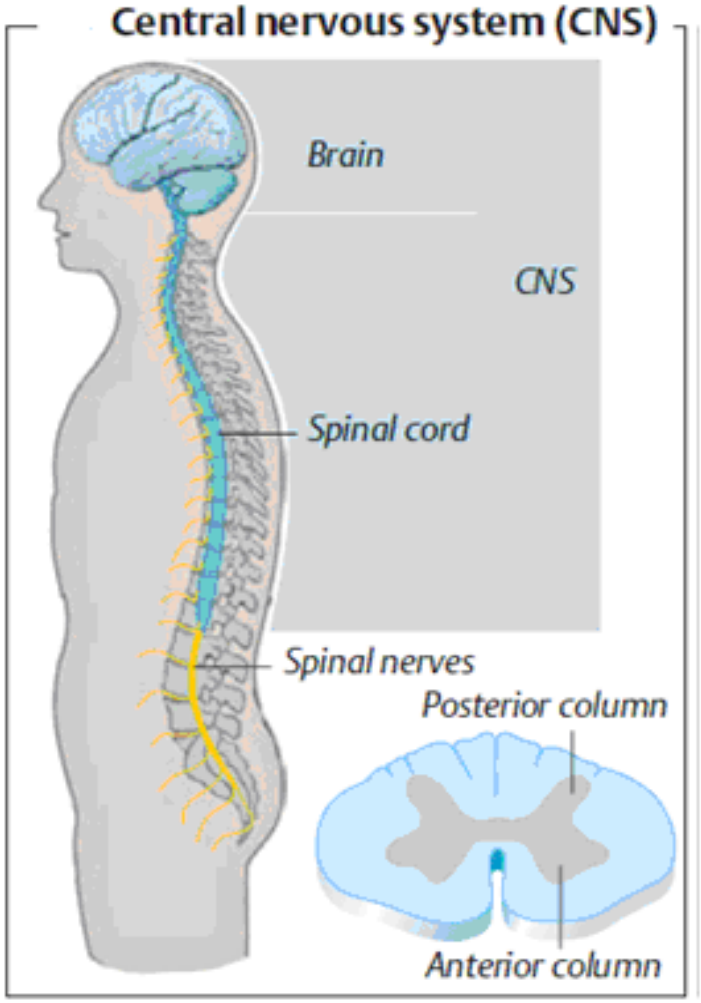
Organization of Nervous System

II) Functionally

Sensory N.S.	Motor N.S.	Intellectual N.S.
Detects **changes in internal and external** environments and **informs the CNS about them.**	**Initiates and controls the motor activities** of skeletal muscles, plain muscles, cardiac muscles **and even glands.**	Provides **basis for; consciousness,** memory, learning, thoughts, **emotions and behavior.**



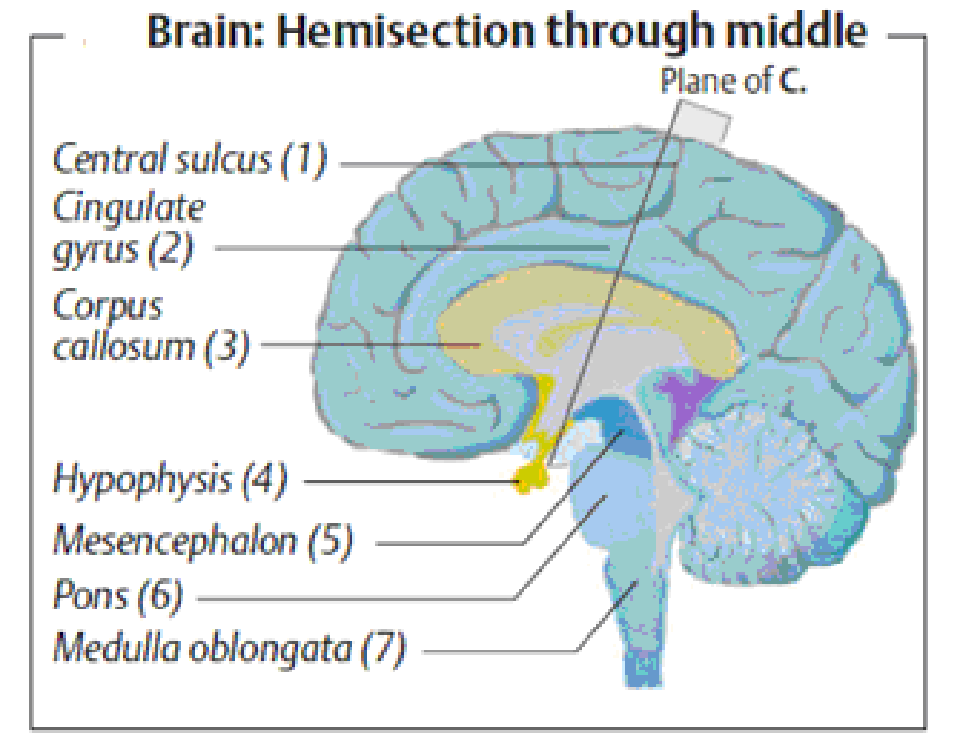


Fig. : Anatomy of the nervous system

I) Anatomically

Central Nervous System		Peripheral N.S.
A) Brain: **Prosencephalon:** 1. **Telencephalpon (two cerebral hemispheres**) 2. Diencephalon includes **thalamus, hypothalamus, subthalamus** **Mesencephalon:** midbrain **Rhombencephalon** Includes ▪ **cerebellum** ▪ **Pons** ▪ **Medulla oblongata**	**B) Spinal cord** Consists of: 31 segments ▪ **8 cervical** ▪ **12 thoracic** ▪ **5 lumbar** ▪ **5 sacral** ▪ **1 coccygeal**	▪ **12 pairs of cranial NS.** ▪ **31 pairs of spinal NS.**

