997 pg 52). The barrier controls the movement of the organic and inorganic ions. It prevents peripheral neurotransmitters escaping and toxins entering the CNS.

6. The Cerebrum

The brain (**Encephalon)** is a highly complex organ, which weighs about 1400g and is divided into three major areas: **Cerebrum, Brain Stem** and **Cerebellum**.

Figure 6.1 The cerebrum, cerebellum and brainstem (adapted from Marieb 2007 pp 435)



6.1 The Hemispheres

The Cerebrum consists of two **Cerebral Hemispheres**. They are separated incompletely by the **Great Longitudinal Fissure.**

What is the other name for a fissure?

There are three other fissures. These are called: -

- **Lateral Fissure of Sylvius**: Separates the temporal lobe from the fronto-parietal lobes.
- **Central Fissure of Rolando**: Separates the frontal and parietal lobes.
- **Parietal-Occipital Fissure**: Separates the occipital lobe from the frontal and parietal lobe.

The surface gyri and white mater contains neuroglia and nerve fibres. There are three types of myelinated nerve fibres:

a) **Transverse**: These interconnect the two hemispheres.
b) **Projection:** These connect the cerebral cortex to the lower portion of the brain and spinal cord.
c) **Association:** These connect the various areas within the hemispheres.

(Hickey 1997 pg 53)

What is the structure that connects the hemispheres?

What are the divisions of the hemispheres called?

6.2 The Lobes.

The **frontal lobe** is situated at the front of the cerebrum. It has a variety of functions: -

- Controls autonomic functions (e.g. respiratory and blood pressure)
- Allows concentration
- Increases depth and abstract ability in thought and memory
- Aids word formation (Broca's area)
- Controls motor function in motor cortex

The **Parietal lobe** is situated on the top of the cerebrum. It has several functions: -

- Allows sensibility
- Sensation of touch, position, pressure and vibration
- Allows analysis of sensory information
- Defines shape, size, weight, texture, consistency
- Allows awareness of body orientation

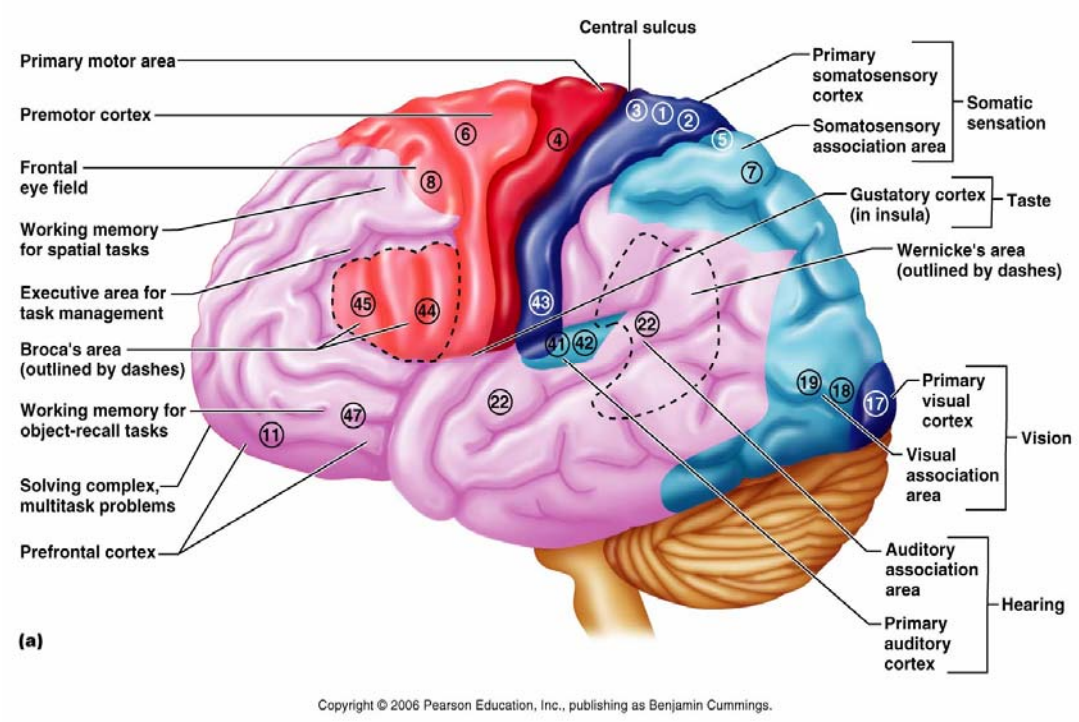
The **Temporal lobe** is situated to the side of the cerebrum. It has: -

- Auditory receptive area (Wernicke's)
- Interpretative area for the integration of auditory, visual and somatic information
- Allows memory and intellectual ability.

The **Occipital lobe** is situated posteriorly in the cerebrum.

What does it control?

Figure 6.2 The structures of the cerebral Cortex (From Marieb 2007 pp437)



6.3 The Basal Ganglia.

The basal ganglia are a group of nuclei deep within the hemispheres. It is composed of: -

- **Lenticular nucleus** (made up of the globus pallidus and putamen)
- **Caudate nucleus**
- **Amygdaloid**
- **Claustrum**

The **Corpus striatum** is the combined name for the Lenticular nucleus and the caudate nuclei. The role of the basal ganglia is to control fine body motor control.

What disease can be associated with this part of the body?

6.4 The Diencephalon

The diencephalon is made up of the **Thalamus, Hypothalamus, Subthalamus** and **Epithalamus.**

The **Thalamus** is the last point where nerve impulses are processed before they continue ascending up to the cortex (Hickey 1997). It has several roles: -

1) Conscious awareness
2) Focusing attention
3) The reticular activating system
4) The limbic system.

The **Epithalamus** is made up of the pineal gland. Its role is in the food getting reflex and in development and growth.

The **Hypothalamus** is located in the optic chiasm and it is connected to the pituitary gland by the pituitary stalk. It is part of the limbic system and has a role in ensuring the preservation of an individual (Fitzgerald et al 2003)

What does the hypothalamus control?

The **Subthalamus** is related to the basal ganglia in function (fine motor control).

6.5 The Internal Capsule.

The internal capsule is where a group of sensory and motor nerve fibres collect in the thalamus – hypothalamus region. It provides a connection for the brain and spinal cord. It has an essential role in controlling motor and sensory function.

6.6 The Pituitary Gland

The pituitary gland (or Hypophysis) is found in the base of the skull and connects to the hypothalamus by the hypophysial stalk (or infundibulum). The role of the gland is to secrete hormones. The pituitary gland has two lobes; anterior and posterior. The anterior lobe secretes: - growth stimulating hormone (GSH), adrenal stimulating hormone (ACTH), thyroid stimulating hormone (TSH), Prolactin, follicle stimulating hormone (FSH) and Luteinizing hormone (LH) (Hickey 1997).

What does the posterior lobe secrete?

