

The Physiology of Pain

Basic Neuroscience

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The behaviour of humans is a result of the actions of nerves. Nerves form the basis of Thoughts, sensations and actions both reflex and considered.

Nerves can affect behaviour in many ways

pain

pleasure

sex

anxiety

love

fear

hunger

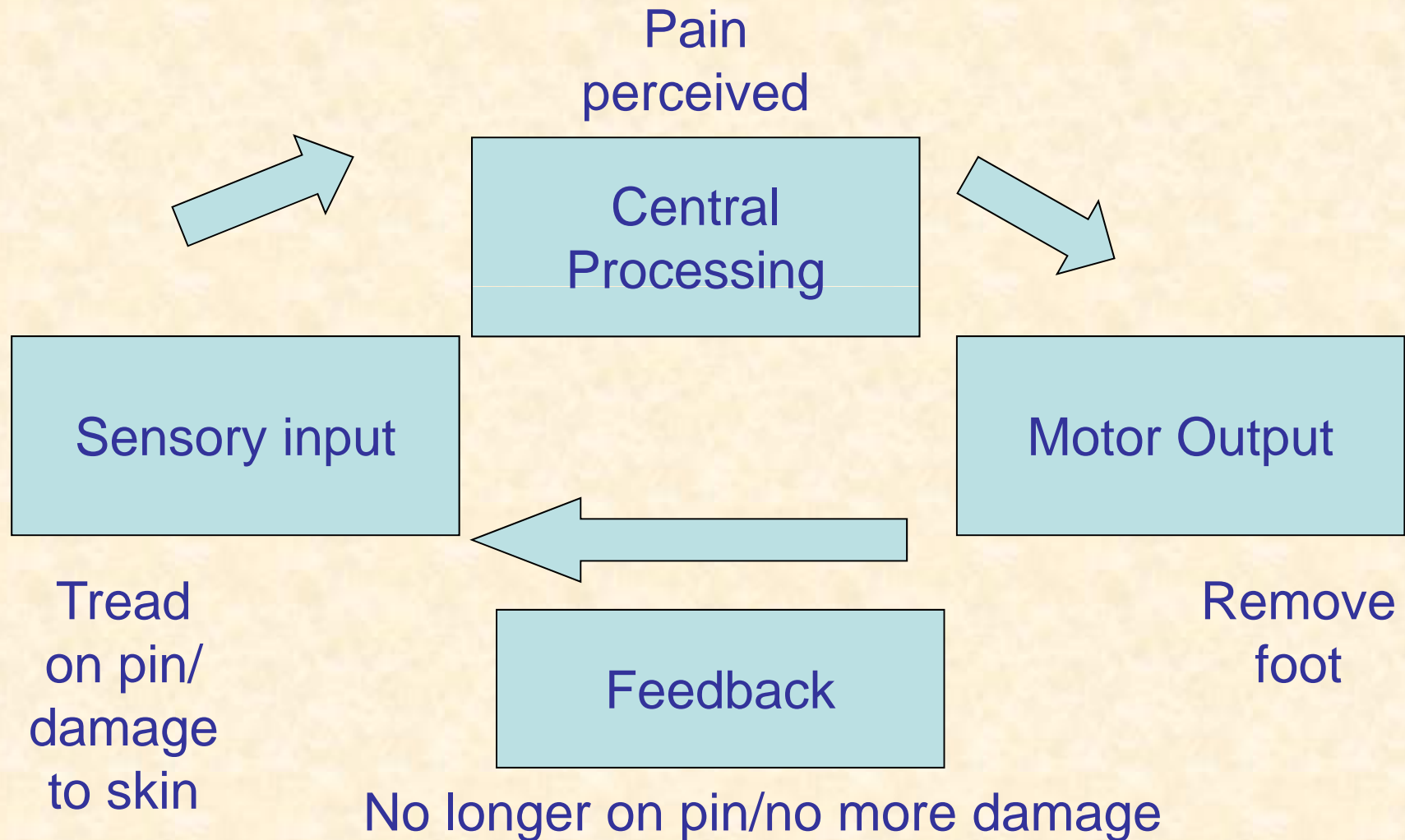
anger

memory

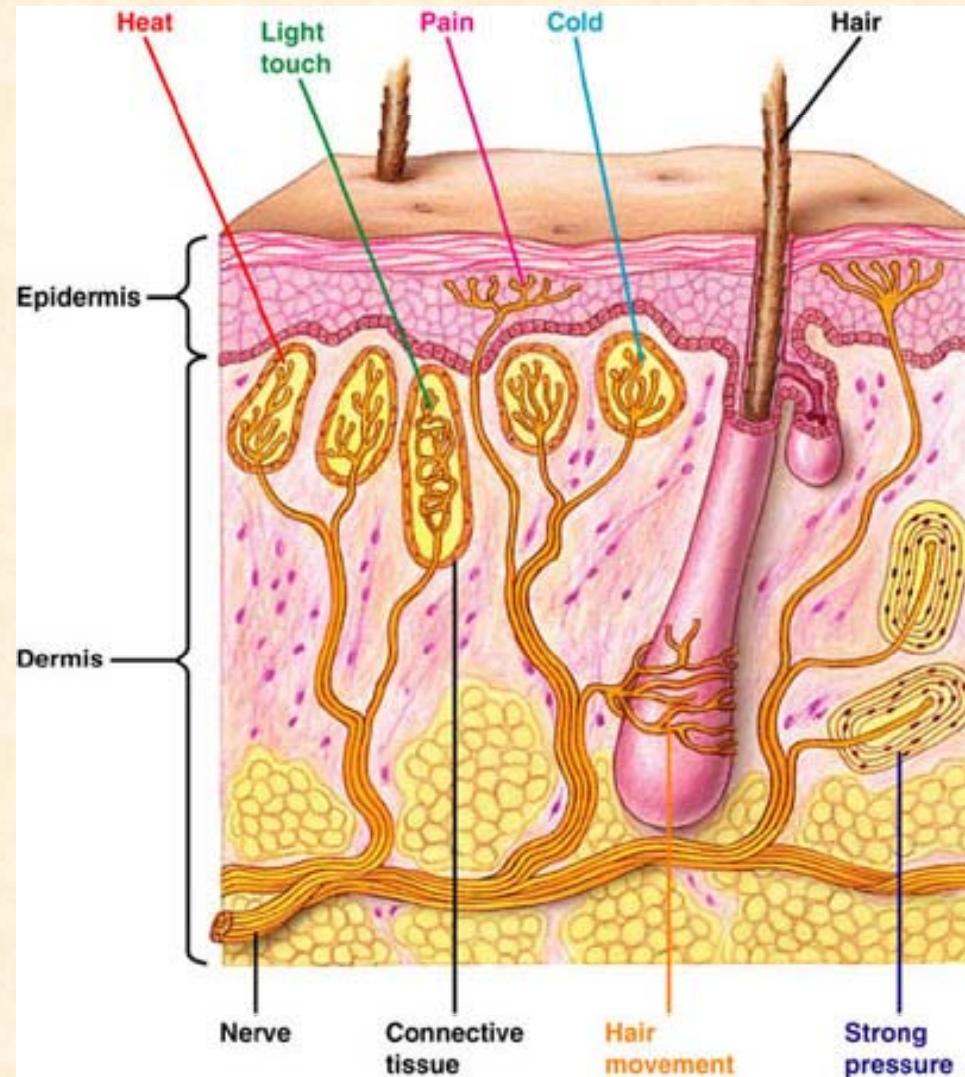
This lecture explains the basic structure and function of nerves.

How do nerves produce behaviour?

It is all based on a simple neuronal circuit or reflex arc.



Sensory reception



<http://fig.cox.miami.edu/~cmallery/150/neuro/c7.49.3.skin.jpg>

Sensory (afferent) nerves receive information and convert it into a form the nervous system understands - electrical energy.

Sensory receptors are either specialised nerve endings or free nerve endings (pain receptors).

Smell

Blood pressure

Muscle length

Muscle tension

Sound

Balance

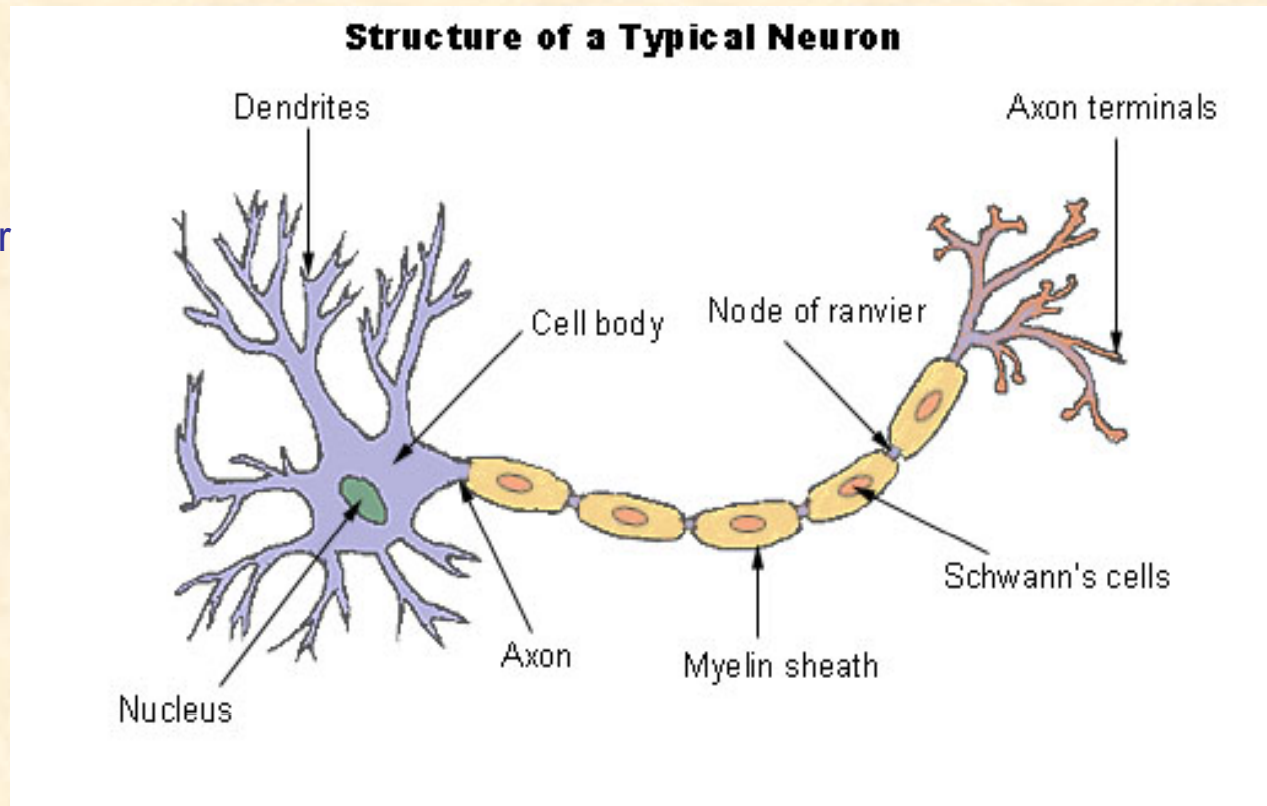
Light

Taste

Chemical composition of the blood

The basic unit of the nervous system – The nerve

Receives information from receptor in tissue or from other nerves



Sends on information to other nerves or muscles

How nerves send information

Information detected by sense organs is transmitted along nerves in electrical pulses.

The electricity is generated by changes in the concentrations of positive and negative ions inside and outside the cell membrane.

Under normal resting conditions the inside of the cell membrane has a negative charge and the outside has a positive charge.

The action potential

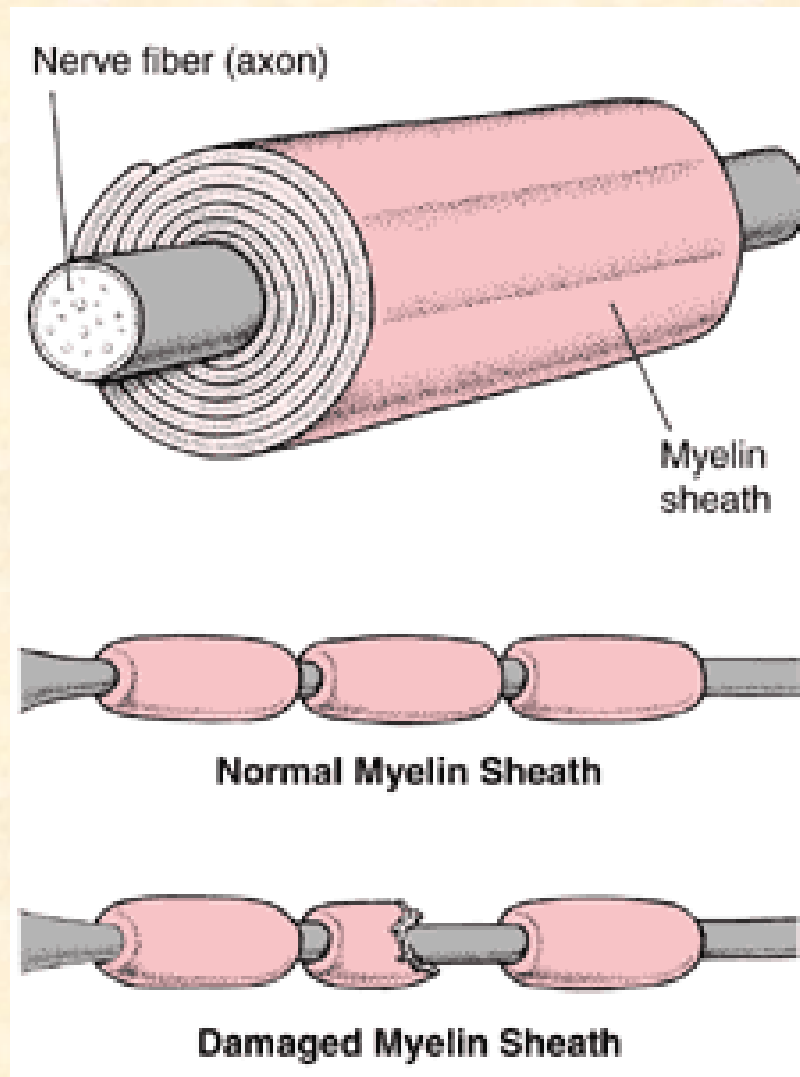
Altering the permeability of the membrane to ions changes the membrane potential and electricity can be transmitted along the nerve axon.