The Sensory System

- It is **the division of the nervous system concerned** with the detection of the stimuli (as regard nature, locality and intensity) and **informs the specialized centers in CNS to adopt adequate responses.**

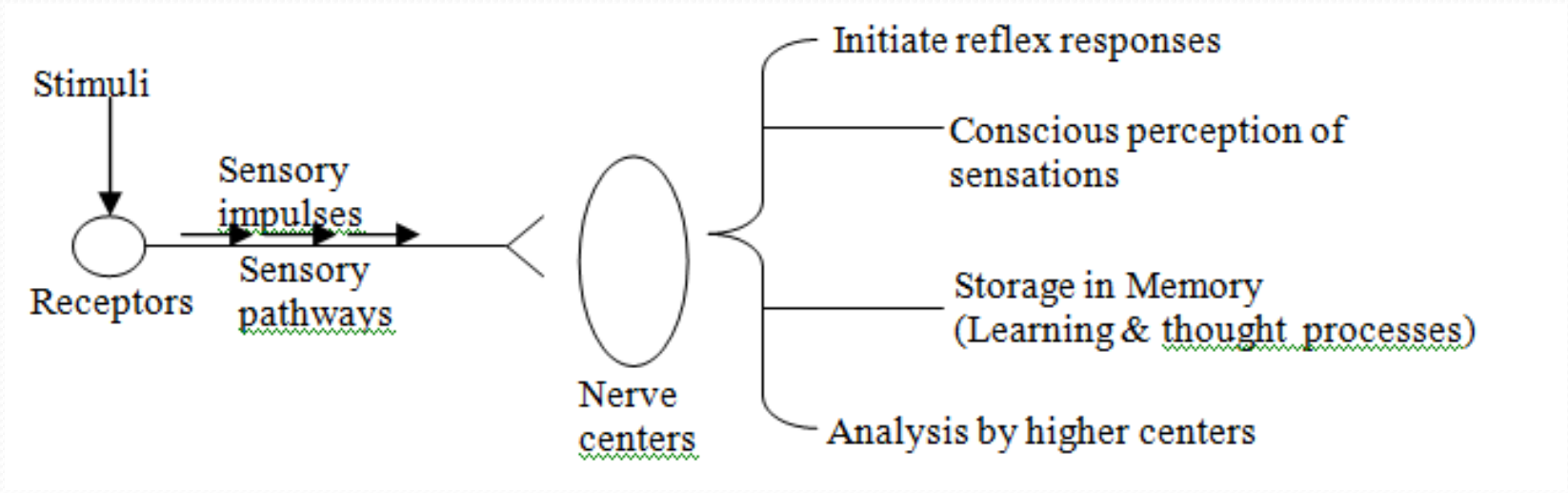


Fig.: Significance of reflex action

Components of the sensory nervous system:

a) Sensory receptors. Then,

b) **Afferent nerve fibers – that carry impulses to,**

c) Specific areas **in the brain & spinal cord** (sensory centers).

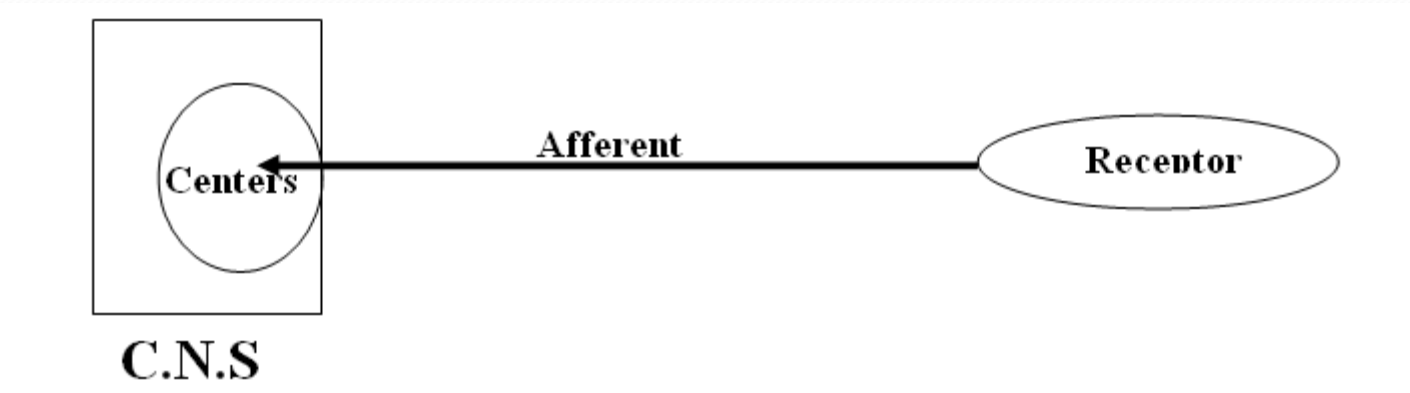


Fig. : Components of the sensory nervous system

Sensory Receptors

Definition:

- **Specialized microscopic structures** located at the peripheral terminations **of the afferent nerves.**

Functions of the receptors:

- They **detect the stimuli** and **convert t**hese stimuli into nerve impulses which are then conducted along the afferent **nerves to the sensory centers in central nervous** system i.e. the receptors act as "detectors and transducers".