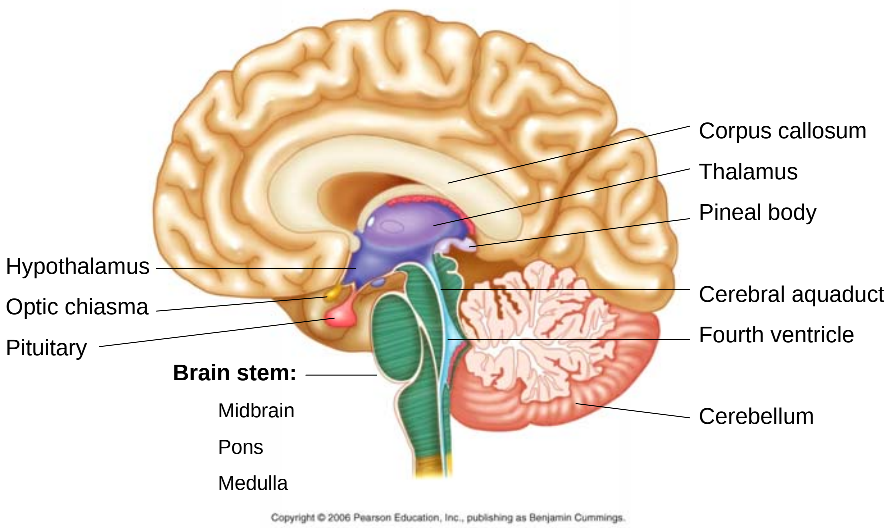
The hypothalamus controls the neuroendocrine system using the Hypothalamohypophysial tract (controls the posterior lobe secretions) and the Hypophysial Portal system (control the anterior lobe secretions).

7. The Cerebellum

The Cerebellum is situated in the posterior fossa and is connected to the brain stem by three paired cerebellar peduncles. It has ‘two hemispheres that are connected by the vermis’ (Fitzgerald et al 2003 pg 32)

What is the main function of the cerebellum?

Figure 7.1 The cerebrum and associated structures (from Marieb 2007 pp445)



The cerebellum is made up of three layers: -

a) The **Cortex:** This is composed of the **granular**, the **piriform** and the **molecular** layers.
b) The **White Matter**: This contains the afferent and efferent impulse connections.
c) The **Cerebellar nuclei** (the Dentate, the Fastigial, the Interposed and the Vestibular nuclei).

The cerebellum can also be divided anteriorly to posteriorly. The **Spinocerebellum** strip is controls posture and gait. The **Vestibulocerebellum** strip is controls responses to the Vestibular nucleus allowing coordination of space and movement. The **Pontocerebellum** strip coordinates voluntary muscle activity and tone (Fitzgerald et al 2003). The cerebellar peduncles are tracts that carry information from the cerebellum to the brainstem.

8. The Brainstem

The brainstem is composed of three main parts; the **Midbrain, Pons** and **Medulla.** The brain stem has ascending and descending tracts which carry information from the cerebral hemispheres to the spinal cord as vice versa. Ten of the twelve cranial nerves originate in the brainstem. The brain stem also contains a complex network of fibres called the **Reticular Formation**.

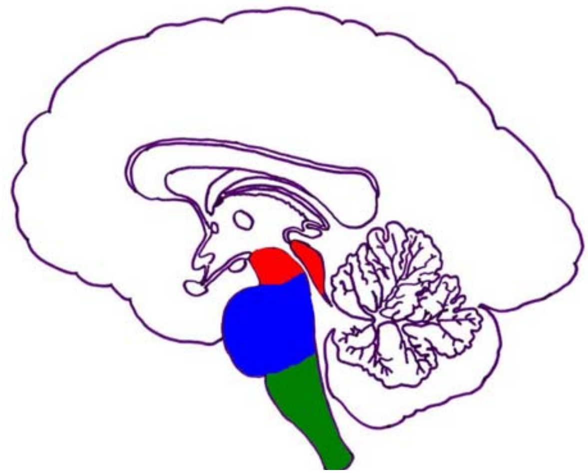


Figure 8.1 The brainstem (Palmer & Knight 2008)

8.1 The Midbrain

The midbrain sits between the diencephalon and the pons. It is made up of the tectum (roof), the tegmentum (posterior part) and the crus cerebri (peduncle).

Which two cranial nerves are located in the midbrain?

The midbrain acts as a passageway for the hemispheres and the lower brain and it is also the centre for the auditory and visual reflexes.

8.2 The Pons

The Pons is situated between the midbrain and the medulla. It is divided into the ventral (basal) and the dorsal (tegmentum). The pons acts as a connection between the midbrain and the medulla allowing fibres to travel through from one to the other. Within the tegmentum the spinothalamic tracts and parts of the reticular activating system (controls consciousness) can be located.

What are the major functions of the pons?

The V, VI, VII and VIII cranial nerve nuclei are located in the pons.

8.3 The Medulla

The Medulla oblongata is situated between the pons and the spinal cord. The corticospinal tracts (pyramidal) cross the medulla. The medulla controls a variety of functions including;

'transmission of information for head and eye movement co-ordination, motor and sensory tract pathways, cardiac, respiratory and vasomotor centres' (Hickey 1997 pg 59).

What cranial nerve nuclei are found in the medulla?

8.4 The Reticular Activating System.

The reticular formation (RF) is a group of complex and diffuse fibres that originates in the brain stem extending up into the cerebral cortex via the thalamus (see fig 8.2). The reticular activating system (RAS) is involved in the normal regulation of consciousness focusing on attention, the sleep-wake cycle and sensory perception (Marieb 2007; Hickey 2003).

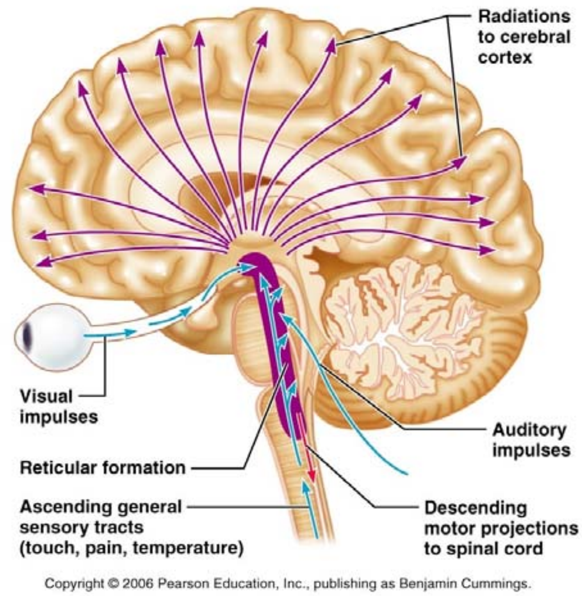


Figure 8.2 (Marieb 2007 pp 455)

8.5 The Limbic System

The Limbic system is a group of fibres and tracts that form around the brainstem. This limbic system is composed of the hypothalamus, the cingulated nucleus, the fornix, the hippocampus, the thalamus and the Amygdaloid nucleus (Fitzgerald et al 2002). It has a series of complex functions including; basic instincts, short-term drive and emotional drives.