When the inside of the membrane becomes more positive an action potential is produced.

Saltatory conduction

Saltatory conduction is possible due to the myelination of nerves

Myelin is produced by specialised cells, it is a fatty substance that acts as an electrical insulator and allows fast transmission of the electrical signal along the axon.



<http://www.blackwellpublishing.com/matthews/actionp.html>

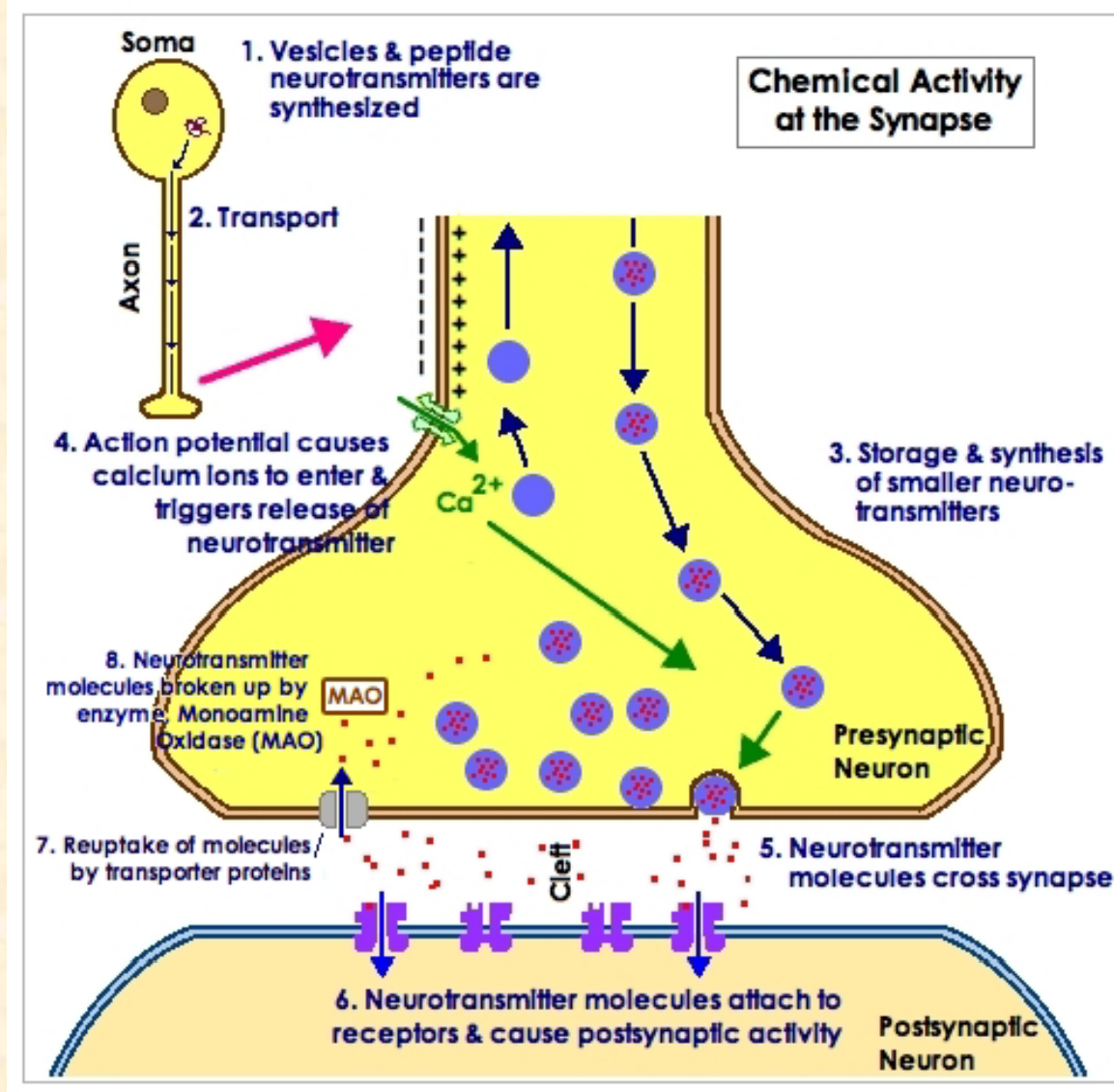
Synapses

Why do we need synapses?

A nerve action potential can travel in either direction along a nerve axon.

Conduction can be bi-directional.

If two action potentials were travelling towards each other they would collide and cancel each other out.



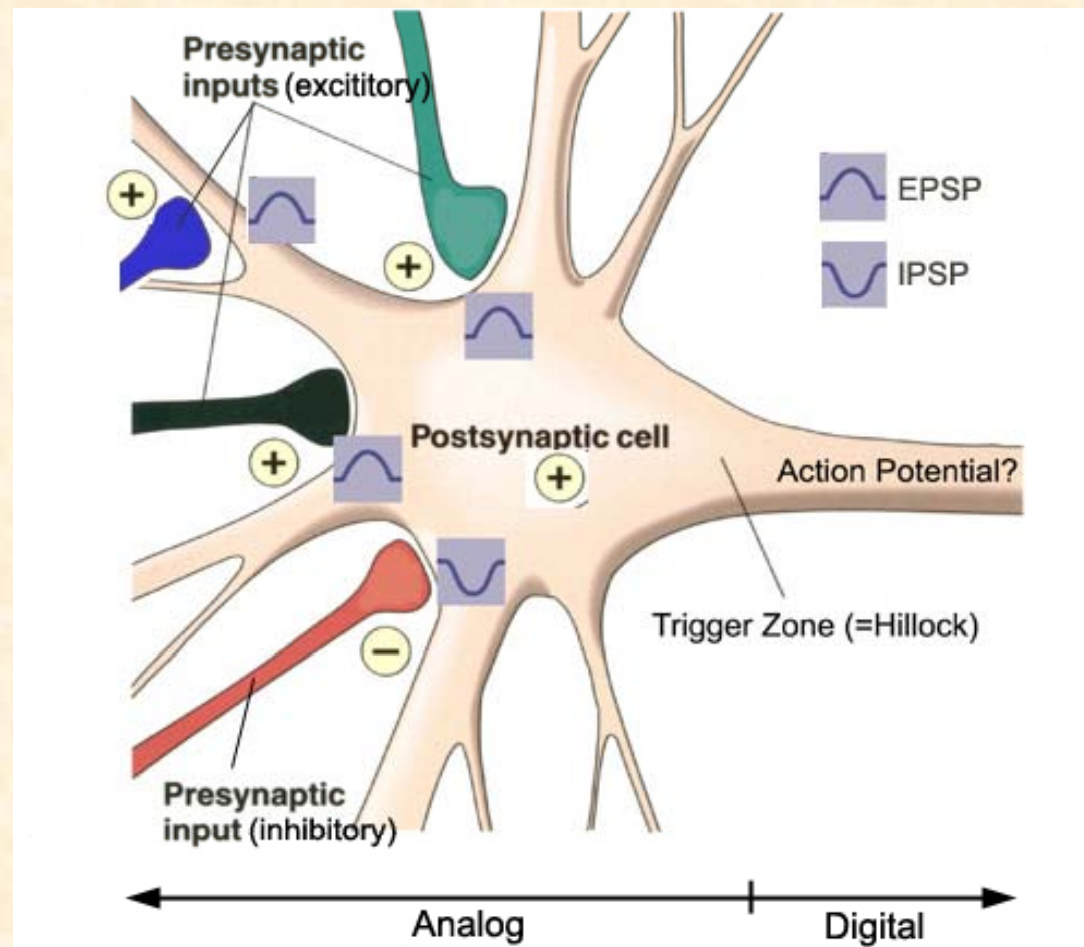


This is a good animation of the synapse

<http://bcs.whfreeman.com/thelifewire/content/chp44/4402003.html>

Summation

A postsynaptic cell can receive many inputs, both excitatory and inhibitory, onto the dendrites, cell body and axon.



Activation of a single excitatory synapse is not sufficient to produce an action potential in the postsynaptic cell.

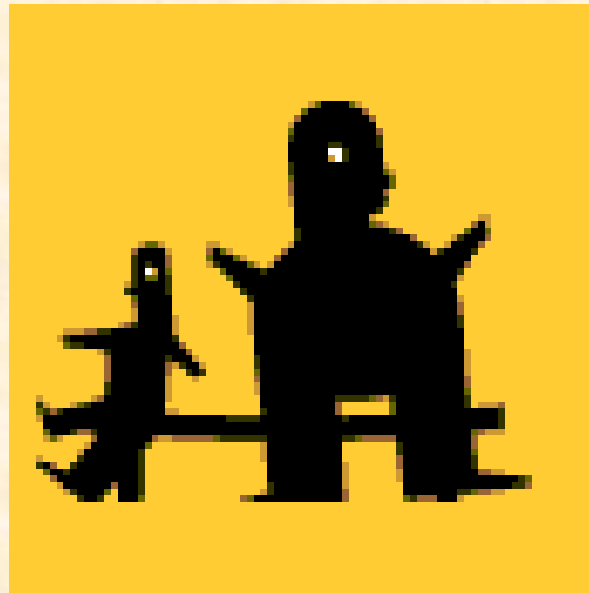
For generation of a postsynaptic action potential multiple inputs are required.

This is known as summation.

This can either be by repetitive inputs from a single cell
Temporal summation

Or many inputs simultaneously from different cells
Spatial summation

Therefore neuronal activity is dependant upon the **balance** of the active excitatory and inhibitory inputs



A few of useful websites



<http://people.eku.edu/ritchisong/RITCHISO//301notes2.htm>

http://wps.aw.com/bc_moyes_animalphys_1/0,10309,2332737-,00.html

<http://faculty.washington.edu/chudler/introb.html#hrh>

<http://science.nhmccd.edu/biol/ap1int.htm#nervous>

Cell Signalling

All processes within the body require cell to cell communication

Fighting infections

Digestion

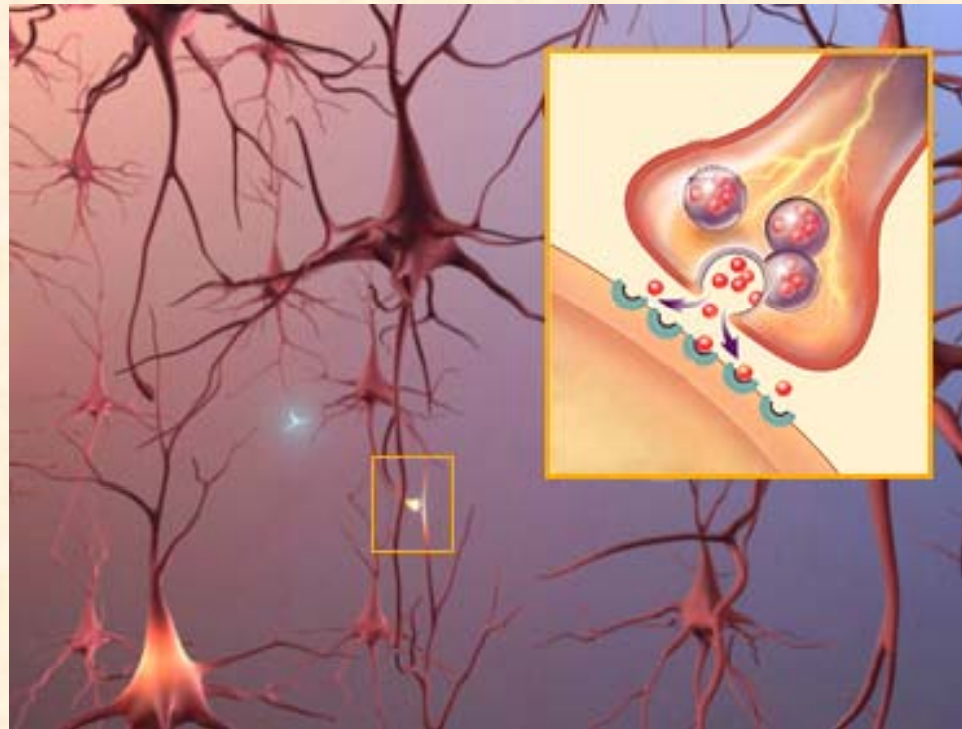
Muscle contraction

Memory

There are two main types of cellular communication

Electrical and Chemical

Nerves utilise both electrical and chemical signalling



<http://www.alz.org/brain/images/06a.jpg>

Complexity of Cell Signalling

Diversity – Same signal can have different effects on different cells under different conditions