Physiological classification of receptors:

1) According to the location:

They can be classified to (i) ***External receptors*** "on the **body surface mainly in skin**" or (ii) ***Internal receptors*** "in deeper structures & viscera".

2) According to the nature of the stimulus:

They are classified into 5 major classes:

i) Mechanoreceptors: They are stimulated **by the mechanical forms of energy. They include:**

- **Touch Receptors "in the skin".**
- Baroreceptors "in the aortic arch & carotid sinus" that detect the **changes in ABPr.**
- Proprioceptors "**in the muscles – tendons – ligaments & joints**" e.g. muscle spindle & golgi tendon organs.
- **Pressure receptors in the skin &** deeper structures e.g. pacinian corpuscles.
- Sound receptors.
- **Vestibular receptors** that detect the changes in the equilibrium of the body.
- **Stretch receptors as in alveoli, urinary bladder & right atrium.**

ii) Chemoreceptors: respond more easily to the chemical stimuli e.g.

- Taste & smell receptors.
- **Chemoreceptors in the aortic and carotid bodies.**
- Central chemoreceptors in the brain stem.
- **Hypothalamic glucoreceptors & osmoreceptors.**

iii) Thermal receptors:

- Respond to changes in temperature. **They include cold receptors** which respond to the drop of temperature & **warm receptors** which respond to **the increase in temperature.**

iv) Pain receptors:

- Respond **to the injurious or painful stimuli.**

v) Photoreceptors or electromagnetic receptors:

- **Respond to the electromagnetic waves of light. They** are found in the retina.

Properties of Receptors

1. **Specificity (Adequate stimulus).**
2. Excitability (Receptor potential).
3. **Rate of discharge from the receptors (detection of the stimulus intensity).**
4. Adaptation of the receptors.

A) Specificity

- The receptors show a high degree of specificity that is **"Each type of receptors is more sensitive to a particular type of stimuli called the adequate stimulus and its stimulation gives rise to a particular type of sensation called the modality of sensation whatever the way of stimulation".** This is called **Muller's law of specific nervous energies**

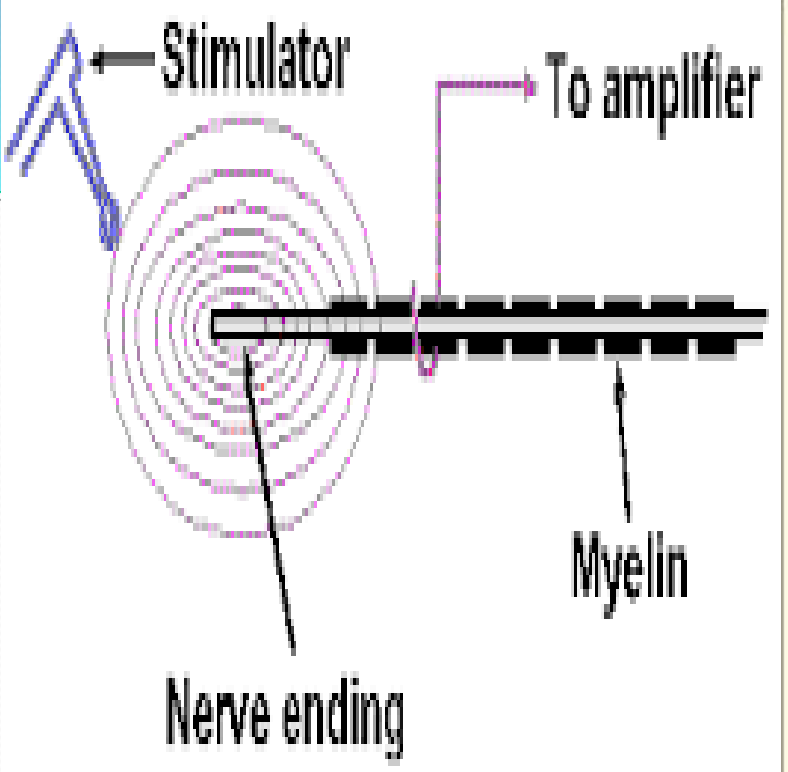
Example:

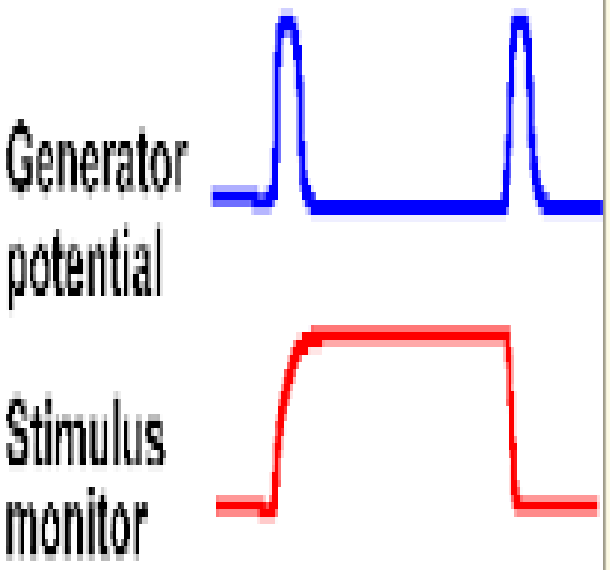
- **Retinal receptors** are highly sensitive to the light waves.
- **Auditory receptors** are highly sensitive to the sound waves…etc.

