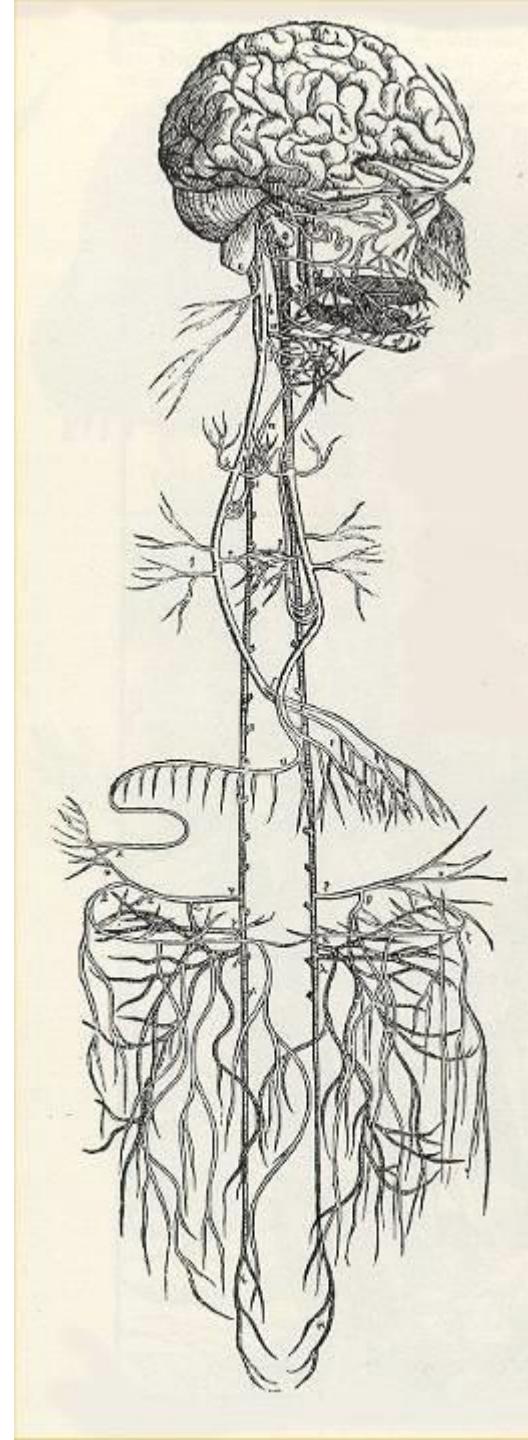


Systema nervosum periphericum

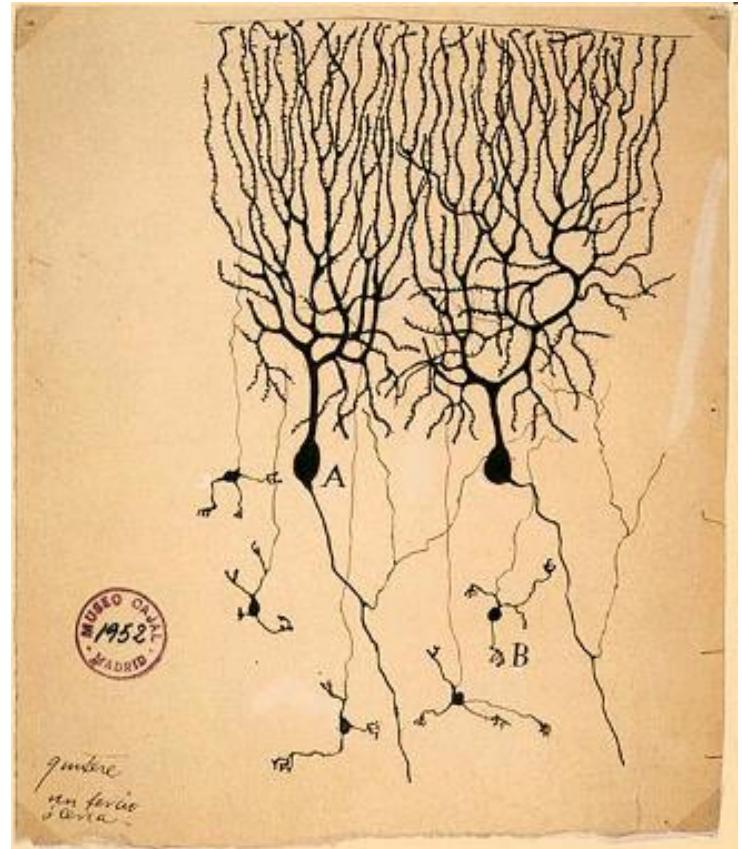
Peripheral nervous system

David Kachlík



Terminology

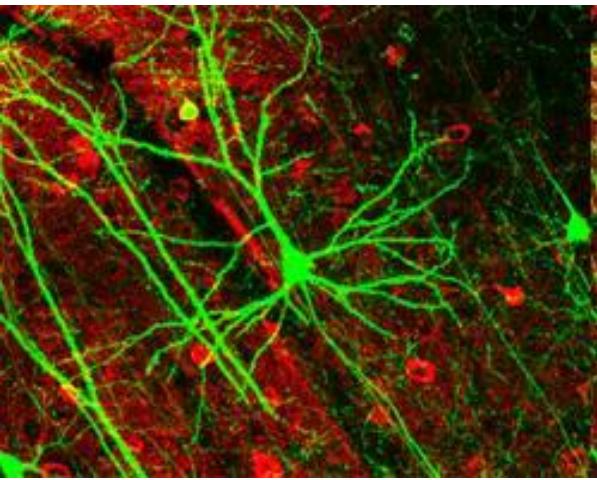
- neuron
 - perikaryon / soma (nerve cell body)
 - axon
 - dendritum (dendrite)
- neuroglia
- neurofibra (nerve fiber)
- nervus (nerve)
- nucleus
- ganglion



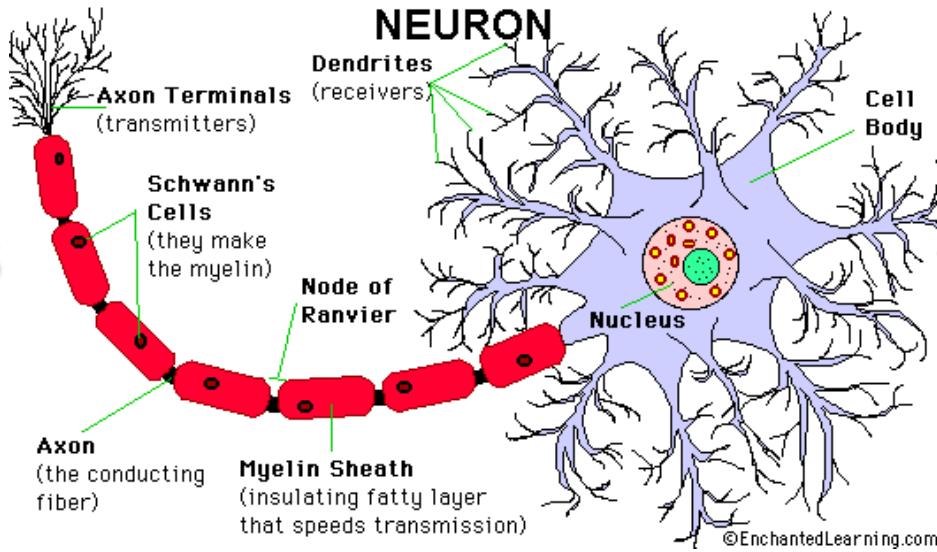
Drawing of Purkyně cells (A) and granule cells (B) from pigeon cerebellum by Santiago Ramón y Cajal (1899)

Cell types in CNS

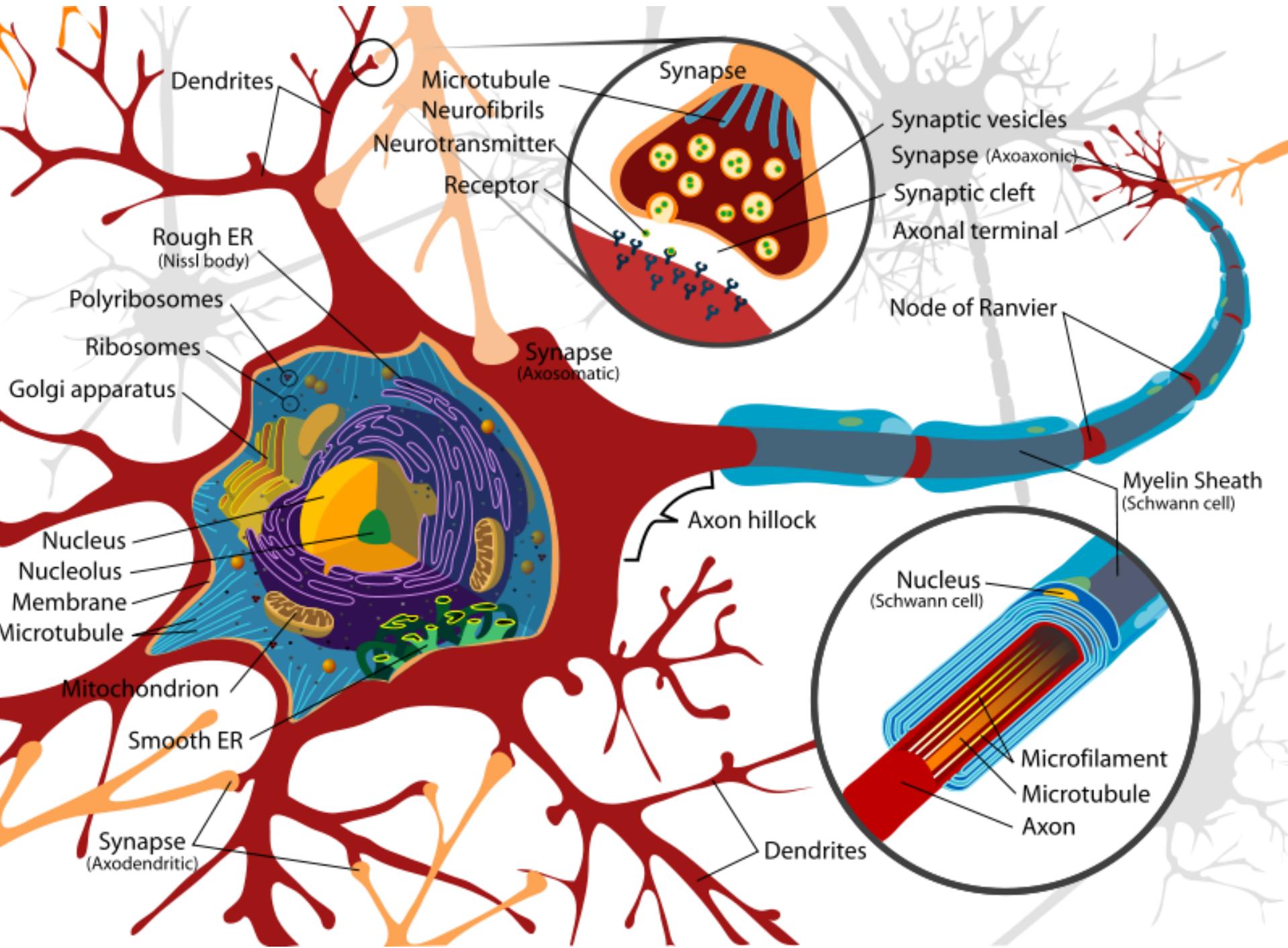
- neurons
 - multipolar, bipolar, pseudounipolar, unipolar
- neuroglia
 - astrocytes
 - oligodendrocytes
 - microglia
 - ependymal cells
 - propes ependymal cells, tanyctyes



Neurons

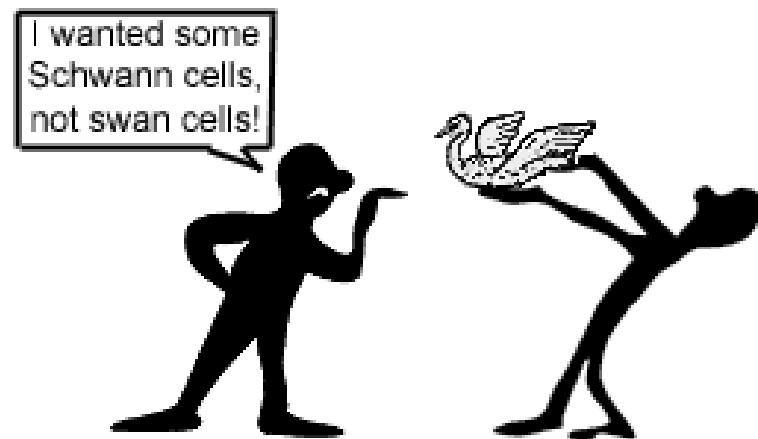


- basic unit of nervous tissue
- receive, process and transmit signals
- size: from 5 μm (granular cells of cerebellum) to 150 μm (Purkinje cells of cerebellum)
- some can multiply even after birth
- synapsis interconnects neurons



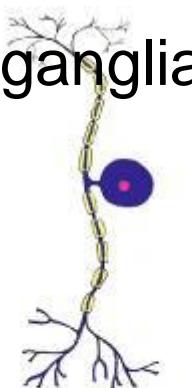
Neuroglia

- CNS:
 - oligodendroglia
 - astrocytes
 - microglia
 - ependymal cells
- PNS
 - satellite cells
 - Schwann cells

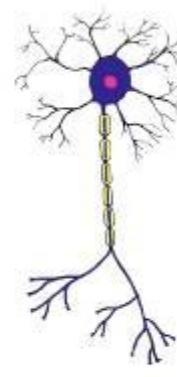


Neuron types according to shape

- multipolar
 - more than 2 processes (axon + dendrites)
 - majority of neurons
- bipolar
 - two processes only (axon + dendrite)
 - retina, ganglia n. VIII, olfactory mucosa
- pseudounipolar
 - one process bifurcated into peripheral and central processes (shape „T“)
 - somatosensory and viscerosensory ganglia
- unipolar
 - only one process
 - rods and cones in retina



