Overview of sensory and motor systems

Ganglia and nuclei (Dorlands)
A **ganglion** is a "group of nerve cell bodies located outside of the CNS". Usually the term ganglion is applied to things outside the CNS, but occasionally the term is incorporated into the CNS (i.e.: basal ganglia etc). A **nucleus** refers to a "group of nerve cell bodies located within the CNS". Usually the nerve cell bodies all contribute to a single nerve.

Examples of ganglia include: dorsal root ganglion (sensory nerve cell bodies), cranial nerve ganglia, sympathetic and parasympathetic ganglia.

Nerves and tracts (Dorlands)
Nerves are bundles of axons, or groupings of axons, located outside the CNS. **Tracts** are bundles of axons or groupings of axons, located within the CNS – and usually these tracts are myelinated (white matter). The nomenclature of tracts usually derives from the origin and destination point.

Many tracts cross the midline (Notes)
By now, we all should know that usually one of the hemispheres controls/receives information from the opposite side of the body, with relation to the midline. This implies: right brain controls left side, left brain controls right side. Technically, we should be saying: right hemisphere, left side and left hemisphere, right side.

There are exceptions when one hemisphere actually controls/receives input from both sides of the body, or the side it is located in. For example: left brain, right and left body or left brain (**bilateral**), left side of body only (**ipsilateral** – "situated on or affecting the same side" - Dorlands).

Motor Systems (Chapter 11 *in* Marieb 4th Ed)
Below is a summary of the complete nervous system (the colour coded what is explained briefly in the lecture notes)
NERVOUS SYSTEM

- Central Nervous System
  - Brain
  - Spinal Cord
- Peripheral Nervous System
  - Afferent division
  - Efferent division
    - **Somatic nervous system – regulate skeletal muscle**
    - Autonomic nervous system
      - **Parasympathetic – regulate cardiac, smooth, glands**
      - **Sympathetic – regulate cardiac, smooth, glands**

Somatic (voluntary) motor systems (Nolte 5th Ed pp 449)
This arm of the nervous system is referred to as the voluntary aspect. We are able to control the usage of this nervous system. It is concerned with contraction of skeletal muscles. It involves sensory information travelling to the spinal cord from the skeletal muscles, which is then interpreted by the brain which resends information to the spinal cord, then leaving the spinal cord to act on the specific muscle according to the brain's wishes.

The target of the CNS (i.e.: UMNs) are the Lower motor neurons (**LMNs** – located in ventral horn of spinal cord + motor cranial nerve nuclei in brain stem), whose axons leave the spinal cord via the ventral roots – travel to their specific muscle groups and divide into numerous terminal branches to form a neuromuscular junction. A single neuron + all of the skeletal fibres it innervates (due to huge number of terminal branches) is called a **motor unit**. The size of the motor unit depends on the level of precision control required. The larger the less fine movements needed. It is important to note that LMNs control muscles on the same side (ipsilateral) of the body.

Sometimes **interneurons** are present in the spinal cord. These are usually present in **reflex arcs** – which require no brain input. Sensory information is sent to the spinal cord, which is integrated and sent back to the motor neuron (by means of a interneuron) which acts on the specific target muscle. Interneurons are also present when information is coming from UMN systems.

As the UMNs descend, they are refined by the cerebellum + basal ganglia. Lesions of LMNs results in muscle wasting, weakness, atrophy of muscles, decreased muscle tone, hyporeflexia (reflex arcs don't work efficiently).

UMN systems: Corticospinal tract (Nolte 5th Ed pp 453 Fig 18-6)
It was discovered that stimulation of certain areas of the cerebral cortex results in movements of the contralateral side of the body. Thus, since the precentral gyrus had the lowest threshold potential for stimulation – it became known as the **primary motor cortex**. The cell bodies of the **corticospinal tracts** are located within the primary motor cortex and nearby structures. The corticospinal tract is responsible for **voluntary muscle control** of the opposite side of the body. Below is a neat summary (refer to class summary diagram):

- **Corticospinal tract**:
  - **Forebrain** (Telencephalon + Diencephalon):
    - Contains the cell bodies of CST located within the precentral gyrus (primary motor cortex) + adjacent structures
    - Fibres travel through posterior limb of internal capsule (adjacent to thalamus)
  - **Midbrain**
    - Fibres travel through the cerebral peduncles
  - **Pons**
    - Fibres travel through the basal pons area
  - **Medulla**
    - Fibres travel in the pyramid of medulla, and cross the midline at the decussation of pyramid
  - This is now called the lateral corticospinal tracts (represents about 80-90% of fibres), uncrossed fibres called anterior corticospinal tracts (represents about 10-20% of fibres – most cross within the spinal cord using interneurons or with LMNs) → synapse with interneurons or LMNs of ventral horn → muscle fibres