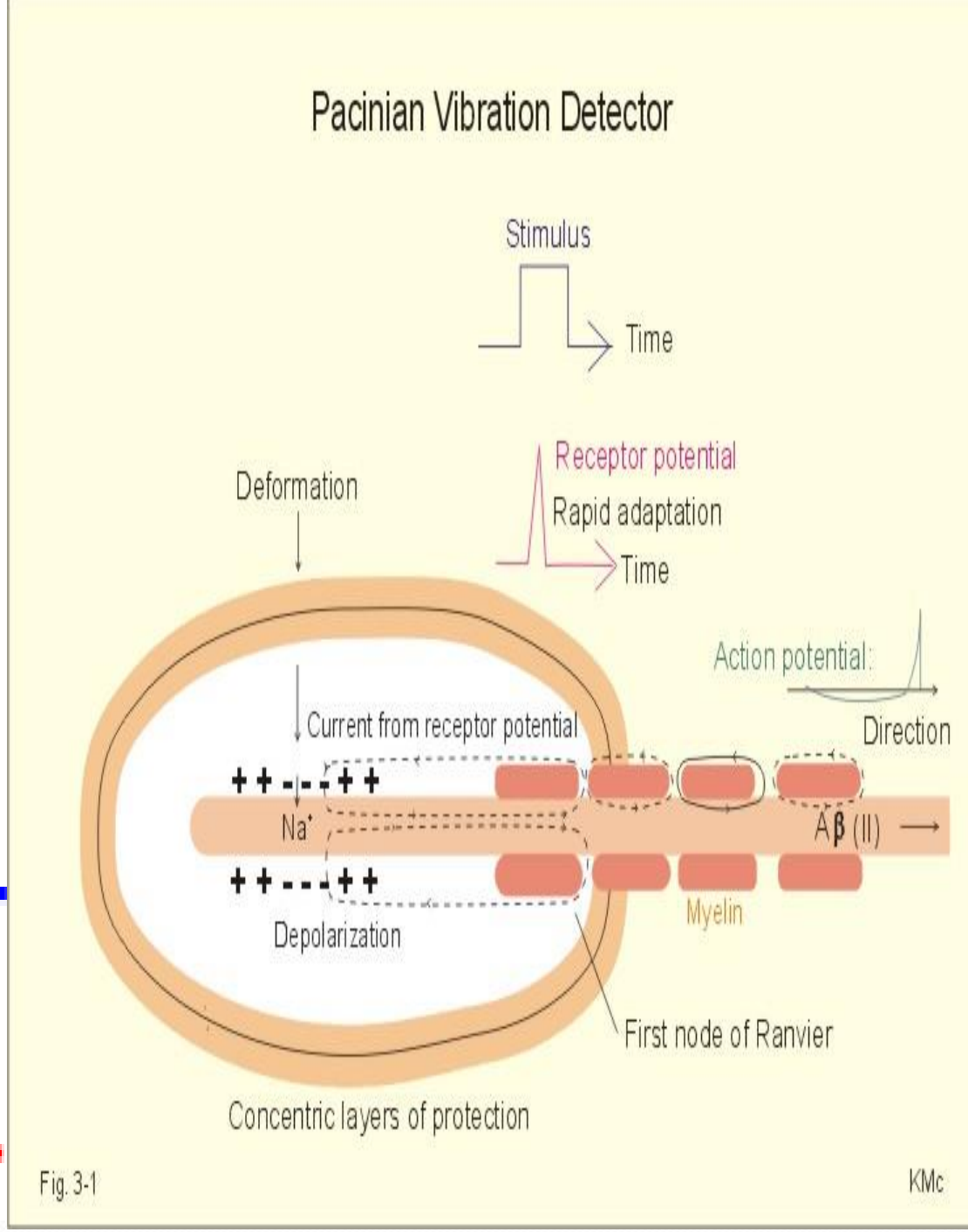
B) Excitability “Receptor Potential”

- The excitability of the receptors means**; the ability of the receptors to respond to their adequate stimuli.**
- ***Mechanism of stimulation of the receptors and generation of action potential in the nerve fibers:***

- Most of the body receptors on adequate stimulation show depolarization through the increased permeability of their membranes to Na^+. **Only the visual receptors (Rods & Cones) when stimulated adequately, they show hyperpolarization**.
- The potential changes that occur in the receptors on adequate stimulation called **"The Receptor Potential" and are usually in the form of depolarizations.**


Stimulator
To amplifier
Myelin
Nerve ending


Generator potential
Stimulus monitor


Pacinian Vibration Detector
Stimulus
Time
Deformation
Receptor potential
Rapid adaptation
Time
Action potential:
Direction
Current from receptor potential
Na+
Aβ (II)
Depolarization
Myelin
First node of Ranvier
Concentric layers of protection
Fig. 3-1
KMc

C) Rate of Discharge from Receptors

- The frequency of impulses discharged from the receptors through the afferent nerves **is directly proportionate with the logarithm intensity of the stimulus.**
- **This is called Weber- Fechner Law.**

$$R = \log S \times K$$

Where **R** = rate of discharge, **S** = strength of stimulus, **K** = constant.

D) Adaptation of Sensory Receptors

Definition:

- Means the decline **"decrease" in the rate of discharge from the receptors inspite of prolonged constant stimulation.**

- According to the speed of decline "Rate of adaptation" in the rate of discharge from receptors **we can classify the receptors into 2 main categories:**

A) Rapidly adapting receptors (Phasic Receptors):

- **This type of receptors start discharge at a high rate** then the discharge decreases rapidly and even stop within short period of time.