9. The Cranial Nerves

There are twelve cranial nerves, which form part of the peripheral nervous system. Each nerve has a number (roman numeral) and a name. The nerves may have a sensory or motor function or may have a combined role.

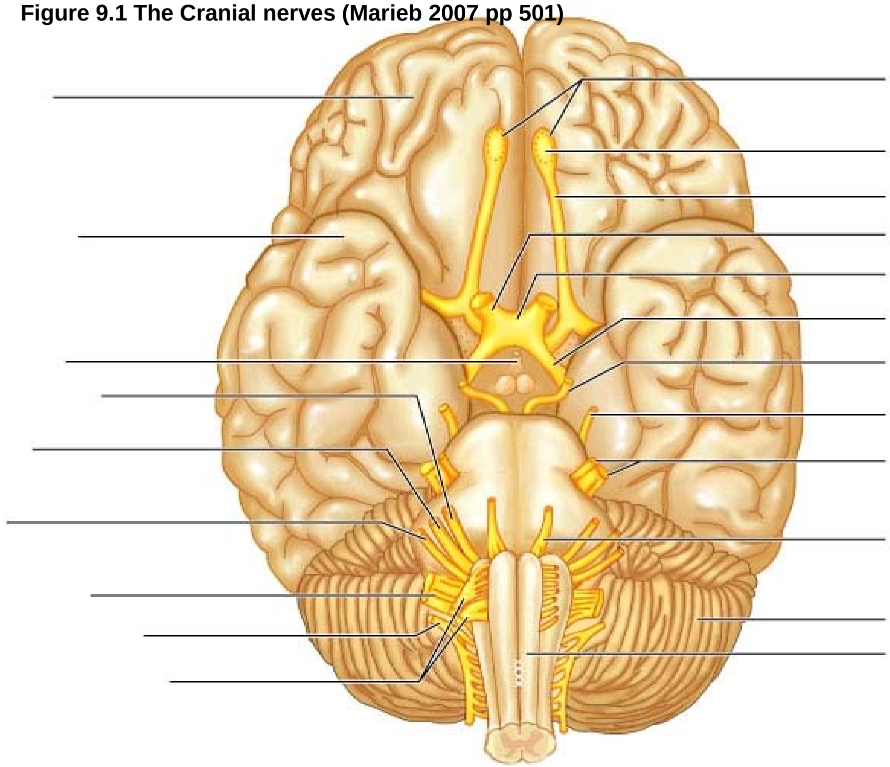
The first two cranial nerves originate in the brain, travelling through the cerebral hemispheres, whilst the remaining ten originate from the brainstem.

Acronyms can be used to assist in remembering the 12 cranial nerves, one is:-

On **O**ld **O**lympus **T**owering **T**op **A** **F**amous **V**ocal **G**erman **V**iewed **S**ome **H**ouses

Can you think of another acronym?

Figure 9.1 The Cranial nerves (Marieb 2007 pp 501)



(a)

Cranial nerve I: The Olfactory nerve

The olfactory nerve is a sensory nerve, which deals with the sense of smell.

In each nostril are specialised receptors. The olfactory nerve is made up of olfactory chemoreceptor cells whose axons end in the olfactory bulb. The olfactory tract then continues to the medial olfactory area and the lateral olfactory area in the frontal lobe where the information is then processed.

Cranial Nerve II: The Optic nerve.

What is the role of the optic nerve?

The optic nerve arises from retina. The nerve runs posteriorly until it meets the other optic nerve at the optic chiasm.

The visual pathways

The rods and cones of the retina are photoreceptors, which are stimulated by light. Impulses travel down the optic nerves. The optic nerve has two branches in each hemisphere; the nasal tract and the temporal tract. These meet at the chiasma where the nasal tracts then cross over whilst the temporal tracts remain the same side. The nerve tracts then continue back terminating in the lateral geniculate nucleus. Optic radiations tract fans back to the optic cortex of the occipital lobe where the impulses area processed.

Figure 9.2 Cranial Nerve II (From Table 13.2 Marieb (2007 pp 502)

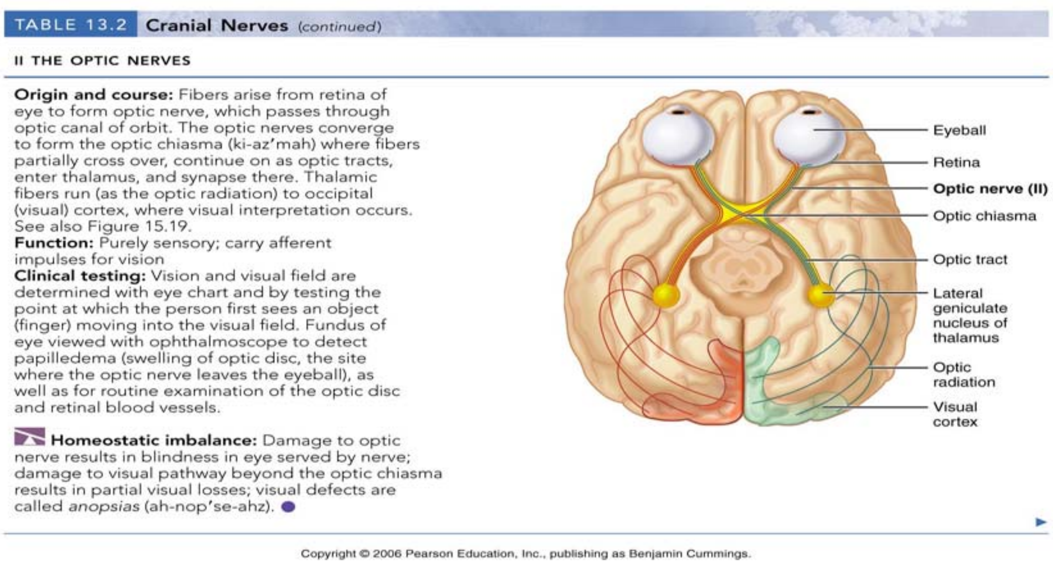


TABLE 13.2 **Cranial Nerves** *(continued)*

II THE OPTIC NERVES

Origin and course: Fibers arise from retina of eye to form optic nerve, which passes through optic canal of orbit. The optic nerves converge to form the optic chiasma (ki-az′mah) where fibers partially cross over, continue on as optic tracts, enter thalamus, and synapse there. Thalamic fibers run (as the optic radiation) to occipital (visual) cortex, where visual interpretation occurs. See also Figure 15.19.

Function: Purely sensory; carry afferent impulses for vision

Clinical testing: Vision and visual field are determined with eye chart and by testing the point at which the person first sees an object (finger) moving into the visual field. Fundus of eye viewed with ophthalmoscope to detect papilledema (swelling of optic disc, the site where the optic nerve leaves the eyeball), as well as for routine examination of the optic disc and retinal blood vessels.