If any of the fibres are damaged, then it will affect the contralateral side of the body.
UMN systems: Corticobulbar tracts (Nolte 5th ed pp 460 Fig 18-17)
This tract is responsible for control of **muscles** of the **head/neck**. It follows a similar pathway to CST, but one major difference is that it can control muscles on both sides of the body compared to the CST, which can only do one side. That is, the CBT can innervate LMNs located ipsilaterally or contralaterally (either directly or via interneurons).

The UMNs here target the LMNs of the cranial nerve motor nuclei (**V, VII, IX, X, XI, XII**).

- Corticobulbar tract
  - **Forebrain** (Telencephalon + Diencephalon):
    - Contains the cell bodies of CBT located within the precentral gyrus (primary motor cortex) + adjacent structures
    - Fibres in genu of internal capsule (adjacent to thalamus)
  - **Midbrain**
    - Fibres travel through the cerebral peduncles
  - **Pons**
    - Fibres cross the midline
    - Fibres synapse on motor nuclei of cranial nerves (either directly on LMNs or via interneurons)
  - **Medulla**
    - Fibres cross the midline
    - Bilateral branches to right and left side of medulla serving the motor nuclei of cranial nerves (either directly on LMNs or via interneurons).

Damage to any of the UMNs results in: weakness and mild atrophy of muscles, increased muscle tone, and hyperflexia.

Other UMN systems (Nolte 5th Ed pp 452 Fig 18-6)
There are a number of other tracts which are also important. Below is a brief summary of these tracts (Refer to notes for summary and diagrams):

- **Rubrospinal tracts**
  - Alternate routes for the mediation of voluntary movement
  - (refer to class diagram) Originates in red nucleus of midbrain → crosses the midline → descends in lateral part of brain stem tegmentum → travels in company with lateral corticospinal tract
- **Tectospinal tracts**
  - Originates from the tectum (roof of midbrain) → superior colliculus → projects to contralateral aspect of cervical spinal cord via anterior funiculus
- **Lateral and medial vestibulospinal tracts**
  - Important mediators of postural adjustments and head movements
  - Arise from vestibular nuclei and project to spinal cord
- **Reticulospinal tracts**
  - Arise from parts of pontine and cerebellar reticular formation (what does this mean – email me if you know) – project to spinal cord.

<u>Control of eye movements</u>
Eye movements are very complex. To give you a brief summary: the **extraocular muscles** are controlled by LMNs located in the midbrain and pons. These LMNs contribute to cranial nerves 3,4,6. More in detail in other lectures

Cerebellum (Nolte 5th Ed pp 487 – mainly notes)
The cerebellum is mainly concerned with the processing of **unconscious sensory information** coming from the body's proprioceptors etc, but it is still connected to the motor systems because damage causes: abnormal movements, distorted equilibrium. The main function of the cerebellum is to **continually monitor** what is **happening** in the body (what the body is actually doing) and compare this to the what the body intends to do (**motor plan**). The comparison enables it to make fine adjustments.

The sensory information from the muscles, joints etc arrives at the cerebellum by way of **spinocerebellar tracts**.

The cerebellar receives multiple inputs and briefly these are:

- **Vestibular nuclei** (vestibulocerebellar tract)
- **Cerebral cortex** (→ via pontine nuclei)
- **Spinocerebellar tracts**
- The climbing fibre input to the cerebellum arises in the **inferior olivary nucleus**

The cerebellar continues in multiple outputs to the UMNs (not LMNs) and briefly these are:

- **Cerebral cortex** via thalamus (diencephalon)
- **Red nucleus** of midbrain (note the tracts described earlier)
- **Vestibular nuclei**
- **Reticular nuclei**

Note the tracts earlier

Damage to the cerebellum causes postural instability, limb ataxia (uncoordinated movements).

Basal Ganglia (Nolte 5th Ed pp 465 – mainly notes)
Damage to the basal ganglia (really should be named **basal nuclei**) results in specific symptoms including: involuntary movements, tremors, and increased muscle tone. The basal ganglia includes: **caudate nucleus**, **putamen**, **globus pallidus**, **subthalamic nucleus**, and **substantia nigra** (**compact** & **reticular**). There is a bridge of gray matter extending between

the caudate and putamen nuclei – therefore forming a 'striped appearance' – together called the **striatum**. The putamen and globus pallidus are referred to as the **lenticular nucleus**.