Example: they are mostly tactile as: **pacinian corpuscles, Meissner's corpuscle, hair receptors in the skin and some mechanoreceptors in the skin and joints.**

Significance of rapid adaptation:

- The RARs rapidly inform the central nervous system about the onset and the termination of stimulation and also, **on changing the intensity of the stimulus.**
- There is no need for continuous information of the central nervous system about the presence of the stimuli for example, **the contact of our clothes. Otherwise they would be distracting if they were**

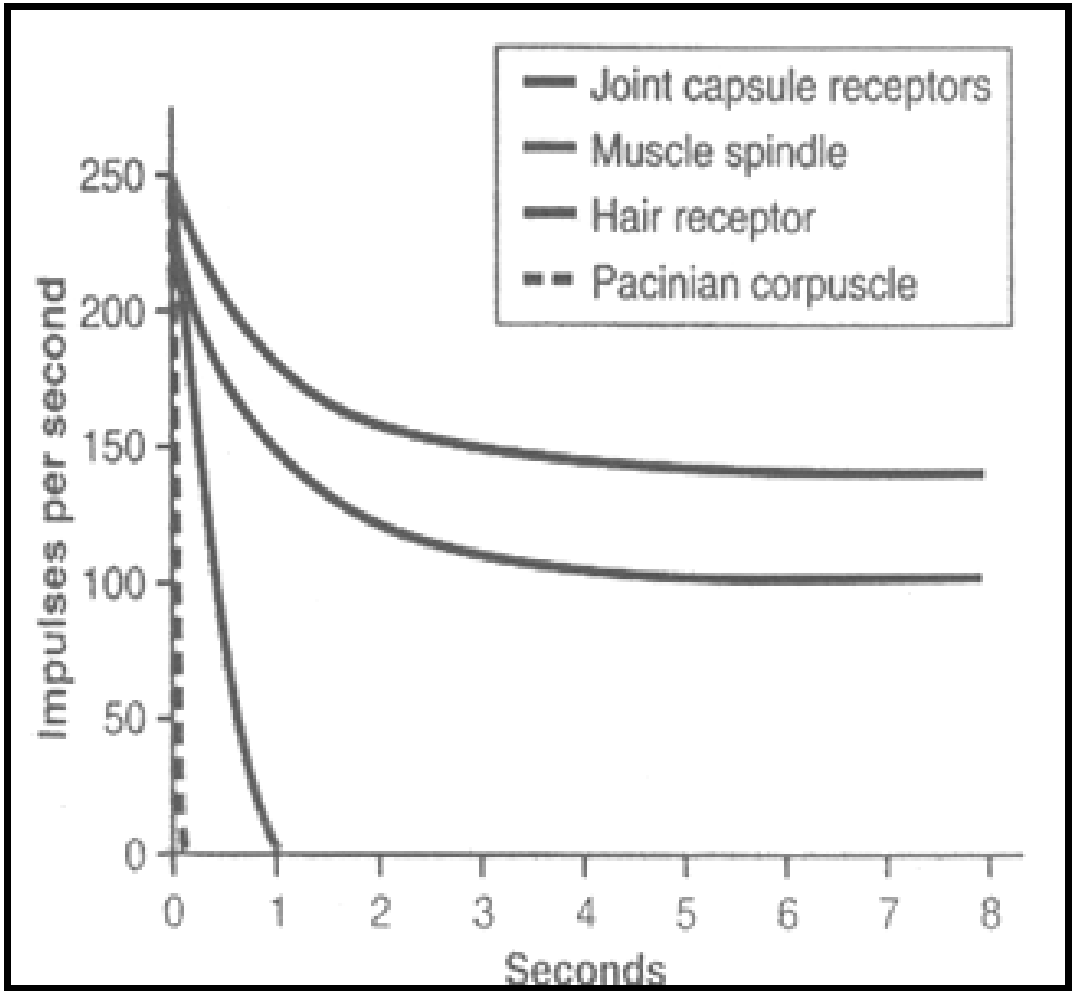


Fig. (7): Classification of receptors according to adaptation.

B) Slowly adapting receptors (tonic receptors)

These types of receptors continue discharge of impulses even though at a lower rate as long as the stimulus is applied.

Examples:

- Mechanoreceptors as muscle spindles & Golgi tendon organs.
- **Arterial baroreceptors**.
- Chemoreceptors of aortic & carotid bodies.
- **Pain receptors.**
- Cold receptors.

Significance:

They maintain sensory information and so subserve vital functions e.g.:

1. Continuous discharge from arterial baroreceptors plays a role in the regulation of the Bl. Pr. & Heart rate.
2. **Continuous discharge from the muscle spindles and joint receptors play a role in the maintenance of the body posture and equilibrium.**
3. Continuous discharge from; pain receptors continuously inform the C.N.S. **about the presence of injurious agents to initiate protective mechanisms.**

Coding of Sensory Information

Definition:

- It is the ability of higher centers of the brain to identify the:

a) **Intensity of the stimulus (intensity discrimination),**

b) Locality of stimulus (locality discrimination), and

c) **Type of the stimulus (modality discrimination).**

"That is to say converting a receptor stimulus to a recognizable sensation".

a) Modality Discrimination

- The type of the stimulus **can be identified from the type of receptor stimulated** where the receptors are specific according to the Muller's law.
- Also, each receptor **leads to specific afferent which travel along specific pathways till specific area in the sensory cortex**. This is called ***"labeled-line principle"***.