PSEUDOUNIPOLÁRNÍ

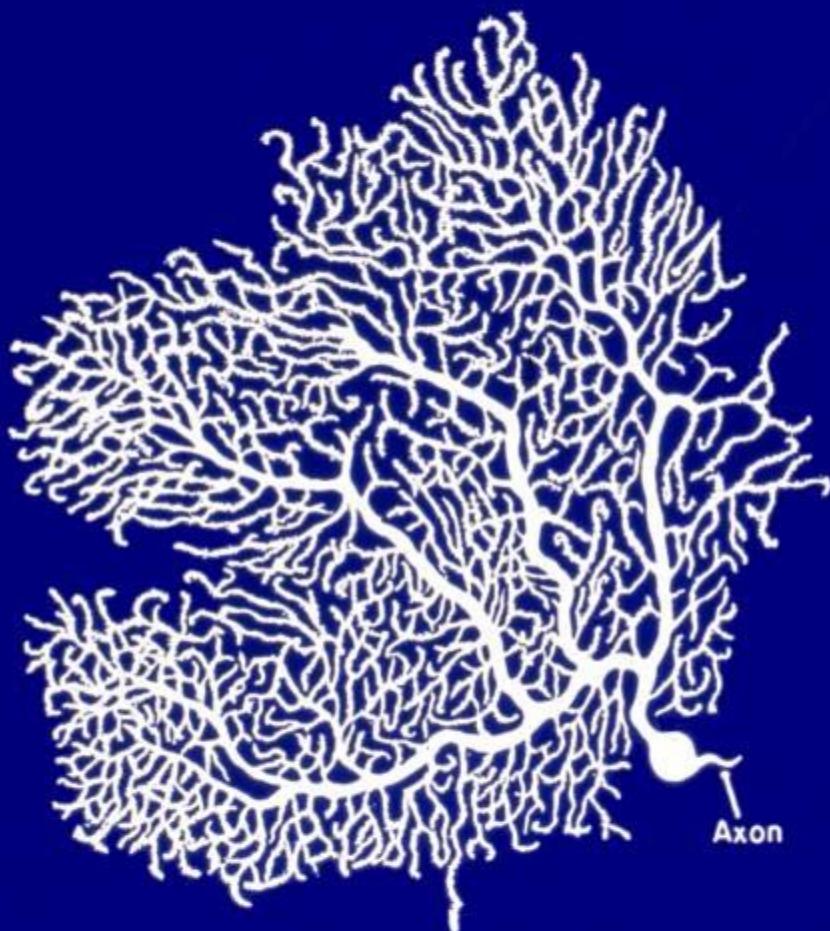


MULTIPOLÁRNÍ

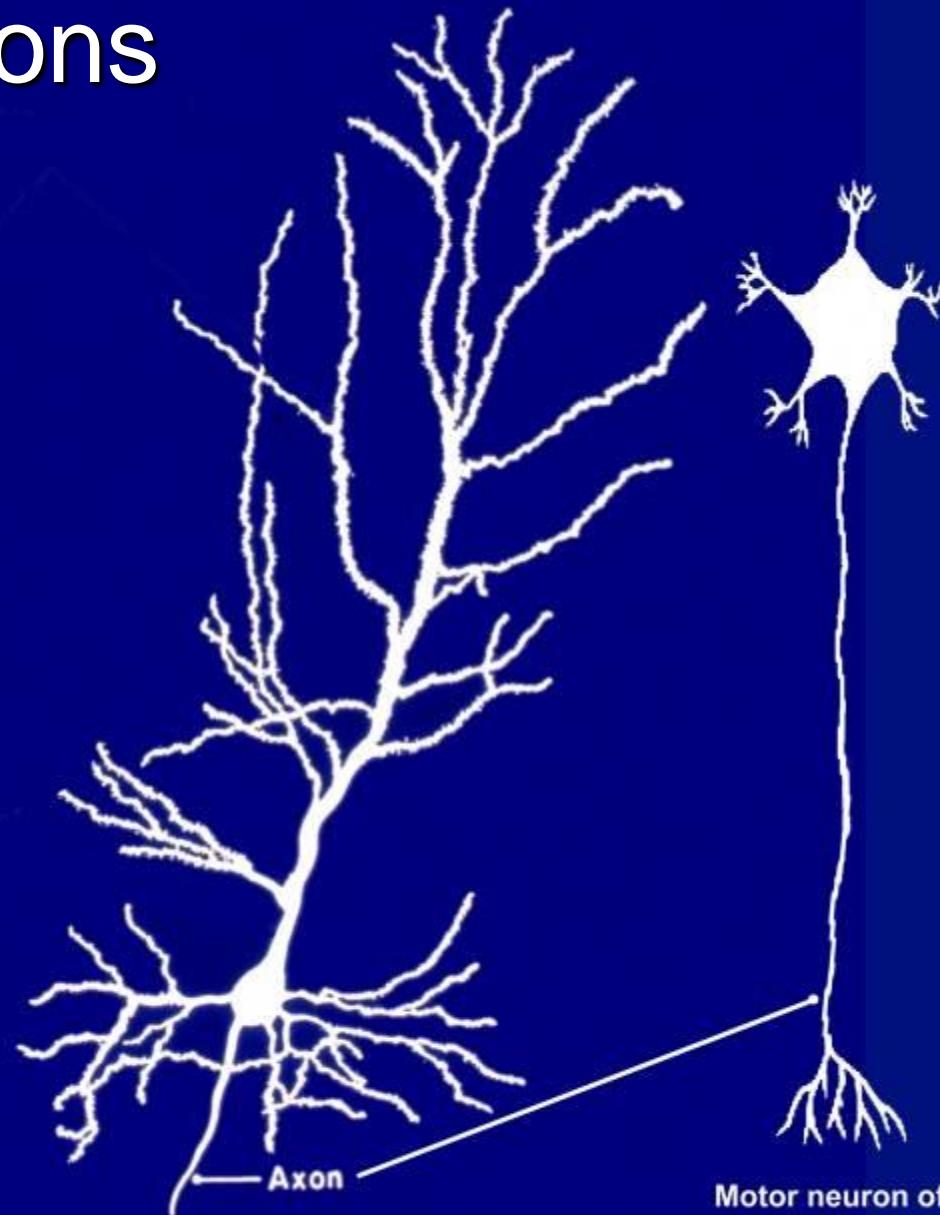


BIPOLÁRNÍ

Shapes of neurons



Purkinje cell of
cerebellar cortex



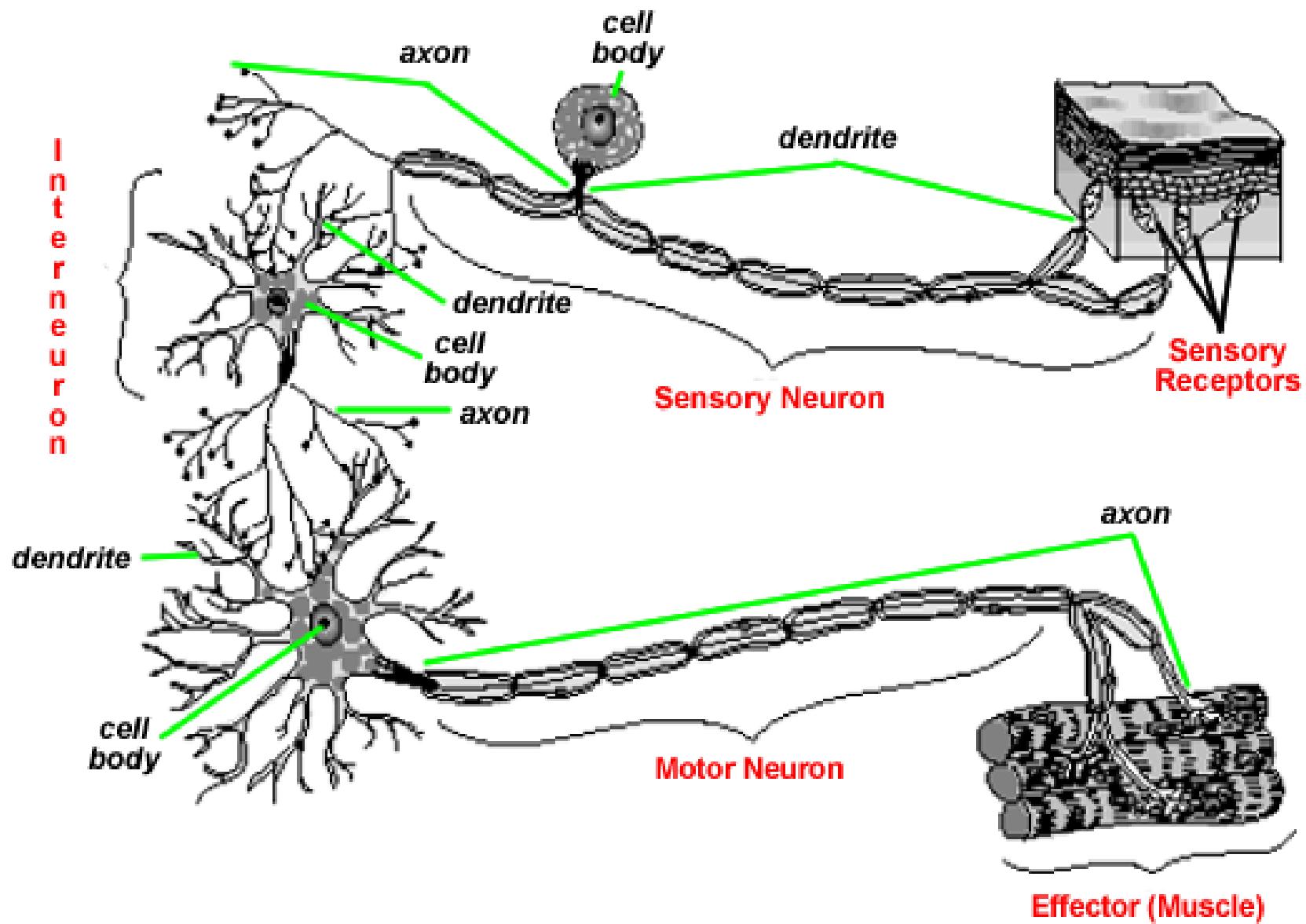
Pyramidal cell of
cerebral cortex

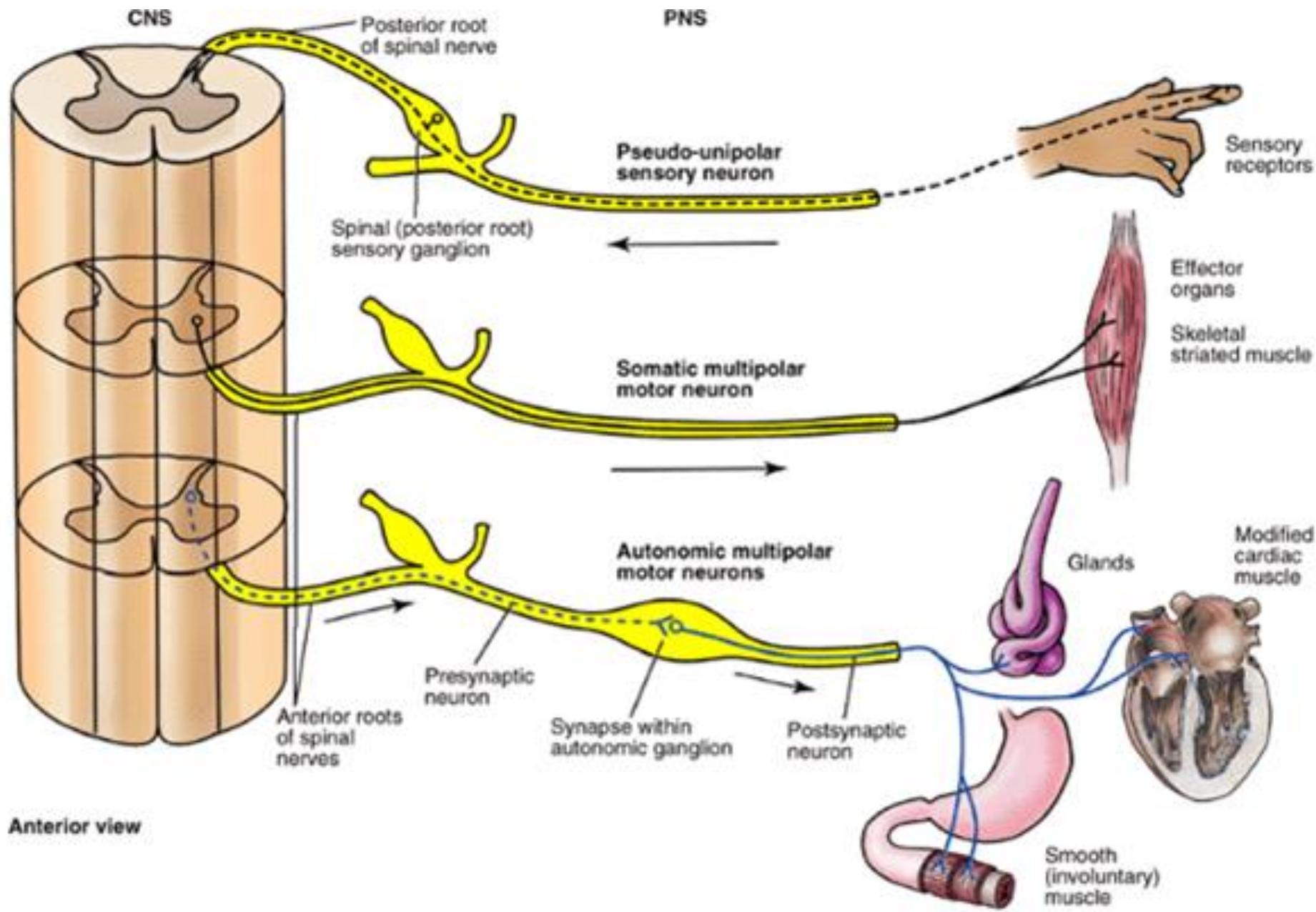
Motor neuron of
spinal cord

Neuron types according to function

- motor neuron / motoneurons (efferent, centrifugal)
 - axons from CNS to periphery (effector organ)
 - somatomotor to skeletal muscles
 - visceromotor to smooth and cardiac muscles and glands
- sensory neurons (afferent, centripetal)
 - axons from periphery to CNS
 - receive information receptors
 - skin (somatosensory) = exteroception
 - organs (viscerosensory) = interoception
 - muscles, tendons, joint capsule = proprioception
 - eye, ear, tongue, nose = special sensory
- interneurons
 - complex interconnections between motor and sensory neurons

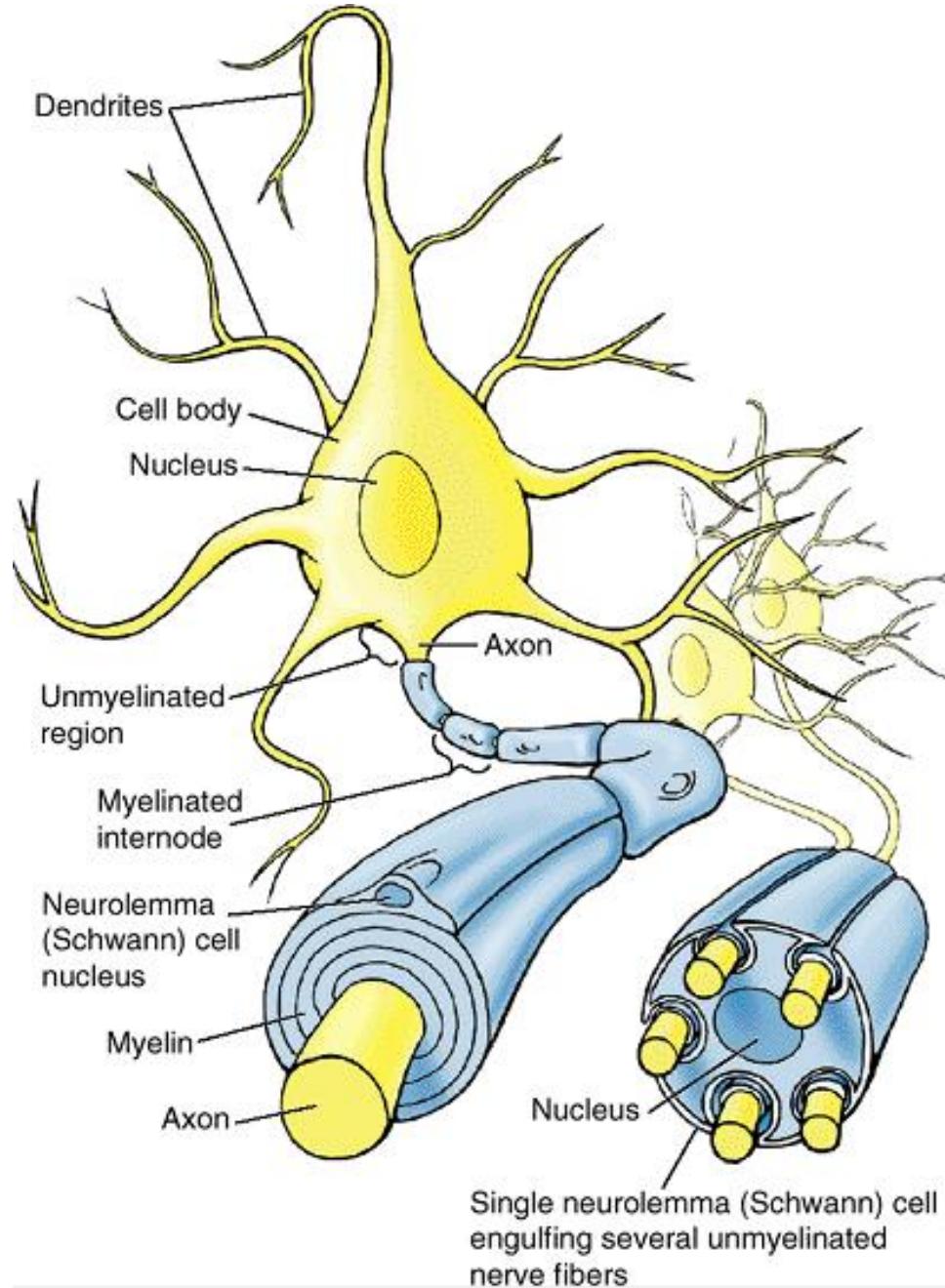
The 3 main types of Neurons

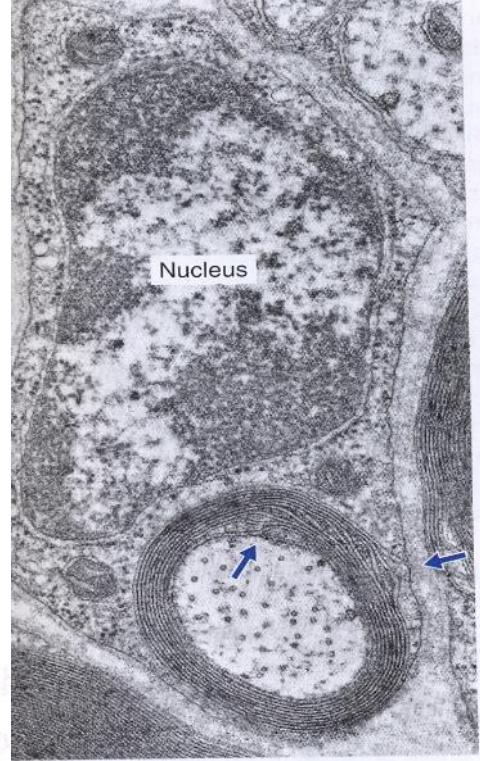
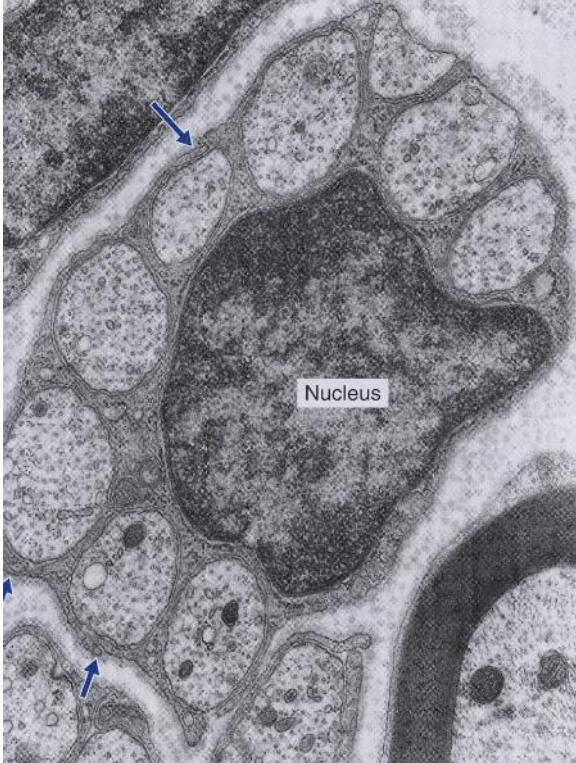




Neurofibra Nerve fibre

- axon
- neurolemma
- gray x white
- myelin sheath (*stratum myelini*)
- Ranvier's nodes (*nodi interruptionis myelini*; myelin sheath gaps)
- oligodendrocytes
- schwannocytes

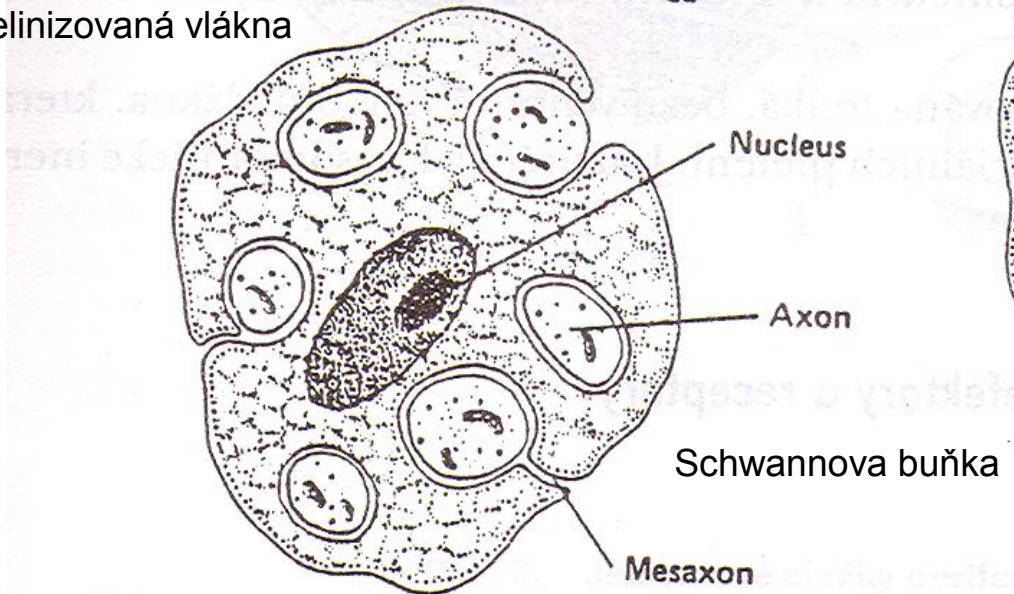




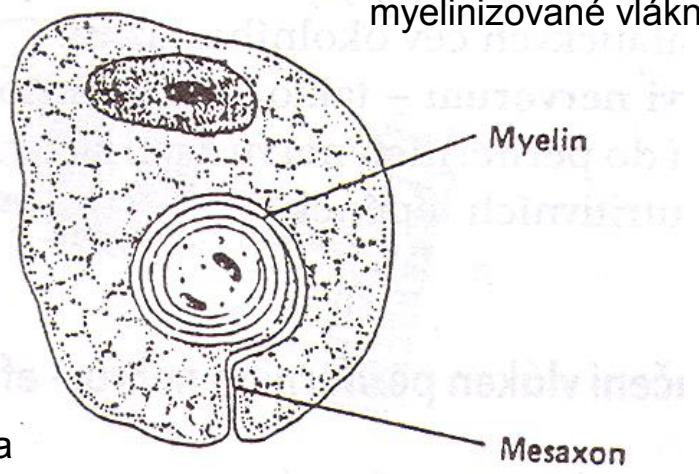
A

B

nemyelinizovaná vlákna

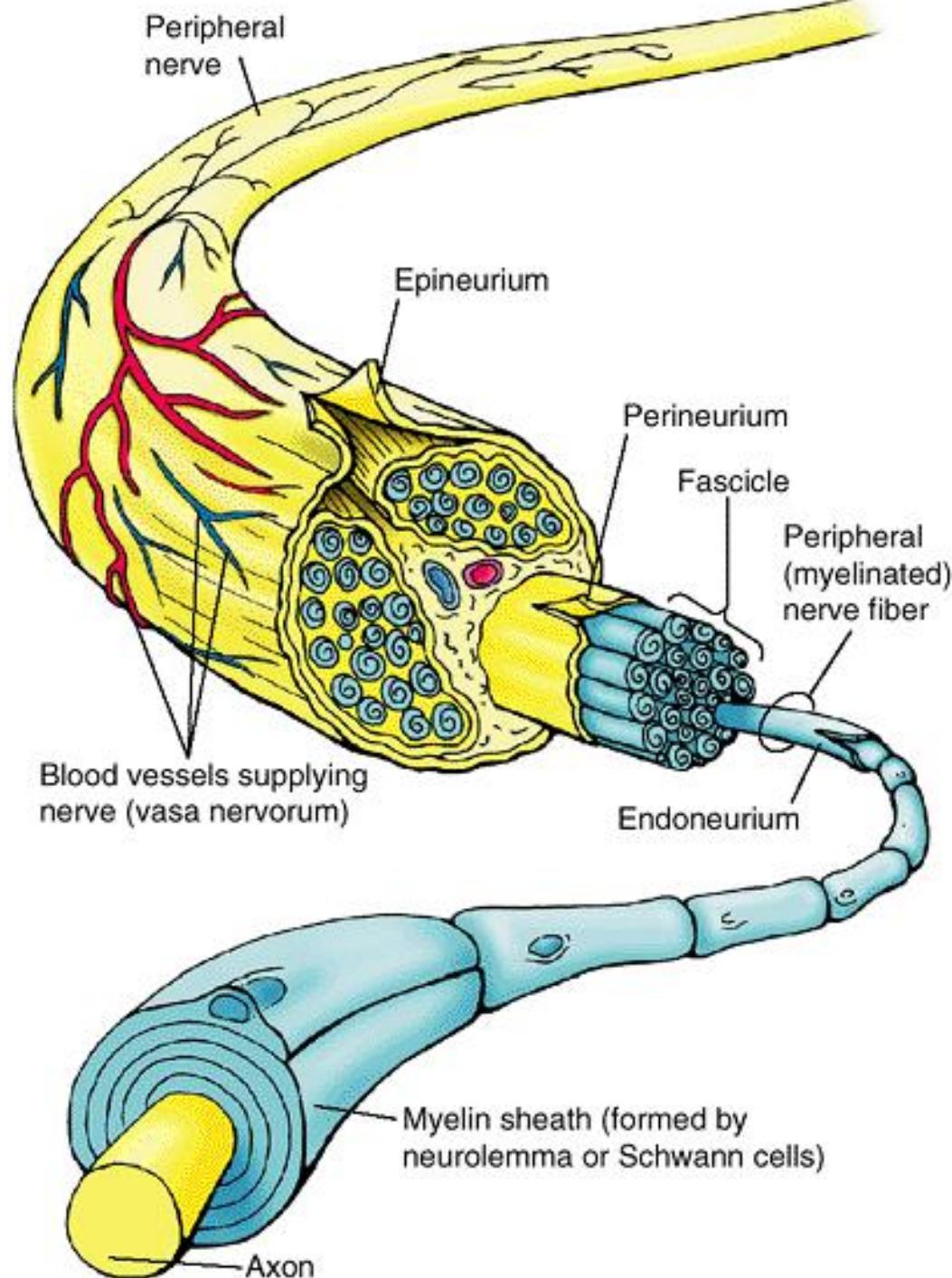


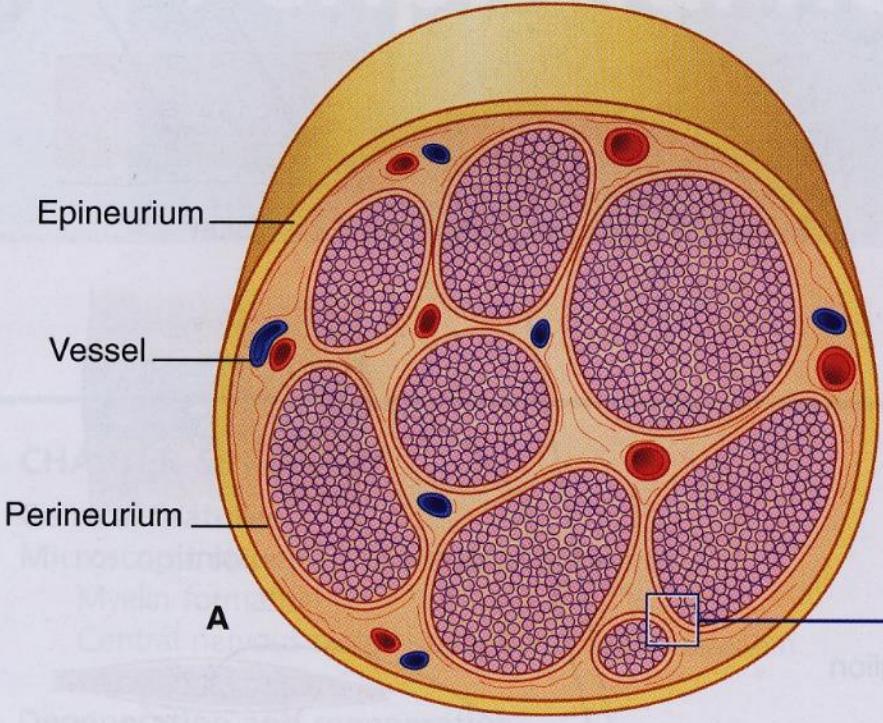
myelinizované vlákno



Nervi Nerves

- composed of nerve fibers
- covered with connective tissue
 - endoneurium
 - perineurium
 - epineurium
- vasa nervorum

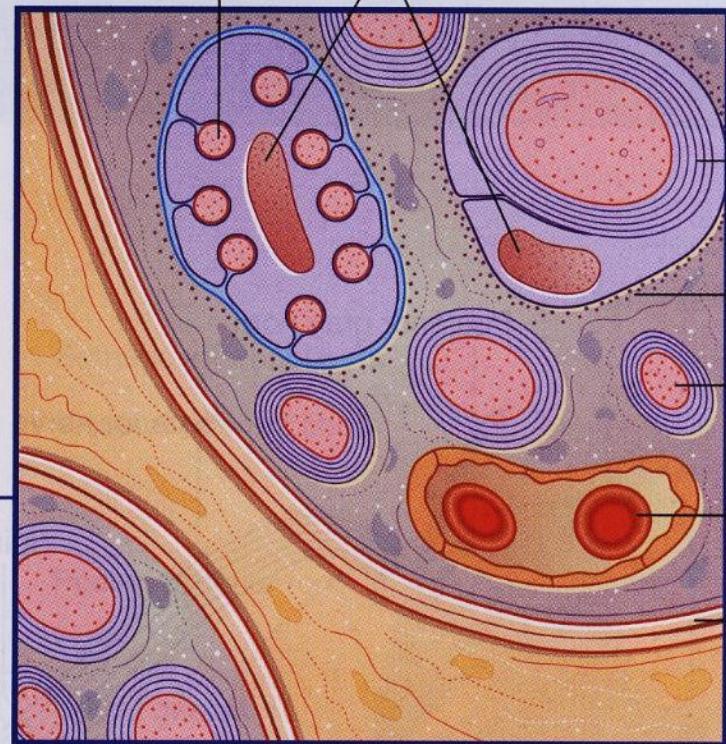




A

Epineurium
Vessel
Perineurium

Unmyelinated axon
Nuclei of Schwann cells



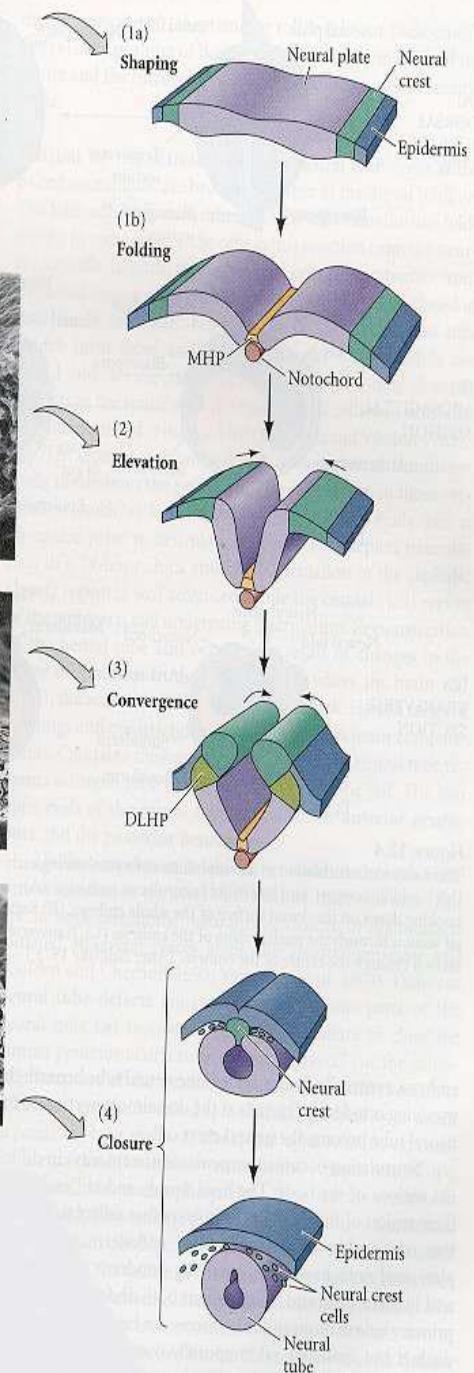
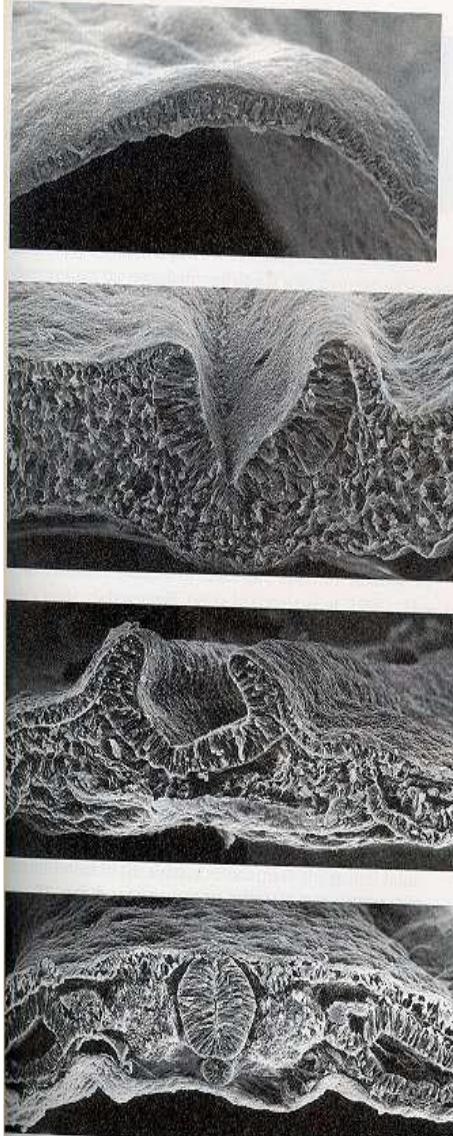
B

Myelin
Endoneurium
Myelinated axon
Erythrocyte
Perineurium

Figure 9.3 Transverse section of a nerve trunk. **(A)** Light microscopy. **(B)** Electron microscopy.

