# CHAPTER 2

## THE SOMATIC SENSATIONS

The various sensations in the body include **(1) Somatic sensations** (from the skin and deep tissues e.g. muscles, joints and bones) **(2) Visceral sensations (3) Special sensations** (vision, hearing, smell, taste and equilibrium) **(4) Organic sensations** (e.g. hunger, thirst and sexual sensations).

### The sensory pathway or axis

The perception of a certain sensation requires that its pathway (or axis) should be intact. A sensory axis includes **(1)** *A receptor* **(2)** *An afferent (or sensory) nerve* that transmits the signals to the nervous system **(3)** *A transmitting tract to the higher centres and cortical sensory areas.*

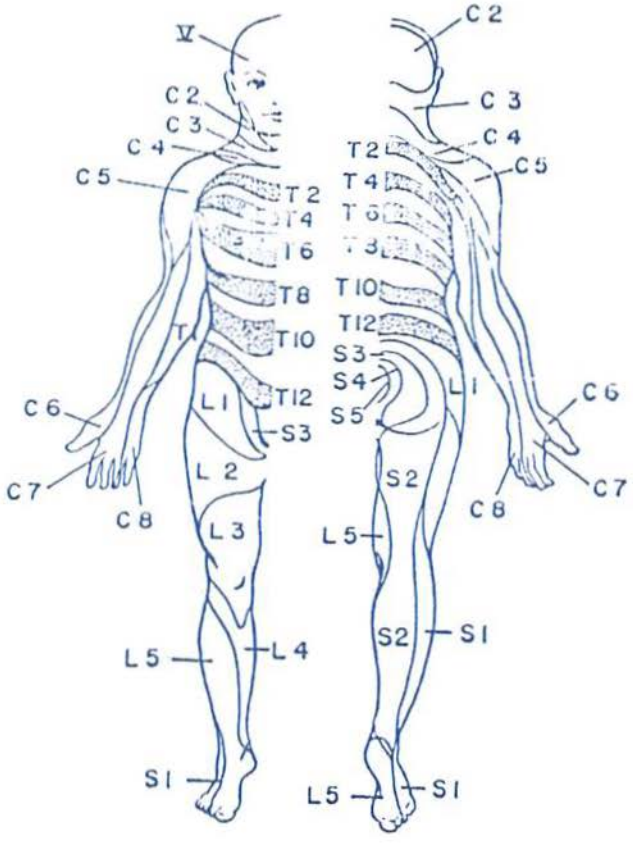



**Figure 5** :The skin dermatomes, anterior view (left) & posterior view (right)

## The sensory unit and the receptive field

The ***sensory unit*** consists of a single afferent nerve and all its peripheral branches whle the ***receptive field*** is the area supplied by a certain unit. There is a ***considerable overlap of the receptive fields*** of neighbouring sensory units. This is evident in the skin in which each spinal nerve innervates a definite area called a ***dermatome*** (figure 5) and these show ***marked overlapping***

## Recruitment of receptors and sensory units

Threshold (or minimal) stimuli activate only the highly-sensitive receptors, leading to a little discharge of impulses. However, as the intensity of stiimulation increases, more receptors become activated (= ***recruitment of receptors***) and more sensory units discharge (= ***recruitment of sensory units***) and this is interpreted by the higher centres as ***an increase in the intensity of the sensation***.

## CLASSIFICATION OF THE SOMATIC SENSATIONS

The somatic sensations can be **classified in 2 ways :**

### (A) ACCORDING TO THE SITE OF THE SENSATION

***(1) Superficial (or exteroceptive) sensations :*** These are the skin sensations (***pain, touch and temperature***).

***(2) Deep sensations :*** These are the sensations from skeletal muscles, tendons, joints, bones and ligaments, and they include the following types : **(a) Proprioceptive sensations :** These include the ***sense of position and the sense of rate of movement*** (= ***kinesthetic sensation***) **(b) Pressure sense (c) Muscle tension sense (d) Muscle sense** (= pain elicited by firm squeeze of skeletal muscles). Sometimes the **vibration sense** is included in this group.

***(3) Combined or synthetic senses :*** These include **stereognosis and the vibration sense (and sometimes tactile discrimination)**.

### (B) ACCORDING TO THE MODALITY OF THE SENSATION

***(1) Mechanoreceptive sensations :*** These include the touch, pressure, vibration, itch and tickle sensations, as well as muscle tension and the proprioceptive sensations.

***(2) Thermoreceptive sensations*** (heat and cold sesations).

***(3) Pain sensation.***

** **During testing any sensation, the patient's eyes must be closed.**

# THE MECHANORECEPTIVE SENSATIONS

## (1) TOUCH (TACTILE) SENSATION

**There are 2 types of touch (tactile) sensation :**

**[A] Crude touch :** This is a **poorly-localized gross tactile sensation**.

- ***Receptors*** **:** Free nerve endings and hair end organs.
- ***Afferent nerves*** **:** *A-delta nerve fibres.*
- ***Central pathway*** **:** Ventral spinothalamic tract (page 22) and also partly in the gracile and cuneate tracts (page 24).
- ***Testing*** **:** By stroking the skin lightly with *a piece of cotton.*

**[B] Fine touch :** This includes **tactile localization and discrimination, stereognosis and the sense of texture of material** (see below).

- ***Receptors*** **:** Meissner's corpuscles and Merkel's disks.
- ***Afferent nerves*** **:** *A-beta nerve fibres.*
- ***Central pathway :*** The gracile and cuneate tracts (page 24).