b) Intensity Discrimination

- The cerebral cortex **discriminate the intensity of the stimulus from the frequency of discharge** from the receptors along the afferent nerves.
- Increasing the intensity of the stimulus → **increases the number of impulses discharged to the cortex due to:**

i) Increasing the amplitude of the receptor potential → increase in the amplitude of the electrotonic current → **repetitive stimulation of the first node of Ranvier *"Weber- Fechner Law"*.**

ii) Increase in the number **of stimulated receptors in the receptive area "Recruitment of receptors".**

c) Locality Discrimination

- Ability of brain to determine accurately the site of stimulation. **It depends upon the topographic area of representation where** "Each part in the body surface is represented by a certain area in the sensory cortex" i.e. **area receives the sensory impulses from it.**
- The stimulation **of certain areas in the cortex leads to a sensation felt in the site or in the body surface** that is represented in this area "According to the law of projection.
-

Pain Sensation

Definition:

- Unpleasant ***sensory and emotional experience*** **associated with actual tissue damage.** The pain receptors are stimulated whenever the tissues are damaged. **In spite of being unpleasant, it is a protective sense, where it directs the person to get rid of the injurious agents.**

Pain receptors:

1. They are **free nerve endings**.

2. Distribution: They are **widely distributed** all over the body:

(i) **More abundant in the skin.**

(ii) Present in deeper structures (muscles – joints – periosteum).

(iii) **Viscera contains little number of pain receptors and even this few number is concentrated in serous membranes** e.g. peritoneum – pleura – pericardium & meninges of the brain. **Liver parenchyma, lung alveoli, brain & bone are devoid of pain receptors.**

3. They are **highly specific** i.e. respond only to tissue damage. The specificity may be to the nature of the injurious agents, so the pain receptors subtypes include:

(i) *Mechanical* pain receptors → respond only to the mechanical trauma e.g. heavy pressure.

(ii) *Chemical* pain receptors → respond to tissue damage produced by chemical agents e.g. conc. H_2SO_4 or high conc. of HCl in the esophagus and environmental irritants.

(iii) *Thermal pain receptors*→ respond to tissue damage produced by thermal stimuli (temperatures >45^oC & <10^oC).

(iv) *Polymodal* pain receptors: respond to the tissue damage produced by a wide variety of painful stimuli (combination of the above stimuli).

4. They are of **high threshold**: **the pain receptors needs sufficient degree of tissue damage to be stimulated**.

5. They are **slowly adapting receptors even non adapting receptors, and this is very important** because it directs the subject to get rid of the injurious agent.

6. Mechanism of pain receptors stimulation:

It may be due to the direct effect of the noxious stimuli, but it has been suggested that the pain is mostly chemically mediated how?

Tissue damage

↓

Release of chemical agents called pain producing compounds

which are of 2 types:

1. One type directly stimulating pain receptors and includes: **K^+, serotonin, histamine, bradykinins, acids and proteolytic enzymes.**	2. One type sensitizing the **receptor membrane by lowering its threshold e.g. substance- P and PGE.**

The stimulation of pain receptors become greater as the pain stimulus continues due to lowering of their threshold.

Classification of Pain

According to the site: 1. Cutaneous pain, 2. Deep pain, 3. Visceral pain.	According to the type 1) Acute (Epicritic - or fast). 2) Chronic (protopathic - dull aching & slow).

1) Cutaneous Pain

* Pain sensation results from the stimulation of pain receptors in the skin.

* Cutaneous pain may be: A- Pricking (fast) pain. B- Burning (slow) pain.

1. Pricking (fast)	2. Burning (slow)
* well localized * Felt **0.1 second after stimulation** * Fast, **where it is transmitted by rapidly conducting A-δ** nerve fibers "neospinothalamic tract". *** Perceived only at the level of the cerebral cortex**, so the C. cortex must be intact.	* Diffuse i.e. felt in a wide area. *** felt one second or more after painful stimulus**. * Slow, where it is transmitted by slowly conducting, **C-non-myelinated nerve fibers "paleospinothalamic tract"**. * **an be precieved at the level of thalamus,** cso still can be felt after the damage of the cerebral cortex.

Reactions to cutaneous pain:

1. **Somatic reactions:** **in the form of skeletal muscle contraction e.g. flexion withdrawal reflex.**
2. **Autonomic reactions:** usually **sympathetic "pressor" in nature especially when the pain is mild e.**g. ↑ heart rate, ↑ arterial blood pressure, pupillary dilatation & ↓ motility of GIT**. In cases of severe pain the reactions are mostly depressor in nature e.g.** ↓ heart rate, ↓ arterial blood pressure, pupillary constriction, nausea and vomiting.
3. **Emotional and psychic reactions:** e.g. **restlessness, anxiety & depression.**
4. **Cutaneous hyperalgesia.**

***Definition*: Increased pain sensibility in the skin area surrounding the primary site of injury**. There are 2 types of hyperalgesia.

a) Primary hyperalgesia (Allodynia):