Integration – interaction of different physiological systems

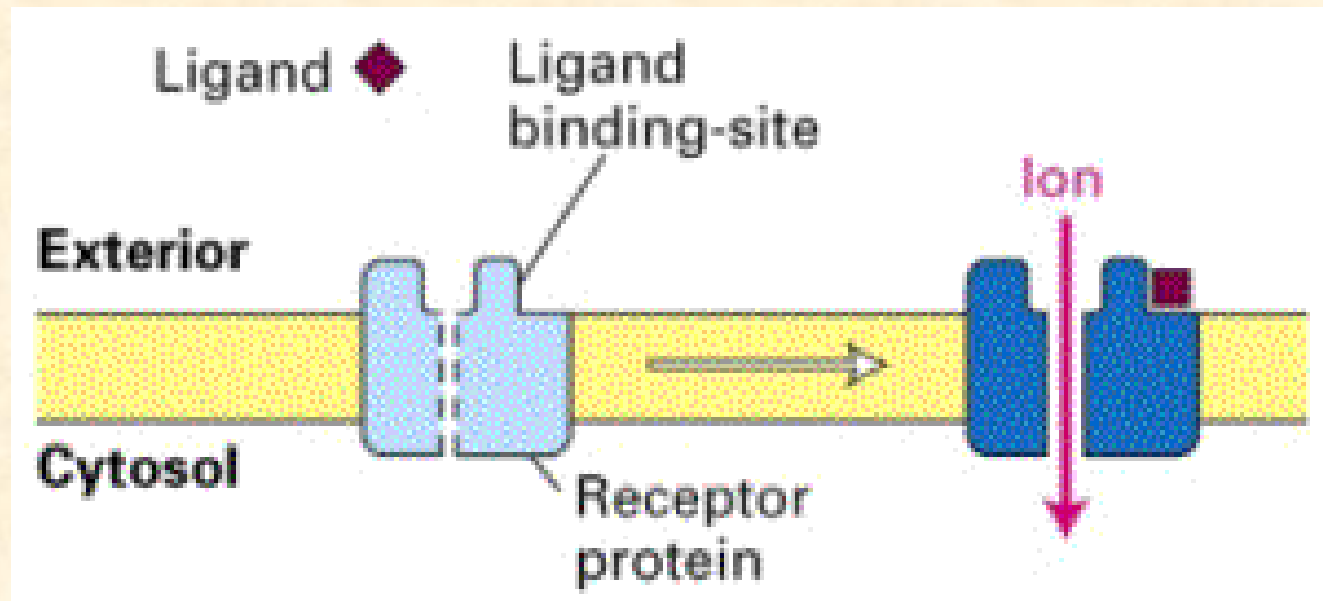
Dynamic – systems can change and respond to different conditions

Receptors

In order for a ligand/neurotransmitter to exert its effect it needs to bind with a receptor.

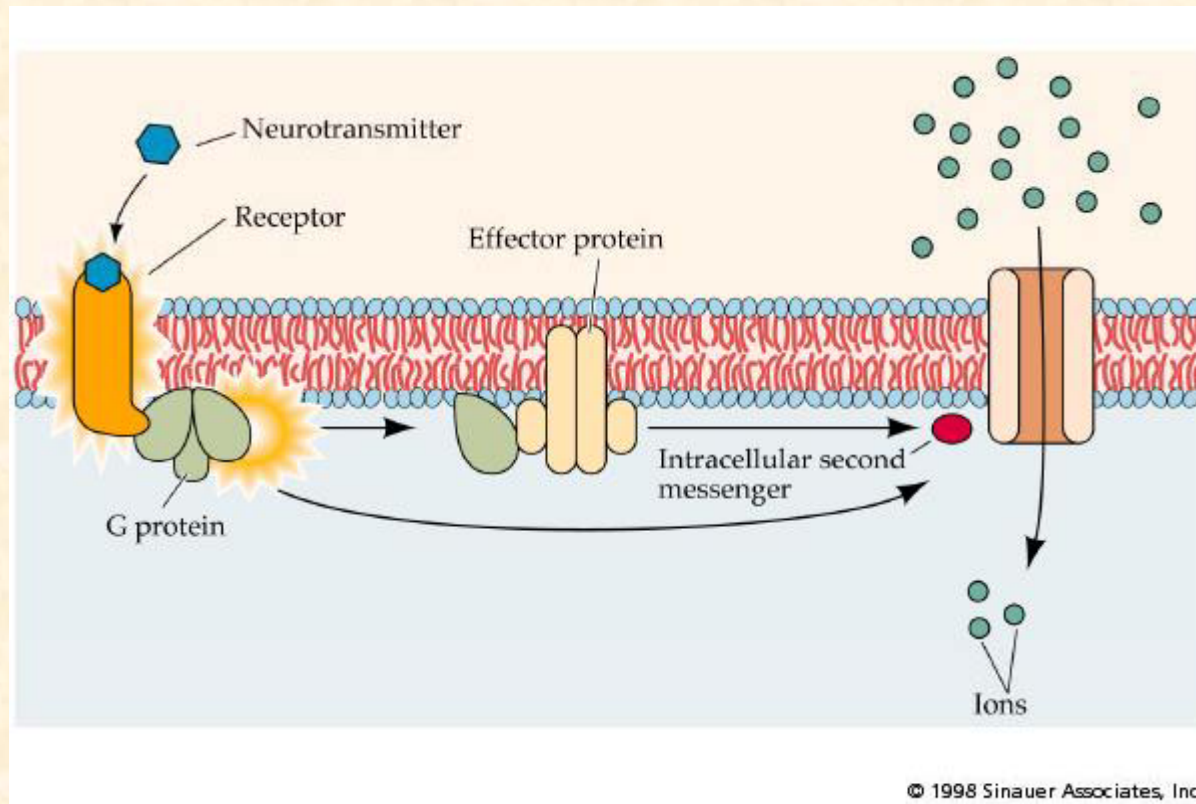
Receptors can be on the cell surface
or can be found inside the cell

Ionotropic Transduction



The binding of the ligand opens an ion channel in the membrane, changing its sensitivity and exerting an effect

Metabotropic Receptors



These receptors work by indirectly opening channels

<http://www.celanphy.science.ru.nl/Bruce%20web/Flash%20Movies.htm>

<http://www.mie.utoronto.ca/labs/lcdlab/biopic/fig/44.18.jpg>

Synaptic Plasticity

Synaptic plasticity is the selective use-dependent changes that can occur in neuronal processing

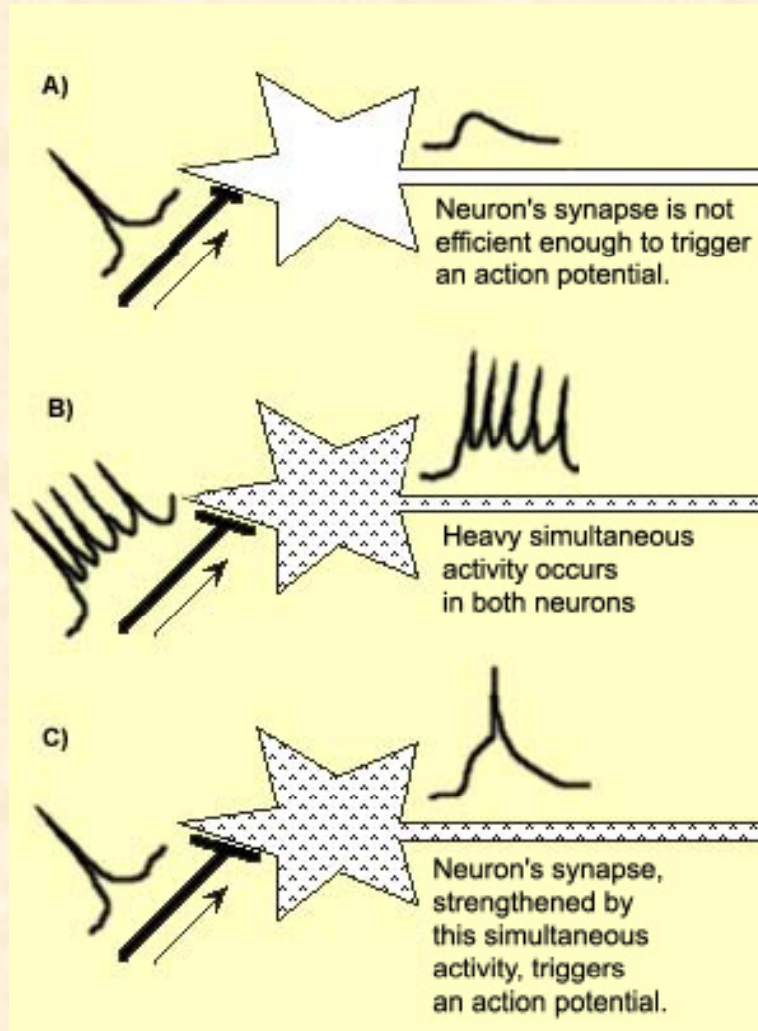
Involves mechanisms that translate a brief change in electrical activity patterns into a modification in synaptic efficacy

LTP – Long-term potentiation

LTD - Long-term depression

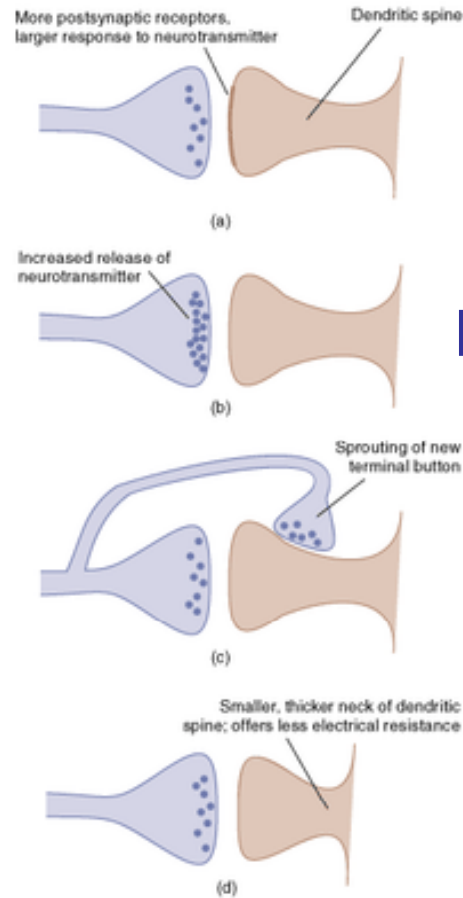
LTP and LTD are central to memory storage

Long-term potentiation



Long-term potentiation can occur through strengthening of synapses

► Hypothetical Changes That Could Account for the Synaptic Strengthening Produced by Long-Term Potentiation