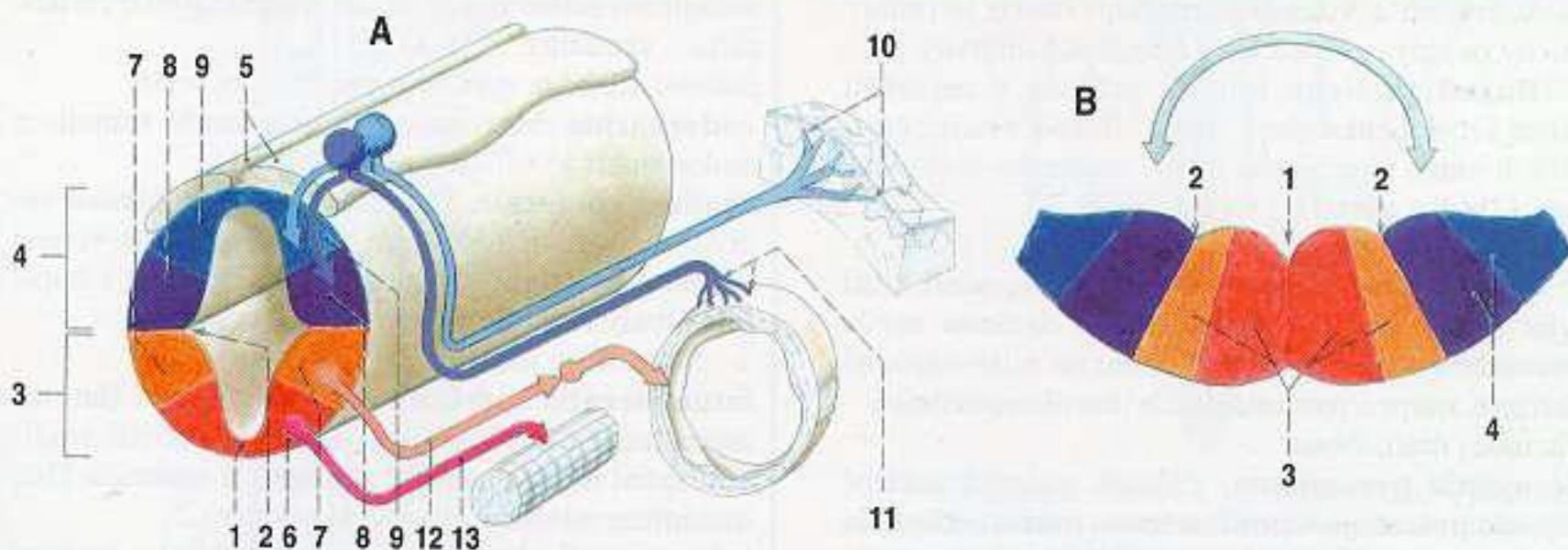
Development

- neural plate
- neural groove
- neural tube
- neural crest



- alar plate
- *sulcus limitans*
- basal plate

- somatosensory
- viscerosensory
- *sulcus limitans*
- visceromotor
- somatomotor



Afferent fibers

- begins at receptors in periphery
 - exteroceptors (somatosensory, special sensory)
 - interoceptors (viscerosensory)
 - proprioceptors
- always synapsed in spinal / cranial ganglia
- enter the posterior spinal horn / brainstem
- ascending tracts in CNS (to cortex, cerebellum, RF)

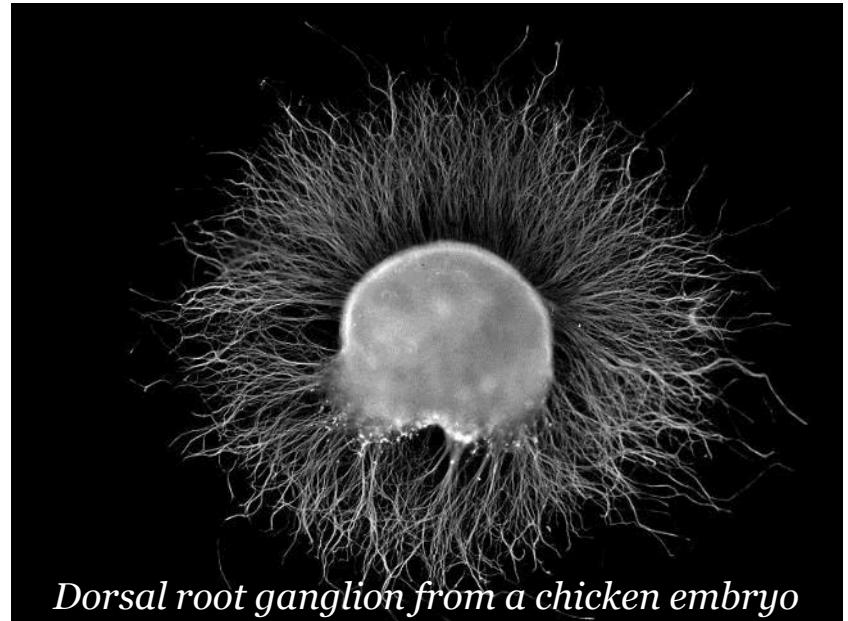
Efferent fibers

- begin at anterior spinal horns
- **somatomotor** (conscious / voluntary movements)
 - motor unit
 - to extrafusal (alpha) and intrafusal fibers (gamma)
 - no ganglia, directly to neuromuscular plate
- **visceromotor** (unconscious / involuntary movements)
 - follow cranial nerves (III, VII, IX, X)
 - leave nervus spinalis as ramus communicans albus („preganglionic“)
 - synapsed in autonomic ganglion to „postganglionic“ and diverge
 - as ramus communicans griseus to spinal nerve and further to periphery
 - via branches of truncus sympathetic

Nuclei and ganglia

= collection of neuron cell bodies

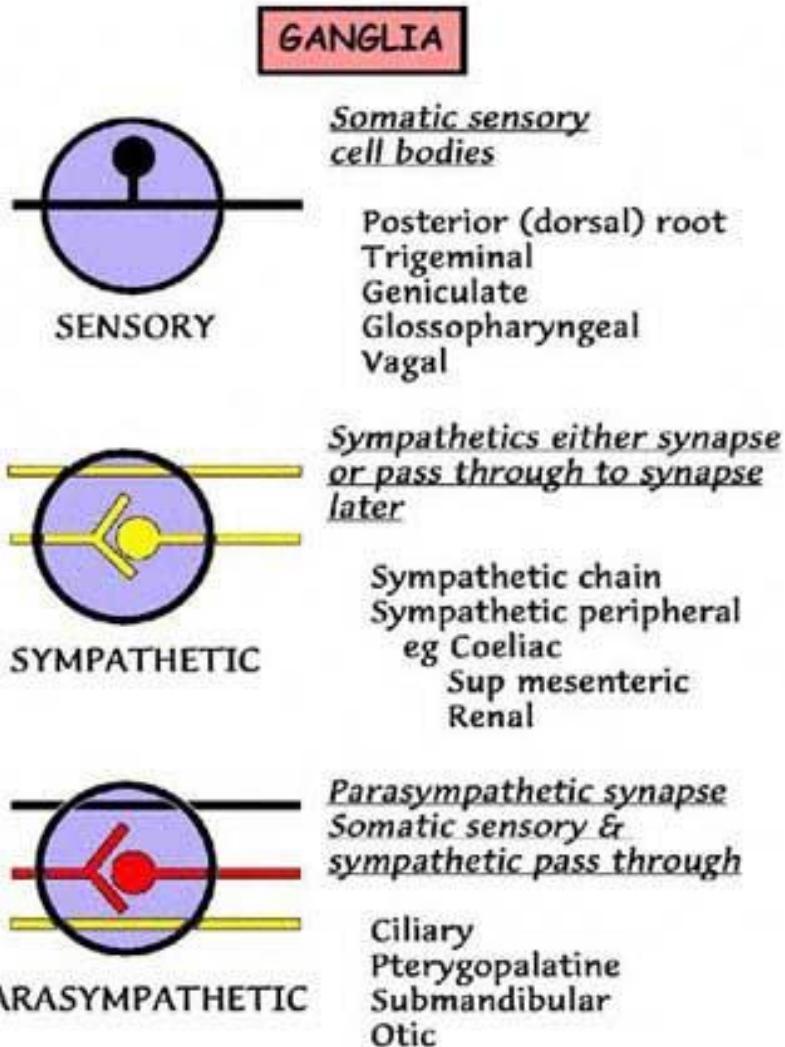
- ganglion
 - outside CNS
 - nerves of all modalities except somatomotor
- nucleus
 - within CNS



Dorsal root ganglion from a chicken embryo

Ganglia

- sensory
 - somatosensory
 - + viscerosensory
 - special sensory
- autonomic (*obsolete term „vegetative“*)
 - sympathetic
 - parasympathetic



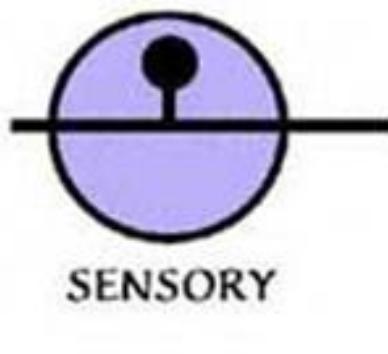
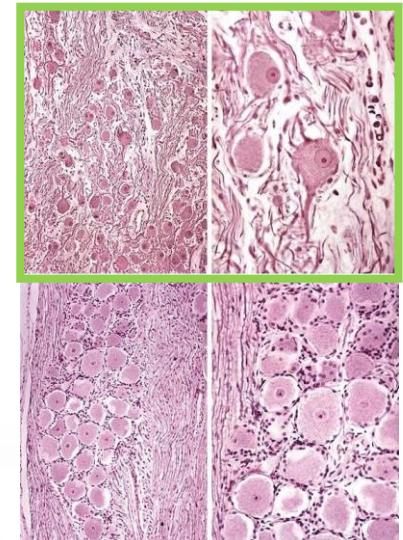
Each nerve has a cell body. For the sensory system this cell body is in the dorsal root ganglion or the equivalent for the sensory cranial nerves. There are no synapses in such ganglia.

In the sympathetic ganglia there are two alternatives. For those nerves that synapse there are cell bodies belonging to the post-ganglionic fibres. Others pass through without synapsing (gut & adrenal).

In the parasympathetic ganglia in the head and neck there is always a synapse with a post-ganglionic cell body.

Somatosensory ganglion

- **gll. spinalia** – at radix posterior n. spinalis
- **gll. of cranial nerves** – III, VII, IX, X
- contain **pseudounipolar neurons** („T-cells“)
- afferent
- mediator je glutamate (GLT)
- fibers do **not** synapse here !

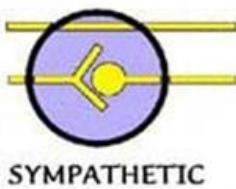
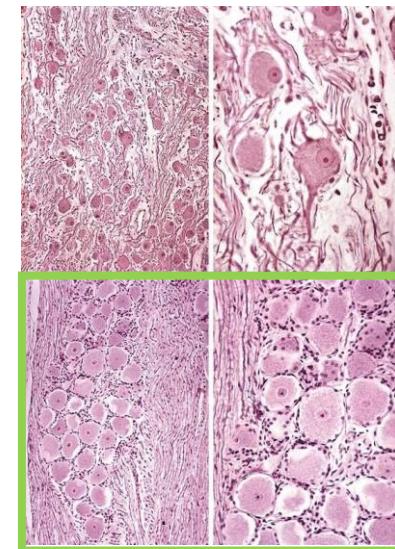


Somatic sensory
cell bodies

Posterior (dorsal) root
Trigeminal
Geniculate
Glossopharyngeal
Vagal

Autonomic ganglion

- **sympathetic** – paravertebral and prevertebral
- **parasympathetic** – cranial (ggl. ciliare, pterygoplatinum, submandibulare, oticum) and organ (within wall of internal organs)
- contain multipolar neurons
- efferent
- mediator is acetylcholine (Ach) in PSy and noradrenaline (Nor) in Sy
- fibers usually do synapse here !



Sympathetics either synapse or pass through to synapse later

Sympathetic chain
Sympathetic peripheral
eg Coeliac
Sup mesenteric
Renal



*Parasympathetic synapse
Somatic sensory & sympathetic pass through*

Ciliary
Pterygopalatine
Submandibular
Otic

Special sensory ganglion

ganglia n. VIII

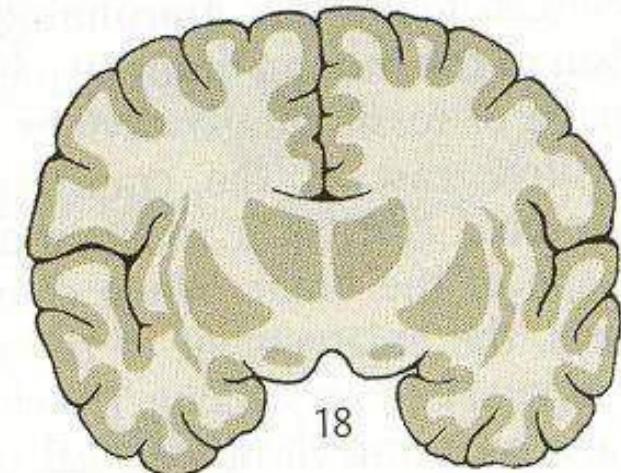
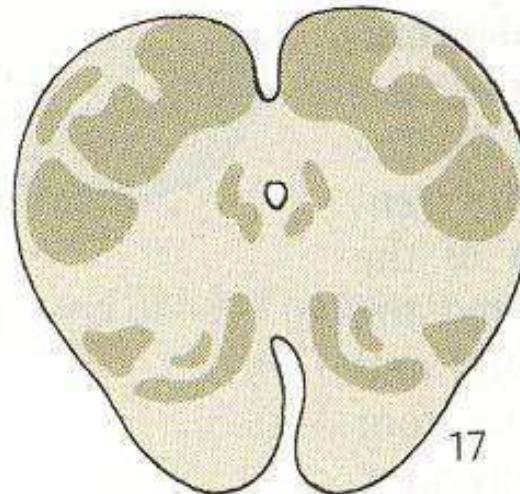
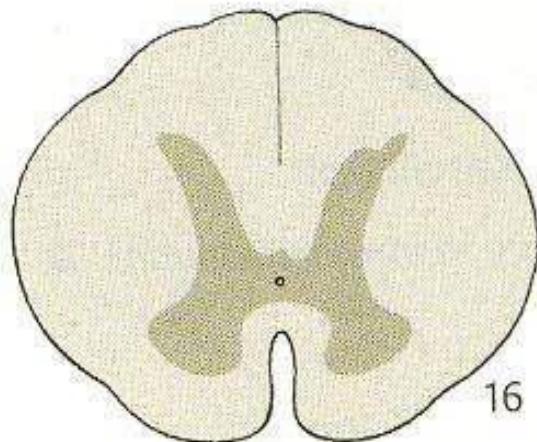
- ggl. cochleare
- ggl. vestibulare
- functionally correspond to sensory ganglion
- afferent
- contain **bipolar neurons**
- fibers do always synapse here

Peripheral nerves can carry 5 kinds of functionally different fibers

- **somatomotor** – to striated musculature of trunk and limbs
- **somatosensory** – from skin and musculature of trunk and limbs (touch, pain, proprioception)
- **visceromotor** – to cardiac and smooth musculature of viscera, blood vessels and glands
- **viscerosensory** – from viscera and heart
- **special sensory** – from special sensory organs (vision, hearing, balance, taste, smell)

The proportion of different fibers vary greatly in particular nerves.

- substantia grisea (gray matter)
 - contains neurons (perikarya and dendrites)
- substantia alba (white matter)
 - bundles of nerve fibers (axons and central processes of pseudounipolar neurons) passing to or from nuclear region,
 - form tract or fasciculus



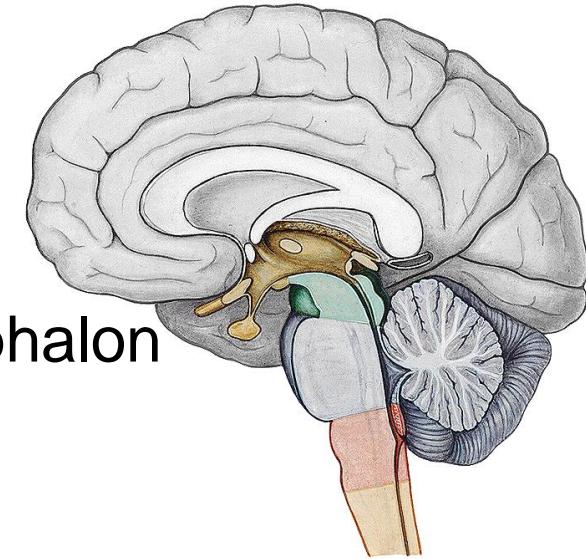
B Distribution of white and gray matter

Basic neuroanatomy - Parts of nervous system

Systema nervosum centrale

(central nervous system)

- medulla spinalis (spinal cord)
- encephalon (brain)
 - truncus encephali (brain stem)
 - medulla oblongata, pons, mesencephalon
 - cerebellum
 - diencephalon
 - thalamus, hypothalamus, epithalamus, metathalamus, subthalamus
 - telencephalon
 - pars pallialis (hemispheres), pars basalis (basal ganglia), pars septalis (septum)