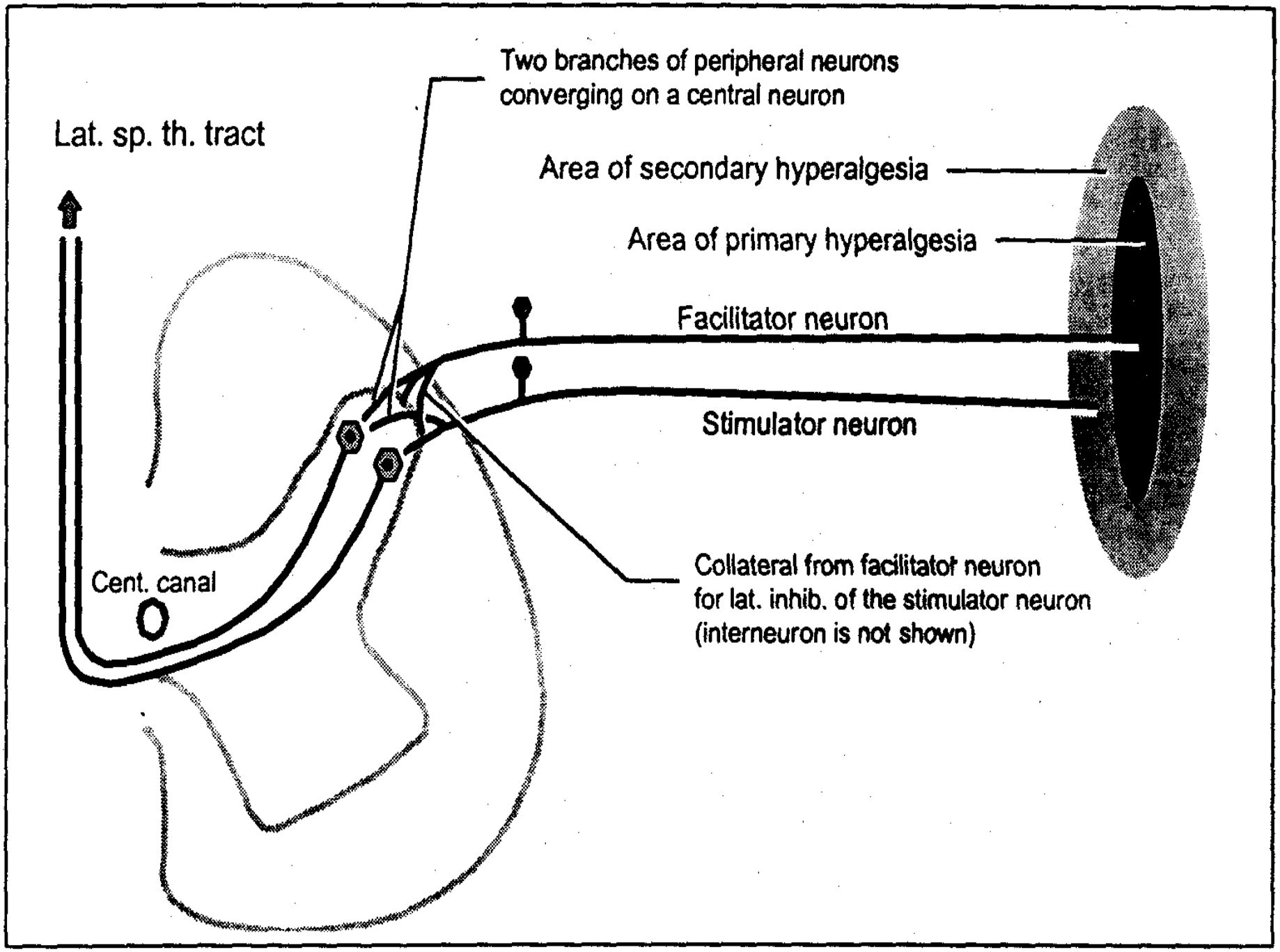
Definition:

- Means **increased pain sensibility in the area of flare to the extent that, the non painfull stimuli produces pain** (as touch produces pain sensation and warm shower produces pain after sunburn).

b) Secondary hyperalgesia:

Definition:

- Means increased pain sensibility **in the healthy skin area surrounding the area of flare to the extent that the mild painful stimuli** produce pain sensation. Its duration is shorter than the 1ry hyperalgesia.


Two branches of peripheral neurons converging on a central neuron
Lat. sp. th. tract
Area of secondary hyperalgesia
Area of primary hyperalgesia
Facilitator neuron
Stimulator neuron
Cent. canal
Collateral from facilitatot neuron for lat. inhib. of the stimulator neuron (interneuron is not shown)

2) Deep Pain

Results from **the stimulation of pain receptors present in the deeper structures** e.g. muscles – tendons – ligaments – joints & periosteum.

Causes of deep pain

i) **Injury or trauma to the muscles – bones – ligaments** in the form of tears, fractures, or avulsions.

ii) **Inflammation: e.g. arthritis – myositis – osteomyelitis.**

iii) Ischaemia → **marked ↓↓ in blood supply leads to pain called ischaemic pain.**

Characters of deep pain

1. **Poorly localized, and usually it is of dull aching or burning nature.**
2. Transmitted mainly by the C-non myelinated nerve fibers.
3. Usually associated **with reflex spasm of the nearby or the surrounding muscles**. This limits or immobilizes the injured part and so minimizes the tissue damage.
4. Usually **associated with parasympathetic manifestations e.g. Nausea, vomiting, ↓ H.R. & ↓ blood pressure**.
5. May be associated **with hyperalgesia in the skin area overlying the site of injury.**

Ischaemic Pain

Definition

This type of pain results **from the decrease in the blood supply or flow to an active organ** e.g. skeletal muscles, smooth muscles & cardiac muscles.

Causes of ischaemia:

The ischaemia to an active organ may result from:

- **Severe arteriosclerosis or severe spasm.**
- Partial obstruction by thrombosis.
- **Compression from outside as in muscular spasm "Cramps"**.