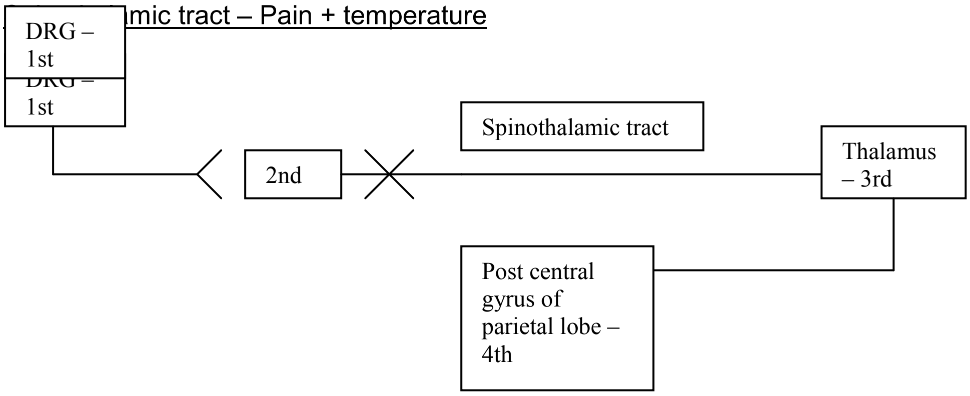
The inputs to the basal ganglia are from the cerebral cortex to the straitum, the outputs are to UMNs (not LMNs), usually the internal segment of globus pallidus and substantia nigra to the thalamus → cerebral cortex.

Degeneration of basal ganglia results in Parkinson's and Huntington's disease.

Sensory Systems (mainly notes)
Sensory tracts provide information about the outside world to the brain and about the state of the body. Basically, receptors transmit the sensory information to the dorsal root ganglion and from here – the information is sent to the spinal cord – across the midline. From here, the information is projected via ascending axons via the thalamus straight to the cerebral cortex. The **olfactory sensory system** is the only system which **does not travel** through the **thalamus**.

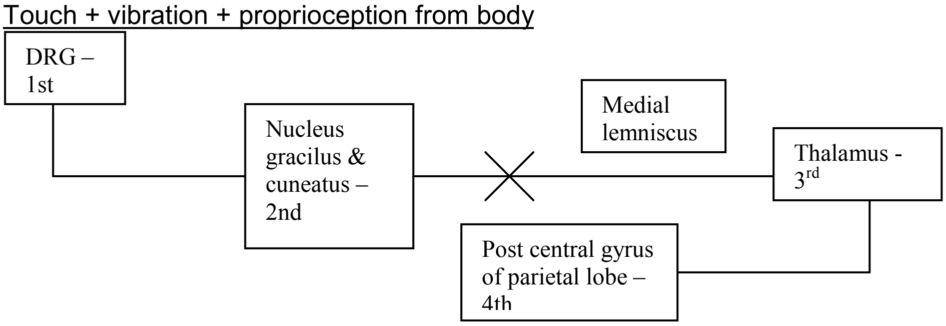
Sensory systems can also only involve the spinal cord, not requiring any input from higher centres. These include: **monosynaptic reflexes**, or **polysynaptic reflexes**.

mic tract – Pain + temperature



- Primary sensory neuron located in DRG → synapse with neuron in dorsal horn of spinal cord → axons cross the midline at same level → then ascend as the spinothalamic tract (anterolaterally in spinal cord) → continues through brain stem → synapse with thalamus (ventroposterolateral thalamic nuclei) → posterior limb of internal capsule → post central gyrus of parietal lobe

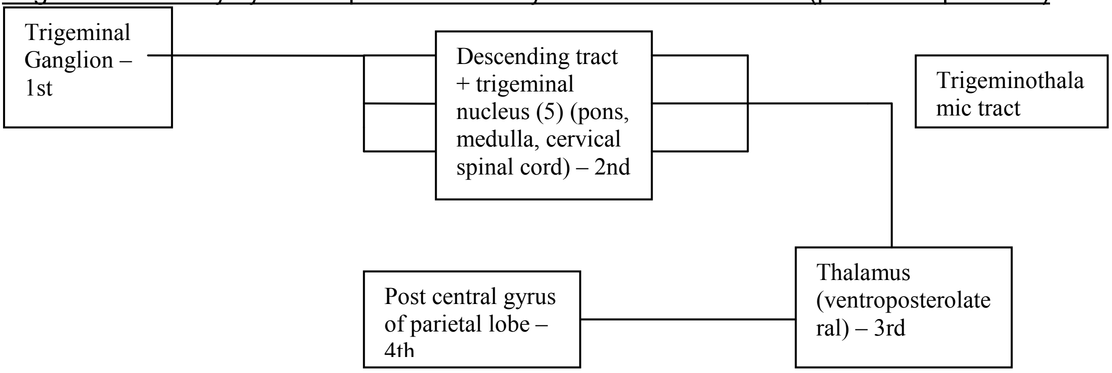
Touch + vibration + proprioception from body