### *Tactile Localization (topognosis)*

This is the ability to localize a touched skin point *while the eyes are closed.* It is ***tested*** by touching the skin lightly ***with a marker pencil*** (e.g. a charcoal pencil) and the subject is asked to touch the stimulated point by another pencil. The closer the 2 touch points to each other, the more accurate is the localization. This sensation is ***affected by the same factors that affect tactile discrimination*** (see next).

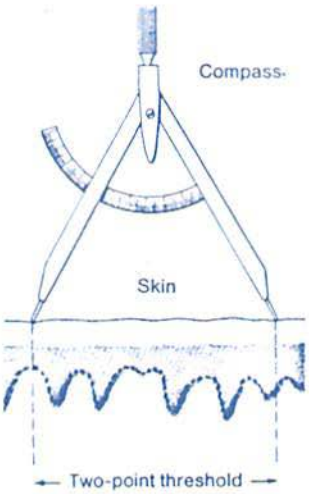



**Figure 6** : The Weber compass.

### Tactile Discrimination (T.D. or 2 point discrimination)

T.D. is the ability to distinguish 2 touch stimuli applied simultaneously to the skin as 2 separate points of touch. It is ***tested*** by *repeated* touching the skin with the 2 blunt points of a ***Weber compass*** (figure 6), starting by a closed compass, then increasing the distance between its limbs gradually till finding the ***2-point threshold*** (i.e. the minimal distance at which the 2 points are separately perceived). It is a highly educated cortical sensation that requires *excitation of 2 separate receptors and 2 separate areas in the sensory cortex*. Accordingly, it is more acute (i.e. the 2-point threshold is small) in areas that are ***rich in receptors and their representation in the sensory cortex is wide*** such as the lips and fingers (e.g. it is only about 3 mm in the fingers) while it is less acute (i.e. the 2-point threshold is large) in areas lacking these characteristics such as the shoulders, thighs and back (e.g. it is 65 mm or more in the back).

Other cutaneous sensations (e.g. pain and cold) can also be tested for localization and discrimination. However, the discrimination acuity is ***maximal in the fovea centralis*** (the central part of the eye's retina) which can distinguish very close light rays (refer to special senses).

### Stereognosis

This is the ability to recognize the nature of objects by handling them ***without using vision*** (from their shapes, sizes, weights, etc.). It is tested by giving the subject ***a familiar object*** (e.g. a key, pen or coin) and ***with closed eyes***, he is asked to recognize its nature. It is a *highly educated cortical sensation* that depends mainly on the tactile and pressure sensations as well as the *integrity of the high cortical sensory centres*.

***The sense of texture of material*** is *a type of stereognosis*. It is the sensation evoked by touching materials and is concerned with identification of their natures. It is tested by asking the subject to differntiate between various materials e.g. pieces of cloth whether made of silk, wool or cotton.

## (2) THE PRESSURE SENSATION

This sensation is perceived mainly by the ***Pacinian corpuscles and Ruffini's endings*** in the skin (for light pressure) and subcutaneous tissues (for deep pressure). It is tested by asking the subject to differentiate between various weights *without lifting them* (by placing them in his hand *while it is supported on a table*). Like touch, there are 2 types of pressure sensation : **fine** (which is transmitted by the gracile and cuneate tracts) and **crude** (which is also transmitted by the ventral spinothalamic tract).

***The muscle tension sensation*** is the sensation evoked by traction on the tendons and is concerned with *discrimination of weights during lifting them*. Its receptors are the Golgi tendon organs, and is transmitted by the gracile and cuneate tracts. It is tested by asking the subject to differentiate between various weights placed in *his unsupported hand*.

## (3) THE VIBRATION SENSE

This is the sense of buzzing (or thrill) that is felt when the *base of a vibrating tuning fork* is placed on the skin. During testing, it is better to place the tuning fork ***on a bony prominence*** e.g. the lower end of the radius bone or one of the malleoli, because ***bone magnifies the sense of vibration***. It is produced as a result of ***rhythmic pressure stimuli*** (which is interpreted as vibration) that stimulate ***2 types of rapidly adapting mechanorecepiors*** **(a)** ***Meissner's corpuscles***, which respond to vibrations up to *80 Hertz* **(b)** ***Pacinian corpuscles***, which respond to vibrations up to *800 Hertz*.

***Vibration is closely related to proprioception***. Both are transmitted by the ***gracile and cuneate tracts***, and both are impaired if these tracts degenerate e.g. in cases of pernicious anemia, tabes dorsalis and diabetes mellitus.

## (4) THE TICKLE AND ITCH SENSATIONS

Tickle is a pleasurable sensation (often causing laugh) that results from mild tactile stimulation of the skin, while itch is an annoying sensation that results from skin irritation by moving tactile stimuli (e.g. a crawling flea).

- ***Receptors*** : Rapidly-adapting free nerve endings.
- ***Afferent nerves*** : Unmyelinated type C nerve fibres.
- ***Central pathway*** : Ventral spinothalamic tract.

Itch often initiates the ***scratch reflex*** which helps removal of the stimulus, and also ***initiates pain signals*** which help suppression of this sensation.

## (5) THE PROPRIOCEPTIVE SENSATIONS

These sensations arise mainly from receptors in the deep structures (specially the muscles & joints) including the *muscle spindles and Golgi tendon organ-like receptors in addition to spray (Ruffini's) endings and Pacinian corpuscles in the synovia and ligaments of joints*. They are transmitted to the high centres by the gracile and cuneate tracts, and include 2 types :

### (a) Sense of position (static proprioception)

This is the ***conscious perception of the position of different parts of the***

***body with respect to each other***. It is tested by placing one of the patient's limbs, toes or fingers in an unusual position (with his *eyes closed*), and asking him to place the corresponding part in the other side at a similar position

### *(b) Sense of movement (dynamic proprioception)*

This is the ***sensation of movement of joints***. It is tested by moving one of the patient's fingers or toes *passively* (i.e. by the examiner) while *his eyes are closed,* and asking him to determine the start and end of the movement, as well as its rate and direction.