Mechanism of ischaemic pain:

- During rest **with normal blood supply the exercising muscles produce certain substances** e.g. K^+ and or lactic acid which if accumulated will stimulate pain receptors, but with normal blood supply they are washed rapidly.
- **In cases of ischaemia, these substances will accumulate and stimulate the pain receptors.**

Examples:

A) Cardiac pain (Anginal pain):

It results from ↓↓ bloody supply to the cardiac muscles.

B) Muscle spasm (cramps)

3) Visceral Pain

* Pain sensation **results from the stimulation of pain receptors in the viscera.**

* Sharp cut in the viscera **does not produce pain but diffuse stimulation of pain receptors causes pain.**

Causes:

1. **Spasm of the smooth muscles** in the wall of the viscus "Colic".

2. **Overdistension of hollow organs** e.g.: Stomach, uterus & urinary bladder. The pain receptors in both conditions are stimulated by ischaemia **resulting from compression of the blood vessels & may be mechanically by the stimuli.**

3. **Trauma.**
4. Inflammation.
5. Chemical causes **as irritation by HCl & bile pigments.**
6. **Thrombosis as in superior mesenteric artery.**

Characters of the visceral pain

1. **It may be, colicky pain, or burning pain, or dull aching pain and poorly localized.**

2. Usually **associated with somatic reactions in the form of contraction of the overlying muscles**.

3. It is usually associated with parasympathetic manifestations or reactions **as ↓ in H.R, ↓ in A.B.P., pupillary constriction; nausea & vomiting.**

5. It is usually referred.

Referred Pain

Definition:

Pain from the viscera **is frequently poorly localized and usually not felt in the affected viscera** themselves, but in the skin area **or somatic tissue supplied by the same spinal dorsal roots** which innervate the diseased viscus. Such pain is known as **Referred Pain.**

i.e. Pain **aroused in a viscus and felt in a related somatic structure (both the viscus and somatic structure originated from the same embryonic segment or dermatome**).

Examples of Referred pain:

1. **Appendicitis pain:** always starts and **felt in the skin area surrounding the umbilicus later on localized to the right iliac fossa** when the peritoneal covering is involved.
2. **Cardiac pain:** usually felt in or referred to, **the retrosternal region, base of the left side of the neck, inner side of the arm, fore-arm,** or even in little finger. It may be felt in the epigastric region.
3. **Gall bladder pain:** usually referred **to the epigatric region, may be the right shoulder & neck.**
4. **Renal and ureteric pain:** usually **referred to back behind the kidney and it may be referred to the anterior abdominal** wall near the inguinal region.
5. **Gastric and esophageal pain:**

   * Pain from the esophagus is usually felt **in lower neck and midline chest region.**

   * Gastric pain is usually referred to the epigastrium in the abdominal wall.

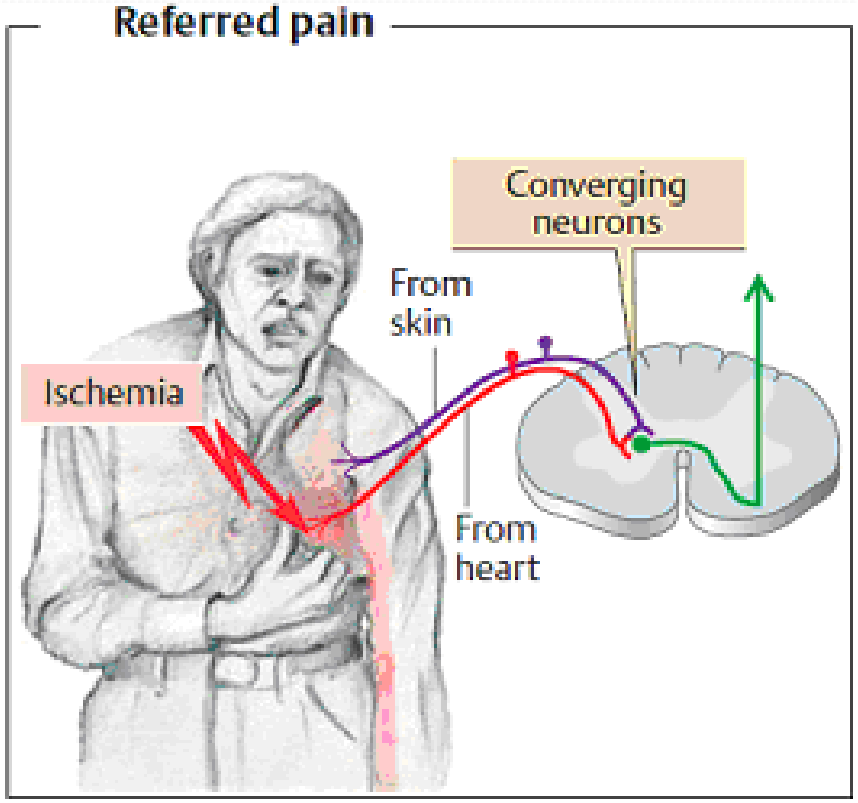


Fig. (14): Referred pain.

Mechanism of referred pain:

It can be explained on the basis of **convergence-projection theory**.

* The pain carrying fibers **from the diseased viscus & from the related somatic structures converge on the same SGR cells** "Dorsal horn cells" and ascend to the same cortical neurons.

* Since **the cortical sensory areas accustomed to receive pain impulses from the somatic structure**. So when the viscus is injured or diseased the impulses **from it perceived by the cortex as if coming from the somatic structure** so, the pain sensation is projected to or felt in (referred) to the somatic structure