- Primary sensory neuron located in dorsal root ganglion → travel through dorsal columns of spinal cord (fasciculus gracilis and fasciculus cuneatus) → secondary sensory neurons located in nucleus gracilis and nucleus cuneatus in medulla (caudal region) → these axons cross midline → ascend in the brain stem as medial lemniscus → tertiary neurons located in thalamus (ventroposterolateral thalamic nucleus) →

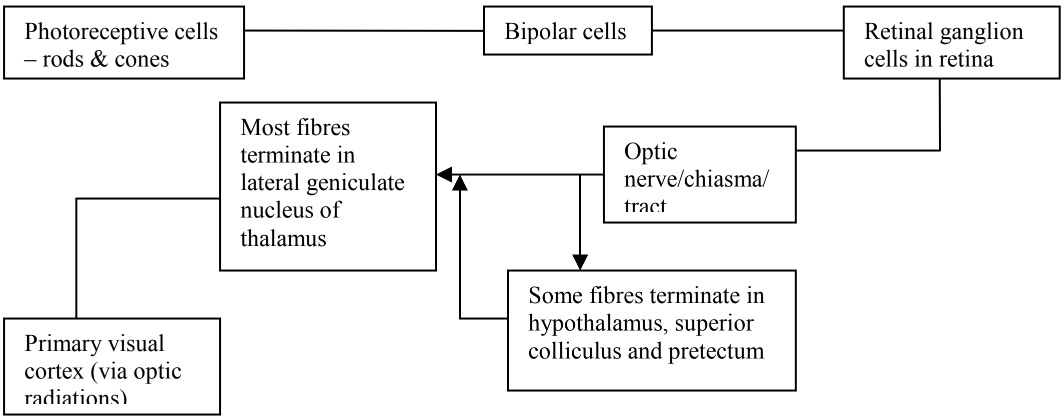
travel through posterior limb of internal capsule → 4^{th} order neurons located in post central gyrus of parietal lobe

Trigeminal sensory system – process sensory information from face (pain + temperature)

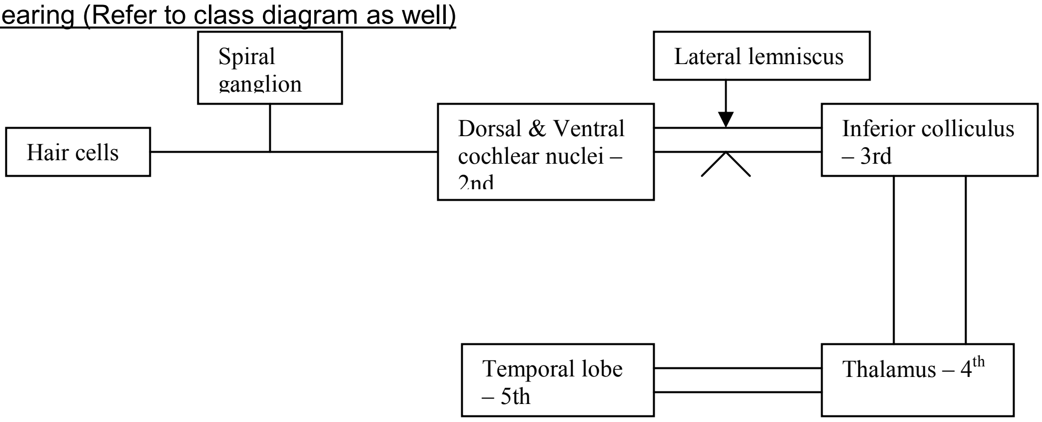


- Primary sensory neuron located in trigeminal ganglion → travels via descending tract to trigeminal nucleus located in pons, medulla, and cervical spinal cord → 2^{nd} neuron ascends to VPM thalamic nucleus (3^{rd}) (trigeminothalamic tract) → travels to post central gyrus of parietal lobe via genu of internal capsule (4^{th}).