** Both types of proprioception are frequently called **kinesthetic sensations** (although only the dynamic type is kinetic).

# THE THERMORECEPTIVE SENSATIONS

## THE THERMORECEPTORS

There are 2 types of thermoreceptors **(1) Internal thermoreceptors** located in the anterior hypothalamus for detection of the head temperature **(2) External thermoreceptors :** These include cold and warmth receptors and also certain pain receptors that are stimulated only by extreme degrees of heat and cold (leading to the freezing cold and burning hot sensations). These receptors are located ***under the epithelial layer of the skin***, and there are ***discrete cold and warmth sensitive spots*** (with thermally-insensitive areas in between), and the ***cold spots are 4-10 times more in number***.

***THE WARMTH RECEPTORS*** are special ***free nerve endings*** that transmit warmth sensation along ***type C afferent nerve fibres*** and respond to temperatures from 30 ° C to over 45 °C. 2 receptors called **VR-1 and VRL-1** that respond to high noxious heat have also been described **(VR = Vanilloid Receptor)**.

***THE COLD RECEPTORS*** **:** The receptors for moderate cold are the **CMR-1** (= Cold and Menthol-sensitive receptors 1). They are free nerve endings that transmit cold sensation along both ***type C and type A-delta nerve fibres*** They respond to temperatures from 10 °C to 38 °C, and also **briskly** (i.e. for a very short time) at about 45 °C (figure 7).

As a result of the overlap of the temperature ranges that stimulate the various thermoreceptors, the discrimination of temperature depends on the degree of stimulation of each of these receptors. ***At temp. below 10 °C and above 45 °C, the thermosensitive pain receptors are brought into action***.

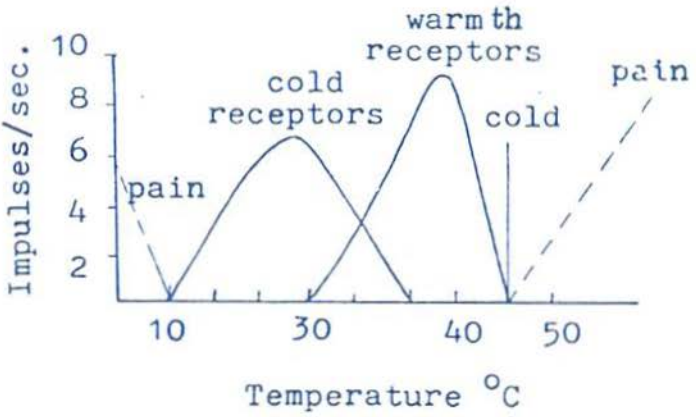



**Figure 7** : Frequency of discharge from thermoreceptors at different temp.

## Paradoxical cold sensation

When the skin is exposed to a temperature of about 45 °C, ***a sensation of cold is first felt*** then the hot sensation follows. This is called paradoxical cold sensation, and it is due to the ***brisk stimulation of the cold receptors at this temperature and also their greater number than the warmth receptors.***

## Stimulation of the thermoreceptors

Thermoreceptors are stimulated ***chemically by changes in their metabolic rates*** that are produced by the thermal stimuli. They detect the ***absolute temperature of the surrounding tissues*** (so the external thermoreceptors detect the subcutaneous tissue temperature). For this reason, cutaneous V.C. produces a cold sensation even in hot weather (e.g. in hemorrhage), while V.D. produces a warmth sensation even in cold weather (e.g. on drinking alcohol).

## Adaptation of the cutaneous thermoreceptors

These receptors are ***moderately adapting and the warmth receptors adapt more rapidly than the cold receptors*** (page 7).

## Central pathway of thermal sensations

The thermal signals are transmitted from one side of the body to the opposite higher centres with the ***pain signals by the lateral spinothalamic tract,*** (page 22) and terminate at the reticular formation and thalamus, and some fibres reach the cortical sensory areas. Recently, it was reported that the thermal sensations also project to the ipsilateral cortex.

## Testing thermal sensations

This is carried out by touching the skin with the fine end of a metal tube that is electrically heated in a controlled manner, and the subject *with closed eyes* is asked to differentiate between various temperatures. ***Test tubes containing hot and cold water at different temperatures can also be used.***

# PAIN SENSATION

Pain is a specific unpleasant sensation but ***its adequate stimulus is not specific*** (it is produced by any ***noxious stimulus*** whether mechanical, thermal or chemical). It has a ***protective function*** and is almost ***non-adapting***.

## Pain receptors (the noci ceptors)

These are ***specific naked free nerve endings***. They are more abundant in the skin than in the deep tissues and viscera, and they are stimulated mainly ***chemically*** by substances released from damaged tissues specially ***K , bradykinin and certain proteolytic enzymes***.