Homeostatic imbalance: Damage to optic nerve results in blindness in eye served by nerve; damage to visual pathway beyond the optic chiasma results in partial visual losses; visual defects are called *anopsias* (ah-nop′se-ahz).

Table 13.2.2

Cranial Nerve III: The Oculomotor nerve.

This is a motor nerve. It has several functions:

- The innervation of four out of the six muscles that control movement of the eyeball (Hickey 1997).
    - Inferior Oblique Muscle: - Upward & outward movement
    - Inferior Rectus: - Downward
    - Superior: - Upward
    - Medial: - Inward
- Innervation of the muscle allowing the lifting/elevation of the upper eyelid.

- Innervation of the smooth muscle of the iris, which controls pupil size (constriction/dilation) and the ciliary body muscles, which allow for lens accommodation.

What is a third nerve palsy?

Cranial Nerve IV: The Trochlear Nerve.

This is a motor nerve innervating the superior oblique muscle of the eyeball, which allows the eyeball to rotate downward and inward.

Cranial Nerve V: The Trigeminal Nerve

This is a mixed nerve and has a joint motor and sensory role. Its sensory component is divided into three branches; the opthalmic, the maxillary and the mandibular conveying light touch, pain and temperature. It is involved in the corneal reflex.

The motor component allows the jaw reflex and the jaw muscles to masticate.

What is trigeminal neuralgia?

Cranial Nerve VI: The Abducens Nerve

This is a motor nerve. It innervates the lateral rectus muscle. This allows the eyeball to rotate outwards. It arises from a nucleus in the floor of the 4^{th} ventricle (Hickey 1997).

Cranial Nerve VII: The Facial Nerve

This is a mixed nerve. The nerve emerges from the pons. The motor component innervates muscles for facial expression. This allows blinking, eye closure, smiling & showing the teeth.
The sensory component innervates the anterior $2/3^{rd}$ of the tongue, the salivary glands and the lacrimal glands.

What is Bell's palsy?

Cranial Nerve VIII: The Vestibularcochlear Nerve

This is a sensory nerve often referred to as the acoustic nerve. It is composed of two branches; the cochlear branch and the vestibular branch.

The Vestibular Branch controls balance, body position and body orientation. The receptor organs are the Cristae ampullare (one in each semi circular canal) and the maculae of utricle and saccule which are all sensitive to movement in one direction (Hickey 1997). Input from the receptors and the cerebellum is received by the Vestibular ganglion.

The Cochlear Branch controls hearing. Sound waves are transmitted through the tympanic membrane to the small bones of the middle ear and onward to the cochlear. Within the cochlear is the spiral organ of Corti, where action potentials are generated which travel along the cochlear nerve to the brainstem. From here, information travels to the auditory cortex in the temporal lobe.

Name three types of disorder associated with CNVIII disorder.

Cranial Nerve IX: The Glossopharyngeal Nerve

This is a mixed nerve with 5 branches. It innervates portion of the pharyngeal muscles; 'conveys taste from the posterior third of the tongue; parasympathetics of the parotid gland; sensation from posterior part of the ear and also conveys sensation from the pharynx, tongue, Eustachian tube, carotid sinus & body' (Hickey 1997 pg 79). It also controls the gag and swallow reflex.

Cranial Nerve X. The Vagus Nerve

Is this a motor, sensory or mixed nerve?

It innervates the organs of the thoracic and abdominal cavities as well as the larynx, pharynx and the palate. It also has an efferent limb of the gag and swallow reflexes. This nerve conveys sensation from the heart, lungs, GI Tract and the carotid sinus & body.

Cranial Nerve XI: The Spinal Accessory Nerve.

This is motor nerve. Its roots originate in the medulla and the cervical spinal cord. It innervates the sternocleidomastoid and trapezius muscles allowing head rotation and shoulder shrugging.

Cranial Nerve XII: The Hypoglossal Nerve.

This is a motor nerve. It innervates the tongue allowing speech and swallow.

10. The Spine And Spinal Cord

10.1 The Spine.

The spine (see Figure 10.1) is composed of individual bones called **vertebrae**, which allow the spinal column to be flexible. There are 33 bones in total.

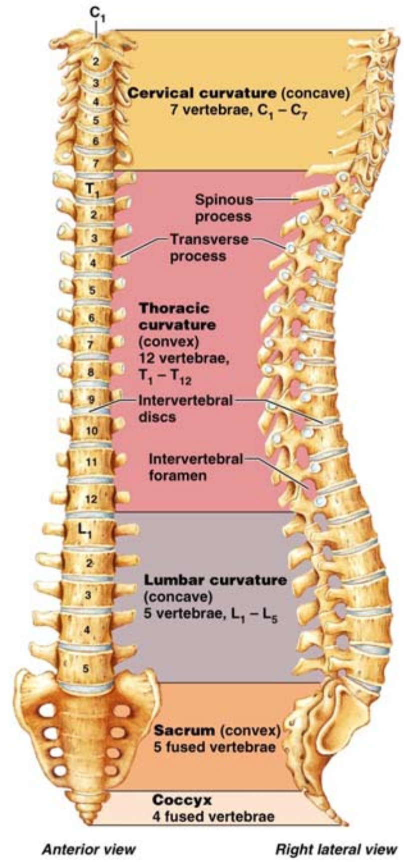


Figure 10.1 The Vertebral Column (From Marieb 2007 pp 219)

How many bones in each subdivision?

Each vertebra has two main parts. The **Arch** is the posterior segment, which is made up of 2 **pedicles**, 2 **lamina** and 7 **processes** (4 articular, 2 transverse and 1 spinous). The **spinal foramen (canal)** provides the spinal cord protection and is formed by the vertebral spinal foramina. The **Body** is the anterior (solid) segment.

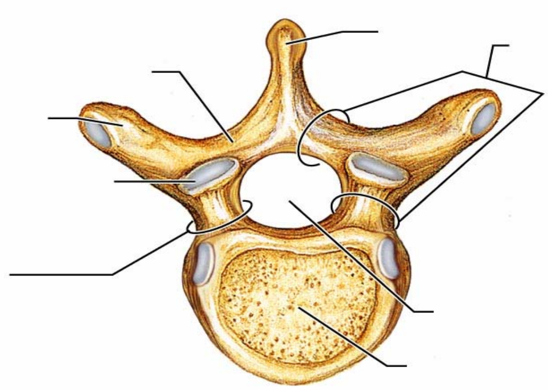
The vertebrae are of different sizes and proportions according to their role.

What are the first two cervical vertebrae known as

The **Odontiod process** is a perpendicular protrusion on the axis, which the atlas sits on. This allows flexion, extension and head rotation. Thoracic vertebrae are larger than cervical vertebrae and limit movement. Lumbar vertebrae allow extension and flexion. The pelvis is fused to the vertebral column by the sacrum.