More receptors

More neurotransmitters

New terminal button

Less resistance



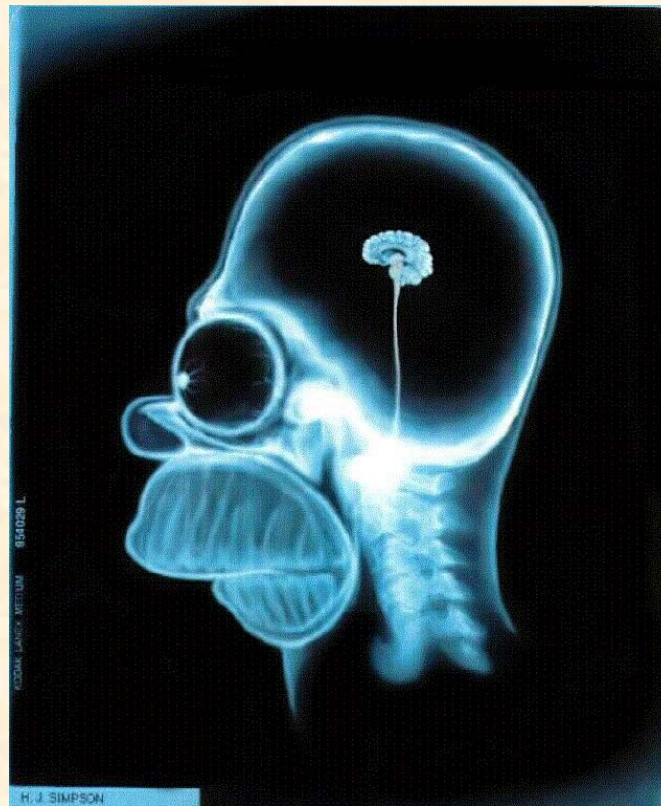
Some e-resources

<http://psycheducation.org/emotion/introduction.htm#Tours>

<http://www.bris.ac.uk/synaptic/public/plasticity.htm>



The Nervous System

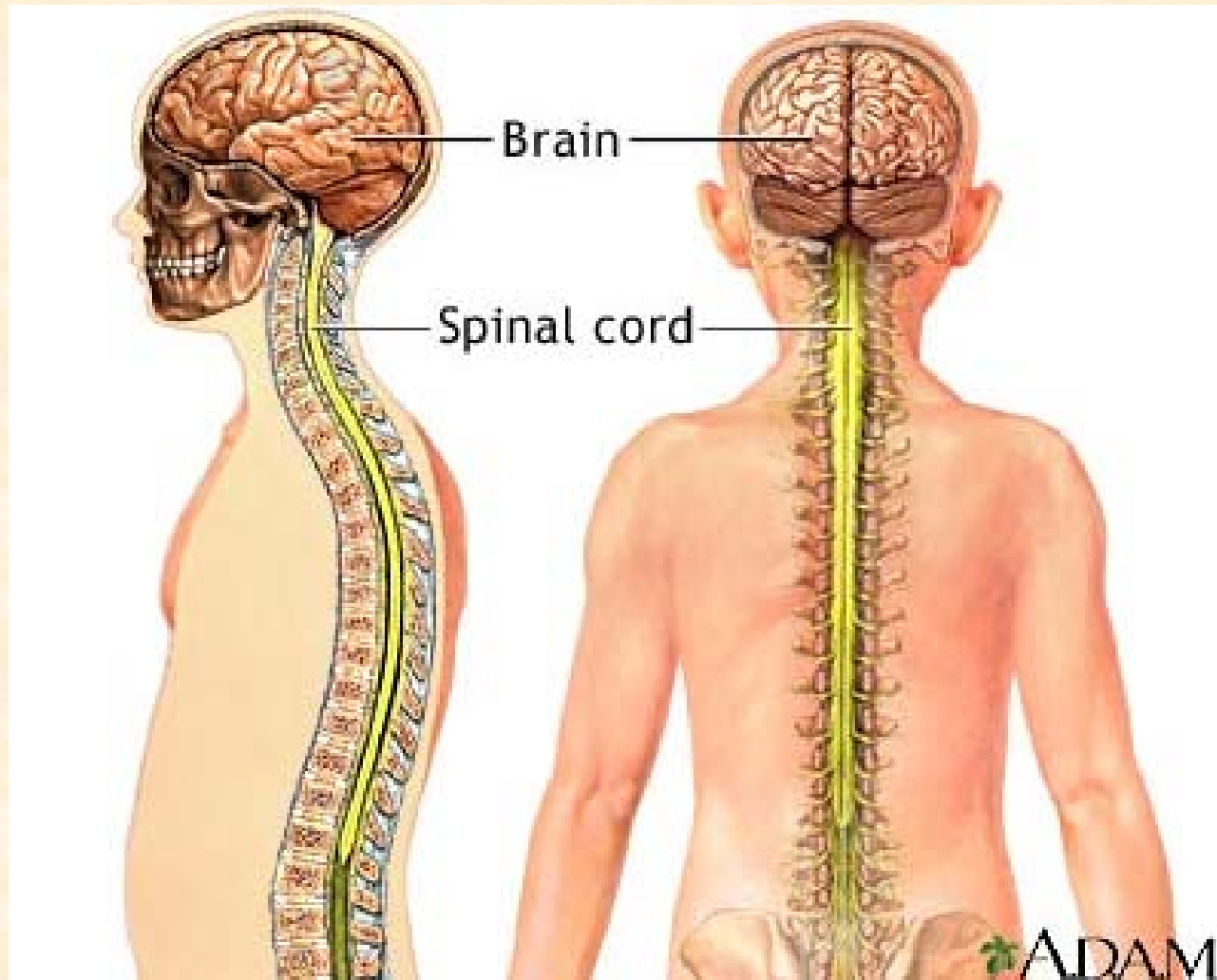


The Nervous System

Anatomically there are two main divisions of the nervous system:

The Central Nervous System (CNS)

This consists of the brain and the spinal cord
There are approximately 10^{10} – 10^{12} neurones in the CNS
It is the body's central processing unit



Central Nervous System

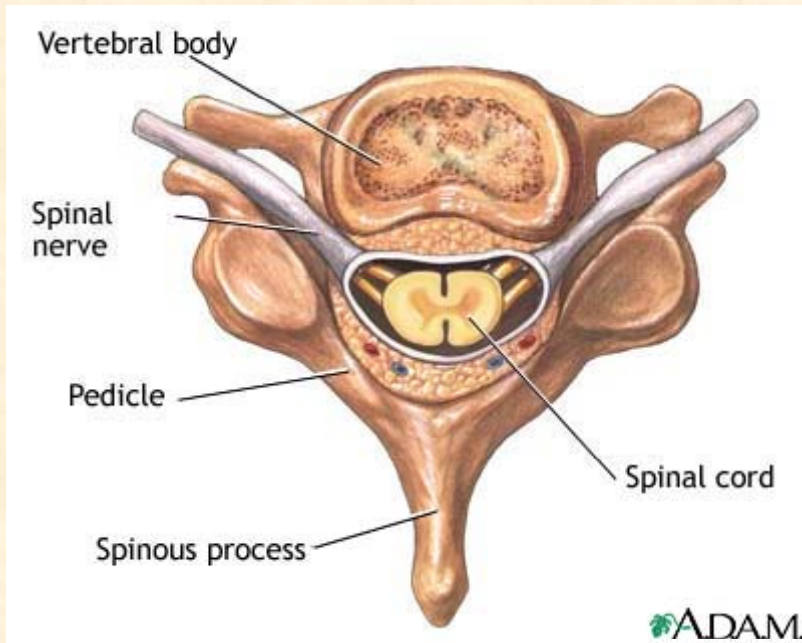
<http://www.nlm.nih.gov/medlineplus/ency/images/ency/fullsize/19588.jpg>

The peripheral nervous system (PNS)
This consists of all the nerves that enter and leave the
central nervous system
(spinal nerves and cranial nerves)

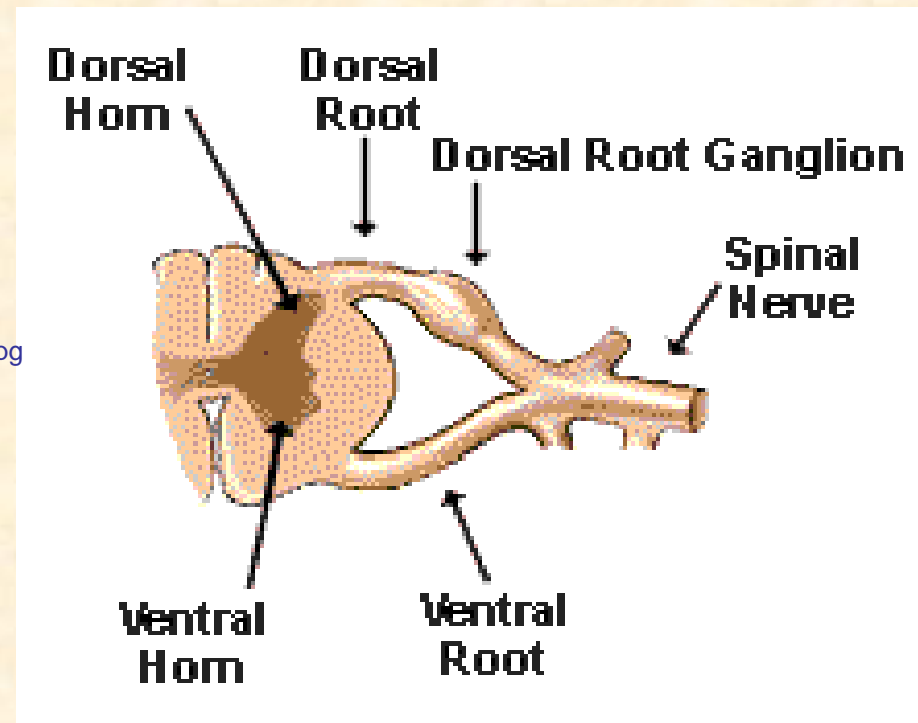


It relays information to and from the CNS
Via sensory afferent and
Motor efferent nerves

The Spinal Cord

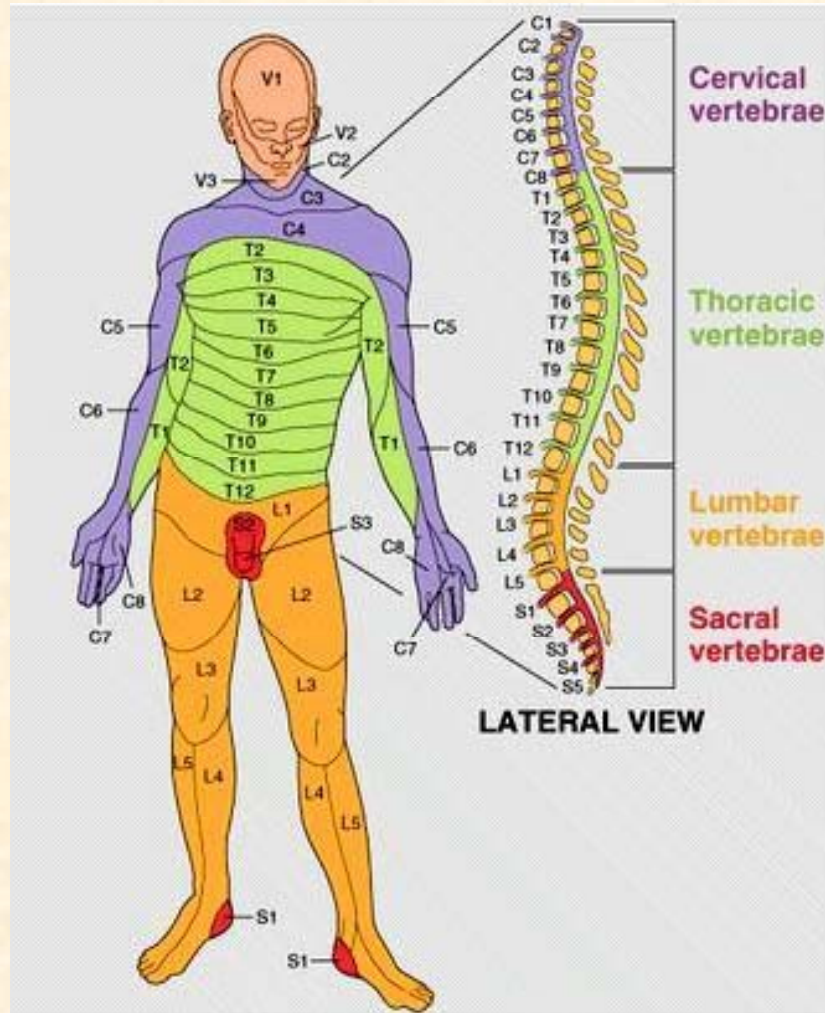


<http://www.enh.org/healthresources/encyclopedia/images/ency/fullsize/9936.jpg>



<http://www.marymount.k12.ny.us/marynet/Studentwebwork01/SpinalCordandPNS/Images/vert3.gif>

Dermatomes



Dermatomes are clearly defined areas of the body surface innervated by specific spinal nerves.

These are useful in diagnosing areas of spinal cord or root damage, which can result in referred pain

Different areas of the body have varying levels of sensory reception.