## Fast and slow pain

According to its site, pain may be classified into ***cutaneous, deep and visceral pain***. However, it is more frequently divided into **fast and slow types**, the differences between which are shown in the following table :

| | FAST PAIN | SLOW PAIN |
|---|---|---|
| **Site (origin)** | Almost only in the Skin | Skin, deep tissues and viscera |
| **Stimulus** | Mainly the mechanical and thermal noxious stimuli | Mechanical, thermal and chemical. noxious stimuli |
| **Quality** | Pricking (sharp or acute) | Burning (aching or chronic) |
| **Perception** | 0.1 second after stimulation | 1 second or more after stimulation |
| **Duration** | Less than one second | Many seconds to a few minutes |
| **Localization** | Well-localized | Diffuse (poorly-localized) |
| **Afferent nerve** | Type A-delta nerve fibres which release glutamate | Type C nerve fibres which release substance P |
| **Carrying tract** | Neospinothalamic tract | Paleospinothalamic tract |
| **Centre in CNS** | Cerebral cortex | Reticular formatiom & thalamus |
| **Initiated reflexes** | Somatic protective reflexes | Autonomic and somatic reflexes |
| **Summation** | Does not occur | Marked (becoming intolerable) |
| **Depression** | By pressure and hypoxia | By local anesthetic drugs |

## Central perception of pain sensation

Pain sensation is transmitted to the higher centres by the **lateral spinothalamic tract** (page 22) which consists of 2 parts **(1)** ***Paleospinothalamic tract*** : This transmits slow pain and terminates *subcortically* specially at the reticular formation and the intralaminar thalamic nuclei **(2)** ***Neospinothalamic tract*** : This transmits fast pain and its fibres relay first in the ventrobasal complex of the thalamus (specially the ventral postero-lateral nucleus) then finally terminate at the cortical somatic sensory areas (figure 8)

** Removal of the cortical somatic sensory areas does not abolish perception of both types of pain. This indicates that pain is generally perceived mainly ***at a subcortical level*** (in the thalamus, reticular formation and other lower centres). However, *the cortical centres are essential for interpretation of the quality and locality of fast pain.*

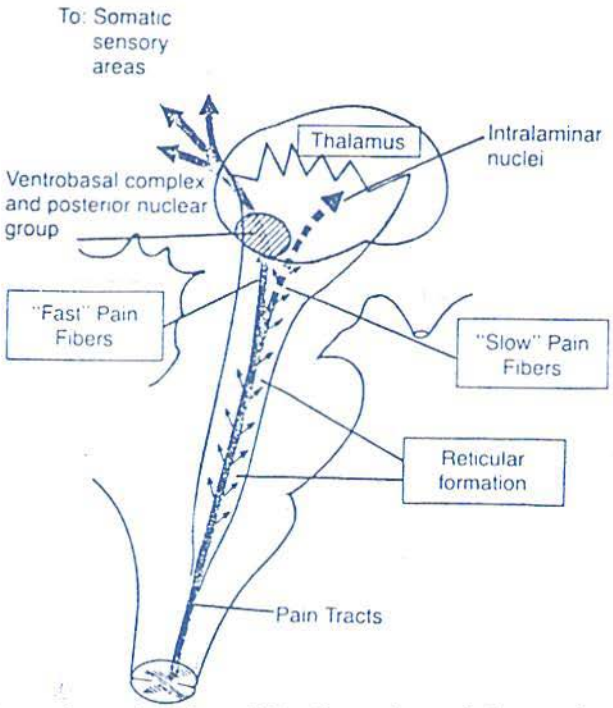



**Figure 8** : Central termination of the fast pain and slow pain nerve fibres.

## CUTANEOUS PAIN

This may be fast well-localized pricking pain or slow diffuse burning pain ***It* is *not referred***, and is *tested* by either pricking the skin with a pin or by heating the subject's skin and recording the temperature at which pain occurs (the normal pain threshold is 45 °C ). It is associated with **(1)** *Somatic effects*

(the withdrawal reflex) **(2)** *Autonomic effects* (usually symp.e.g V.C., tachycardia & rise of the arterial blood pressure, but parasymp. effects may occur if pain is severe e.g. V.D., bradycardia & hypotension) **(3)** *Hyperalgesia.*

## CUTANEOUS HYPERALGESIA

This is pathological hypersensitivity to pain and it is 2 types :

**(1) Primary hyperalgesia :** This occurs in the ***injured skin area*** and the surrounding area of flare (= V.D.), in which the ***pain threshold is lowered***, so that *non-noxious stimuli become painful* (= ***allodynia***). It is due to sensitization of the pain receptors by some substances released from the damaged tissues (histamine, kinins, $K^+$, certain enzymes or prostaglandins). It has also been suggested to be due to release of ***substance P*** from nerve endings as a result of a ***local axon reflex*** through ***antidromic impulses***, which sensitizes the pain nerve endings and also produces V.D. (i.e. flare) of the triple response (refer to circulation).

**(2) Secondary hyperalgesia :** This occurs in the ***healthy skin area*** beyond that of primary hyperalgesia (figure 9). In this area, the ***pain threshold is not lowered but it is normal or even elevated***. However, the pain aroused from such area is ***prolonged and exaggerated***. This is explained by the **convergence facilitation mechanism** which occurs as follows: The central neurons are facilitated by impulses discharged from the area of injury, and afferent fibres from the area of secondary hyperalgesia converge on the facilitated neurons, thus the pain aroused at this area becomes exaggerated.

** Secondary hyperalgesia can occur ***in absence of primary hyperalgesia*** if there is *central facilitation of sensory transmission*. This occurs in certain thalamic and spinal cord lesions, and also in some cases of visceral pain (in which the facilitatory impulses are discharged from the diseased viscus).