Label the Vertebrae below

Figure 10.2a The

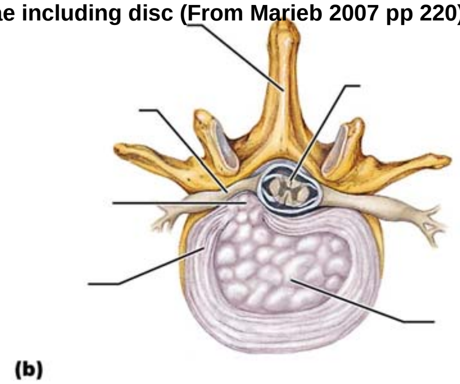


Fibro-cartilaginous **intervertebral discs** lie between the vertebrae. They vary in their shape, size and thickness. Each disc has a gelatinous core (Zejdlik 1992) called the nucleus pulposus. This is enclosed by the annulus fibrosus (a fibrous capsule).

What is the function of the intervertebral disc?

Label the Vertebrae below

Figure 10.2b The Vertebrae including disc (From Marieb 2007 pp 220)

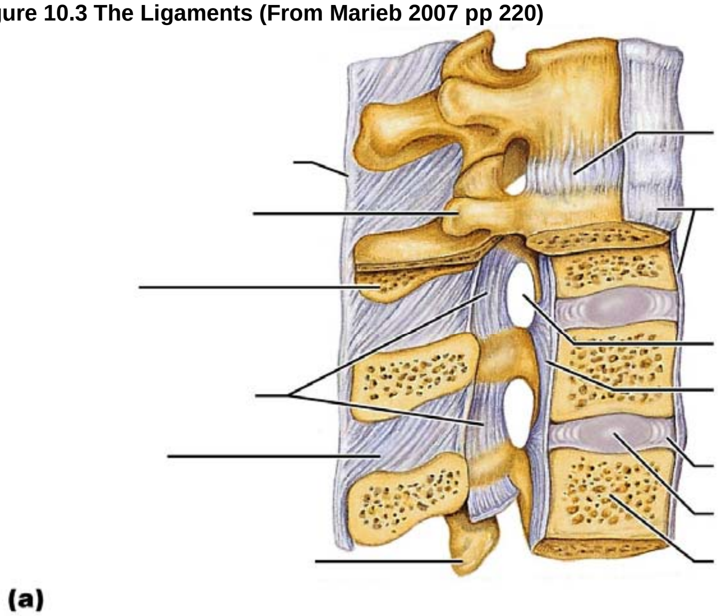


The **Spinal ligaments** (the anterior, posterior and ligament flava) provide stability for the spine. They allow vertebral movement but prevent excessive hyperextension or flexion (Zejdlik 1992).

The **Anterior longitudinal** and the **Posterior longitudinal** ligaments run anterior and posteriorly of the cervical to sacral vertebral bodies. The **Ligamenta Flava** ligaments are located between the lamina. The **Supra-spinal** and the **Interspinal** ligaments extend down between the spinous processes. Between the transverse processes are the **Inter-transverse** ligaments.

Label the ligaments on the diagram below

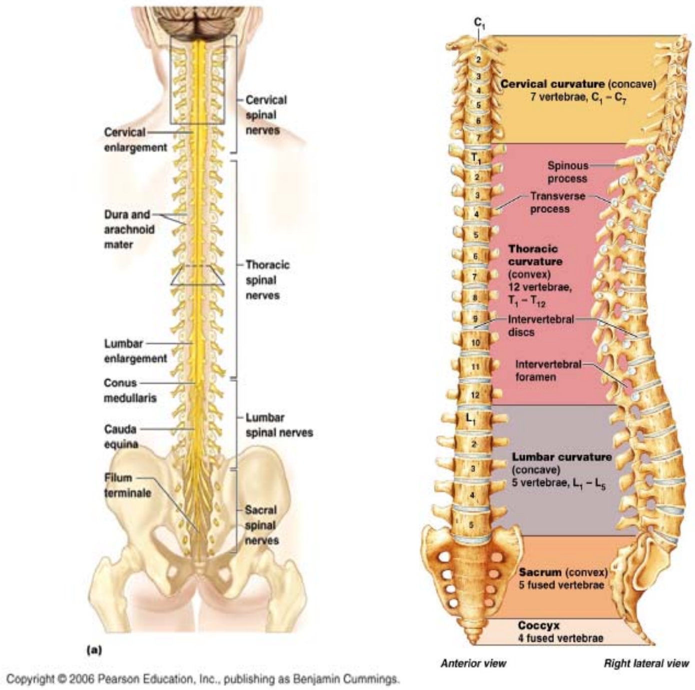
Figure 10.3 The Ligaments (From Marieb 2007 pp 220)



10.2 The Spinal Cord

The spinal cord is part of the central nervous system. It is composed of neurons. It is protected by the vertebral column, covered by meninges and cerebro spinal fluid flows around the spinal cord.

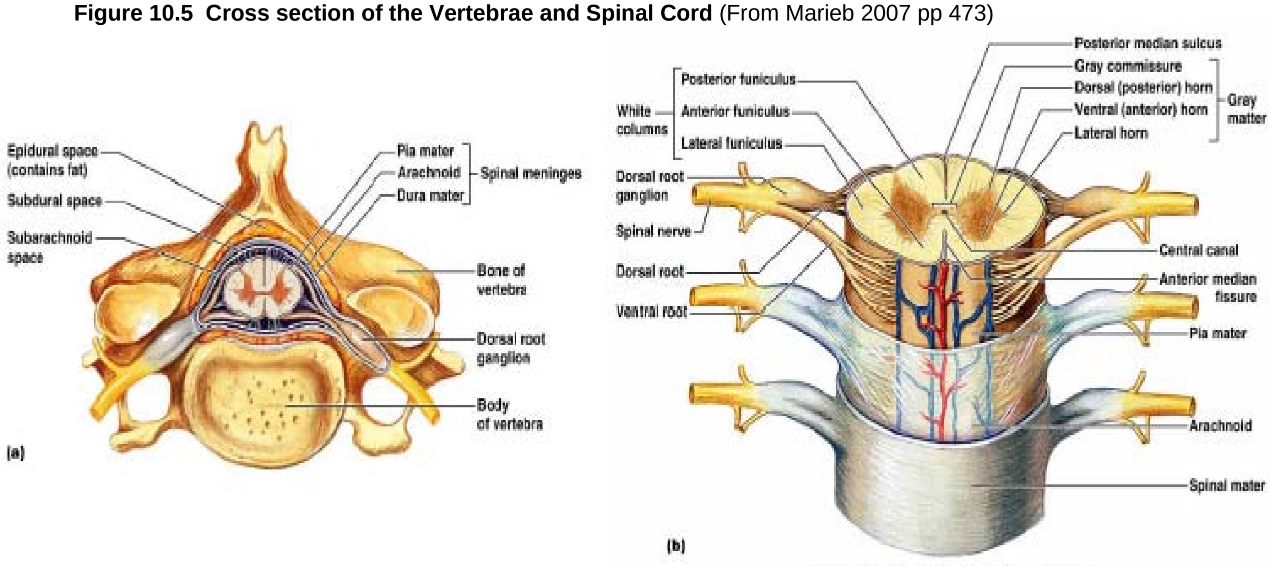
Figure 10.4 The Spinal Cord (From Marieb 2007 pp 471 & 219)



Two principle arteries supply the spinal cord. The '**anterior spinal artery** supplies the anterior 2/3rds of the spinal cord and the **posterior spinal artery** supplies the posterior 1/3rd of the spinal cord' (Zejdlik 1992 pg 57). The spinal cord extends from the foramen magnum and finishes at the 1st/2nd lumbar vertebrae.