The Brain Stem

The brainstem controls our most vital functions

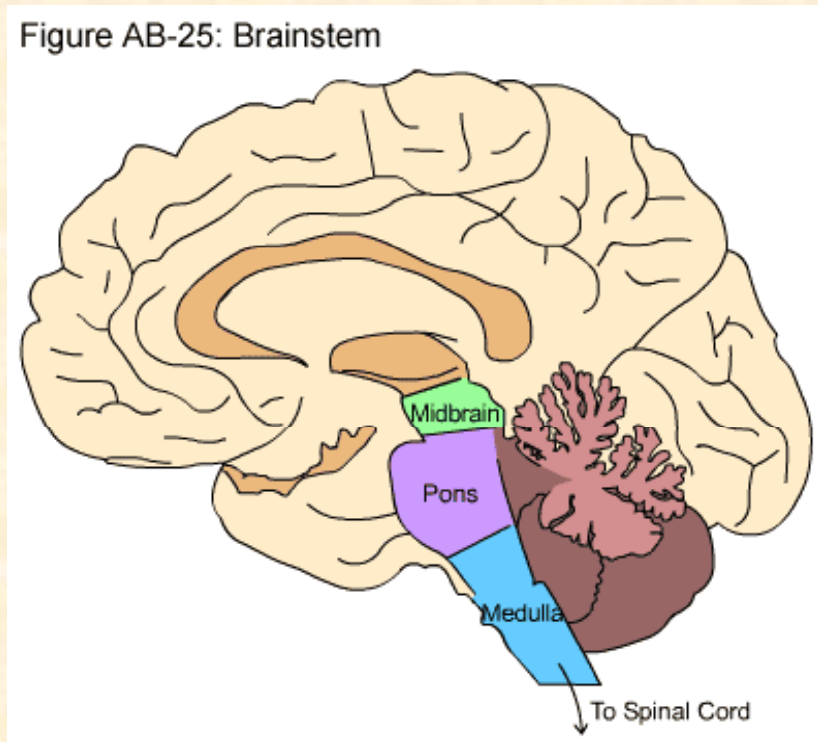
Cardiovascular control

Respiratory control

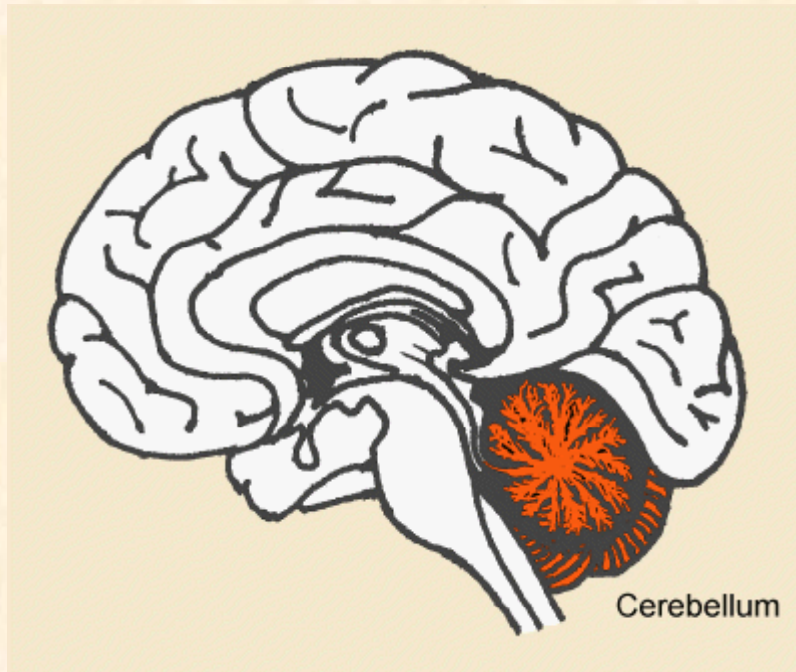
Glandular secretion

Postural control

Swallowing, hiccupping,
vomiting, coughing and
sneezing

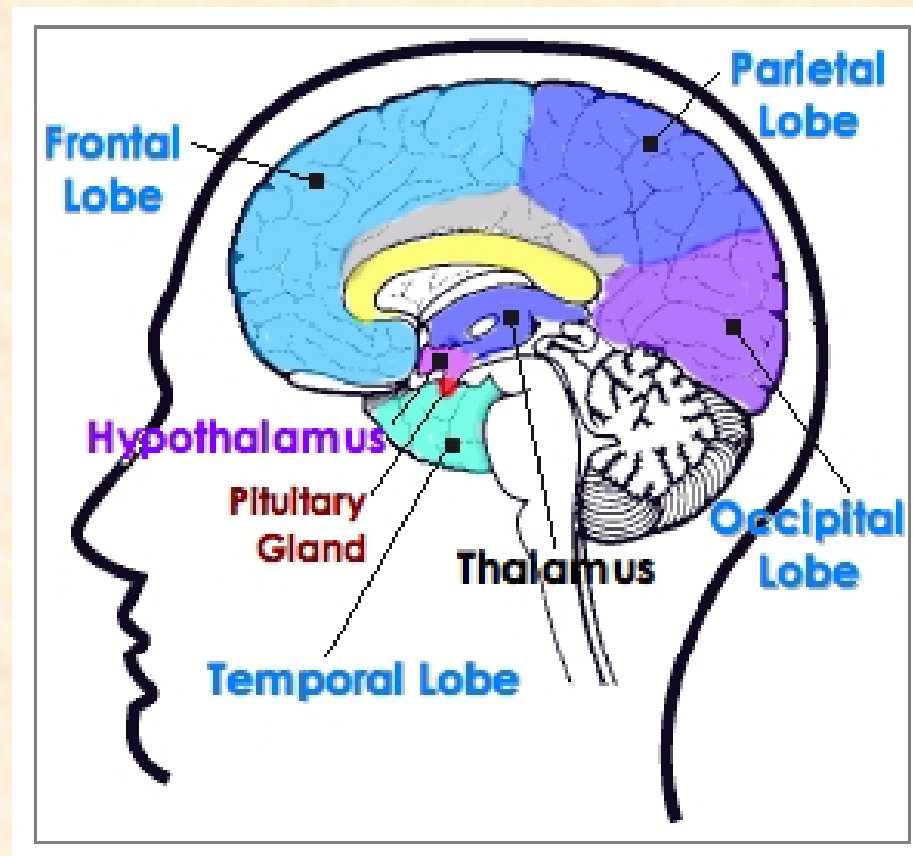


Cerebellum



1. Monitors
motor commands
sensory inputs
2. Compares
motor intention
sensory feedback
3. Adjusts
corrective feedback
for movements
and posture

Thalamus, Hypothalamus



Thalamus

All major sensory inputs converge on the thalamus.

The incoming data is processed and only a small amount of data is then passed on to the cerebral cortex.

The “Clapham Junction” of the brain

Acts as a filter – filters out a lot of unnecessary information

Hypothalamus

The hypothalamus is the main interface between the central nervous system and the endocrine system.

It receives neuronal and hormonal messages and responds by increasing or inhibiting hormone release.

It also acts as the body's thermostat controlling temperature regulation.

Cerebral Cortex



The cerebral cortex - 2 hemispheres joined by the corpus callosum.

Grey matter forms the thin outer layer
White matter forms the inside.

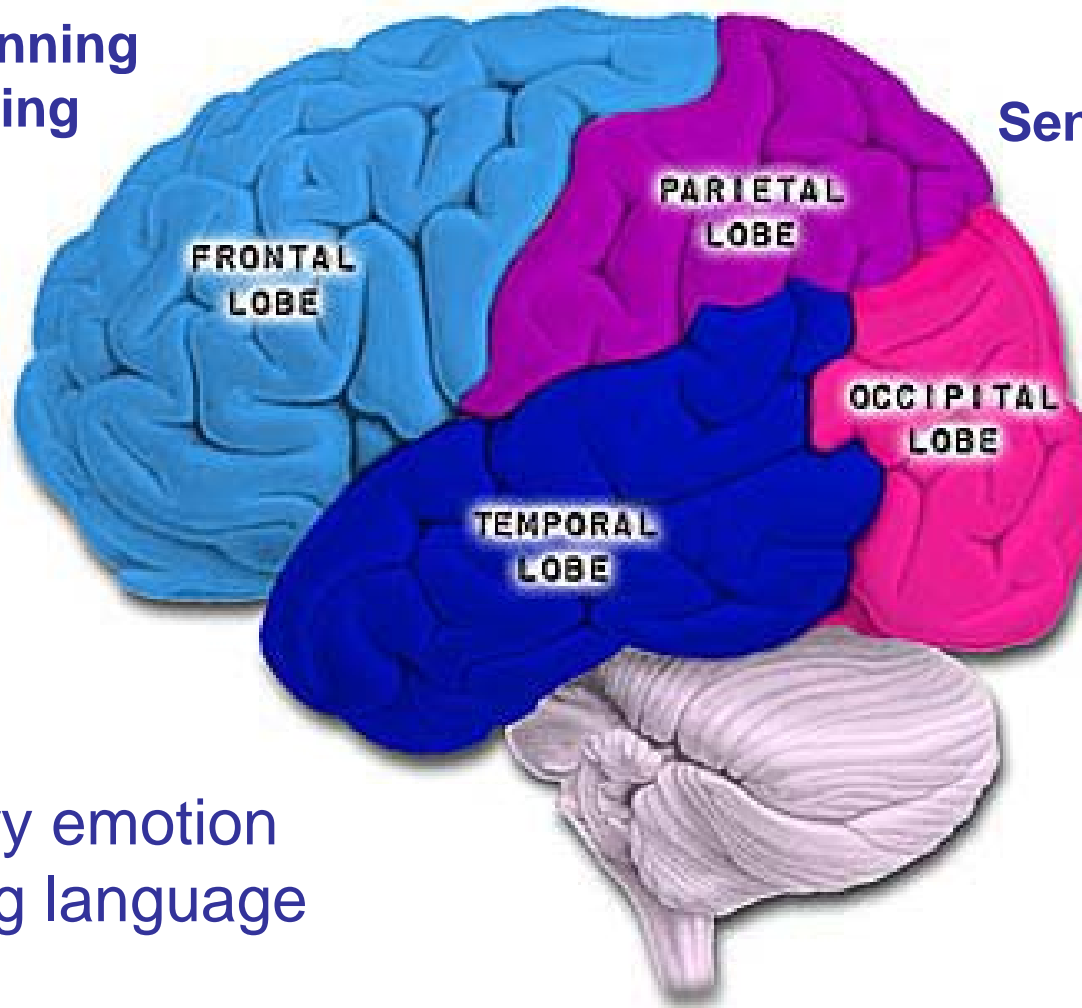
In co-ordination with the thalamus
it provides consciousness of
sensations, our awareness.

It allows us to think, plan and initiate.

Lobes of the Brain

Thinking, planning
Problem solving

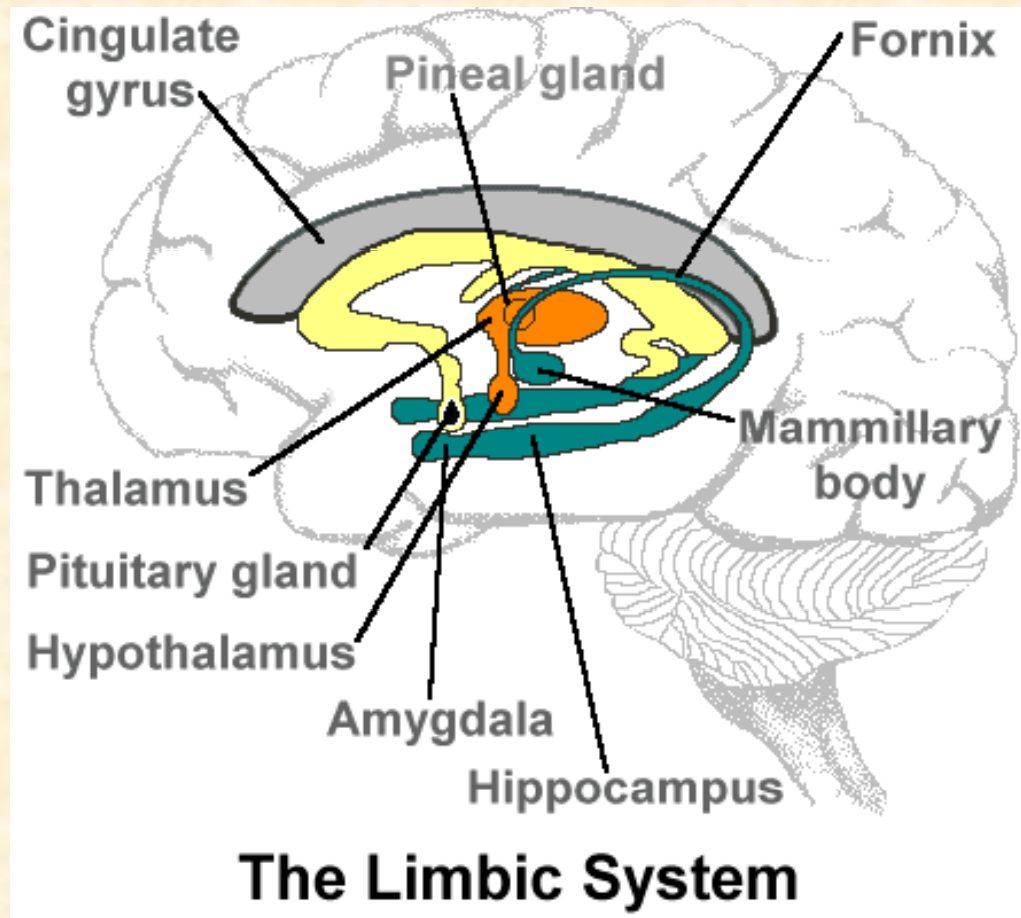
Reception and
Processing
Sensory information