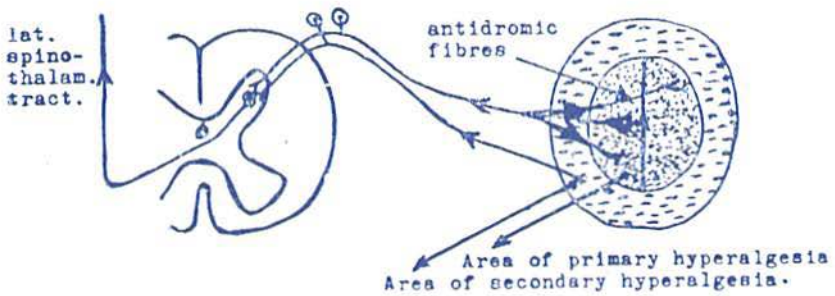



**Figure 9 :** Areas of primary and secondary cutaneous hyperalgesia.

## DEEP PAIN

This originates from muscles, joints, periosteum, etc, and is characterized by **(1)** It is slow pain that is conducted by *type C nerve fibres* **(2)** It is *diffuse*

# REFERRED (RADIATING) PAIN

This is pain that is felt away from its original site. It is most common with ***visceral pain*** (deep pain may be referred but *cutaneous pain is not referred*). The structure in which pain originates and the structure to which pain is referred ***develop from the same embryonic segment***, and frequently they are ***far away from each other*** due to ***migration of the various organs during devlopment***.

## EXAMPLES OF REFERRED PAIN

**(1)** Pain of an inflamed gall bladder is transmitted by afferent *phrenic nerve fibres* (due to *irritation of the diaphragm*) to the 3rd, 4th and 5th cervical spinal segments, so it is usually referred to the ***tip of the right shoulder***.

**(2)** ***Cardiac pain*** is usually referred to the ***left shoulder and inner side of the left arm*** (less frequently to the right shoulder or the epigasrium).

**(3)** Pain from ***the kidneys and ureters*** is referred to the ***testicular region***.

**(4)** ***Gastric pain*** is referred to the abdominal surface above the umbilicus.

**(5)** Pain of ***appendicitis is referred to the umbilical region***.

## MECHANISM OF REFERRED PAIN

The main cause of referred pain is ***convergence of peripheral and visceral pain fibres on the same spinothalamic neurons*** that project to the high centres in the brain (in addition to plasticity in the CNS). It is explained by the **conversion projection mechanism** (figure 11) as follows **:** Pain stimuli from a diseased viscus excite the spinothalamic neurons at a certain segment of the spinal cord, which then discharge to the brain. However, pain is projected to the somatic area from which the sensory nerves enter the same spinal segment. This is because normally the brain does not receive signals from the viscera, and it is even *unaware of their existence*.

** In addition to the referred pain, local pain is usually also felt at the site of the diseased viscus *due to involvement of the parietal peritoneum*. However,

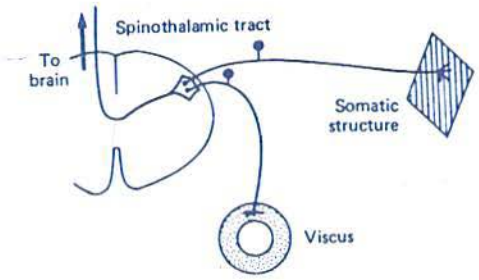


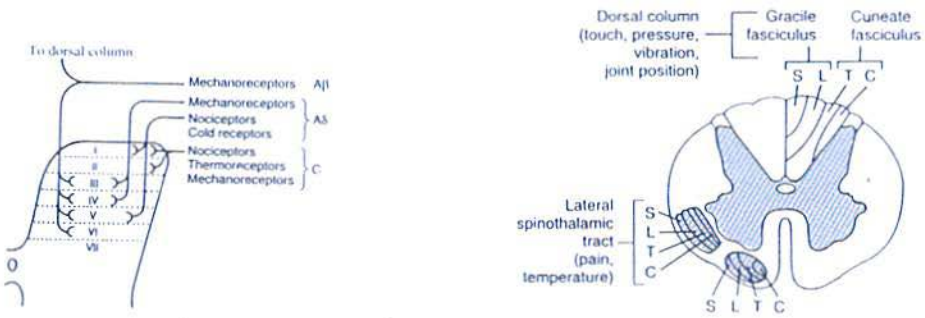

**Figure 11** : The convergence projection mechanism of referred pain.

sometimes, *referred pain only is evident* while the original visceral pain is absent (e.g. cardiac pain may be presented only by pain in the left arm).

## PROTOPATHIC AND EPICRITIC SENSATIONS

**(1) Protopathic (primitive) sensations :** These are *crude sensations* that are *perceived at a subcortical level* (*mainly at the* ***thalamus***). They include *gross movements of joints, crude pain and tactile sensations and extremes of temperature.* These sensations are *diffuse, require strong stimuli to be elicited and are exaggerated* (which is called ***thalamic hyperpathia***).

**(2) Epicritic (cortical) sensations** : These are *fine sensations* that are perceived at the ***sensory cortical areas*** e.g. *tactile localization and discrimination, stereognosis and fine grades of temperature.* These sensations are *well localized, not exaggerated and require no strong stimuli to be elicited.*




**(a)** **(b)**

**Figure 12 : (a)** The laminae at the dorsal horn of gray matter in the spinal cord **(b)** Arrangement of nerve fibres in the various ascending tracts.

## THE SENSORY PATHWAYS (ASCENDING TRACTS)

Each sensory pathway consists of **(1)** The afferent nerves which have their cell bodies in the *dorsal root ganglia and terminate at the various laminae of the dorsal horn of the gray matter* (figure 12 a) **(2)** Second order neurons *that start at the dorsal horns and form bundles called the ascending tracts,* which terminate at *subcortical centres*. Some sensations require *third order neurons* that transmit signals to centres in the cerebral cortex. Depending on position in the spinal cord, there are ***2 systems of the ascending tracts*** called ***the anterolateral and the dorsal column (or lemniscal) systems.***

# (A) THE ANTEROLATERAL SYSTEM

This system consists of the ***lateral and ventral spinothalamic tracts*** which consist mainly of types A delta and C nerve fibres. These tracts conduct signals from the ***opposite side*** (figure 13) and its fibres are arranged in the spinal cord *with the fibres from the sacral region are most superficial while those from the cervical region are most deep* (figure 12 b) .