**Telecephalon
(Hemisphera)**

**Diencephalon
(Hypothalamus)**

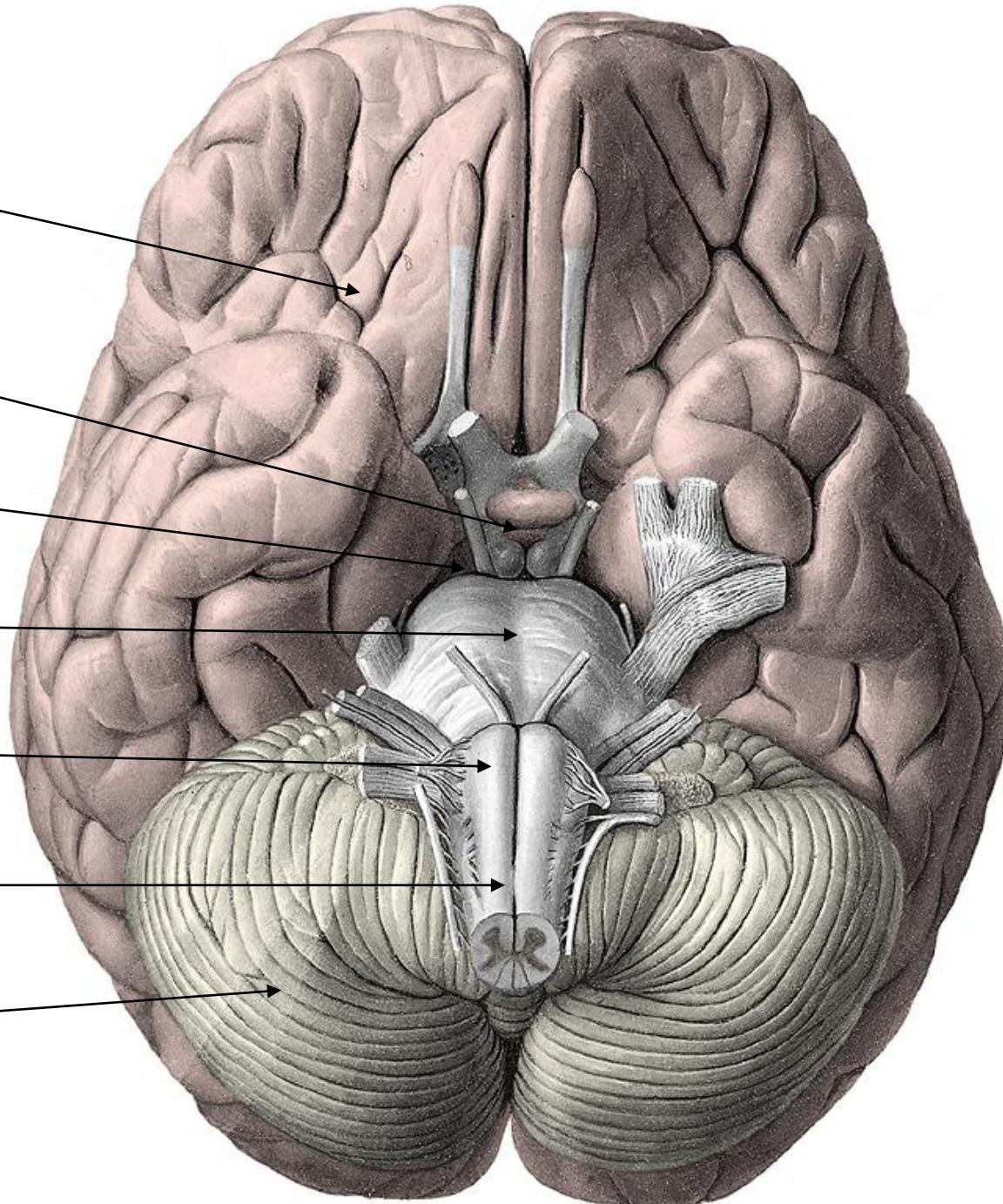
Mesencephalon

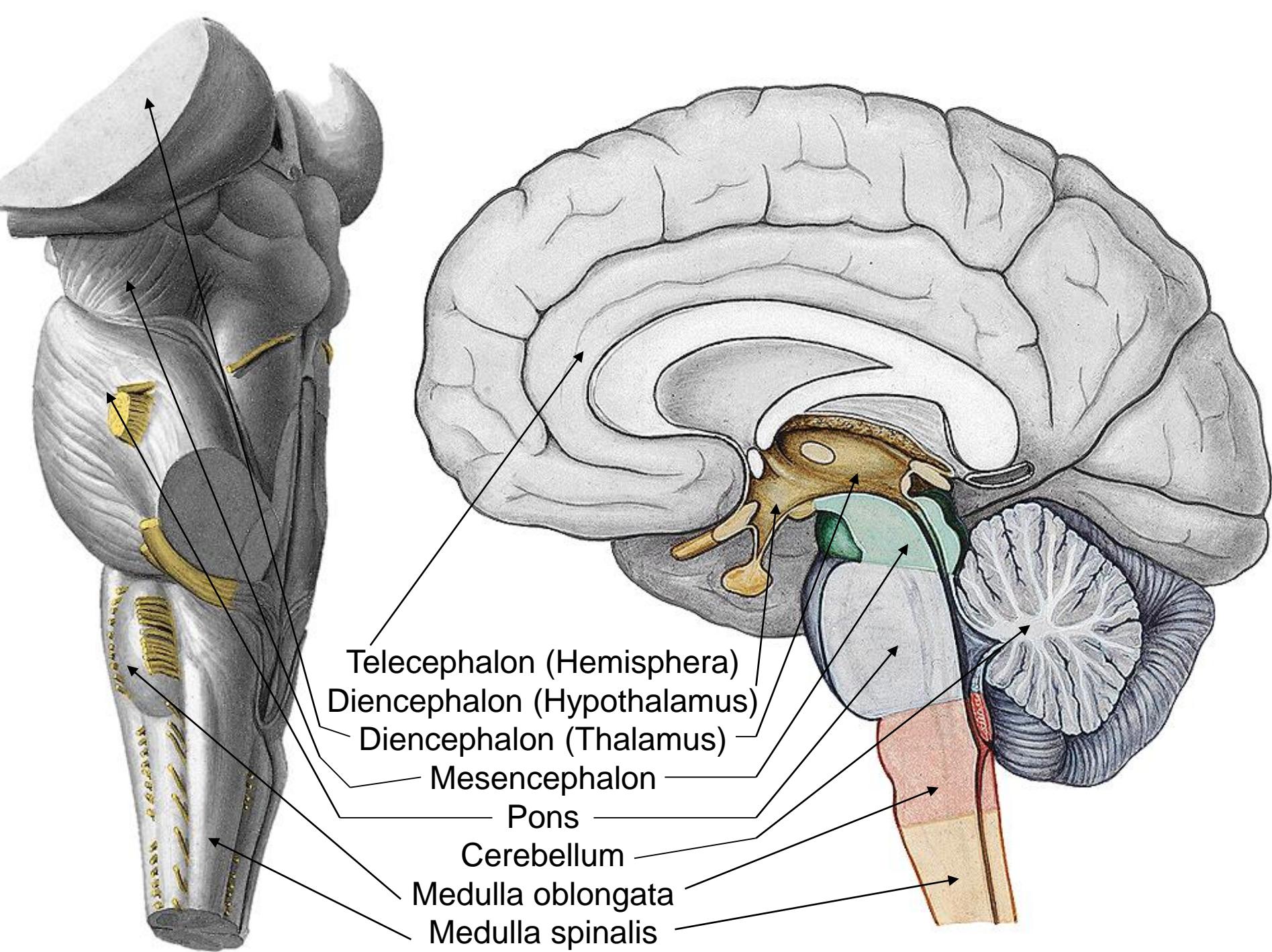
Pons

Medulla oblongata

Medulla spinalis

Cerebellum

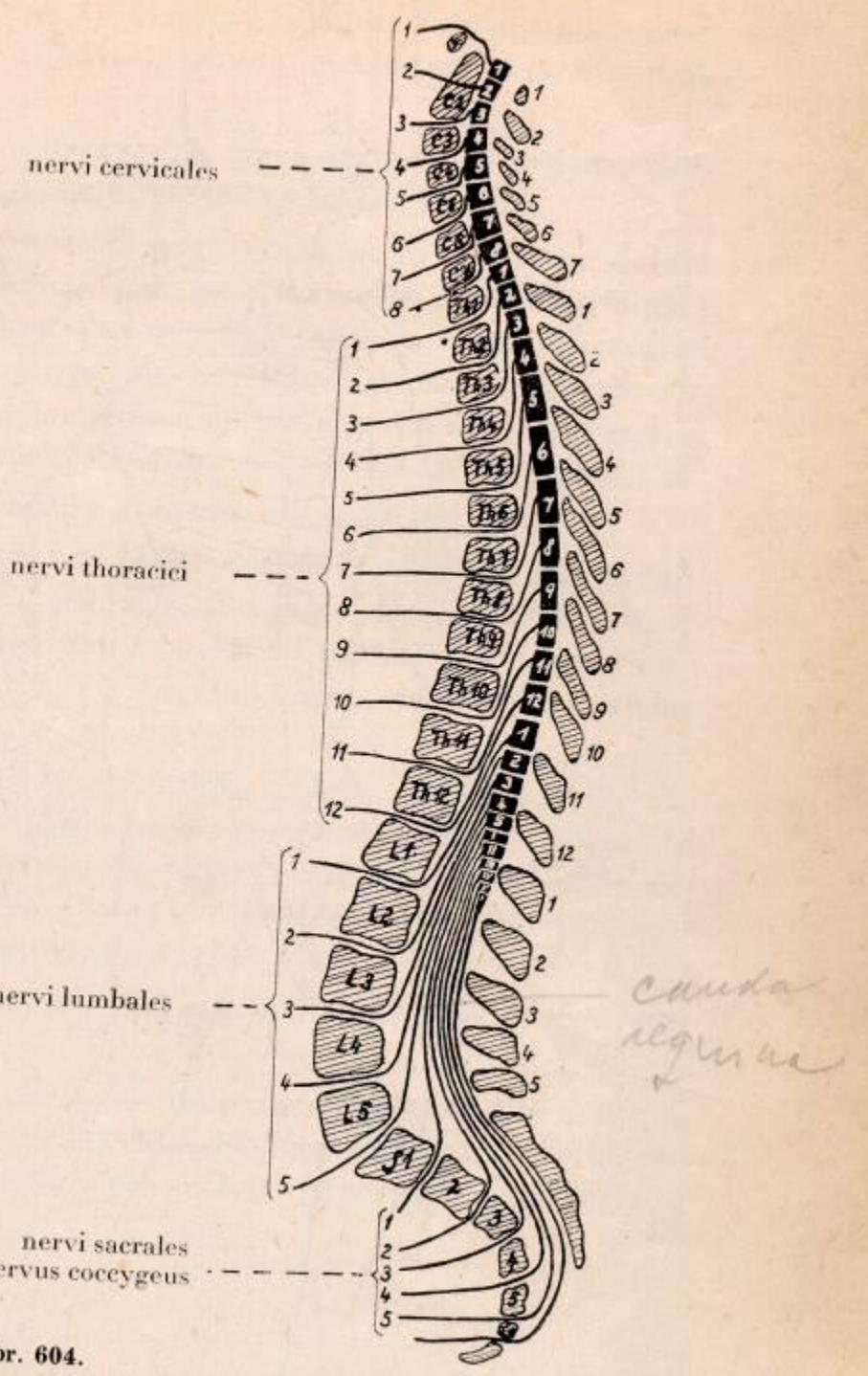
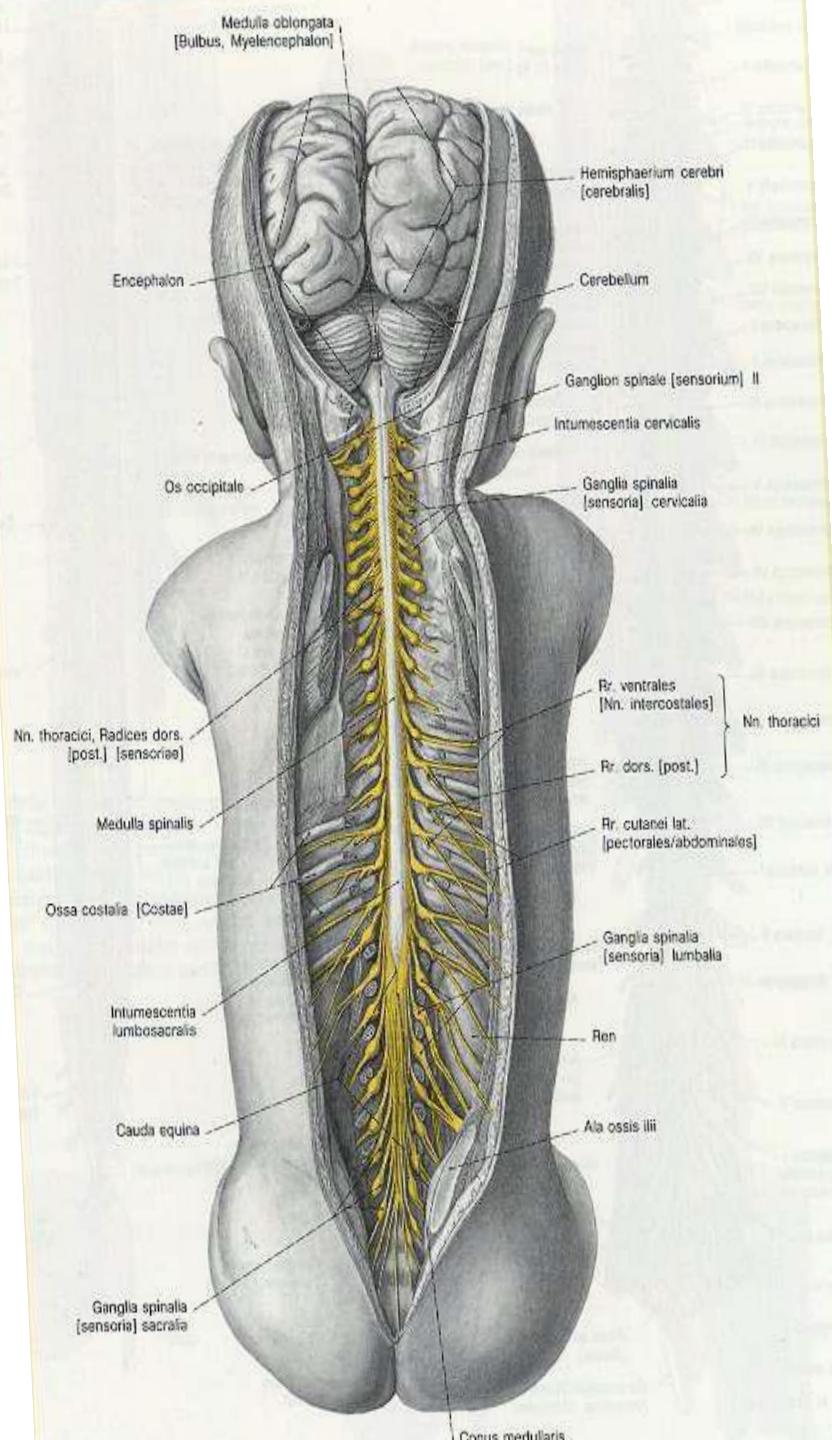




Basic neuroanatomy - Parts of nervous system

Systema nervosum periphericum (peripheral nervous system)

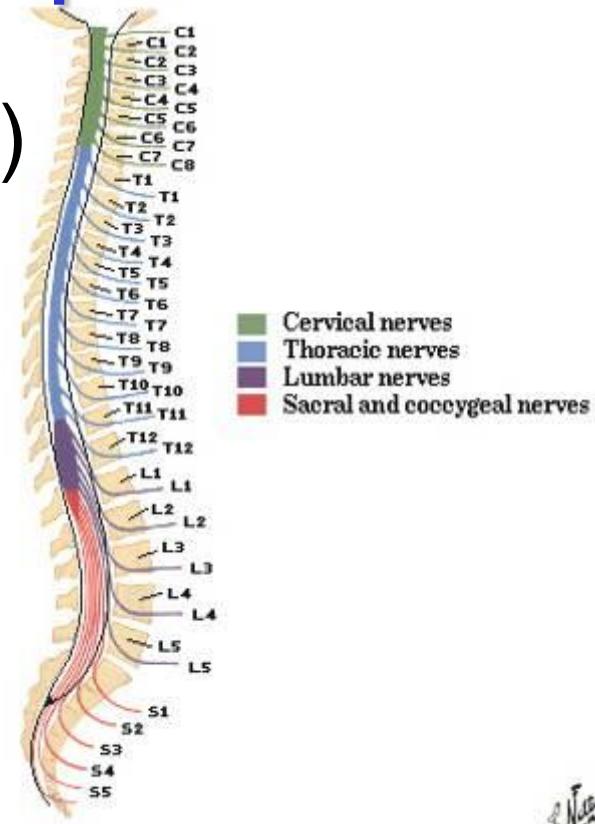
- nervi spinales (spinal nerve)
- nervi craniales (cranial nerves)
- sistema autonomicum (autonomic nerves)
 - obsolete term „vegetative system“
 - pars sympathica (sympathetic)
 - pars parasympathica (parasympathetic)



Nervi spinales – 31 pairs

mixed nerves (different modalities)

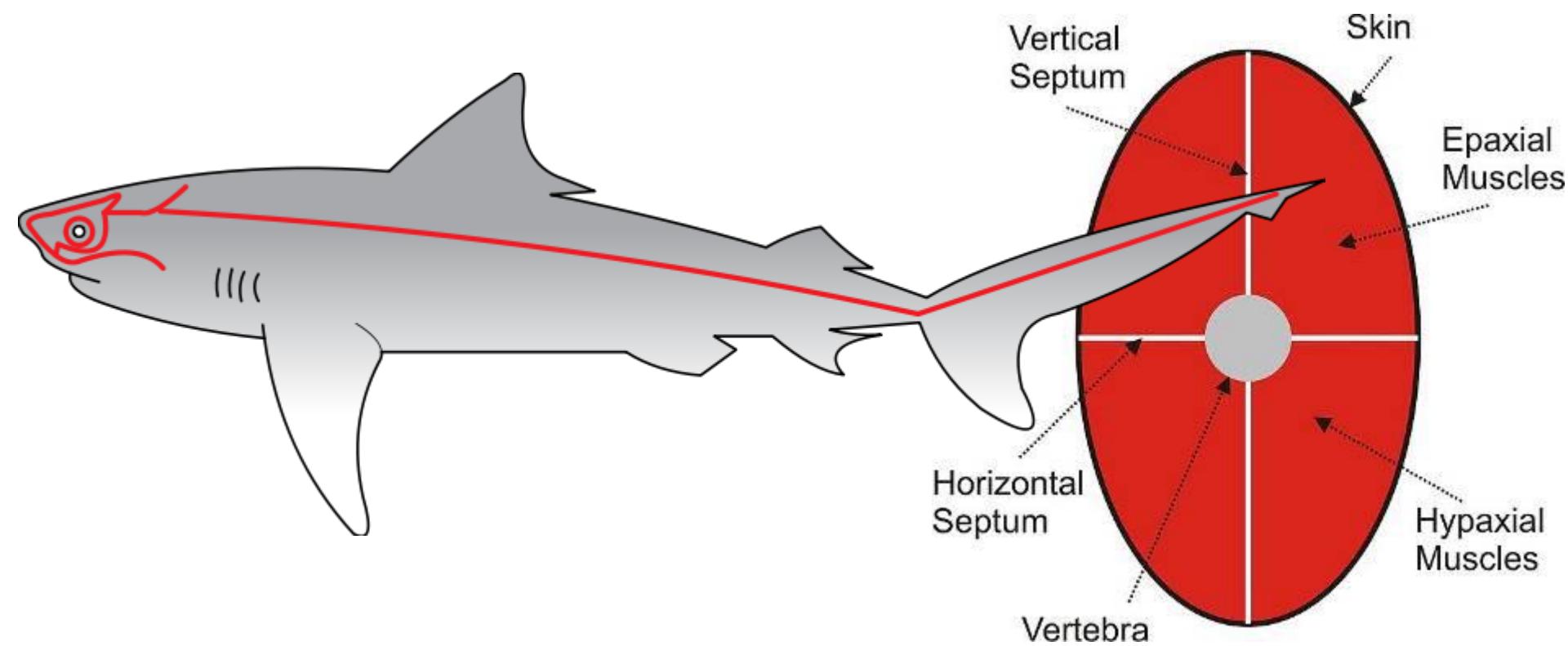
- nervi cervicales – 8 pairs
- nervi thoracici – 12 pairs
- nervi lumbales – 5 pairs
- nervi sacrales – 5 pairs
- nervus coccygeus – 1 pair



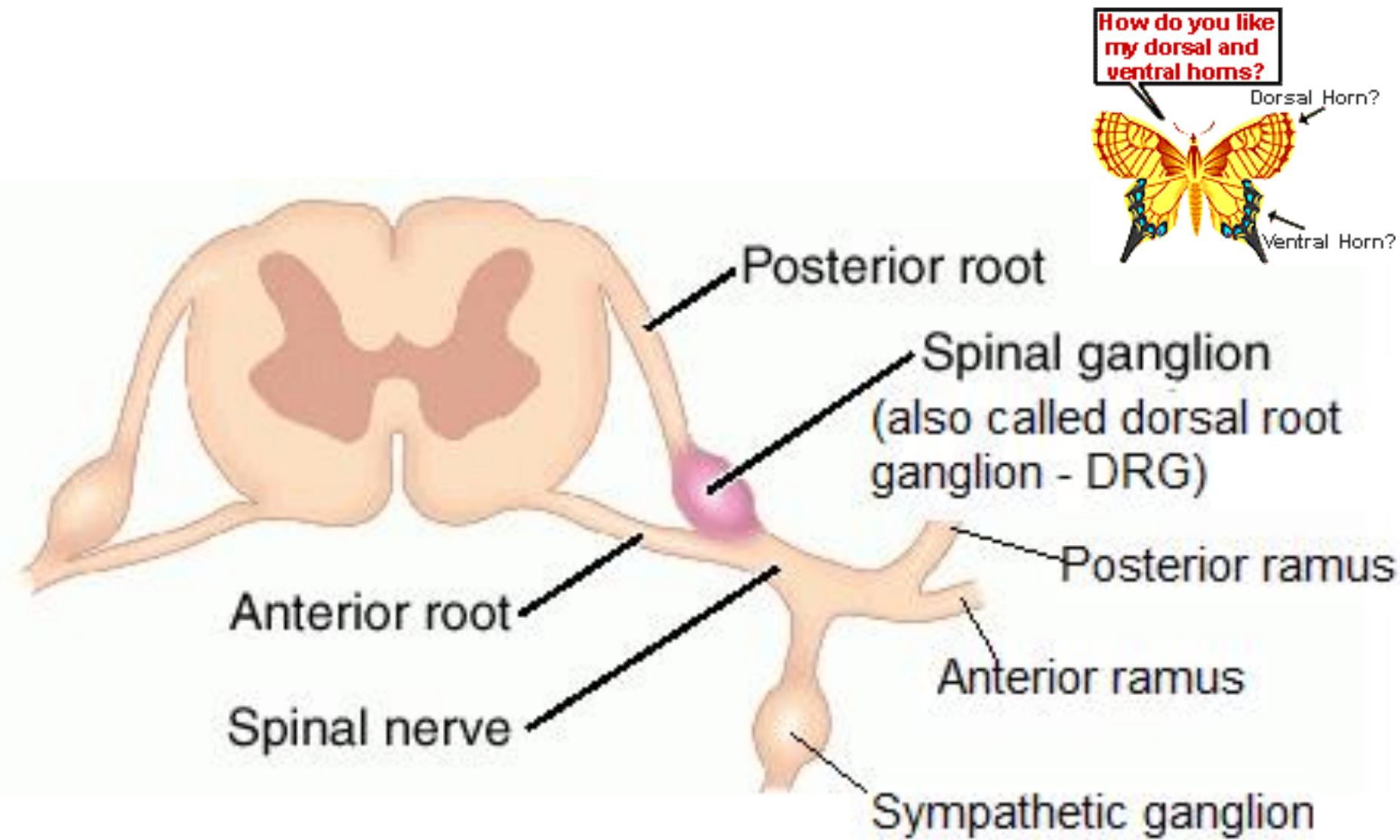
exit via foramen intervertebrale

- S1-S4 already as r. ant+post. via foramina sacralia ant.+post.
- S5 + Co via hiatus sacralis