What is the role of the spinal cord?

Figure 10.5 Cross section of the Vertebrae and Spinal Cord (From Marieb 2007 pp 473)



At L1/2 the cord forms a tapered cone shaped end called the **Conus Medullaris**. This has the reflex centres for bladder, bowel and sexual functions. The **Filum Terminale** continues further down but it does not contain neurons.

The spinal cord is made up of **Grey Matter** (groups of neuronal cell bodies) and **White Matter** (nerve fibres of myelinated neurons). The **grey matter** is situated centrally in and 'H' shape in the cord. The 'horn cells' provide a junction between the central and peripheral nervous system. The anterior horn cells convey motor information from the brain to the muscles and glands of the body, whilst the posterior horn cells convey sensory information up to the brain. The **white matter** has ascending and descending myelinated nerve fibres. Each are grouped into bundles or 'tracts'. They are arranged together according to their functions.

For example:

- Fibres that relay pain and temperature messages are grouped together in the Lateral spinothalamic tract.
- The Corticospinal tract relays messages about voluntary motion
- The Posterior columns relay information about proprioception, deep touch and vibration.

Figure 10.6 Cross section of the spinal cord (From Marieb 2007 pp 475)

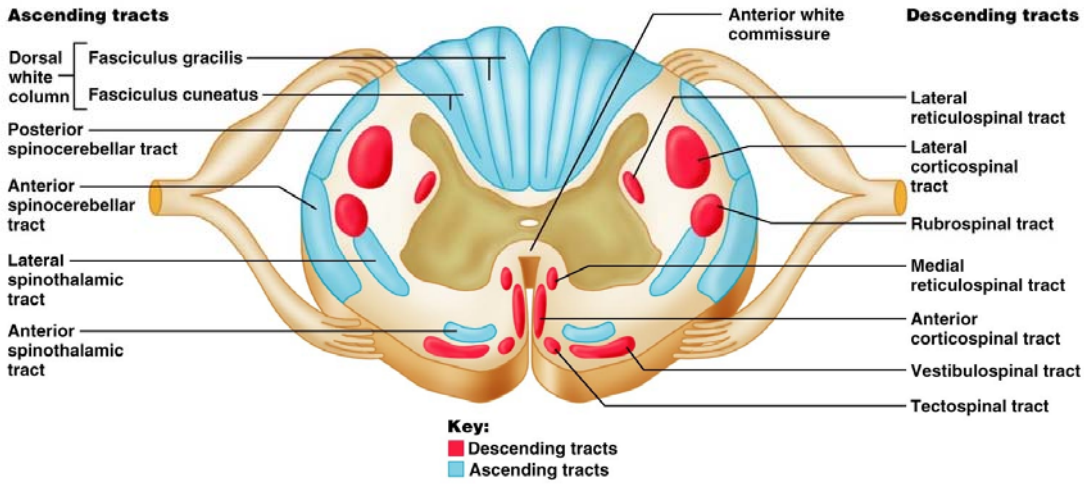
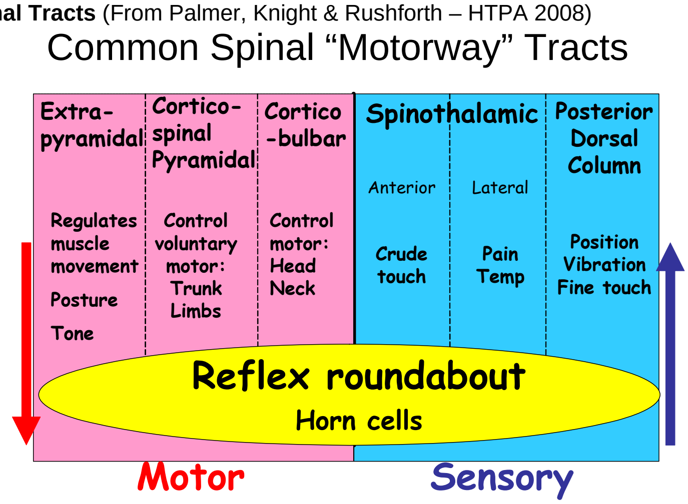


Figure 10.7 Spinal Tracts (From Palmer, Knight & Rushforth – HTPA 2008)



10.3 Spinal Nerves

The spinal nerves are part of the peripheral nervous system. There are two types: -

Efferent (Motor) neurons transmit motor information from the brain via the spinal cord to the appropriate part of the body. The motor tracts are described as either upper motor neurons or lower motor neurons.

- **Upper motor neurons (UMN)** are elongated neurons from the brain running through the spinal cord. The brain can suppress or inhibit the lower motor neurons via the UMN preventing hyperactivity due to focal stimuli (Zejdlik 1992).
- **Lower Motor Neurons (LMN)** start in the spinal cord and travel to the muscle fibres. An involuntary reflex response can occur (a reflex arc) in the LMN. This occurs when a 'LMN transmits a stimulation from a muscle to the cord where it synapses with another LMN, which in turn carries the response back to the muscle'. (Zejdlik 1992 pg 70)

Afferent (Sensory) neurons: - Carry sensory information from the body to the cord and then onward to the brain.

How many pairs of spinal nerves are there?

At each cord division an efferent & afferent nerve occurs bilaterally. Each of the nerves is attached to the spinal cord by a root. Efferent nerves have **Ventral (anterior)** roots and afferent nerves have **Dorsal (posterior)** roots. **Plexuses** occur within the body. Plexuses are a 'network of interlacing nerve fibres' (Hickey 1997 pg 63).

Name the four main plexuses in the body.