## The ventral (anterior) spinothalamic tract

This tract transports ***crude touch & pressure as well as the itch & tickle sensations***. Its pathway consists of the following 3 neurons (figure 13) :

**First order neurons :** These are *A-delta and C afferent nerve fibres*. They enter the spinal cord *via the dorsal roots* and terminate in *the upper 4 laminae of the dorsal horn* (figure 12 a).specially at the ***main sensory nucleus***

**Second order neurons :** These constitute the tract. They start in the dorsal horn, *cross to the opposite side*, ascend in the anterior column of the spinal cord, and terminate in the ***ventro-basal thalamic complex***, specially at the ventral posterolateral nucleus (*VPLN*).

**Third order neurons :** These start in the thalamus, pass in the sensory (= thalamic) radiation in the ***posterior limb of the internal capsule*** and terminate at the cortical sensory areas in the ***postcentral gyrus*** (page 120).

## The lateral spinothalamic tract

This tract transmits ***pain, thermal and sexual sensations.*** It consists of 2 tracts, which are the following :

### *(1) The paleo-spinothalamic tract*

This tract transports ***slow pain and crude thermoreceptive sensations***. Its pathway consists of the following 2 neurons :

**First order neurons :** These are mainly *type C afferent nerve fibres*. They enter the spinal cord via the dorsal roots, ascend or descend a few segments in the ***Lissauer's tract*** then terminate in the *upper 3 laminae of the dorsal horn* specially at the ***substantia gelatinosa of Rolandi*** (= **SGR**) which occupies lamina II and part of lamina III.

**Second order neurons :** These constitute the tract, They start at the SGR, ***cross to the opposite side close to the central canal,*** ascend in the lateral column of the spinal cord and ***terminate at the following sites*** (where the transported sensations are perceived) : *The reticular formation, the periaqueductal gray area in the midbrain and the nonspecific thalamic nuclei* (specially the intralaminar nuclei) in addition to other subcortical centres.

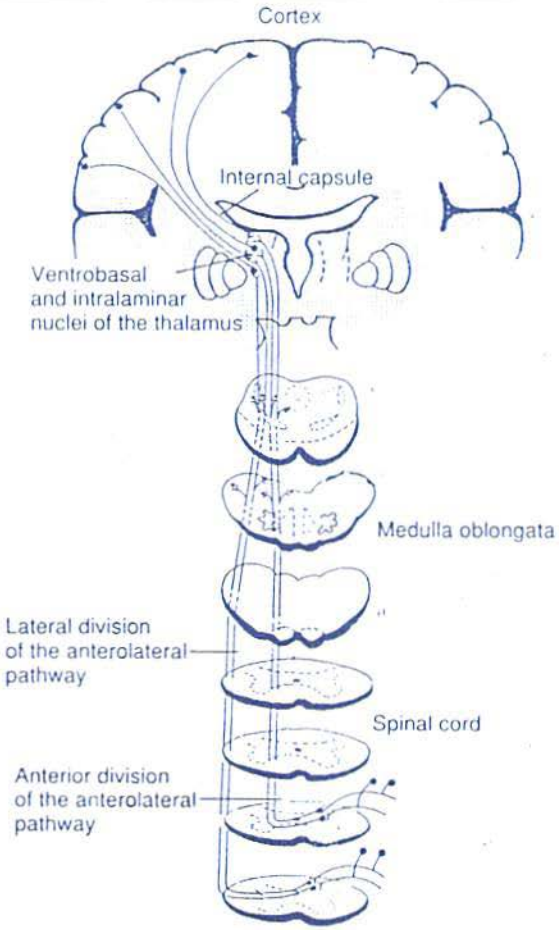



**Figure 13** : The anerolateral system of ascending tracts.

## *(2) The neo-spinothalamic tract*

This tract transports *fast pain and fine thermoreceptive sensations*. Its pathway consists of the following 3 neurons (figure 13) :

**First order neurons :** These are mainly *A-delta afferent nerve fibres*. They ascend or descend in the ***Lissauer's tract*** and finally terminate mainly at *laminae I and V of the dorsal horn* (figure 12 a).

**Second order neurons :** These constitute the tract. They start at the dorsal horns, *cross to the opposite side* and ascend in the lateral column of the spinal cord. In the brain stem, they combine with the paleospinothalamic and ventral spinothalamic tracts forming the **spinal lemniscus**, and together with the fibres of the ventral spinothalamic tract, these fibres finally terminate at the ***thalamic VPLN*** (figure 13).