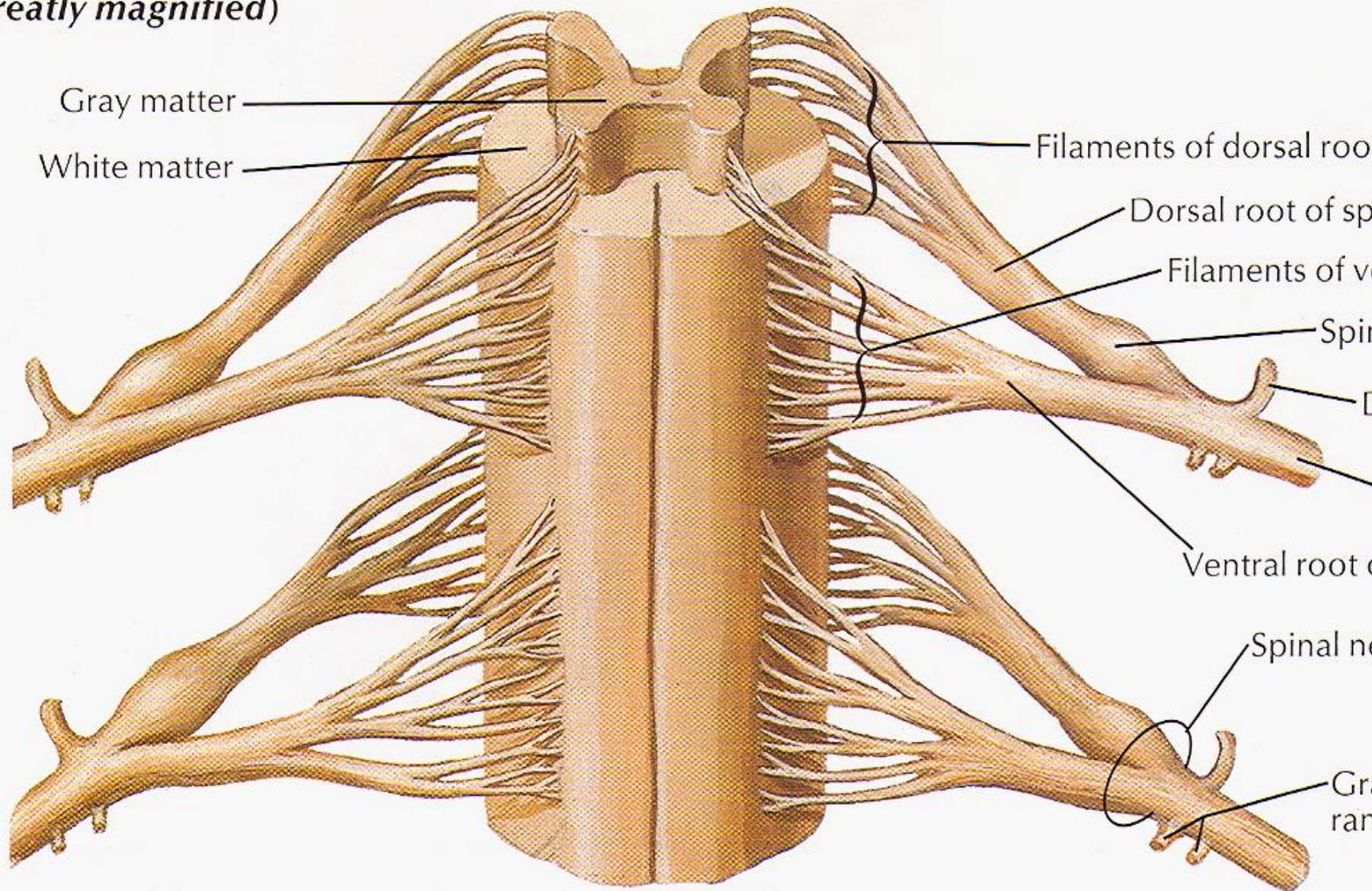
Epaxial and hypaxial muscles



Macroscopy of spinal nerve branching



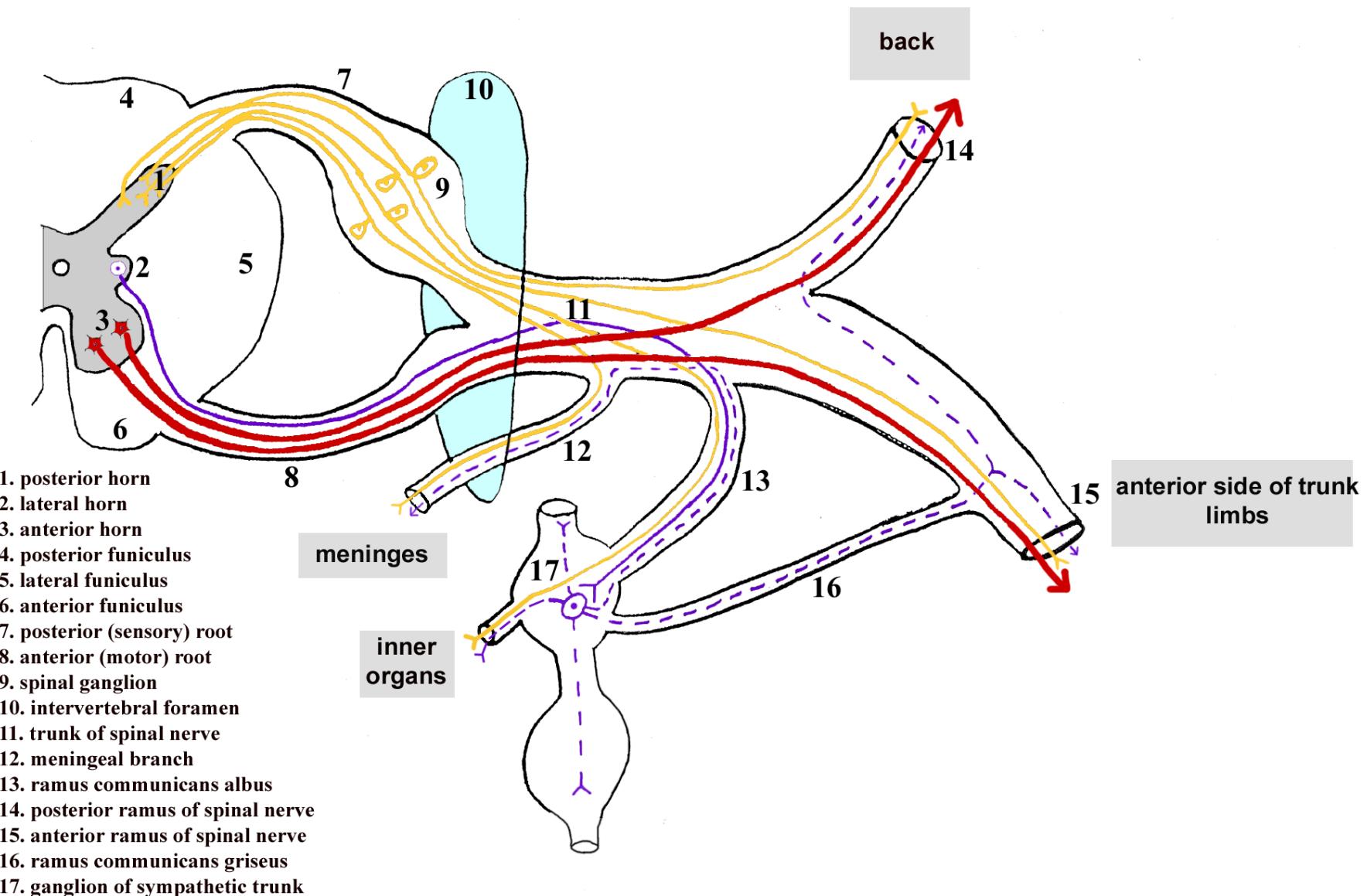
**Membranes removed: anterior view
(greatly magnified)**

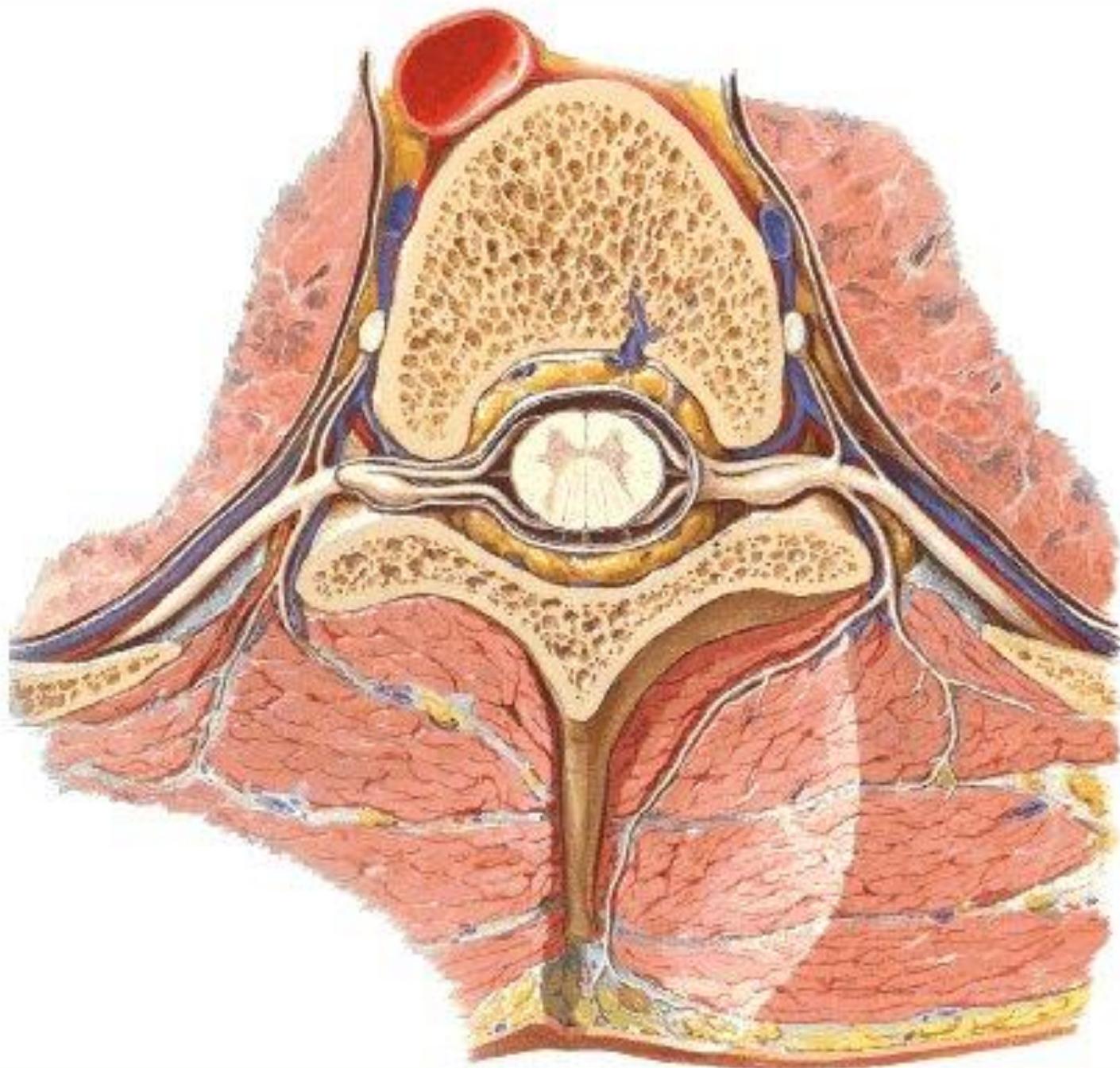


Branches of spinal nerve

- r. anterior → *forms plexuses* → *hypaxial muscles*
- r. posterior → *epaxial muscles*
- r. meningeus
 - recurrent branch to vertebral canal
 - sensory and visceromotor fibers
- r. communicans albus
 - preganglionic fibers to truncus sympatheticus and its ganglia (C8-L3)
- r. communicans griseus
 - postganglionic fibers from ganglion trunci sympathici back to n. spinalis

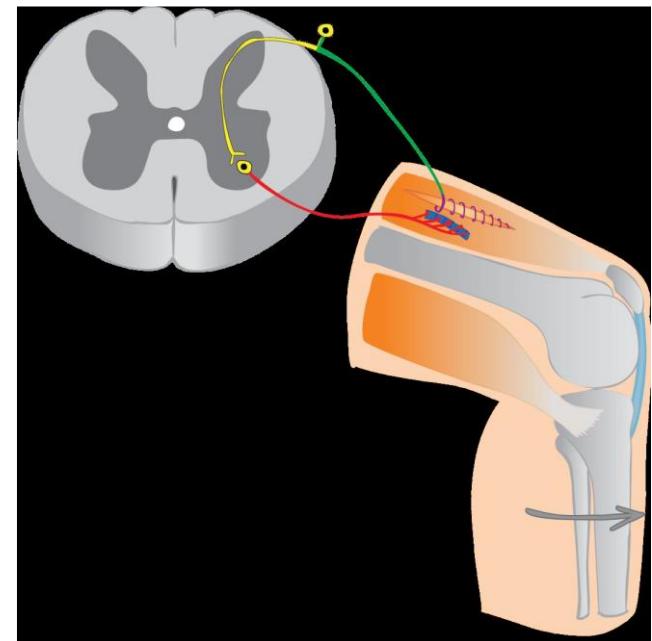
SCHEME OF SPINAL NERVE BRANCHING



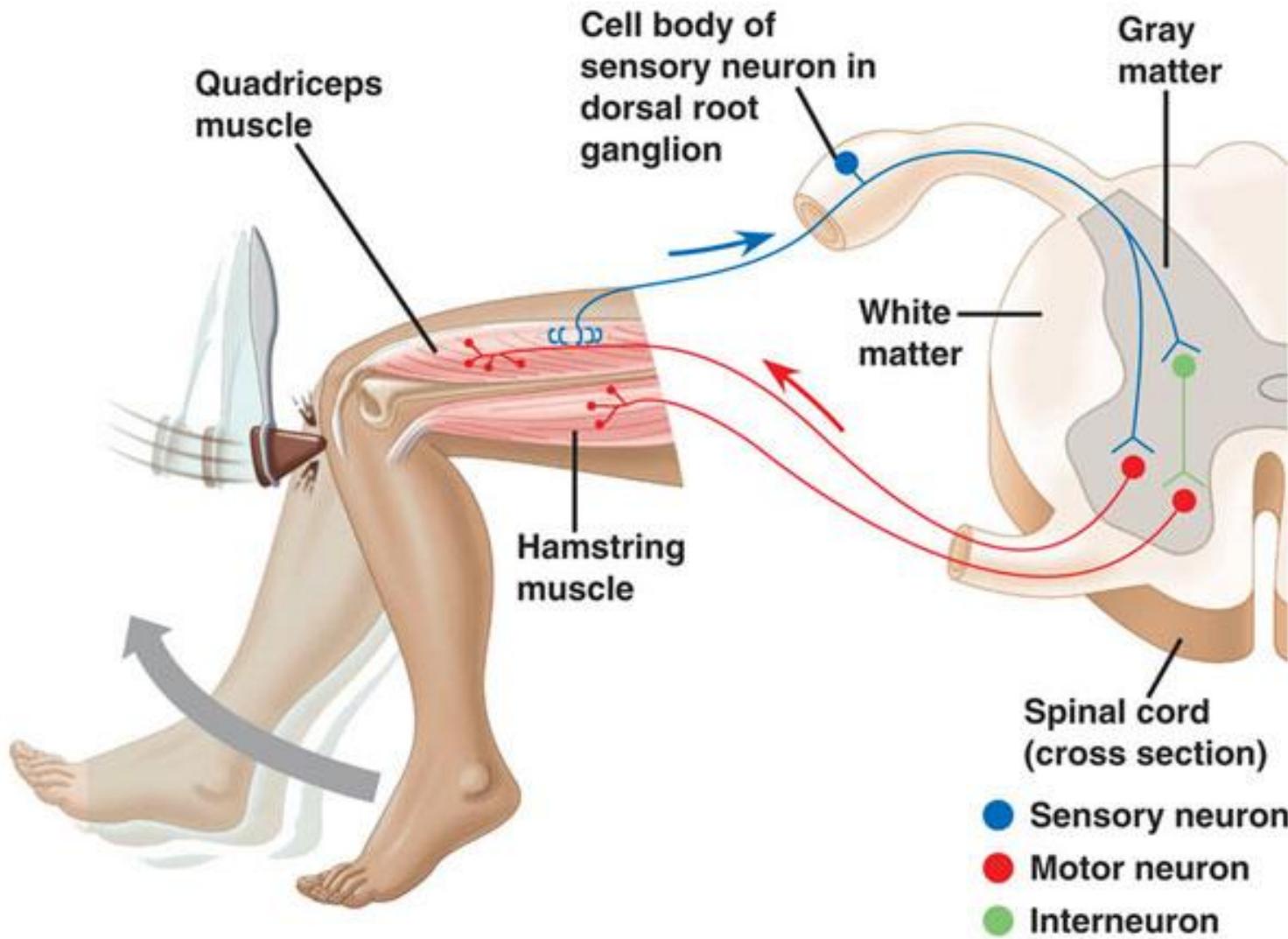


Proprioceptive monosynaptic reflex arc

- jerk reflex
- 1. somatic **receptor** – muscle spindle (intrafusal muscle fibers)
- 2. **afferent limb** – dendrite of pseudounipolar neuron
- 3. integrating center in CNS (synapse)
 - 3.1 somatosensory – pseudounipolar neuron
 - 3.2 somatomotor – alfa-motoneuron
- 4. **efferent limb** – axon of alfa-motoneuron
- 5. **effector** – contraction of striated muscle (agonist)

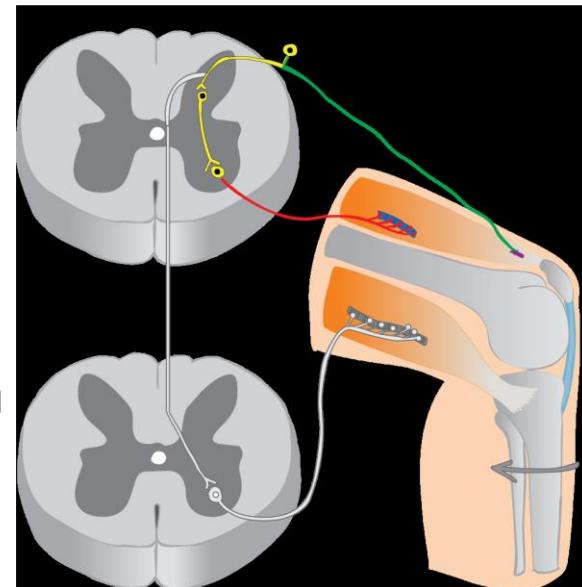


Monosynaptic reflex



Polysynaptic reflex

1. **receptor** – Golgi tendon organ of striated muscle
2. **afferent limb** – peripheral process of pseudounipolar neuron
3. **integrating center** in CNS (synapse)
 - more than 2 neurons
- 3.1 **somatosensory** – pseudounipolar neuron
- 3.2 **interneuron**
- 3.3 **somatomotor** – alfa-motoneuron
4. **efferent limb** – axon of alfa-motoneuron
5. **effector** – relaxation of the stimulated muscle (agonist), dominance of antagonist



TRACTUS PYRAMIDALIS

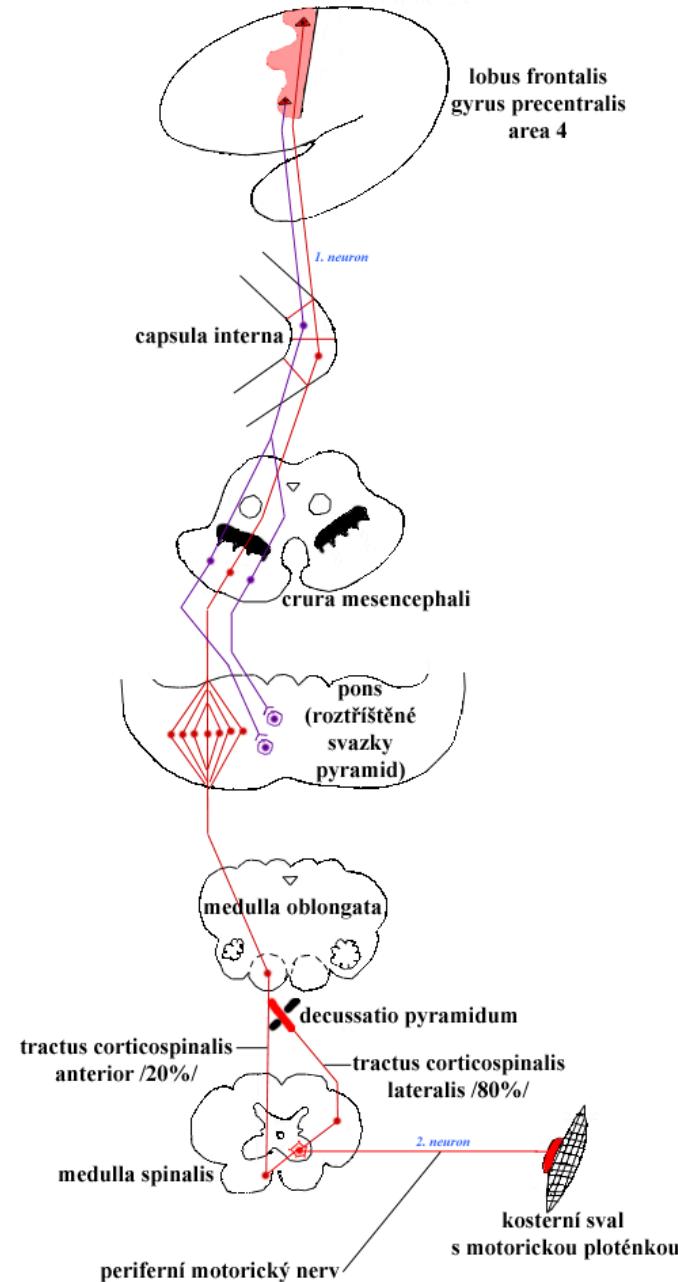
- fibrae corticospinales (zkřížená dráha)

- fibrae corticonucleares

(nezkřížená dráha s výjimkou n. IV a části n. III)

Tractus pyramidalis

- 2-neuron tract
- cortex → muscle
- 1st order neuron = pyramidal cell of cerebral cortex
- 2nd order neuron = alfa-motoneuron of anterior spinal horn
- decussated at level of C1
- lesion: *central contralateral palsy (paralysis)*



Central (= spastic) paralysis/palsy

- lesion of central = 1st = cortical motoneuron (axon travels within tractus pyramidalis)
- elevated muscle tone (= spasticity)
- lesion of voluntary motorics (= paresis) – *checked by muscle test 0-5*
- elevated tendon reflexes (= hyperreflexia)
 - lowered threshold of sensitivity, elevated intensity of muscle response, extended reflexory zone
- pathological pyramidal irritation reflexes (e.g. Babinski)
- discrete muscle hypotrophy
- reduced or absent exteroceptive (= skin) reflexes
- spinal shock (3 days up to several weeks)
 - pseudoflaccid palsy during this period

plegia/paralysis = complete palsy (*muscle test = 0*)

paresis = incomplete/partial palsy

Central (= spastic) paralysis/palsy

ARM AND LEG ON ONE SIDE (HEMIPLEGIC)

arm bent;
hand
spastic
or floppy,
often of
little use

She walks
on tiptoe
or outside
of foot on
affected
side.



this side
completely
or almost
normal

BOTH LEGS ONLY (PARAPLEGIC) or with slight involvement elsewhere (DIPLEGIC)



upper body
usually
normal or
with very
minor signs

Child may
develop
contractures
of ankles
and feet.



BOTH ARMS AND BOTH LEGS (QUADRIPLEGIC)

When he walks, his
arms, head, and
even his mouth may
twist strangely.

Children with all
4 limbs affected
often have such
severe brain damage
that they never
are able to walk.