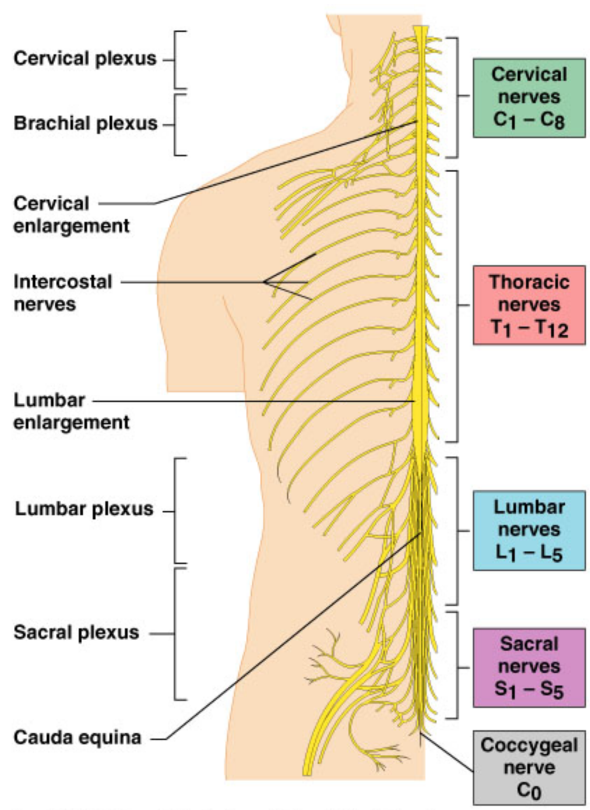
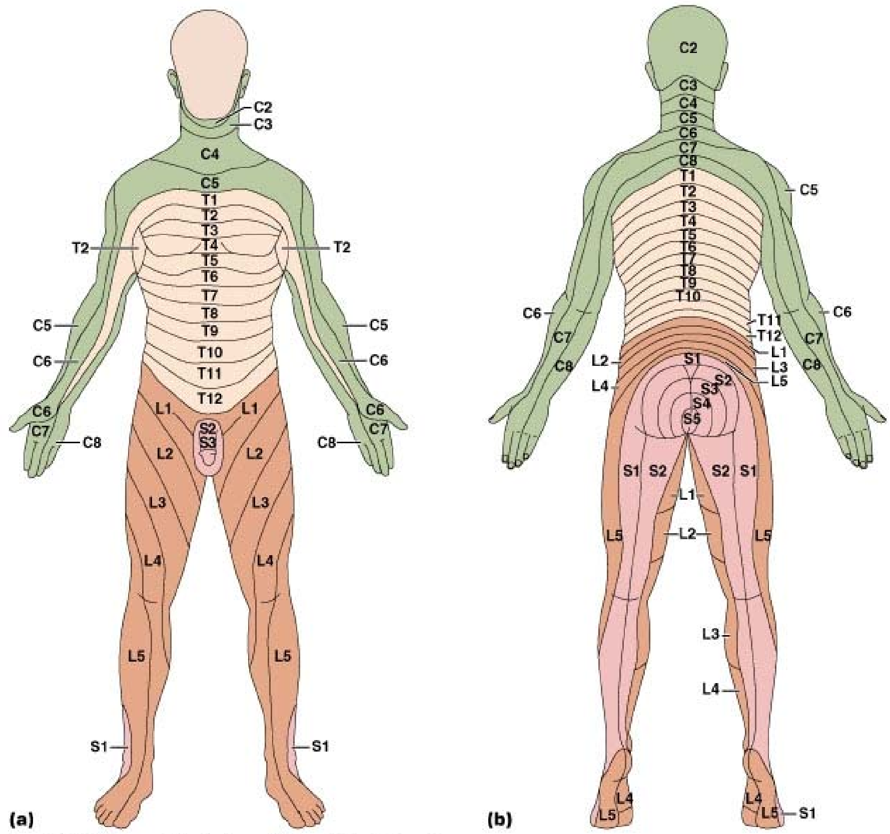


Figure 10.8 The Spinal Nerves (From Marieb 2007 pp 509)

The maps below demonstrate which spinal nerves serve which specific part of the body. Maps showing the areas served by sensory nerves are called **dermatomes** and the areas served by motor nerves are called **myotomes**.

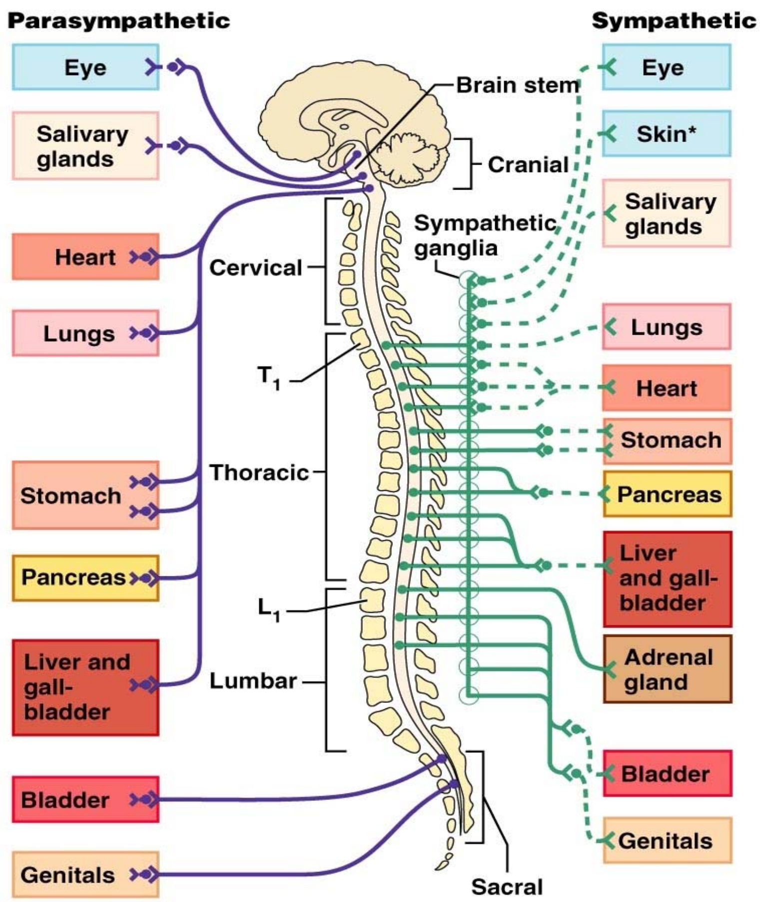
Figure 10.9 Dermatome And Myotome Maps (From Marieb 2007 pp 509)



11 The Autonomic Nervous System

The Autonomic Nervous System (ANS) is a complex network of motor neurons.

Figure 11.1 The Autonomic Nervous System (From Marieb 2007 pp 536)



Is it part of the Peripheral Nervous System (PNS) or the Central Nervous System (CNS)?

The ANS role is to ensure a stable internal environment (Marieb 2007). It has autonomic control over involuntary vital functions. This includes cardiovascular (heart rate, blood pressure & temperature), appetite, fluid balance, GI tract, metabolism and sleep (Zejdlik 1992). The Hypothalamus, brain and spinal cord all play a role in governing the ANS.