**Third order neurons :** These are similar to those of the ventral spinothalamic tract (see above).

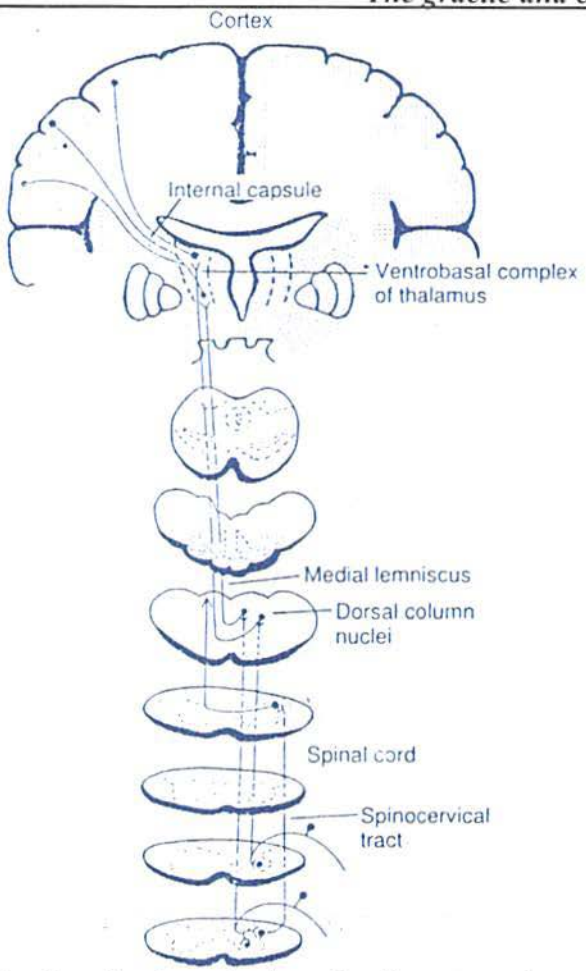



**Figure 14** : The dorsal column (or lemniscal) system of ascending tracts.

## (B) THE DORSAL COLUMN (or LEMNISCAL) SYSTEM

This system includes the ***gracile and cuneate tracts as well as the spinocervical tract*** (figure 14) and it consists mainly of ***types A-alpha and A-beta nerve fibres***. It transmits mainly ***fine sensations from the same side***.

### The gracile and cuneate tracts

These tracts transport **(1)** *Fine tactile sensations* (tactile localization and tactile discrimination) and also crude touch to some extent **(2)** *Stereognosis and texture of material sensation* **(3)** *Fine pressure and muscle tension sensations* **(4)** *The vibration sense* **(5)** The *proprioceptive and kinesthetic sensations* The pathways of these tracts consist of 3 neurons (figure 14) :

**First order neurons :** These are mostly type ***A-beta afferent nerve fibres***. They enter the spinal cord and divide into medial and lateral branches (figure 12 a). The medial branch turns upwards in the ***ipsilateral dorsal column*** and ascends ***without relay as the gracile and cuneate tracts*** till relaying at the ***gracile and cuneate nuclei in the medulla oblongata*** (figure 14).

** The *gracile tract carries sensations from the lower part of the body and lies medially in the dorsal column,* while the *cuneate tract carries sensations from the upper part of the body and lies laterally* (figure 12 b).

** The neurons that form the lateral branch synapse with neurons in laminae III, IV, V and VI of the dorsal horn (figure 12 a) from which some fibres *reenter the dorsal column* and some form the *spinocervical and spinocerebellar tracts*, while other fibres *elicit certain spinal reflexes.*

**Second order neurons :** These start at the gracile and cuneate nuclei in the medulla, cross in the ***sensory decussation*** to the opposite side (in which the fibres are called the ***internal arcuate fibres***), then they ascend as the **medial lemniscus,** and finally they terminate at the thalamus in the **VPLN**.

**Third order neurons :** These start at the thalamic VPLN and terminate at the cortical sensory areas in the postcentral gyrus.

** Some fibres called ***external arcuate fibres*** arise from the gracile and cuneate nuclei and enter the cerebellum via the ***inferior cerebellar peduncle***.

## The spinocervical tract

This is an *accessory pathway to the gracile and cuneate tracts*, but it ***conducts signals at a faster rate***. Its pathway consists of the following ***4 neurons*** :

**First order neurons :** These are the lateral branches from the A-beta afferent nerve fibres (see above).

**Second order neurons :** These form the tract. They start at the dorsal horns (mainly at lamina IV), ascend in the posterolateral column of the spinal cord and terminate at the ***lateral cervical nucleus of the same side*** (this nucleus is present in the upper 2 or 3 cervical segments).

**Third order neurons :** These start at the lateral cervical nucleus, cross to the opposite side and ascend along with the medial lemniscus to the thalamic VPLN (figure 14).

**Fourth order neurons :** These accompany the third order neurons of the gracile and cuneate tracts to the cortical sensory areas (see above)

## The spinocerebellar tracts

There are ***dorsal and ventral spinocerebellar tracts***. They carry ***subconscious proprioceptive signals to the cerebellum***, and their pathways consist of the following neurons (figure 15) :

**First order neurons :** These are the lateral branches from the A-beta afferent nerve fibres (see above).

**Second order neurons :** These form the tracts and they start at the ***Clarke's nucleus*** in lamina VI of the dorsal horns. The fibres of the ***dorsal tract ascend in the same side,*** enter the cerebellum through the *inferior cerebellar peduncle* and terminate in the vermis and intermediate zones. On the

# HEADACHE

This is a painful sensation at the head that is ***referred*** from other structures, and its causes are either ***intracranial or extracranial*** in origin.

## (A) Extracranial causes of headache

**(1)** Eye diseases e.g. glaucoma (due to rise of the intraocular pressure) and hypermetropia (due to persistent contraction of the ciliary muscle), which cause retro-orbital or peri-orbital headache.

**(2)** Teeth diseases associated with toothache.

**(3)** Sinusitis : The headache may be retro-orbital or in the forehead (in case of the frontal sinus) or in the face (in case of the maxillary sinus).

**(4)** Otitis media and otitis externa.

**(5)** Prolonged emotions and tension (psychogenic headache) partly due to spasm of the muscles attached to the scalp and occiput..