The knees press
together.
legs and feet
turned inward

Central (= spastic) paralysis/palsy

Identifying gait abnormalities

SPASTIC GAIT



SCISSORS GAIT



PROPELLIVE GAIT



STEPPAGE GAIT



WADDLING GAIT



Peripheral (= flaccid) paralysis/palsy

- lesion of peripheral = 2nd = motoneuron of anterior spinal horn (perikaryon within spinal cord or axon within nerve)
- reduced muscle tone (= hypotonia)
- lesion of voluntary motorics (= paresis) – *checked by muscle test 0-5*
- reduced or absent tendon reflexes (= hypo-, areflexia)
- absent pathological pyramidal irritation reflexes
- prominent muscle hypotrophy
- reduced or absent exteroceptive (= skin) reflexes
- typical lesions of sensitivity (according to dermatomes)

Mixed paralysis/palsy

- in ALS (= amyotrophic lateral sclerosis)
- concurrent lesion of anterior spinal horns and pyramidal tract
- 2-3 year survival
- *Stephen W. Hawking (1942-2018) – ill from 1963*



Axon regeneration

- PNS
cca 2 mm/day
- CNS
no
regeneration

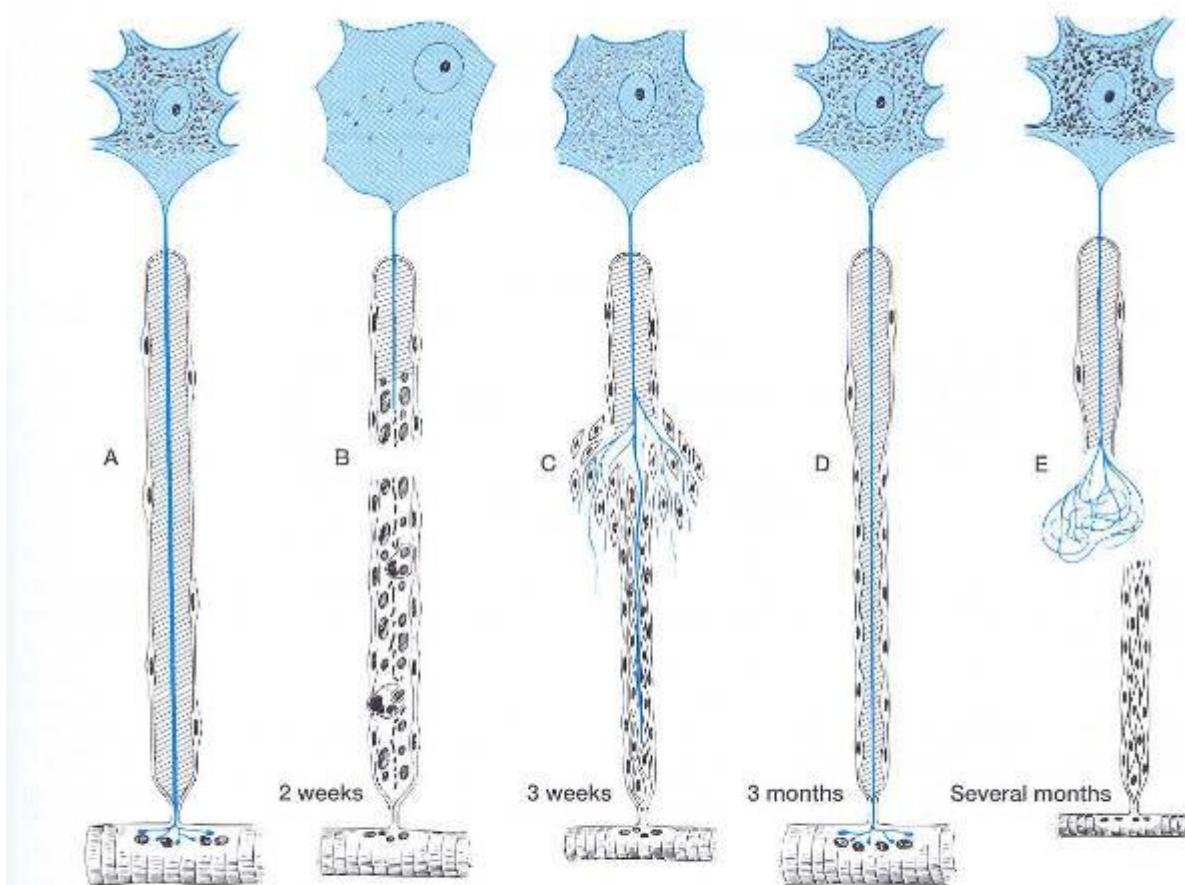


Figure 22–8. Main changes that take place in an injured nerve fiber. **A:** Normal nerve fiber, with its perikaryon and the effector cell (striated skeletal muscle). Notice the position of the neuron nucleus and the amount and distribution of Nissl bodies. **B:** When the fiber is injured, the neuronal nucleus moves to the cell periphery, and Nissl bodies become greatly reduced in number (chromatolysis), and the nerve fiber distal to the injury degenerates along with its myelin sheath. Debris is phagocytized by macrophages. **C:** The muscle fiber shows pronounced disuse atrophy. Schwann cells proliferate, forming a compact cord that is penetrated by the growing axon. The axon grows at a rate of 0.5–3 mm/d. **D:** In this example, the nerve fiber regeneration was successful, and the muscle fiber was also regenerated after receiving nerve stimuli. **E:** When the axon does not penetrate the cord of Schwann cells, its growth is not organized and successful regeneration does not occur. (Redrawn and reproduced, with permission, from Willis RA, Willis AT: *The Principles of Pathology and Bacteriology*, 3rd ed. Butterworth, 1972.)

Difference between rami anteriores et posteriores nervorum spinalium

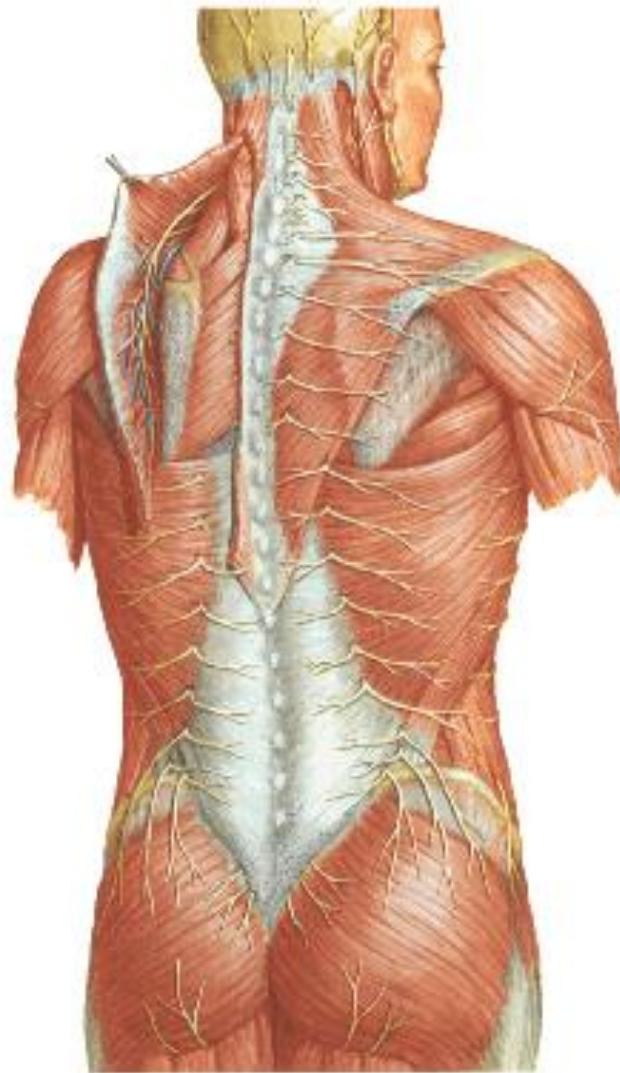
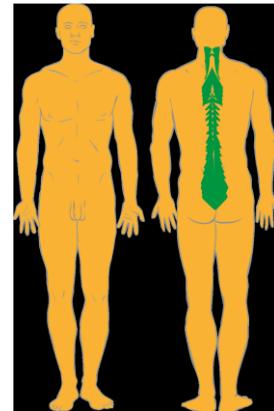
| Rami posteriores | Rami anteriores |
|--|-------------------------------|
| no plexuses | form major somatic plexuses |
| both sensory and motor fibers | both sensory and motor fibers |
| sensory: skin medially close to vertebral column | sensory: skin on rest of body |
| motor: epaxial muscles | motor: hypaxial muscles |

Rami posteriores nervorum spinalium

= posterior branches

(obsolete term „dorsal branches“)

- segmental arrangement
- do not form plexuses
- mixed nerves
- **motor:** deep back (epaxial) muscles
- **sensory:** skin medial at vertebral column



Individual nerves from rami posteriores nervorum spinalium in the neck

motor

sensory

C1 = **n. suboccipitalis**

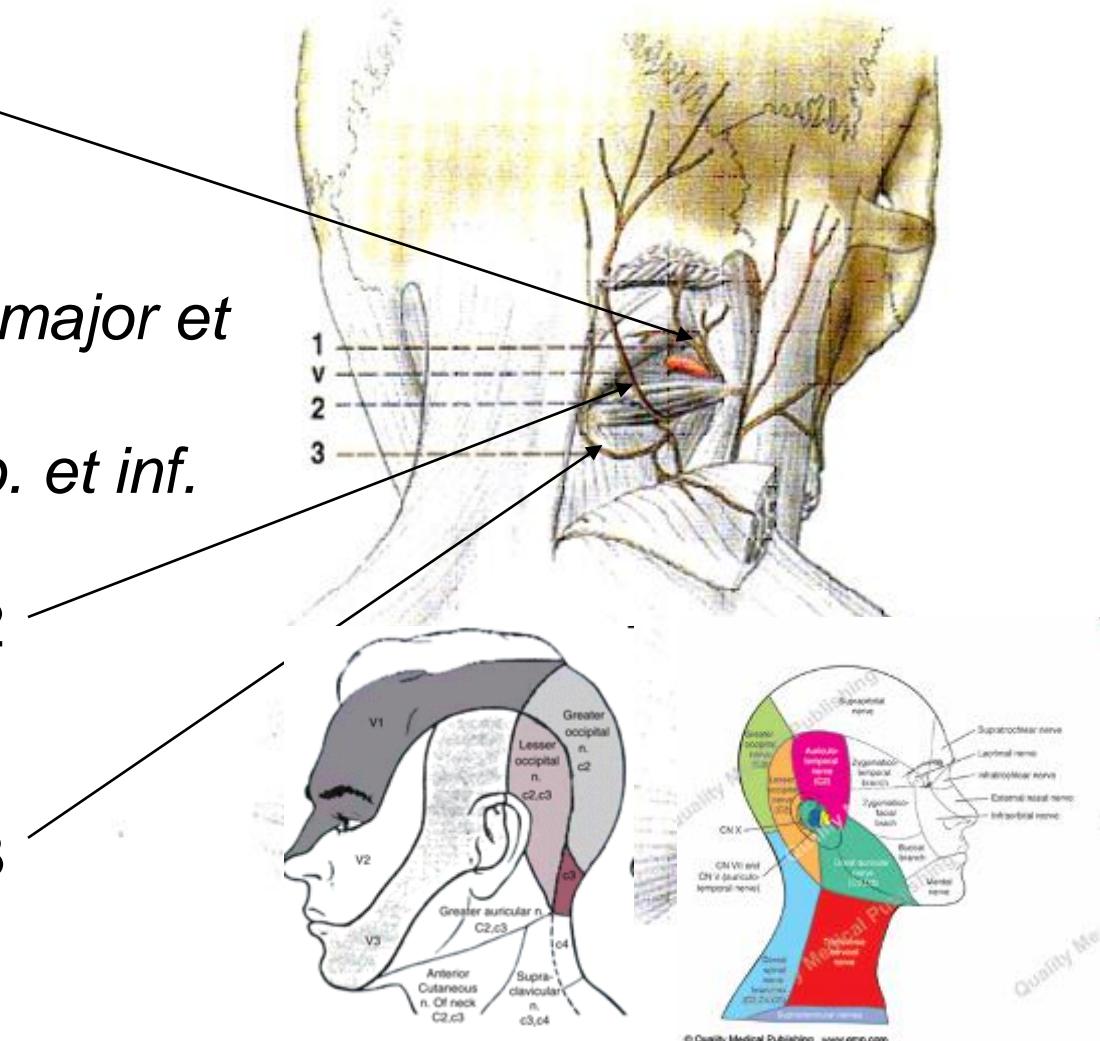
- pure somatomotor
- trigonum suboccipitale

→ *m. rectus capitis post. major et minor*

→ *m. obliquus capitis sup. et inf.*

sensory component of C2
= **n. occipitalis major**

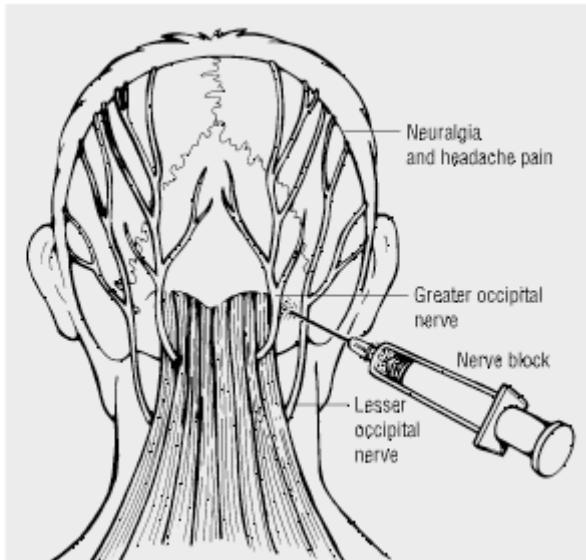
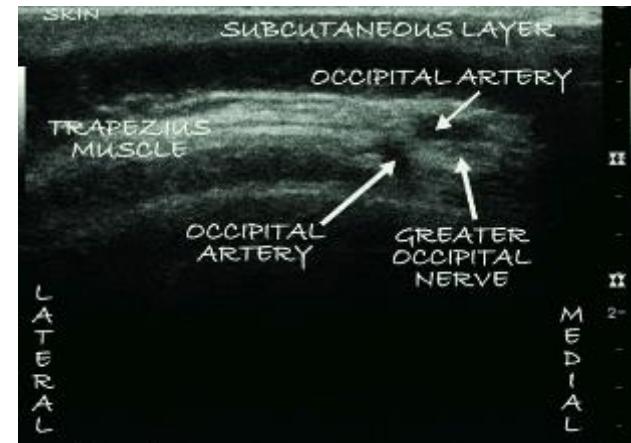
sensory component of C3
= **n. occipitalis tertius**



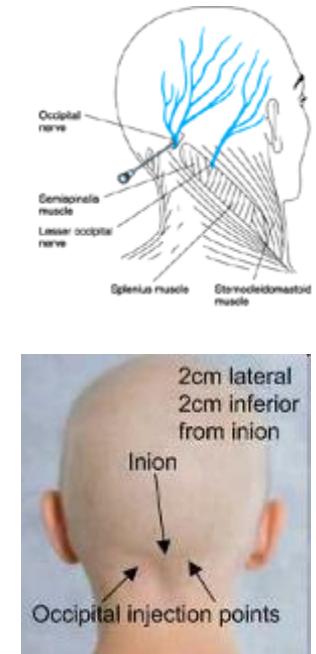
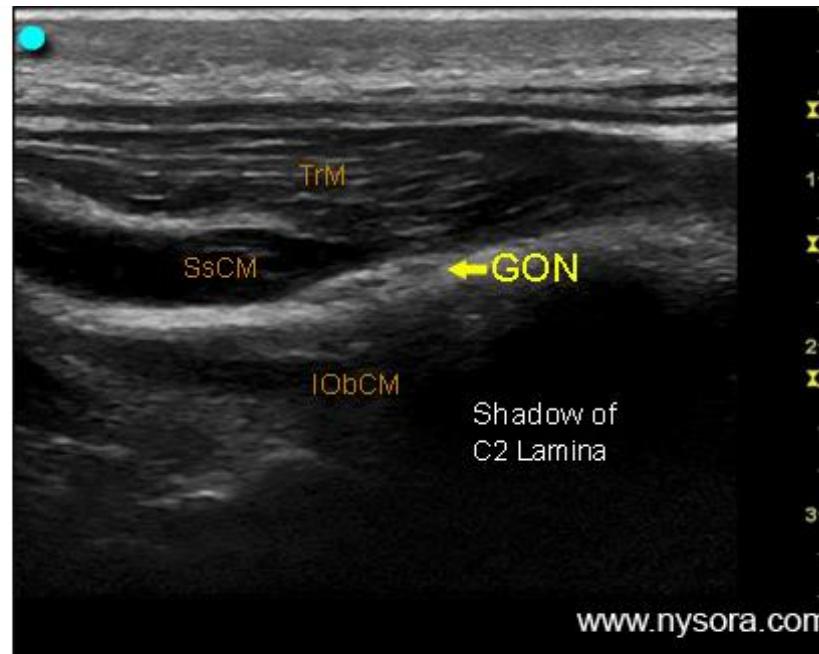
Occipital neuralgia

= Arnold's syndrome

- lesion of n. occipitalis major or minor

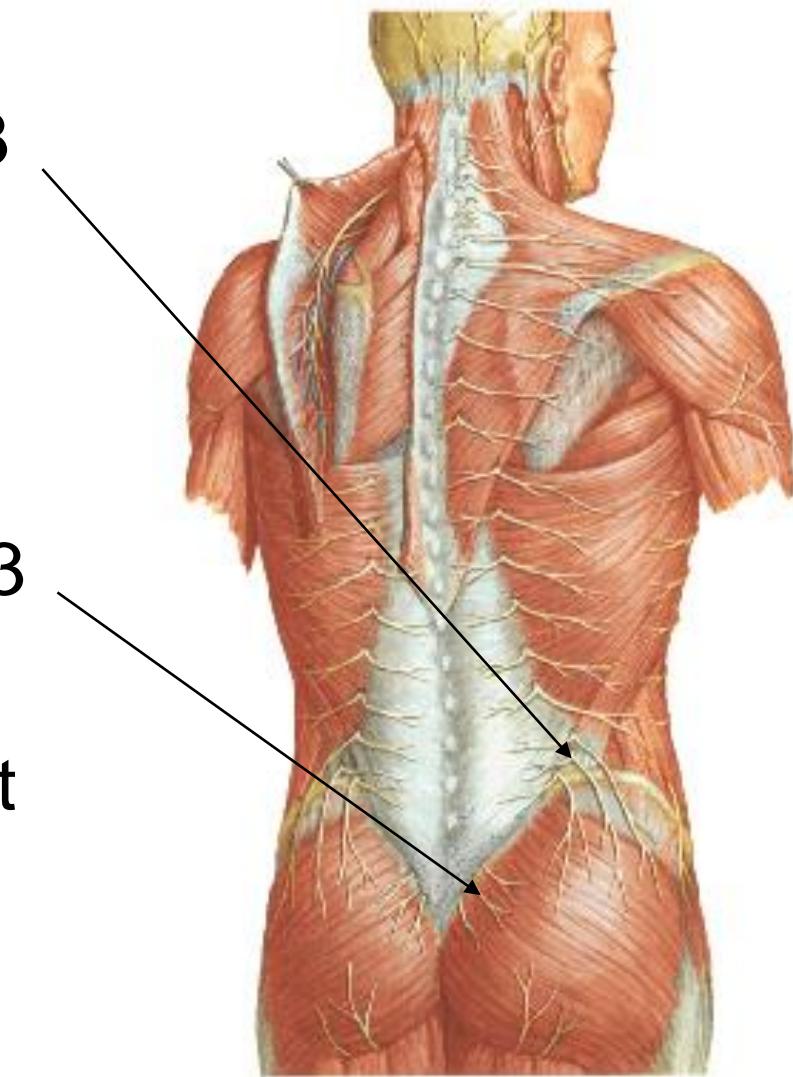


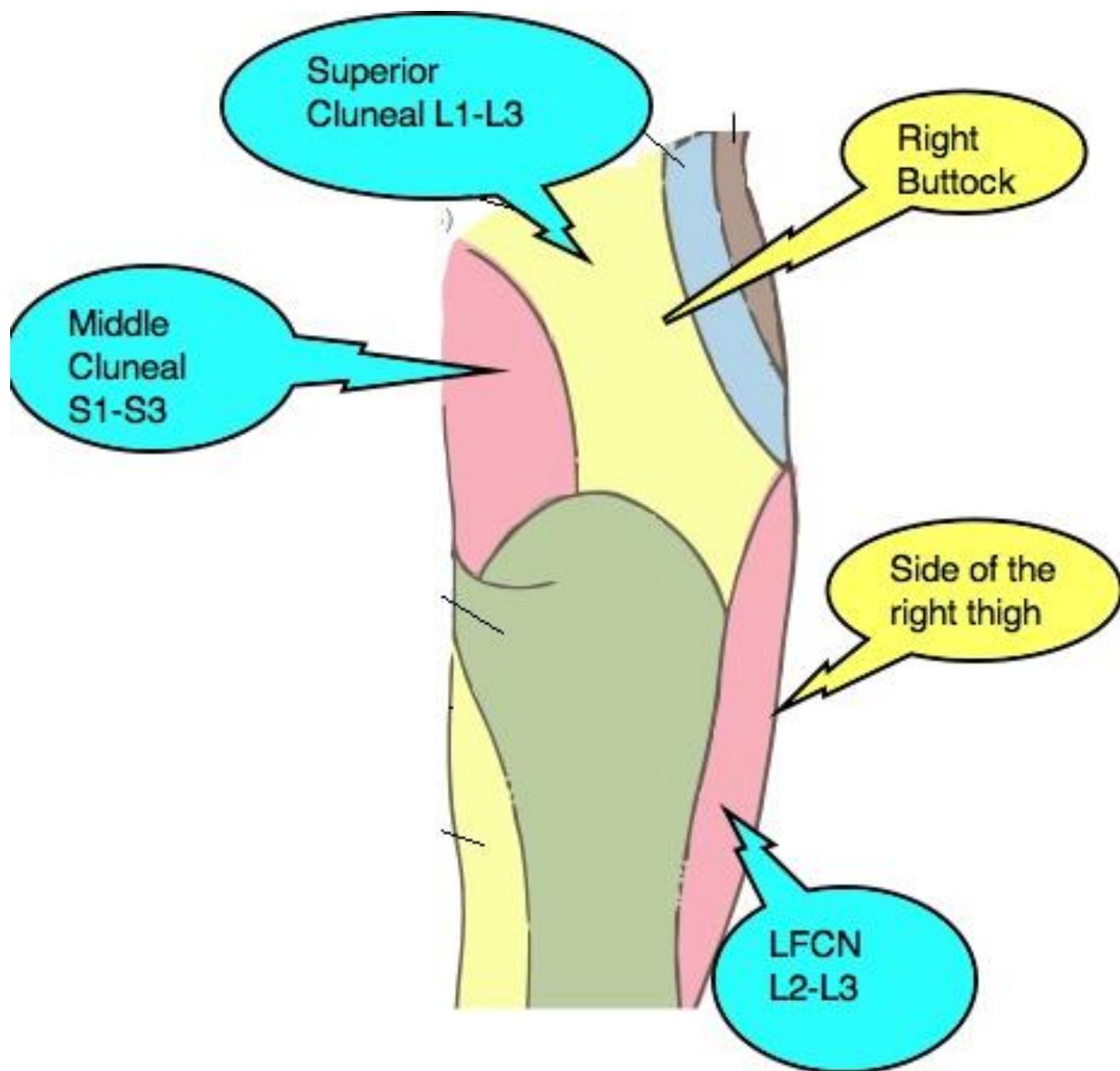
Lateral - Cephalad



Individual nerves from rami posteriores nervorum spinalium in the trunk

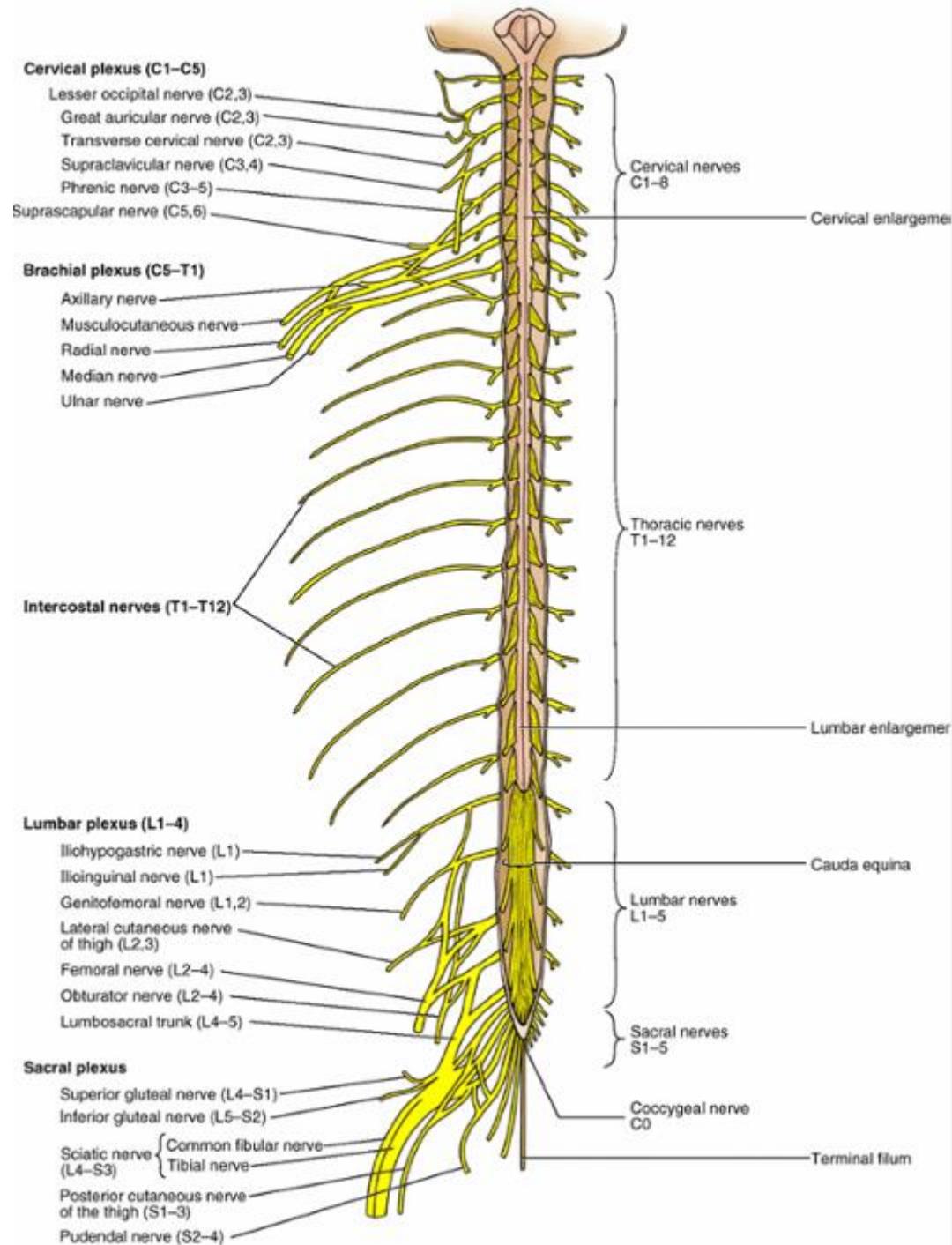
- sensory component of L1–L3
= **nervi clunium superiores**
→ upper part of gluteal region
- sensory component of S1–S3
= **nervi clunium medii**
→ sacral region and lateral part of gluteal region