Vision – Pathway

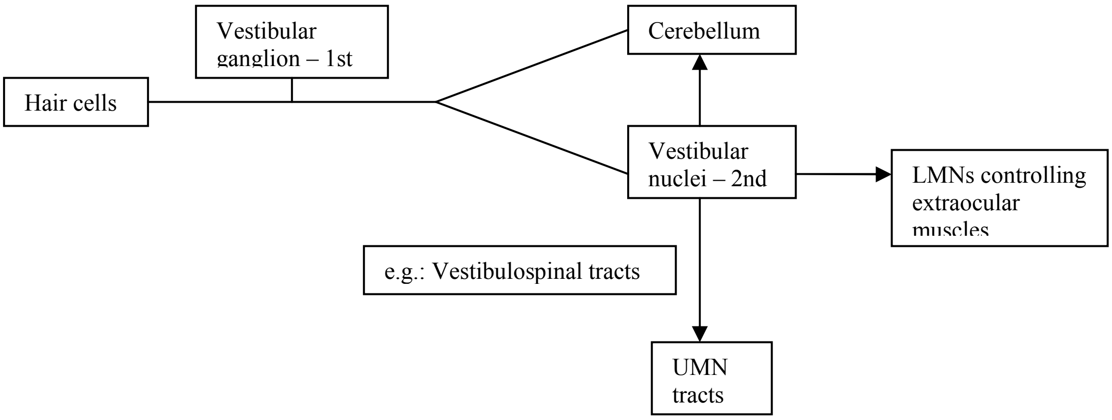


Hearing (Refer to class diagram as well)



- Hair cells pick up sensation → axons of spiral ganglionic cells synapse with the dorsal and ventral cochlear nuclei via cranial nerve VIII (cochlear portion) → most fibres cross the midline (some act ipsilaterally) → axons sent to inferior colliculus (mid brain) via lateral lemniscus → axons send to medial geniculate nucleus of thalamus (4^{th}) → send axons to primary auditory cortex (temporal lobe)

<u>Vestibular system</u>

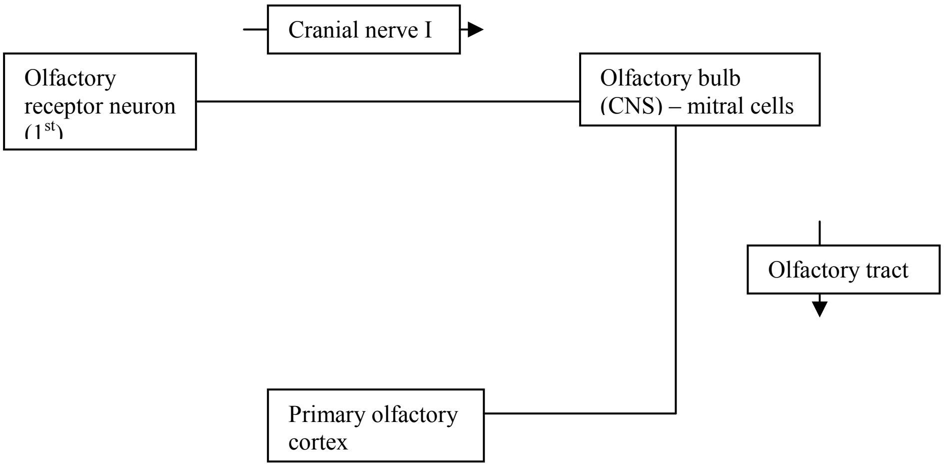


- Receptor cells (hair cells) pick up sensation → synapse with primary sensory neurons located in vestibular ganglion (Scarpa's ganglion) → axons travel to CNS via cranial nerve VIII (vestibular portion) → most synapse with vestibular nuclei although some synapse with cerebellum → from vestibular nuclei projections include: LMN controlling extraocular muscles, UMN tracts (vestibulospinal tracts) → cerebellum

<u>Taste</u>
(Fill in the space given below with a diagram)

- Sensory receptors convey taste to CNS via cranial nerves 7 (anterior 2/3 of tongue), 9 (posterior 1/3 of tongue), and 10 (oropharynx) → primary sensory neuron cell bodies located in petrosal, geniculate and nodose nuclei (respectively) → axons sent to nucleus of solitary tract (2^{nd}) in medulla → some fibres project to VPM of thalamus (3^{rd}) while other fibres go to brainstem nuclei (eg: vagal) → insular cortex → orbital cortex → amygdala → hypothalamus.

<u>Smell</u>



Refer to accompanying notes from lecture for more information