## (B) Intracranial causes of headache

The ***intracranial pain sensitive structures*** include **(a)** The venous sinuses **(b)** The blood vessels of the meninges specially *the middle meningeal artery* **(c)** The dura at the base of the brain **(d)** The tentorium cerebelli.

Irritation of the supra-tentorial pain-sensitive structures initiates signals that are transmitted by *the trigeminal nerve* (leading to frontal headache), while irritation of the infra-tentorial structures initiates signals that are transmitted by the *second cervical nerve* (leading to occipital headache).

***The brain tissue itself is insensitive***, and the commonest causes of intracranial headache include the following :

**(1)** ***Meningeal irritation*** by inflammation (= *meningitis*), tumours, alcohol and ***constipation*** by toxic products absorbed from the colon (*although some authors believe that constipation headache is due to rectal distention*).

**(2)** ***Lowering of CSF pressure*** : Removal of only about 20 ml of the CSF *by a lumbar puncture needle* causes severe headache specially in the upright position due to stretch and distortion of the various dural surfaces.

**(3)** ***Distention of the intracranial arteries*** e.g. in fevers, hypertension (which causes throbbing headache) and ***migraine***. The latter has a genetic tendency and it occurs more in females commonly following prolonged tension or emotions as follows : These conditions lead to reflex V.C. of the cerebral arteries, which results in ischemia, and this is followed by intense V.D. that causes the headache.

## The pain control analgesia system

This is a specific system that blocks pain transmission in the CNS (figure 20). Its **major constituents** include the following :

1. ***The periventricular nuclei*** in the hypothalamus.
2. ***The periaqueductal gray area*** **(PAG)** in the midbrain and upper pons.
3. ***The raphe magnus nucleus*** **(RMN)** in the lower pons and upper medulla.
4. ***A pain inhibitory complex*** **(PIC)** in the dorsal horns of the spinal cord.

**Certain cortical areas are also involved in the pain analgesia system** (specially the ***limbic association areas***), and the principal mediators in this system are the ***opioid peptides*** (see next).

## THE OPIOID PEPTIDES

These are ***morphine-like neurotransmitters that are naturally formed in the body*** (so they are called the ***own body's morphines***). Morphine (the active substance in opium) is a potent analgesic substance that produces its effect by binding to specific ***opiate receptors*** in the nervous system. Similarly, ***the opioid peptides are analgesic substances that act by binding to the opiate receptors***. The most important opioid peptides include the following :

**(1) Enkephalins :** These are 2 types, ***met-enkephalin*** and ***leu-enkephalin***. They are present in all parts of the analgesia system, and are degraded by 2 types of enkephalinase enzymes (A and B).

**(2) Endorphins :** These are several types, the commonest of which is ***beta-endorphin***. Their analgesic effect is more stronger than that of enkephalins.

**(3) Dynorphins :** Like endorphins, these are several types and their analgesic effect is stronger than that of enkephalins. However, they are normally present in minute amounts in the CNS.

## The opiate receptors

These are ***5 types***, and they are specially present in the ***analgesia system and on the central endings of the pain-conducting nerve fibres at the dorsal horns***. They can be stimulated both ***exogenously*** (by morphine) and ***endogenously*** (by the opioid peptides).

## Mechanism of pain control by the analgesia system

The analgesia system produces its effect by ***stimulating the PIC*** (see above). The PIC consists of *short enkephalinergic neurons that terminate on the central endings of the pain-conducting afferent nerves*. The released

enkephalin binds to the opiate receptors present on these nerve endings and ***prevents the release of the pain transmitters*** (=***presynaptic inhibition***)..Pain inhibition by this mechanism occurs through the following 2 pathways :

### (A) Peripheral pathway of pain inhibition (spinal inhibition)

Collaterals from the ***thick A-beta nerve fibres*** that transmit mechano-receptive sensations directly stimulate the PIC. This explains how pain is relieved by counter-irritants, mechanical stimuli (e.g. skin rubbing) and acupuncture (see below). Depending on such mechanism, severe pain can be relieved by *electrical stimulation of the thick sensory nerve fibres.*

### (B) Central pathway of pain inhibition (= supraspinal inhibition)

Excitation of the hypothalamic periventricular nuclei or certain cortical areas (see above) depresses pain as follows (figure 20) :

(1) The nerve fibres from the hypothalamic or the cortical areas release ***beta-endorphin*** which stimulates the PAG.

(2) ***The PAG projects enkephalinergic neurons*** (i.e. neurons which release enkephain) that stimulate the raphe magnus nucleus (RMN).

(3) ***The RMN projects serotonergic neurons*** (i.e. neurons which release serotonin) that block pain signals through ***activating the PIC***.

*It is also probable that the analgesia system can inhibit pain transmission at other points than the PIC, specially at the thalamic intralaminar nuclei and the reticular nuclei in the brain stem.*

## Stress analgesia

Certain stress conditions are associated with analgesia e.g. ***during the stress of a battle,*** severely-wounded soldiers frequently feel no pain till the battle is over. Such analgesia is produced by impulses discharged from the cerebral cortex and hypothalamus, which excite the ***central pathway of pain inhibition*** (see above).

## Acupuncture

Acupuncture relieves pain by ***both activating the peripheral pathway of pain inhibition as well as by psychogenic excitation of the central pathway***. Both mechanisms lead to stimulation of the PIC in the dorsal horns of the spinal cord, which blocks pain transmission by releasing enkephalins (see above). For this reason, the ***efficiency of acupuncture is increased by enkephalinase-inhibitor drugs and is decreased by morphine-antagonist drugs (e.g. naloxone) which block the opiate receptors***.