There are two parts to the ANS: -

- Sympathetic Nervous System (SNS)
- Parasympathetic Nervous System (PNS)

11.1 The Sympathetic Nervous System.

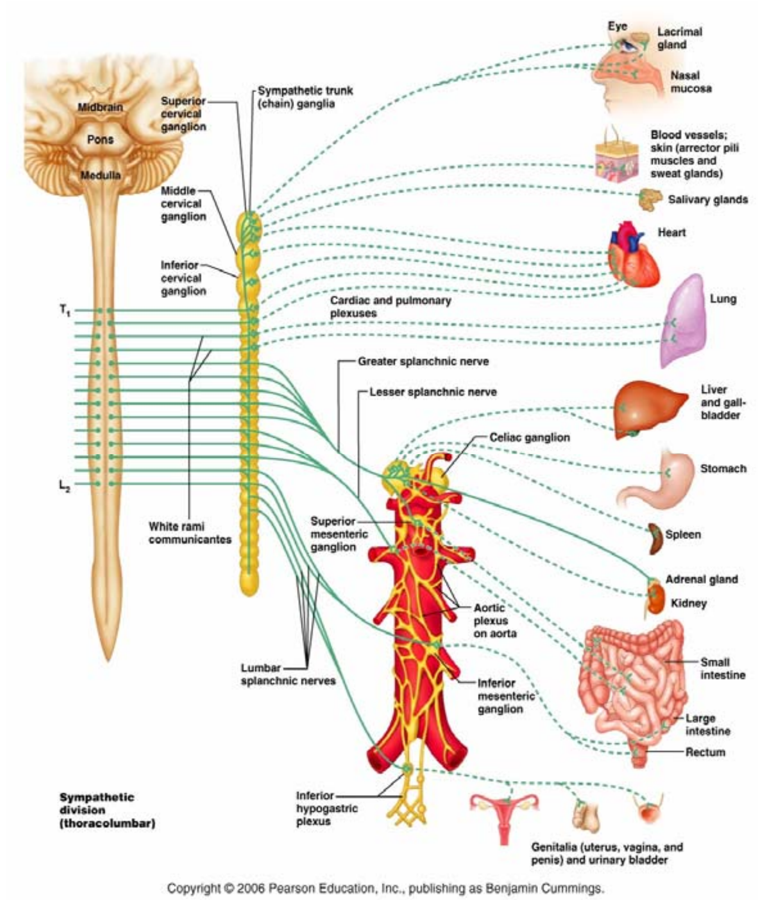
It is part of a persons “fight or flight” phenomenon. It is triggered by stressful situations.

Its role is: -

- It allows the body to increase heart rate, blood pressure & respirations.
- It will reduce non-vital functions such as GI activity & urinary requirements.
- It also ensures that extra red blood cells released by the spleen for any additional energy requirements.
- The final role is to ensure that the adrenal glands release epinephrine.

The SNS (also known as the Thoraco-Lumbar system) extends from T1 to L2. Where the nerve roots meet and link with a sympathetic ganglion. This group of sympathetic nerve tissue extends from the cranium to the coccyx. The neurotransmitter for this system is norepinephrine.

Figure 11.2 The Sympathetic Nervous System (From Marieb 2007 pp 539)



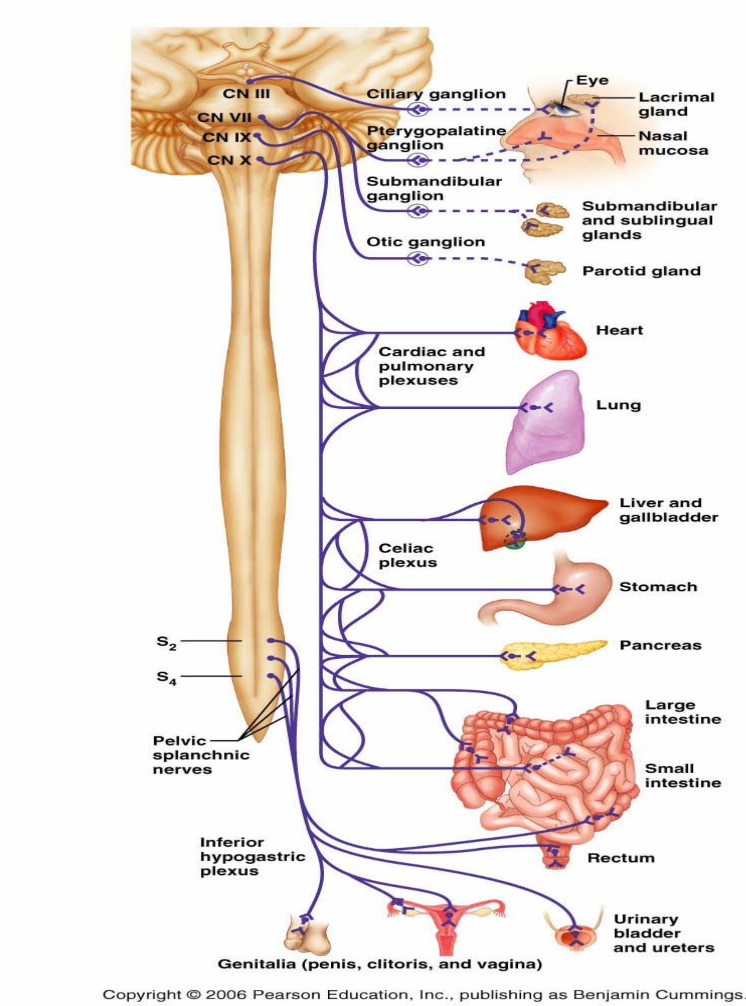
11.2 The Parasympathetic System

This system restores the balance, conserves and ensures normal functions are maintained. Its role is: -

- Reduces heart rate, blood pressure and respiration.
- Ensures non-vital functions are returned to normal function e.g. increase GI activity.

The Parasympathetic system's (also named the Craniosacral System) preganglionic fibres emerge with cranial nerves III, VII, IX and X. The neurotransmitter for this system is Acetylcholine.

Figure 11.3 The Parasympathetic Nervous System (From Marieb 2007 pp 537)



References & Further Reading

- FitzGerald, M.J.T. and Folan-Curran, J., Clinical Neuroanatomy and Related Neuroscience. 2002. 4th Edition. W.B. Saunders. Edinburgh
- Hickey, J.V., The Clinical Practice of Neurological and Neurosurgical Nursing. 1997. 4th Edition. Lippincott. Philadelphia.
- Marieb. E.N. and Hoehn, K., Human Anatomy and Physiology. 2007 7th Edition. Pearson. San Francisco.
- Martin, J, H., Neuroanatomy text and atlas. 2003. 3rd Edition. McGraw-Hill. New York
- Palmer, R.K. & Knight, J., 2008 – Curently unpublished work for Foundation Studies for Caring/Foundation Skills for Caring, Palgrave
- Palmer,R.K., Knight, J. & Rushforth, H., 2008, Principles of History Taking and Physical Assessment (Spinal Nerves), School of Allied Health Professionals, University of Southampton
- Zejjdlik, C.P., Management of Spinal Cord Injury. 1992. 2nd Edition. Jones and Bartlett. Boston.