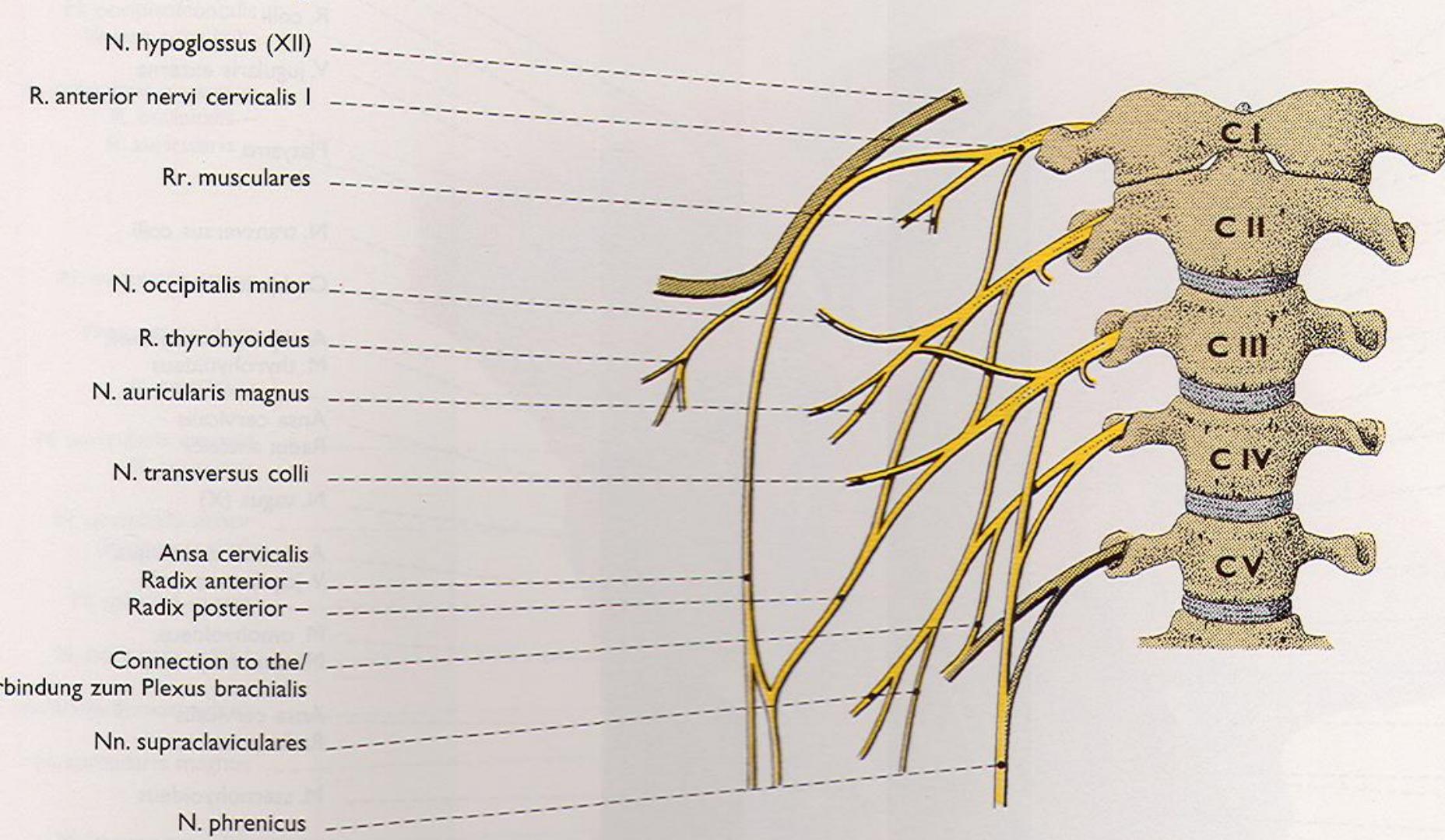
Rami anteriores nervorum spinalium

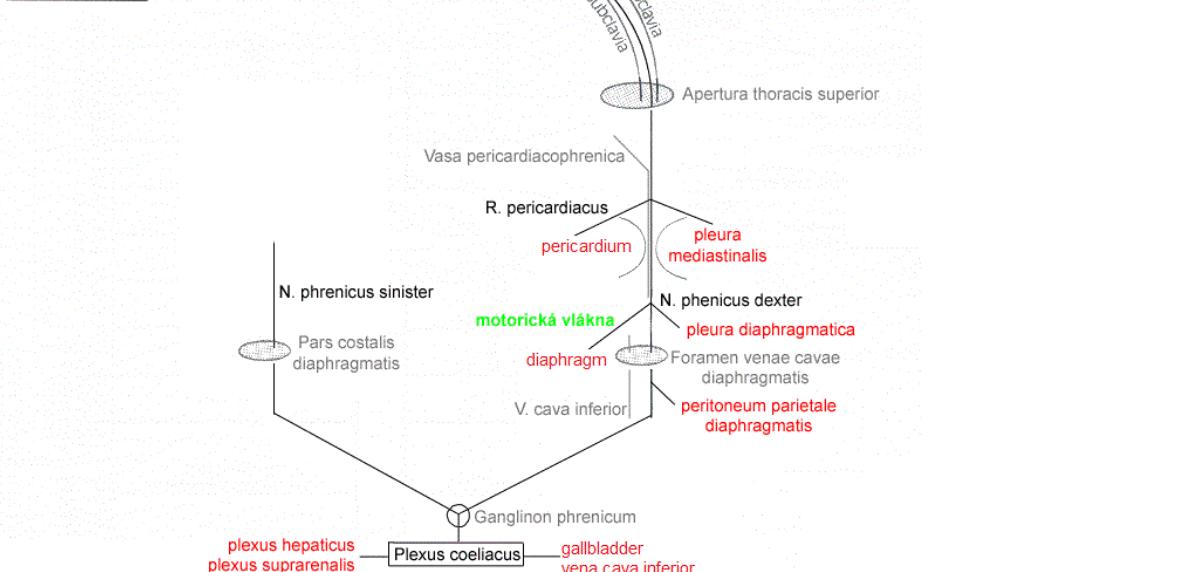
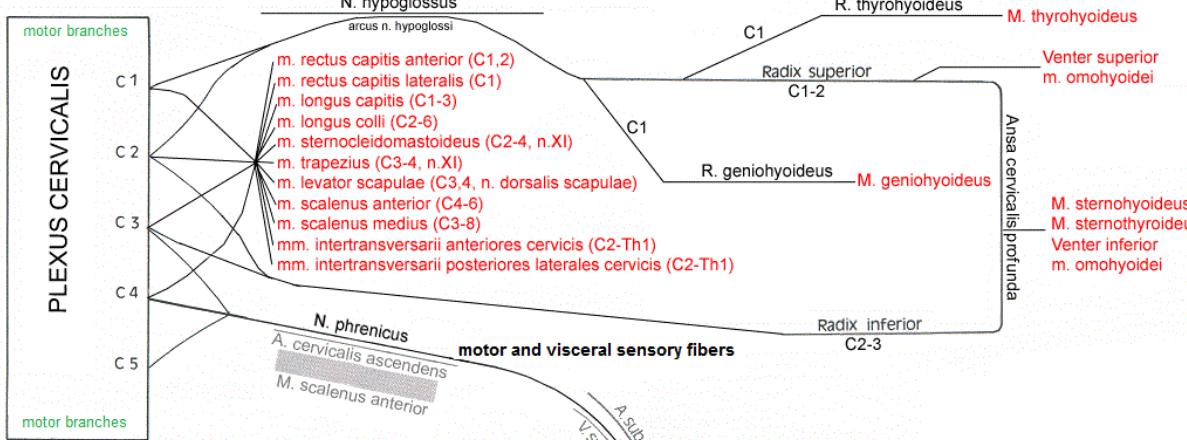
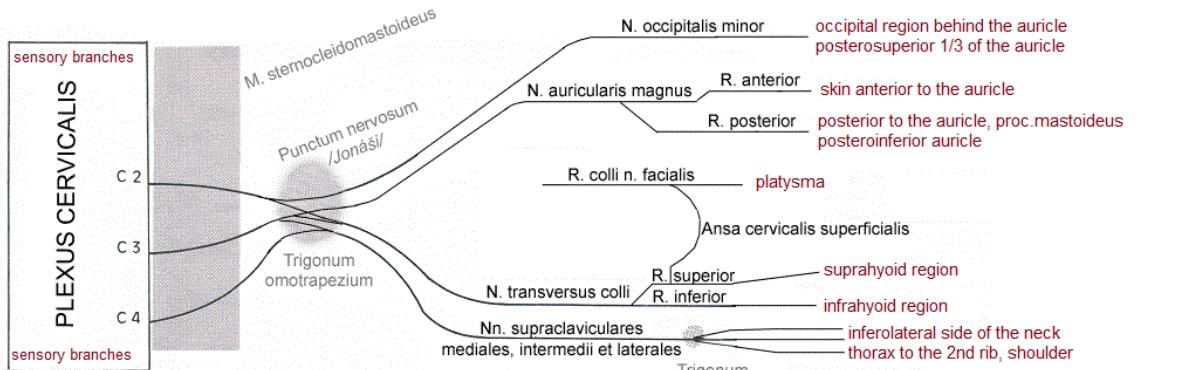
- plexus cervicalis (C1-4)
- plexus brachialis (C4-T1)
- nn. intercostales (T1-T12)
- plexus lumbalis (T12-L4)
- plexus sacralis (L4-S4)
- plexus coccygeus (S5-Co)



Plexus cervicalis (C1–C4)

a

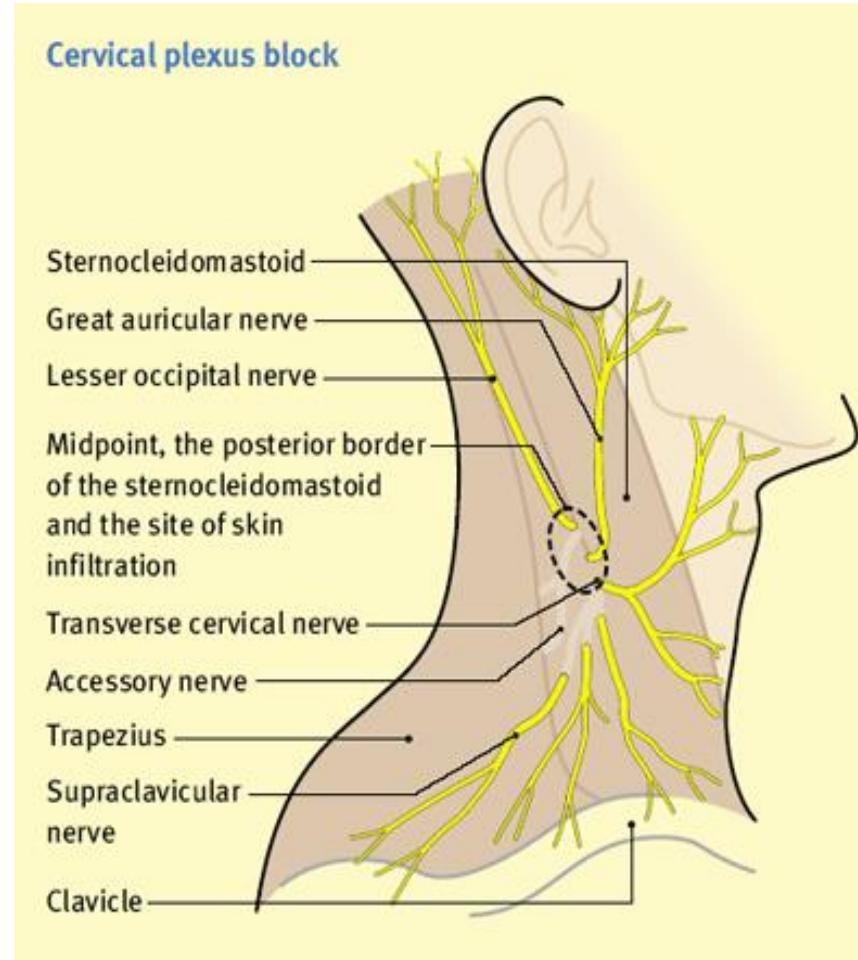




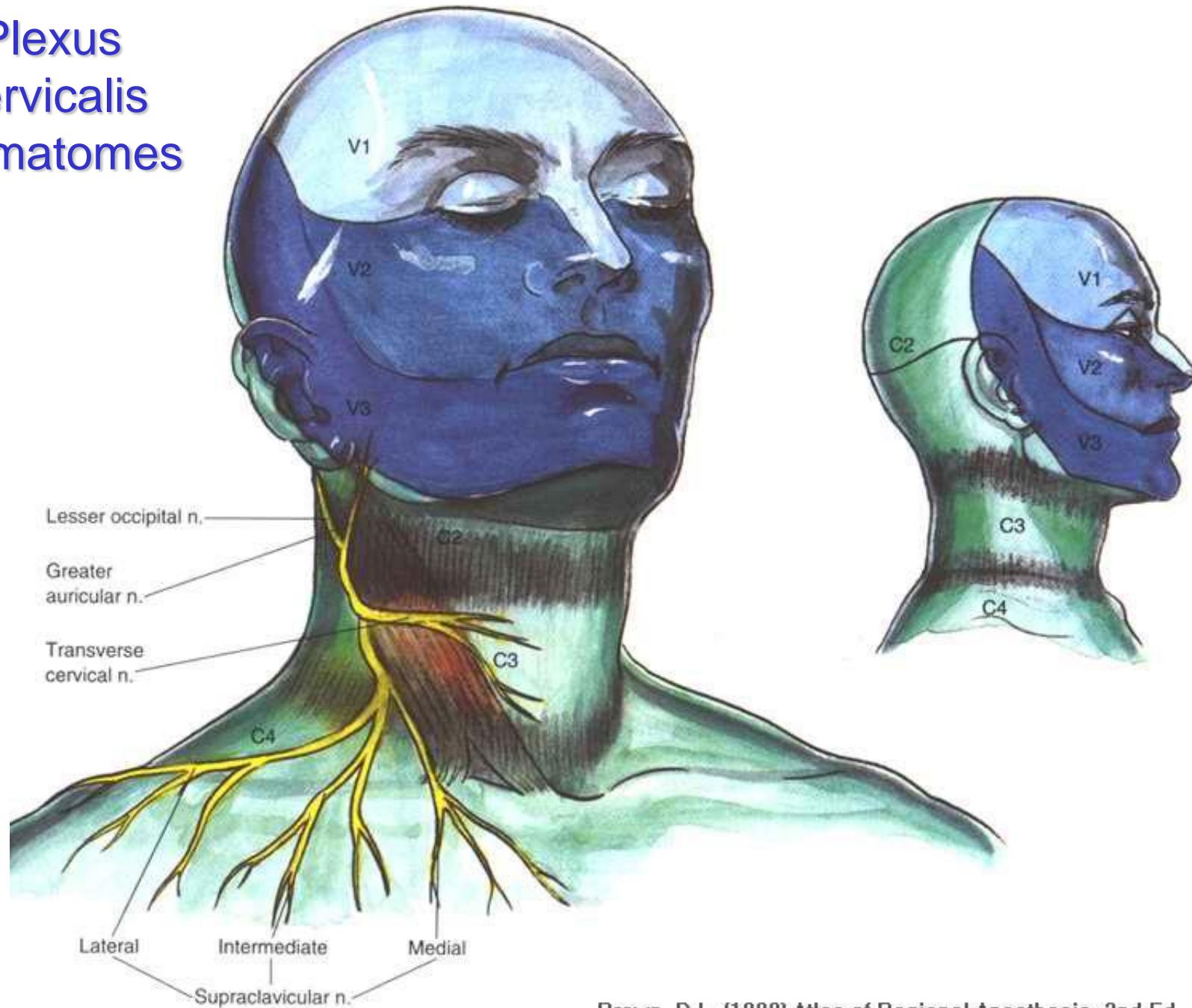
Plexus cervicalis (C1–C4)

sensory branches

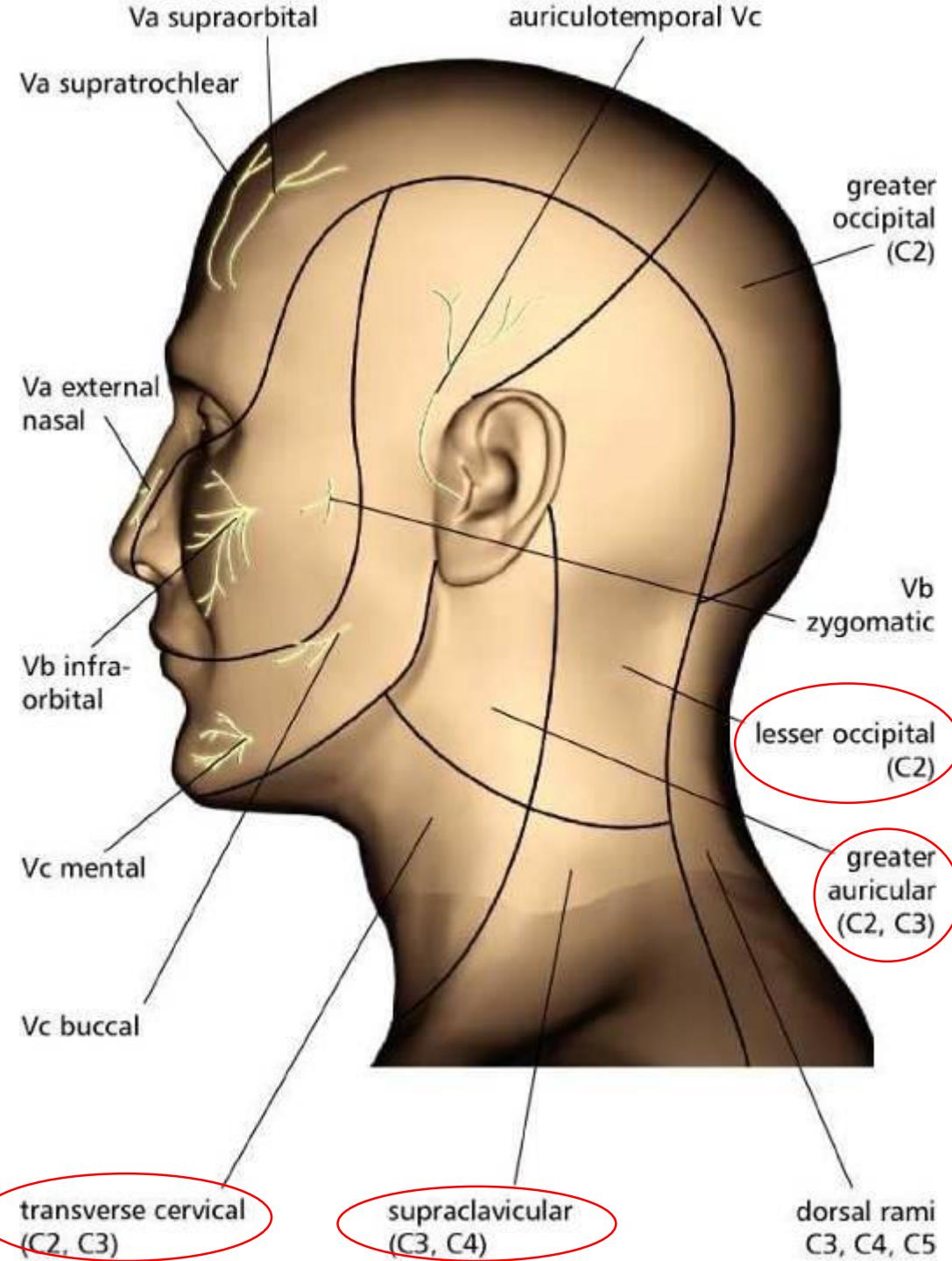
- punctum nervosum Jonáši
- n. occipitalis minor
- n. auricularis magnus
 - r. anterior + posterior
- n. transversus colli
 - r. superior
 - ansa cervicalis superficialis → connection to r. colli n.VII
 - r. inferior
- nn. supraclavicularares
 - mediales, intermedii, laterales