Memory emotion
Hearing language

Vision

The Limbic System



Emotional states
behavioural drives

Memory storage
and retrieval

Linking conscious
and unconscious brain

The Peripheral Nervous System

2 major divisions

Somatic nervous system

Autonomic nervous system

VOLUNTARY CONTROL

COMMUNICATES WITH THE ENVIRONMENT

CONTROL OF SKELETAL MUSCLE

WALKING

TALKING

WRITING

DOING THINGS

INVOLUNTARY CONTROL

MAINTAINS INTERNAL ENVIRONMENT

INDIVIDUAL ORGAN FUNCTION

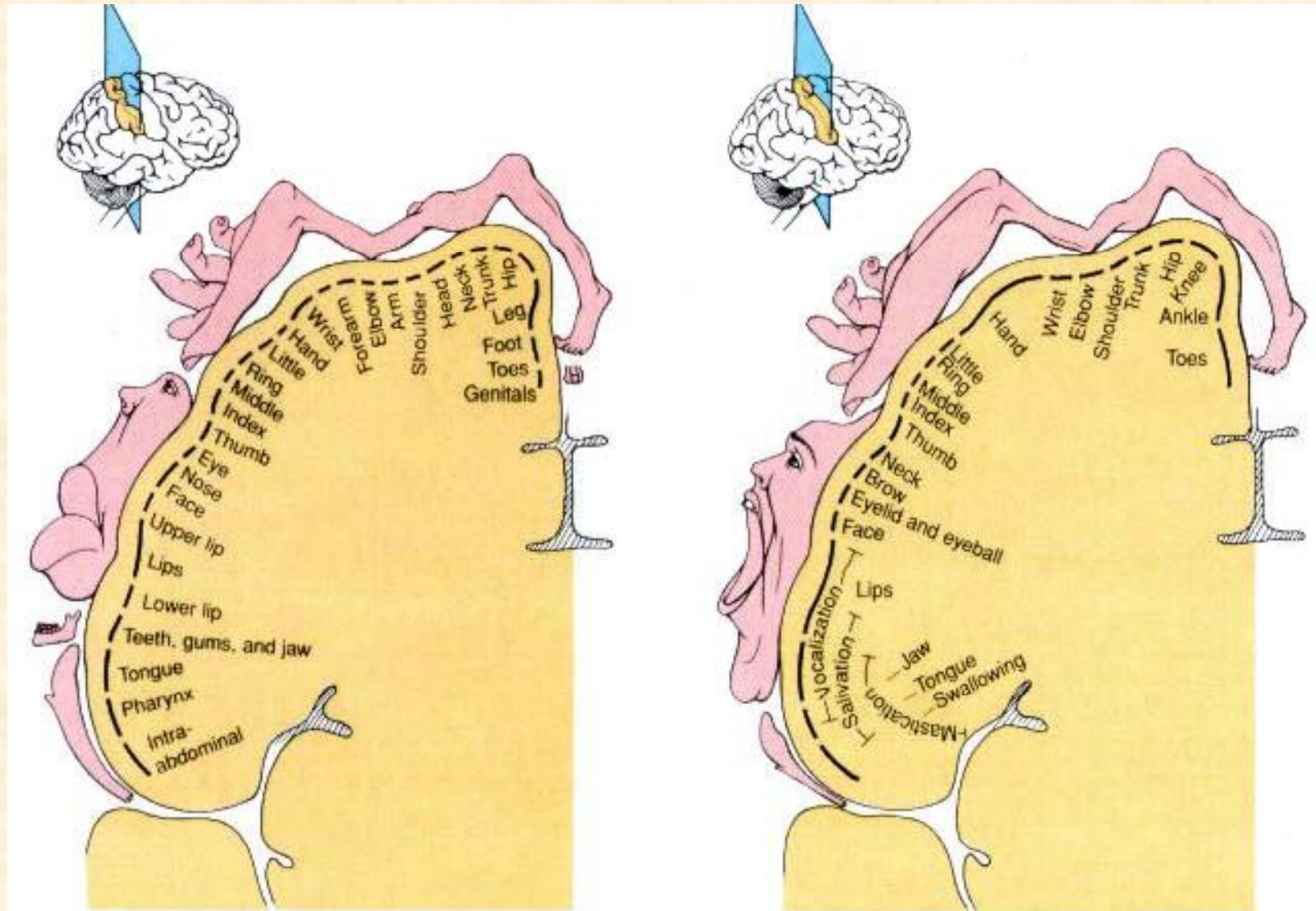
HEART RATE

BLOODPRESSURE

DIGESTIVE SECRETIONS

INTERNAL HOUSEKEEPING

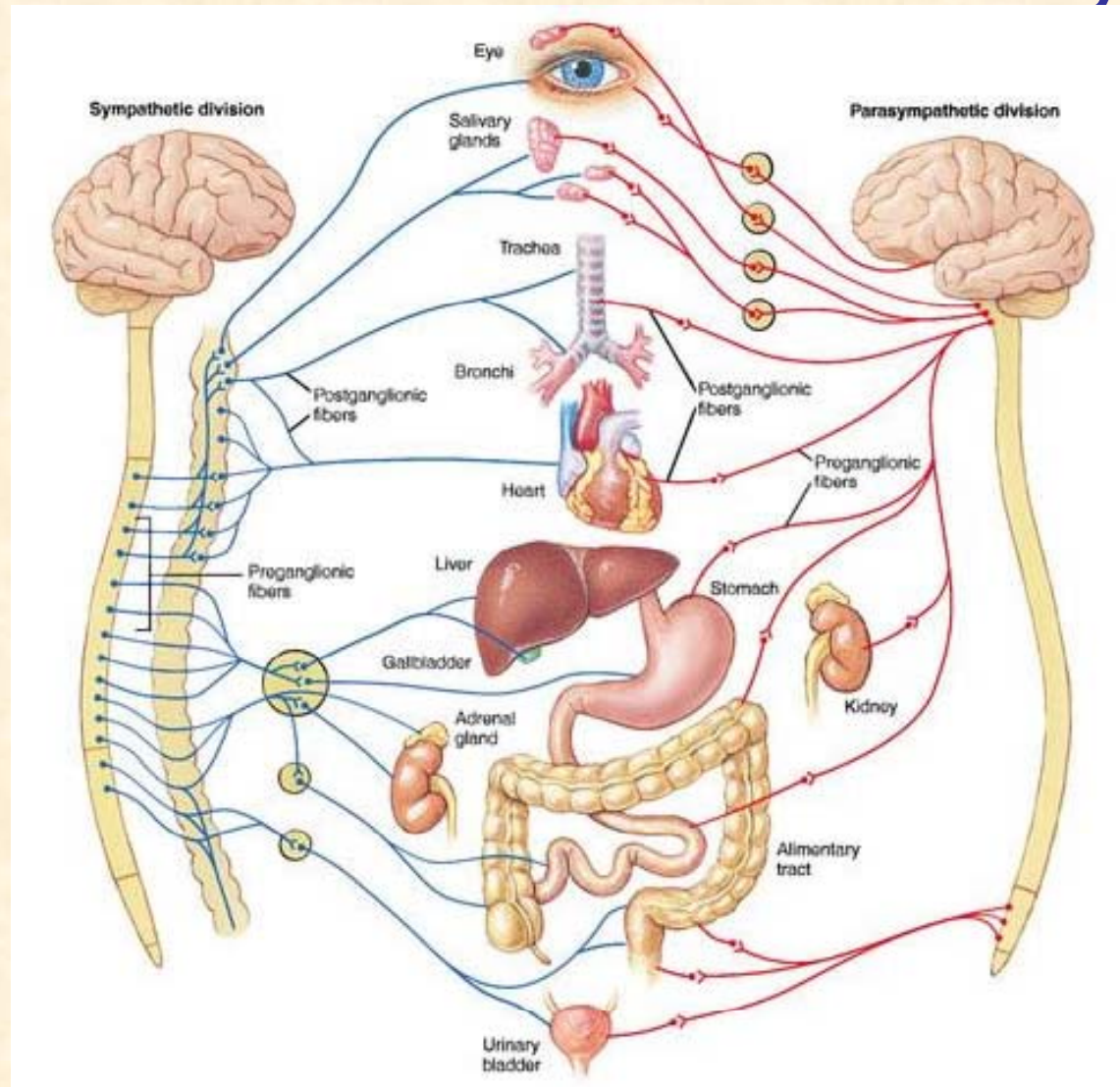
The Homunculus



(a) Somatosensory cortex in right cerebral hemisphere

(b) Motor cortex in right cerebral hemisphere

The Autonomic Nervous System



<http://ardb.bjmu.edu.cn/image/ANS.jpg>

The Autonomic Nervous system

SYMPATHETIC

Pupils dilate
Salivary glands produce thick saliva
Bronchial tubes dilate
Heart rate and force increases

Adrenaline produced
Glucose into blood
Decrease urine produced
Decreased digestion
Bladder sphincter constricts

Perspiration increases
Piloerection
Increased blood flow to muscles

PARASYMPATHETIC

pupils constrict
thin saliva
bronchial tubes constrict
heart rate and force decreases

increased digestion
bladder sphincter dilates

sexual organs stimulated

A good e-resource



<http://www.brainconnection.com/topics/?main=anat/cns>

Pain



Pain is...

“An unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage”².

It is a unique sensory input



What is the purpose of pain?

Pain can be a warning

Pain can be educational

Pain can facilitate healing

Pain can also serve no apparent purpose

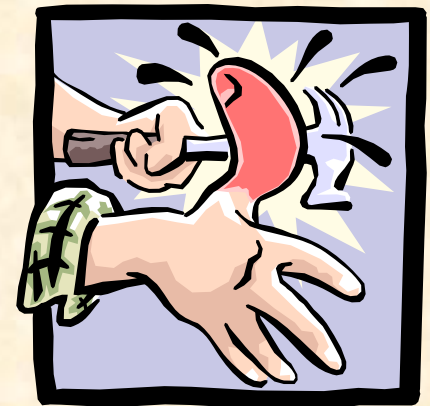
Pain is subjective

Duration of pain

Transient—short lasting and usually self limiting

Acute—short to medium duration, may seek medical aid

Persistent / Chronic -when pain fails to stop after treatment or after original injury has healed



Definitions

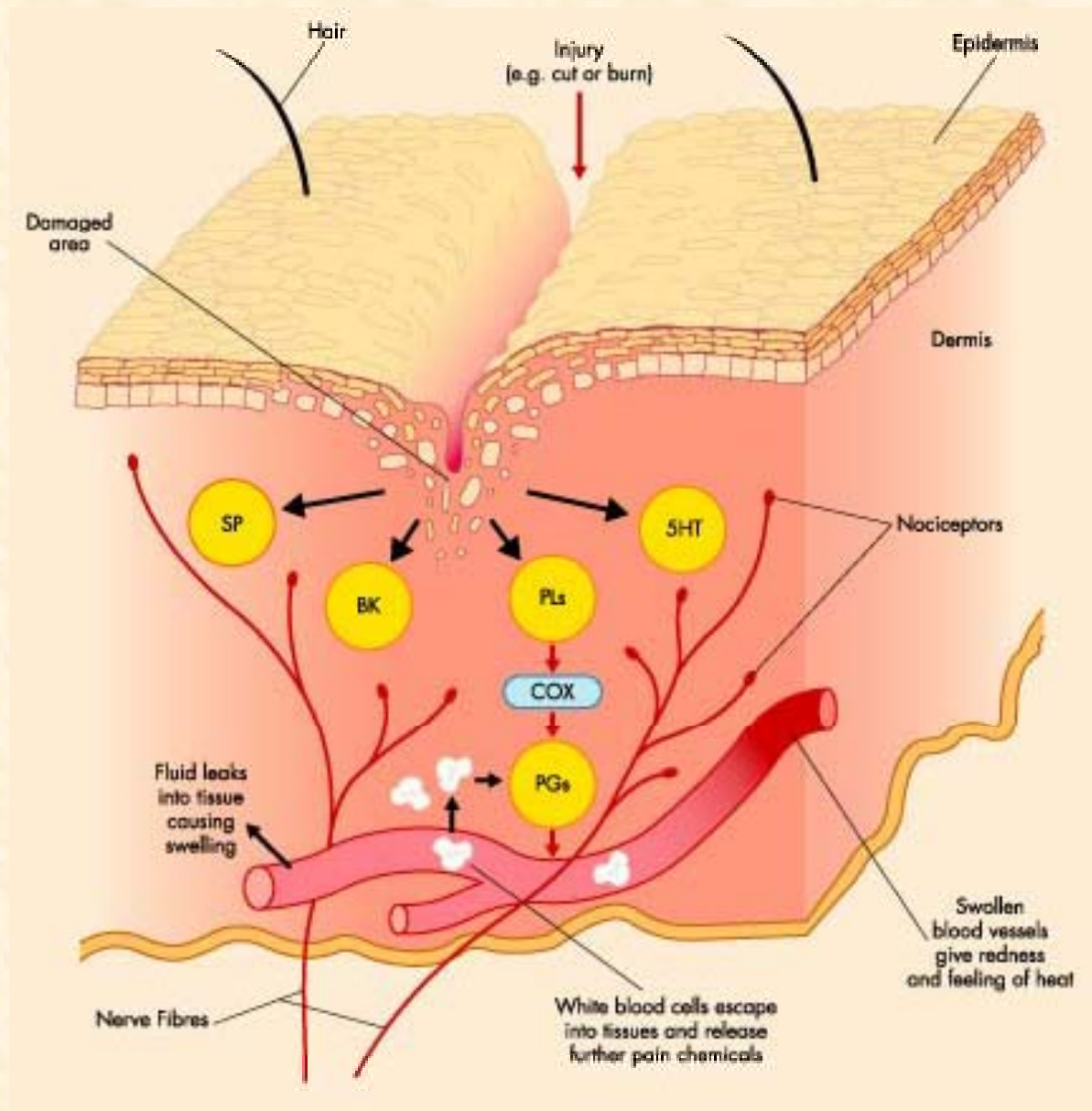
- **Nociception** – not a perception of pain but a response to a stimuli



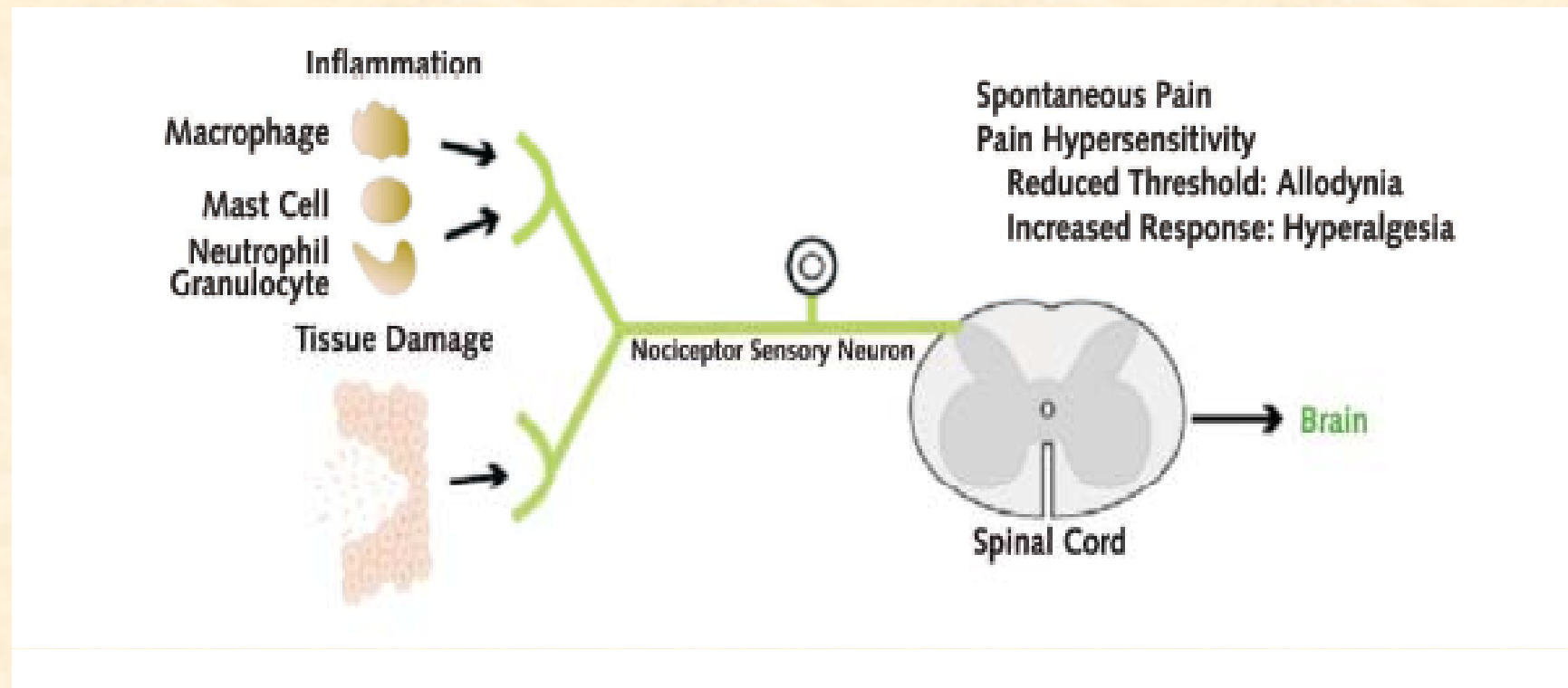
Nociception

is the sensory input you need to receive before you can feel pain.

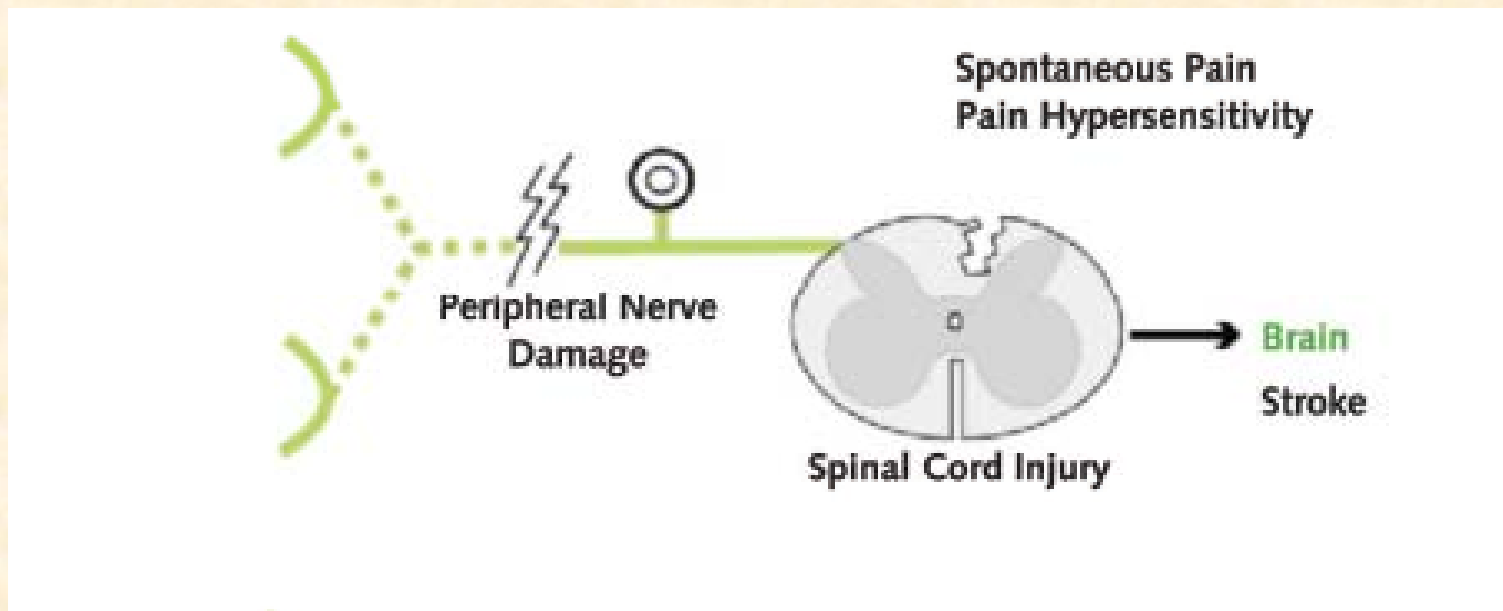
It results from tissue damage



Inflammatory pain



Neuropathic pain



<http://www.the-aps.org/publications/journals/pim/woolf.pdf> accessed 30/09/06

SOMATIC PAIN v VISCERAL PAIN

(somatic) (autonomic)

Well localised

Higher concentrations
of nociceptors



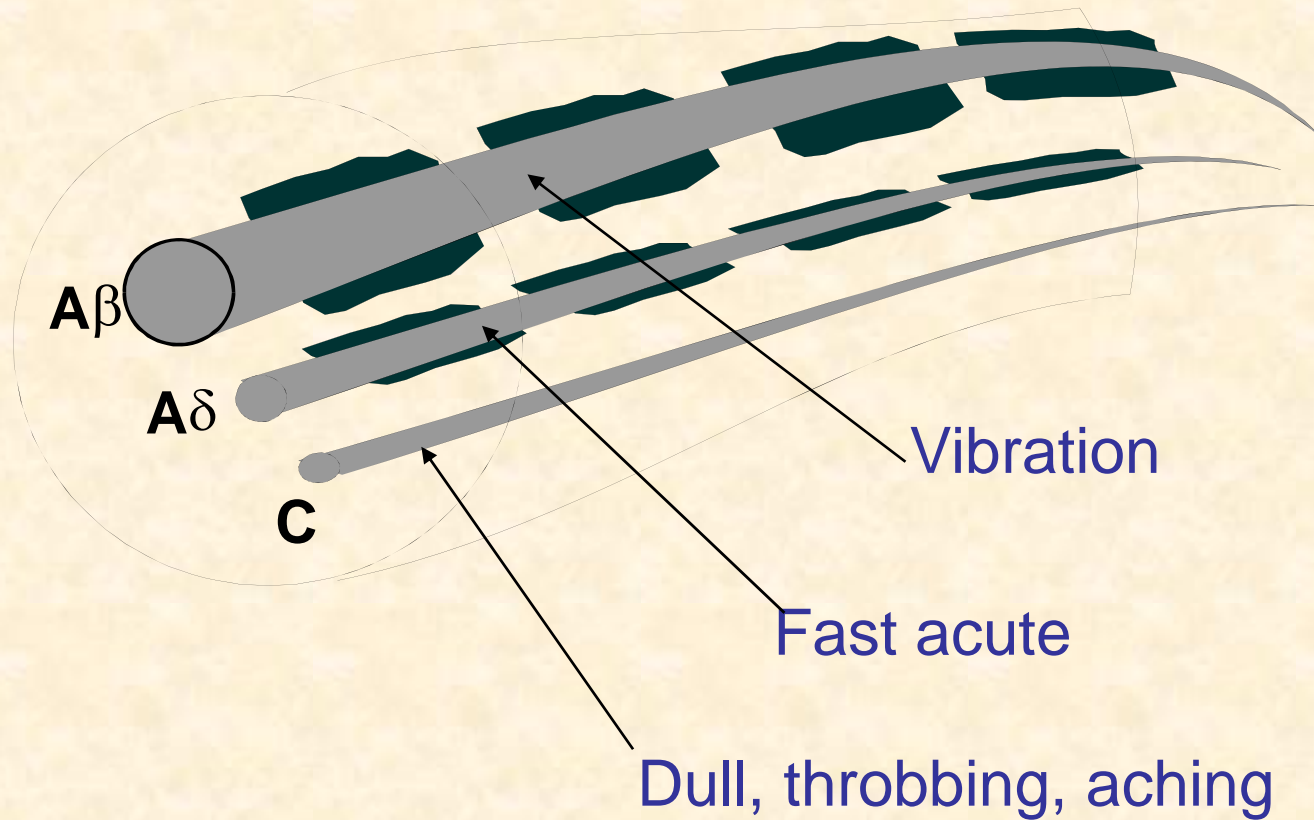
Poorly localised

Unpleasant

Often with nausea

Pain can refer to
somatic structures

A peripheral nerve



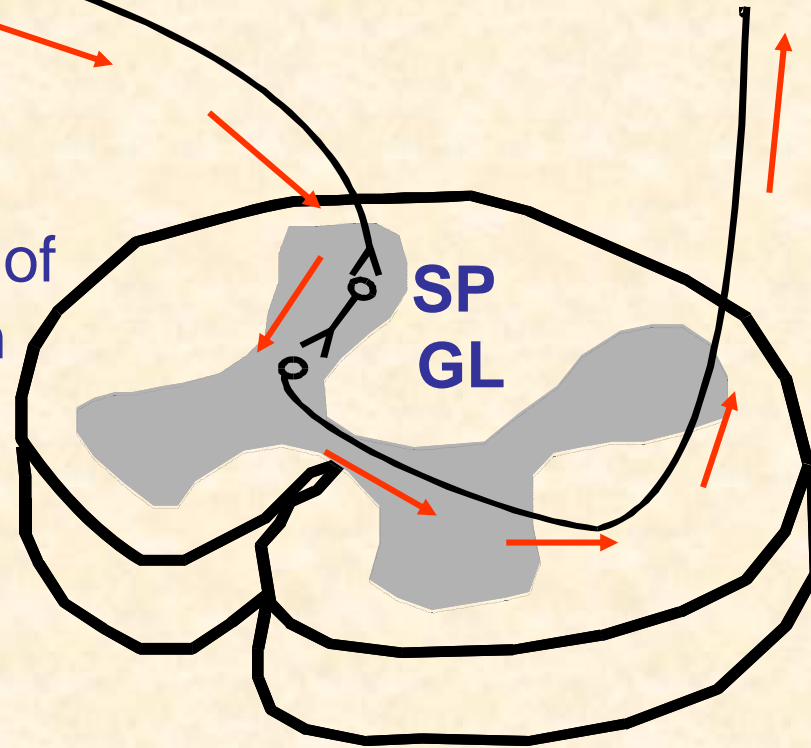
Tissue damage



C fibre

Signal enters the spinal cord and travels to the brain

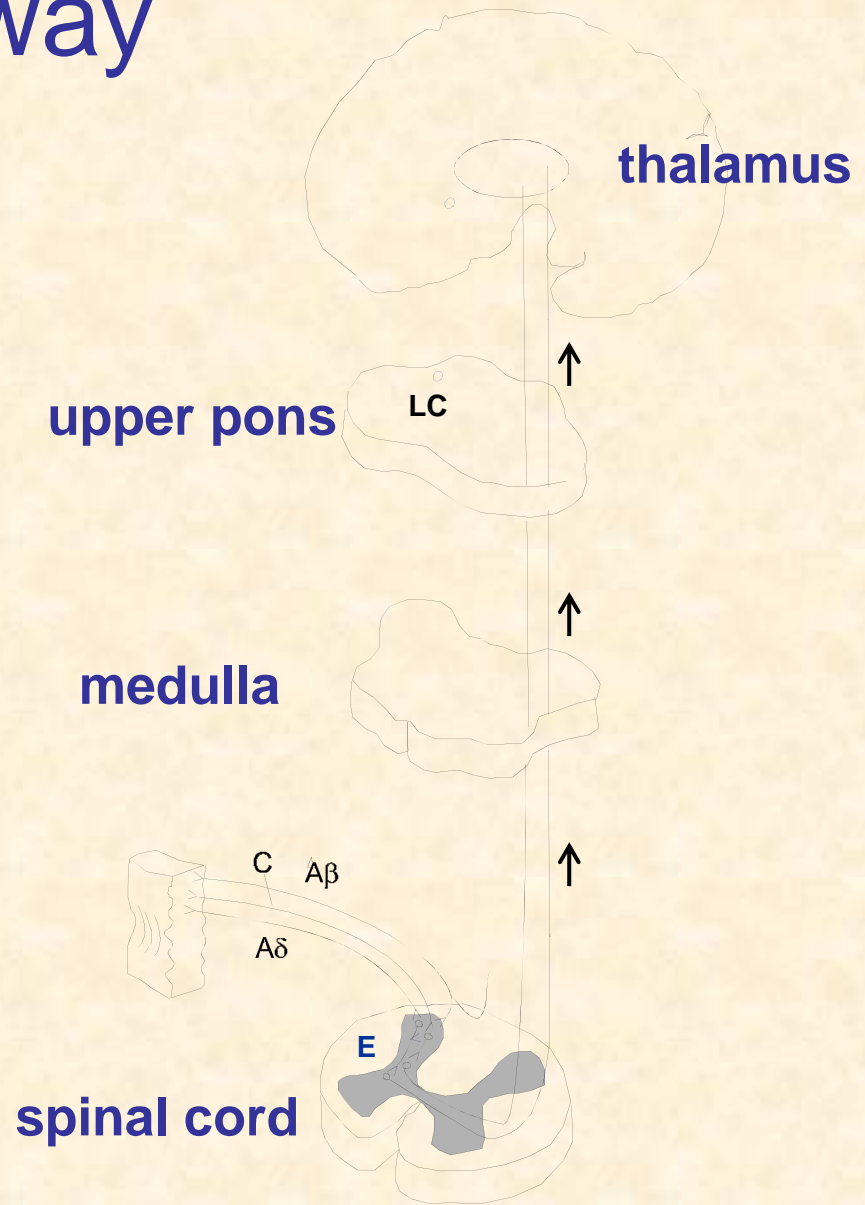
Site for modulation of signal/ sensitisation



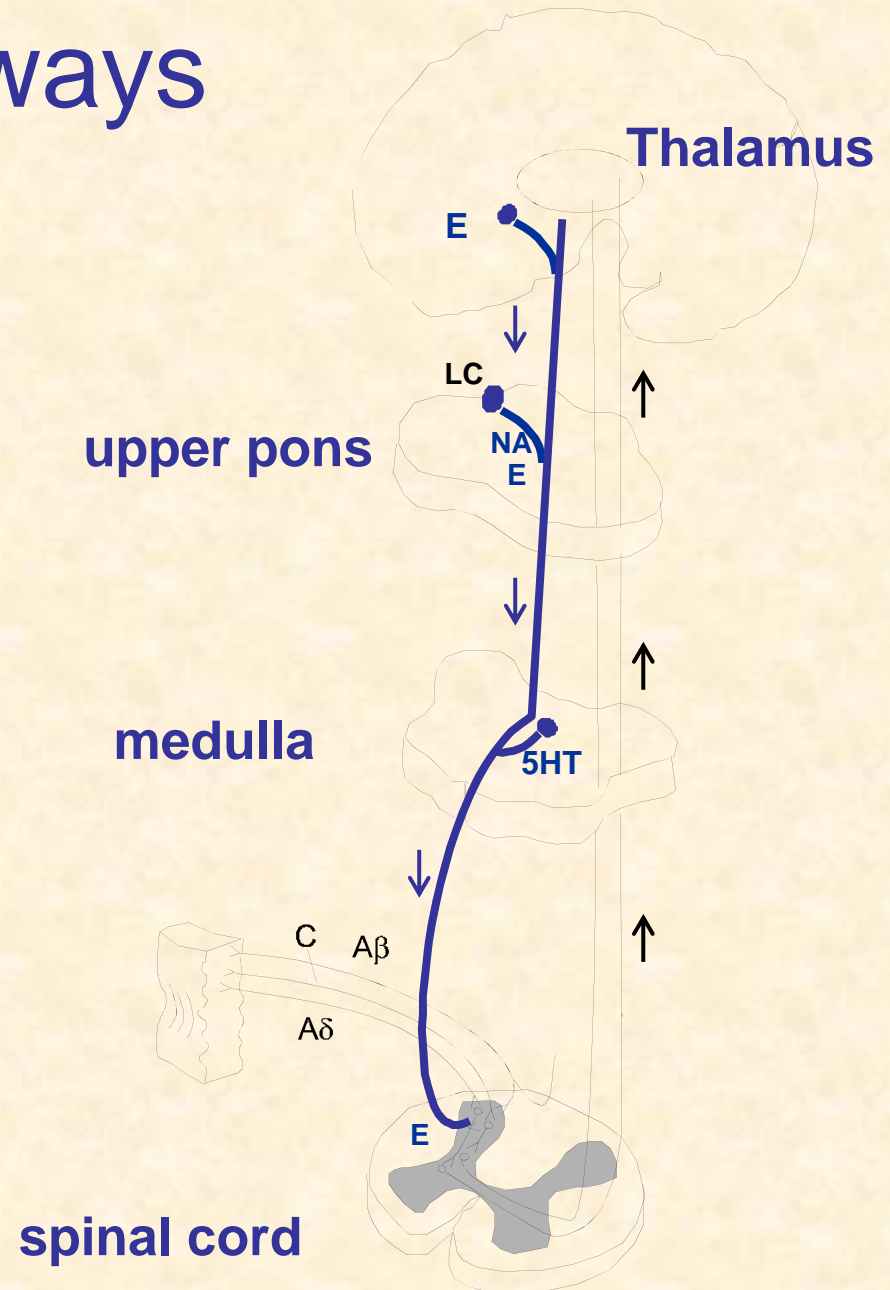
SP substance P

GL glutamate

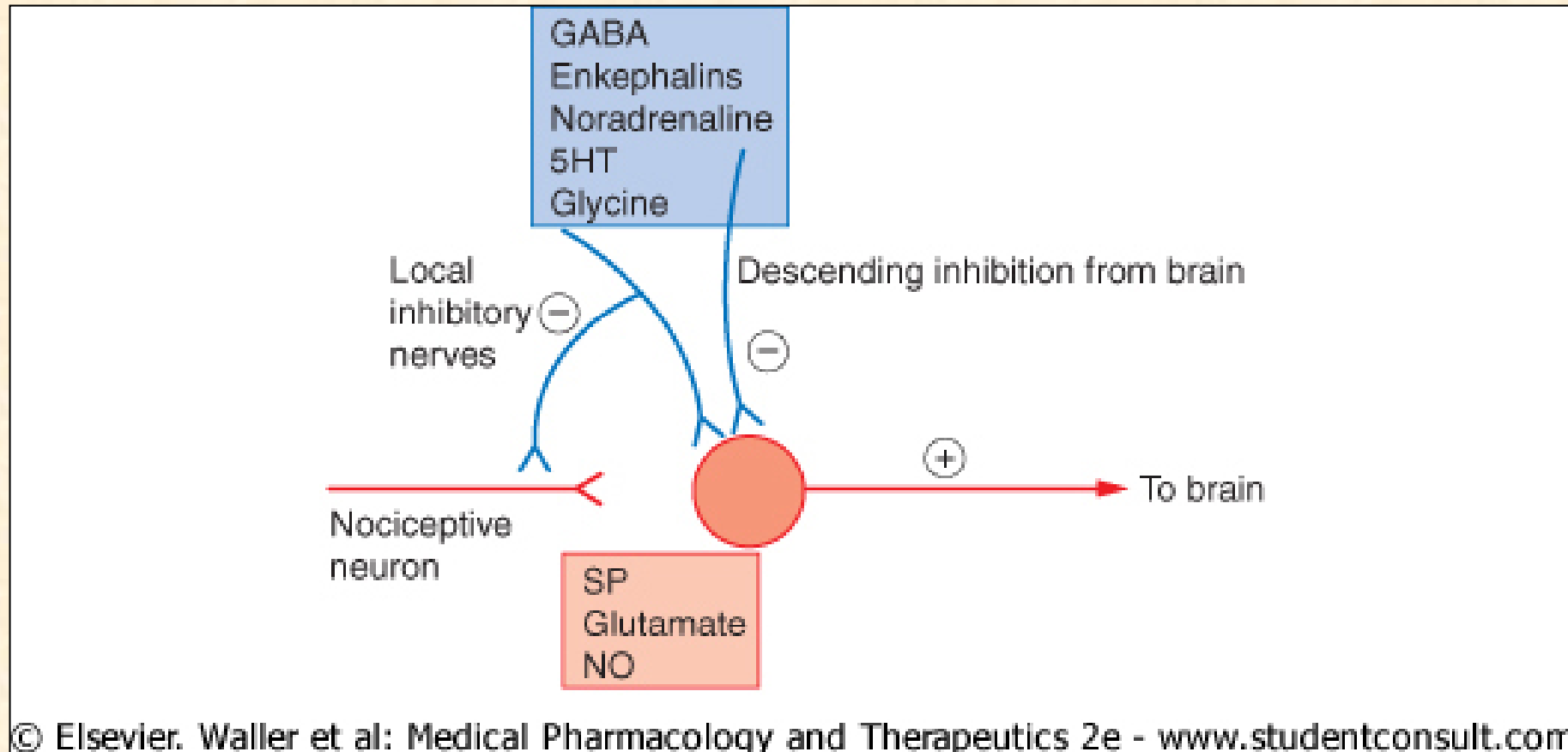
Ascending pathway



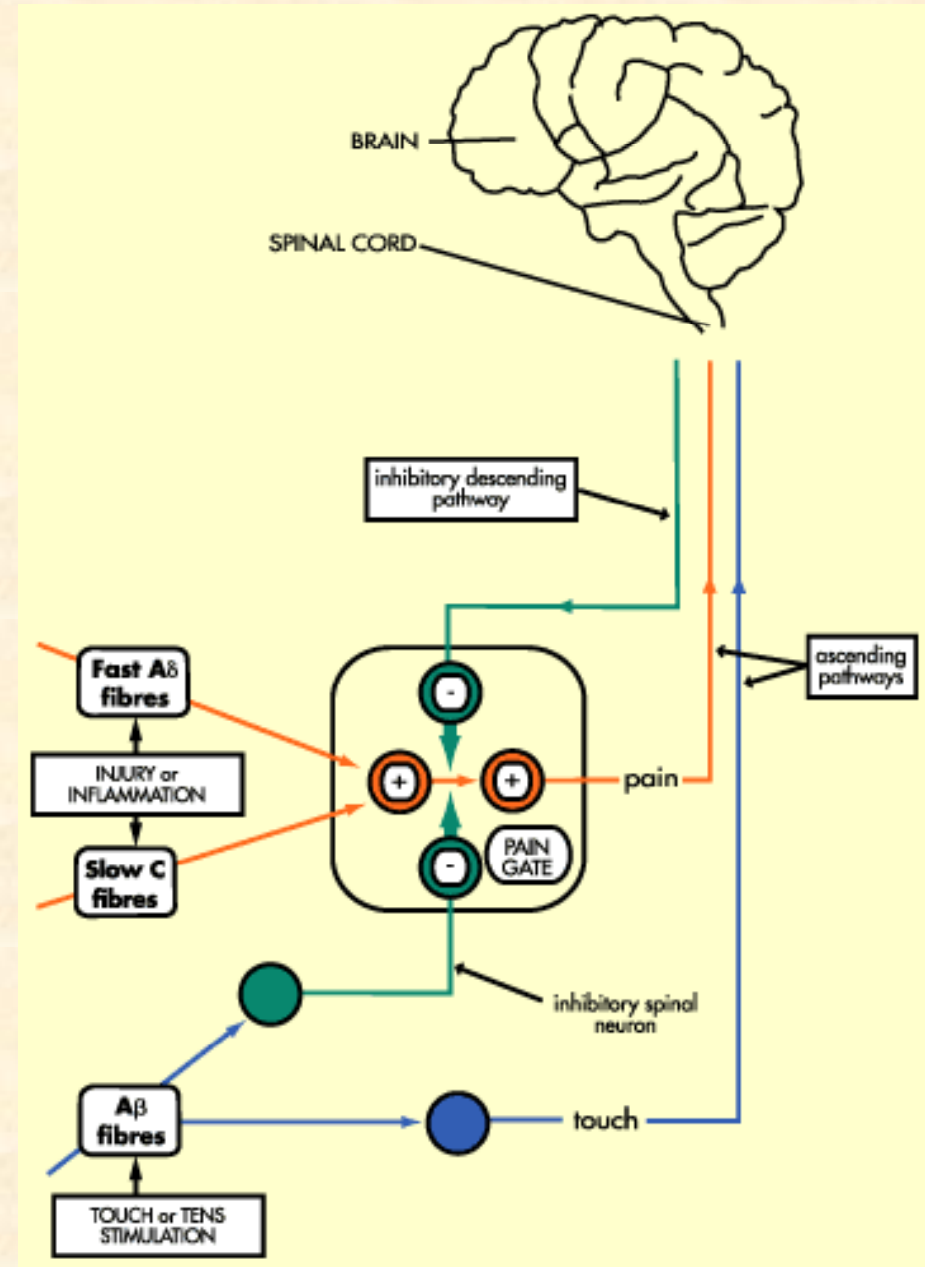
Descending pathways



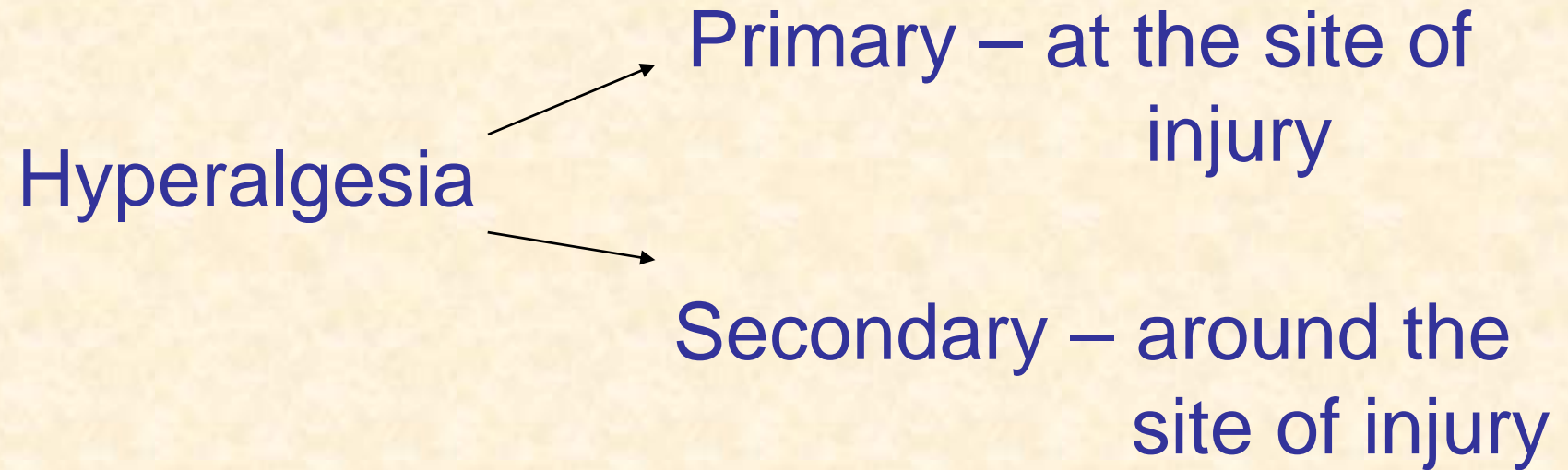
Pain modulation in the dorsal horn



The Gate Theory



Hyperalgesia



Sensitisation

- Peripheral - affects primary neurons
- Central – affects primary and secondary neurons

Neuroplasticity



Wind up

An increase in the excitability of neurons in the spinal cord

Caused by repetitive C fibre mediated input
“field potentials”

Complex regional pain syndrome

Formerly known as
“Sympathetic reflex dystrophy”

- Sensory disturbances
- Motor disturbances
- Autonomic disturbances
- Trophic changes

Fibromyalgia

“Fibrous muscle pain”

- Sensory disturbances
- Localised and referred
- Motor disturbances