Plexus cervicalis dermatomes

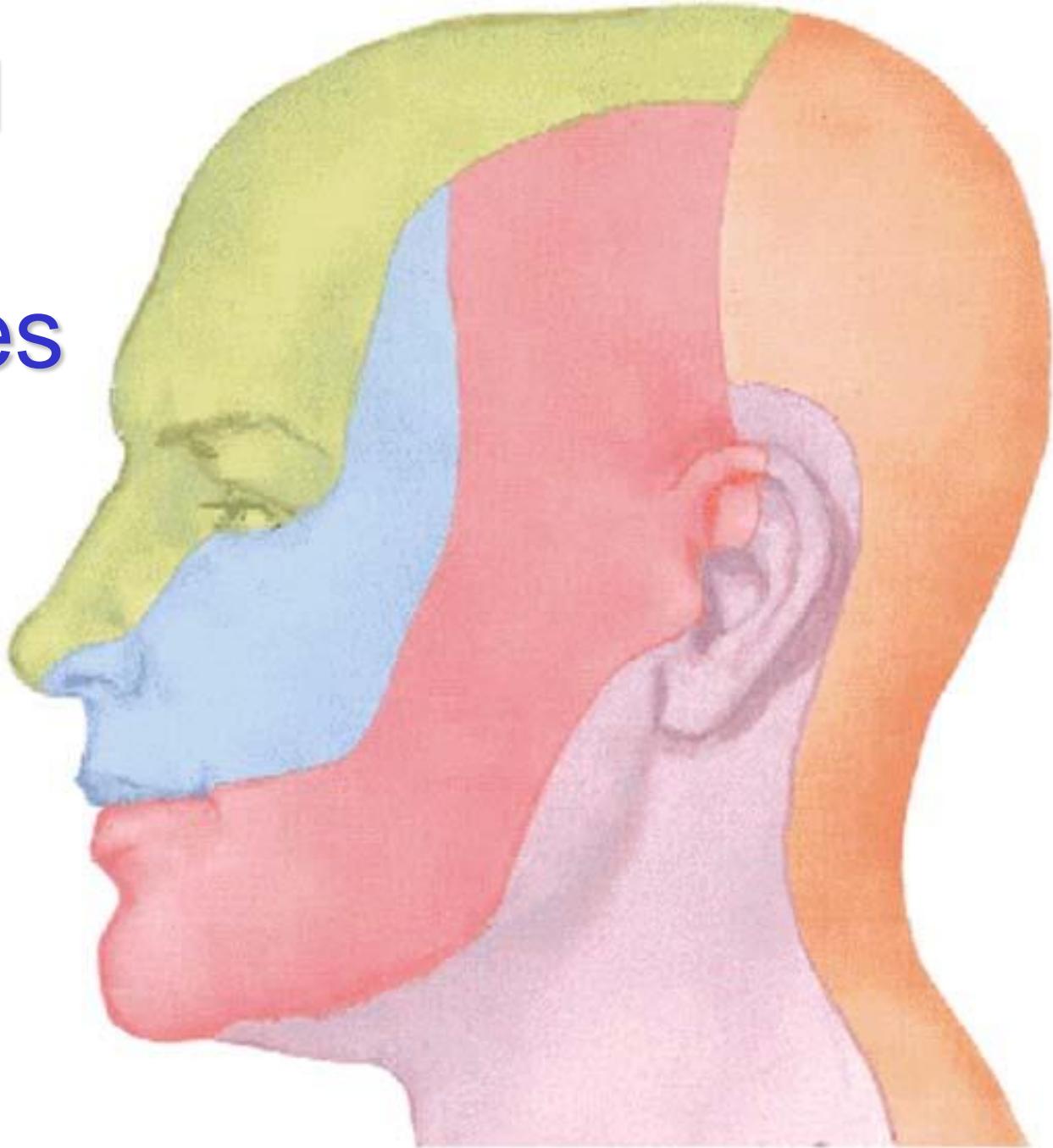


Plexus cervicalis dermatomes

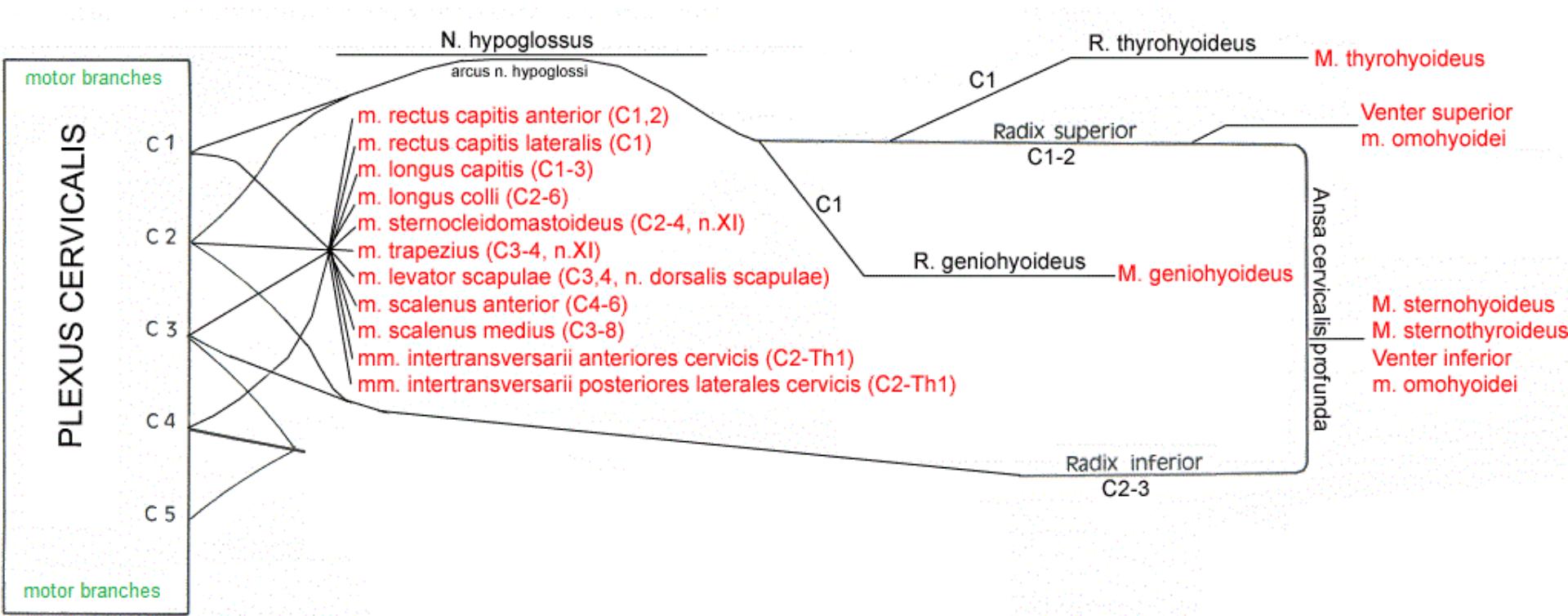


Head and neck dermatomes

- V1
- V2
- V3
- C2
- C3



Plexus cervicalis motor branches



Plexus cervicalis

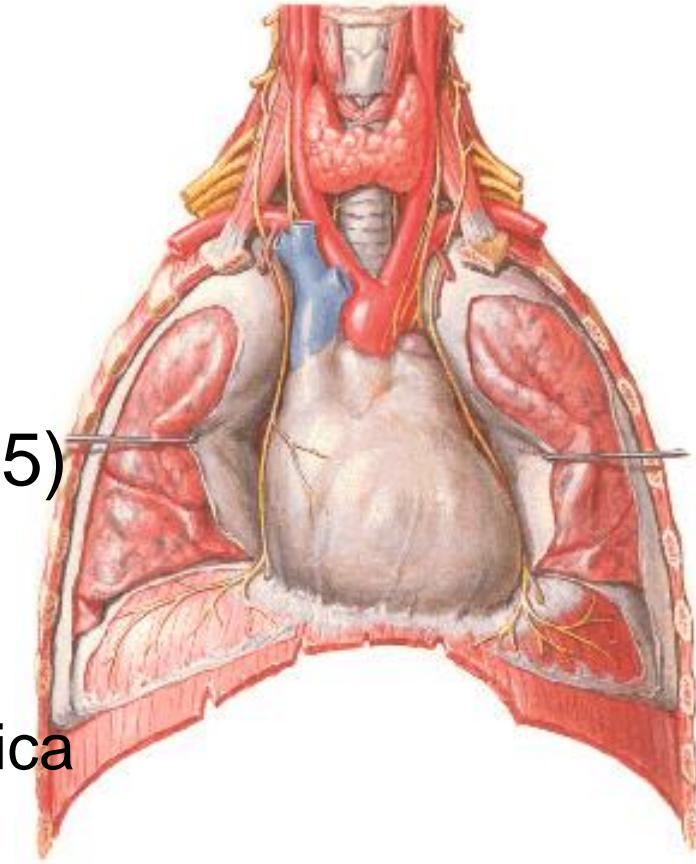
muscles and their motor branches

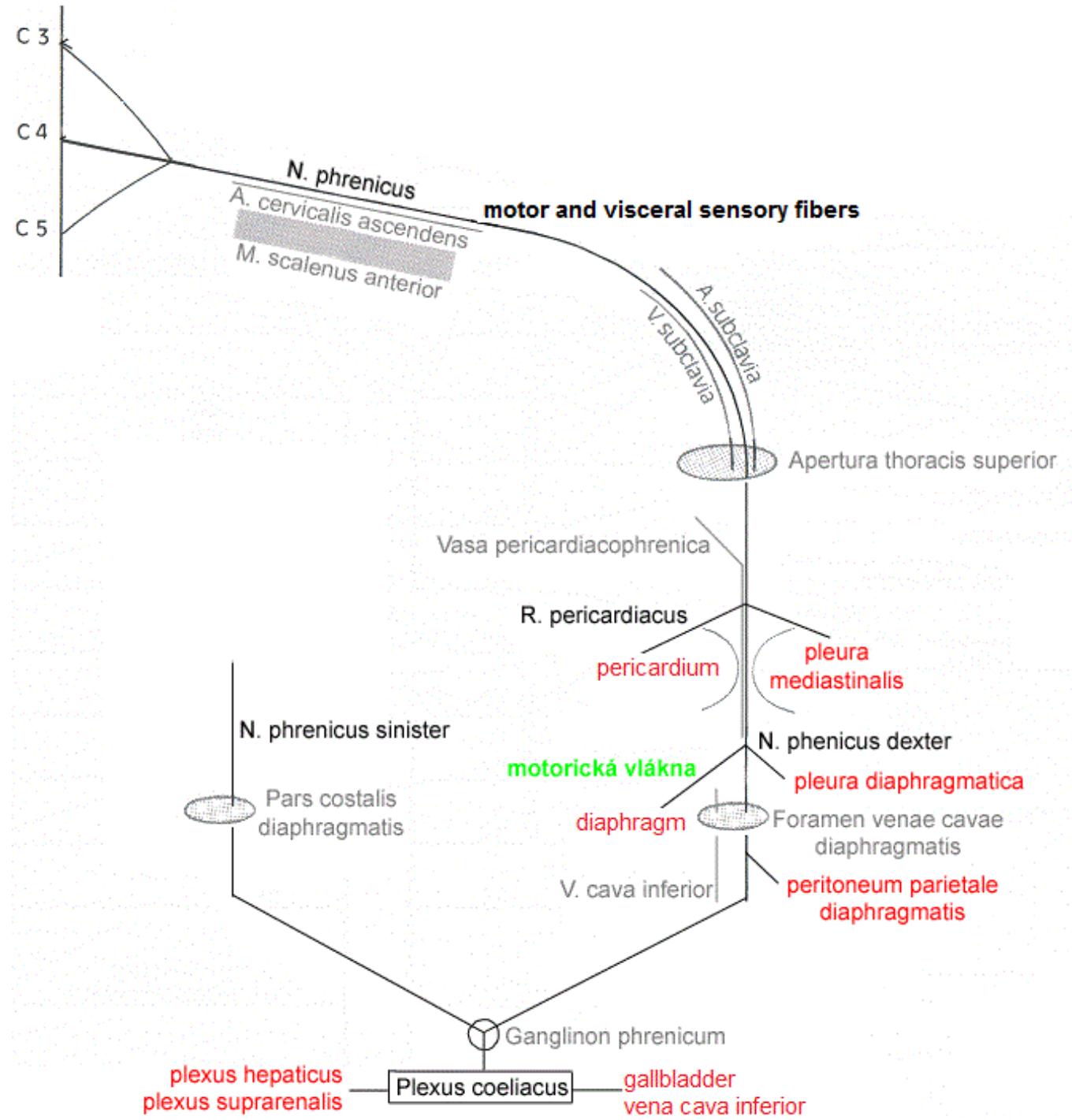
| Muscle | Plexus cervicalis | Plexus brachialis |
|---|------------------------------------|------------------------------|
| m. scalenus ant.+ med. | C3-4 | C5-8 |
| m. sternothyroideus, m. sternohyoideus, m. omohyoideus | ansa cervicalis profunda (C1-3) | - |
| m. thyrohyoideus + m. geniohyoideus | C1 | - |
| m. rectus capitis ant. + lat. | C1 | - |
| m. longus capitis | C1-3 | - |
| m. longus capitis | C3-4 | C5-6 |
| m. sternocleidomastoideus + m. trapezius | C2-4 = ansa Maubraci | - |
| m. levator scapulae | C3-4 | C5 = n. dorsalis scapulae |
| diaphragma | C3-5 = n. phrenicus | C5 |

Plexus cervicalis

N. phrenicus (C3-C5)

- mixed nerve
- major root C4 (minor roots C3+C5)
- motor: **diaphragm**
- sensory:
 - pleura mediastinalis + diaphragmatica
 - pericardium parietale
 - peritoneum parietale (diaphragm + liver + gallbladder)
 - (capsula thymi = Cruchet' s nerve)
- n. phrenicus accessorius
 - branch from C5 via n. subclavius, running laterally
 - joins n. phrenicus at level of 1st rib

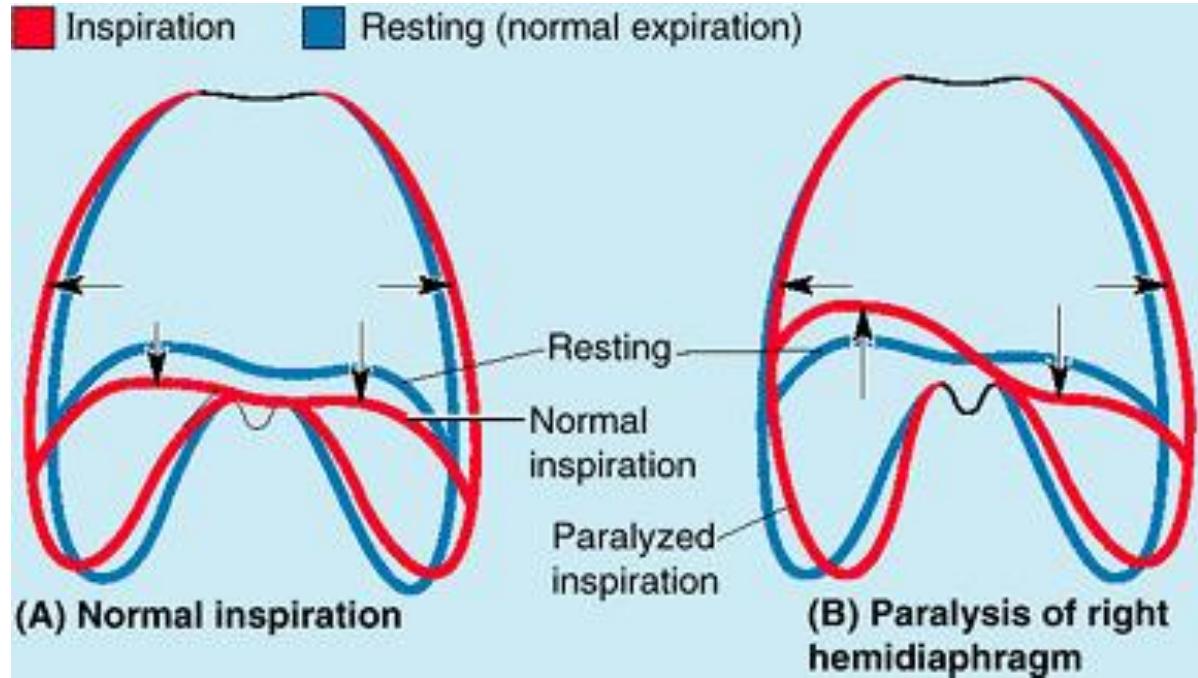




Diaphragm paralysis *palsy of nervus phrenicus*

palsy:

- unilateral → dyspnoe
- bilateral → no breathing



irritation:

jerks, hick-up (= singultus)

e.g. *peritonitis, cerebral damage*

Rami anteriores nervorum thoracicorum T1-12

- ***nn. intercostales + n. subcostalis***
- segmental arrangement
- do not form plexuses
- mixed nerves
- spatiuum intercostale and below 12th rib
- motor: mm. intercostales, anterior and lateral abdominal muscles
- sensory: skin on anterior and lateral aspect of thorax and abdomen, pleura parietalis, peritoneum parietale

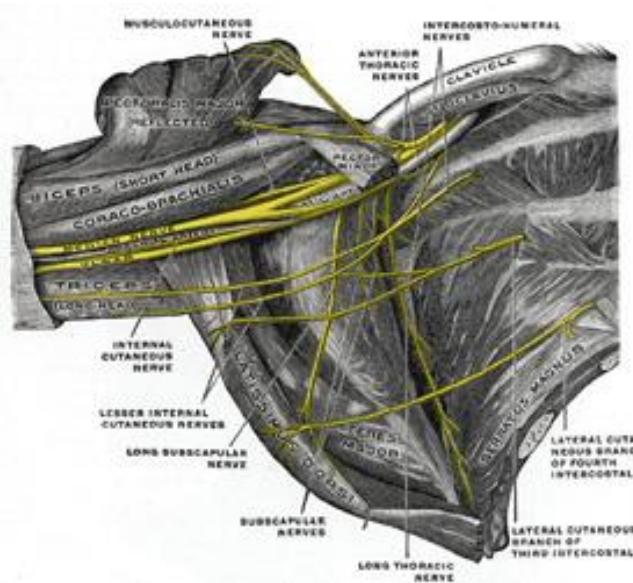
Nervus intercostalis

somatotor branches

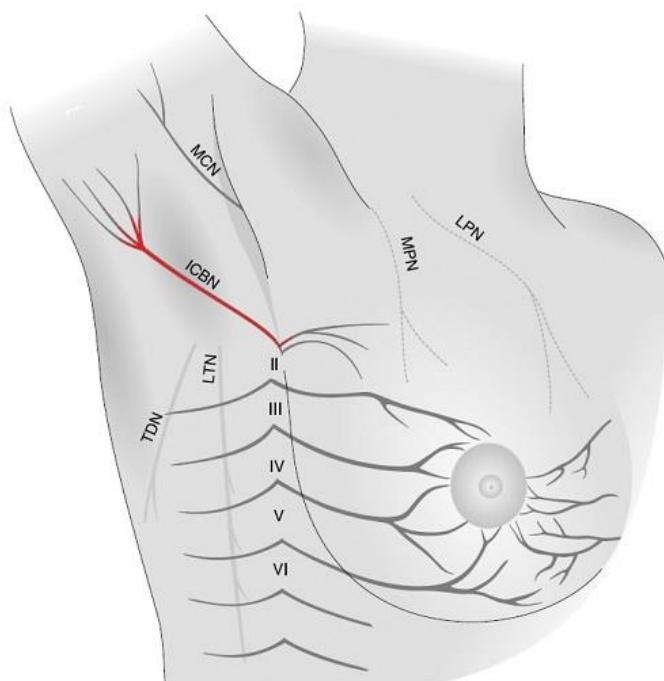
- rr. musculares:
 - mm. intercostales externi, interni, intimi (mm. subcostales)
 - m. transversus thoracis (T1-6)
 - m. serratus post. sup. (T1-4) et in. (T9-12)
 - m. rectus abdominis (T7-12)
 - m. obliquus abdominis ext. (T5-12)
 - m. obliquus abdominis int. (T8-12)
 - m. transversus abdominis (T7-12)
 - m. pyramidalis (T12)
 - m. quadratus lumborum (T12)

Nervus intercostalis somatosensory branches

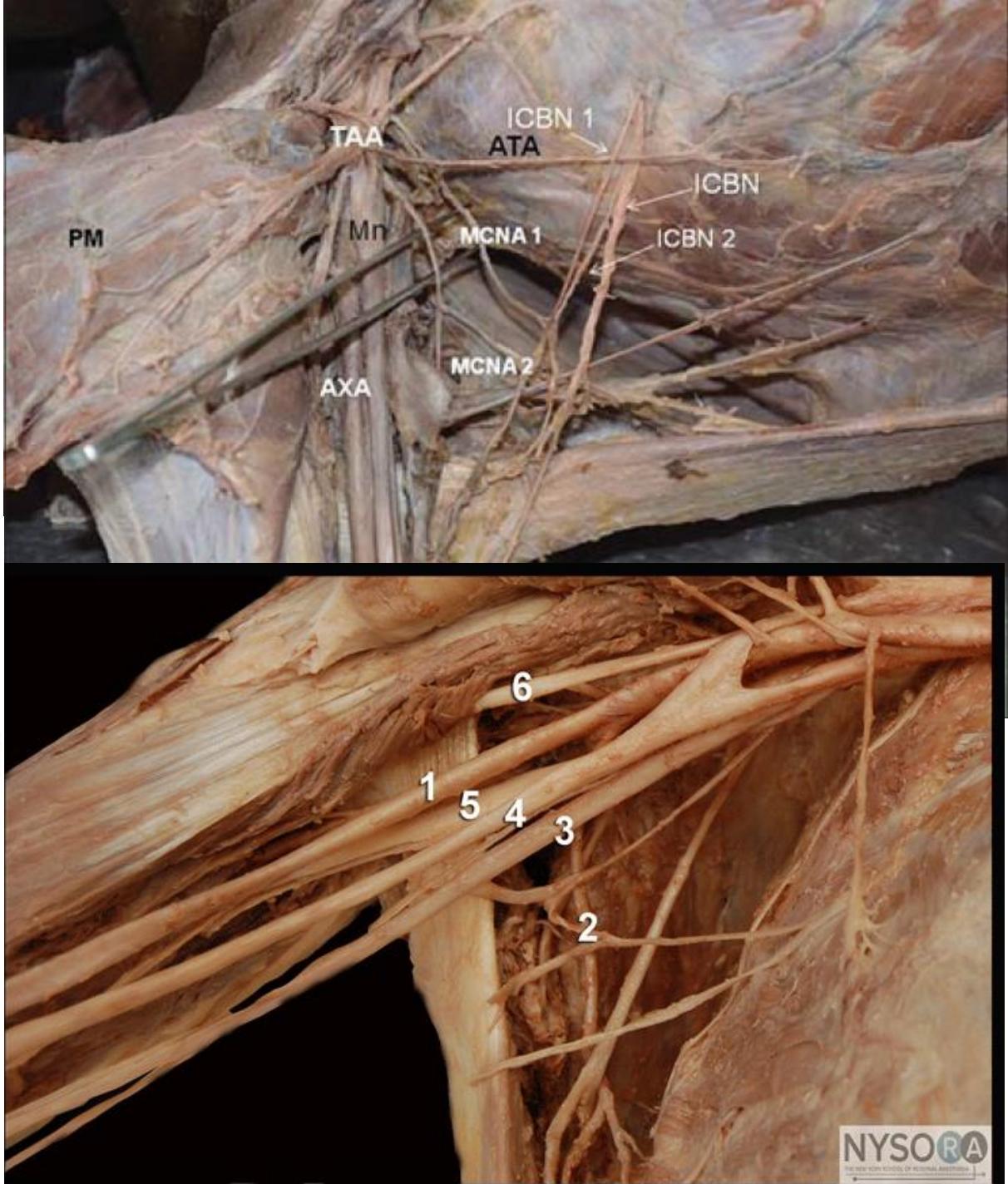
- nn. cutanei laterales
 - rr. mammarii laterales (T4-6)
 - nn. intercostobrachiales (T2-3)
 - n. intercostobrachialis (T2) joins n. cutaneus brachii med.
 - n. intercostobrachialis accessorius (T3)
 - napříč podpažím – *danger of lesion in axillary lymphadenectomy*
- nn. cutanei anteriores
 - rr. mammarii mediales (T4-6)
- rr. pleurales (T1-12) et peritoneales (T7-12)
 - „défense musculaire“



- n.
intercostobrachialis
(T2)
- n.
intercostobrachialis
accessorius (T3)

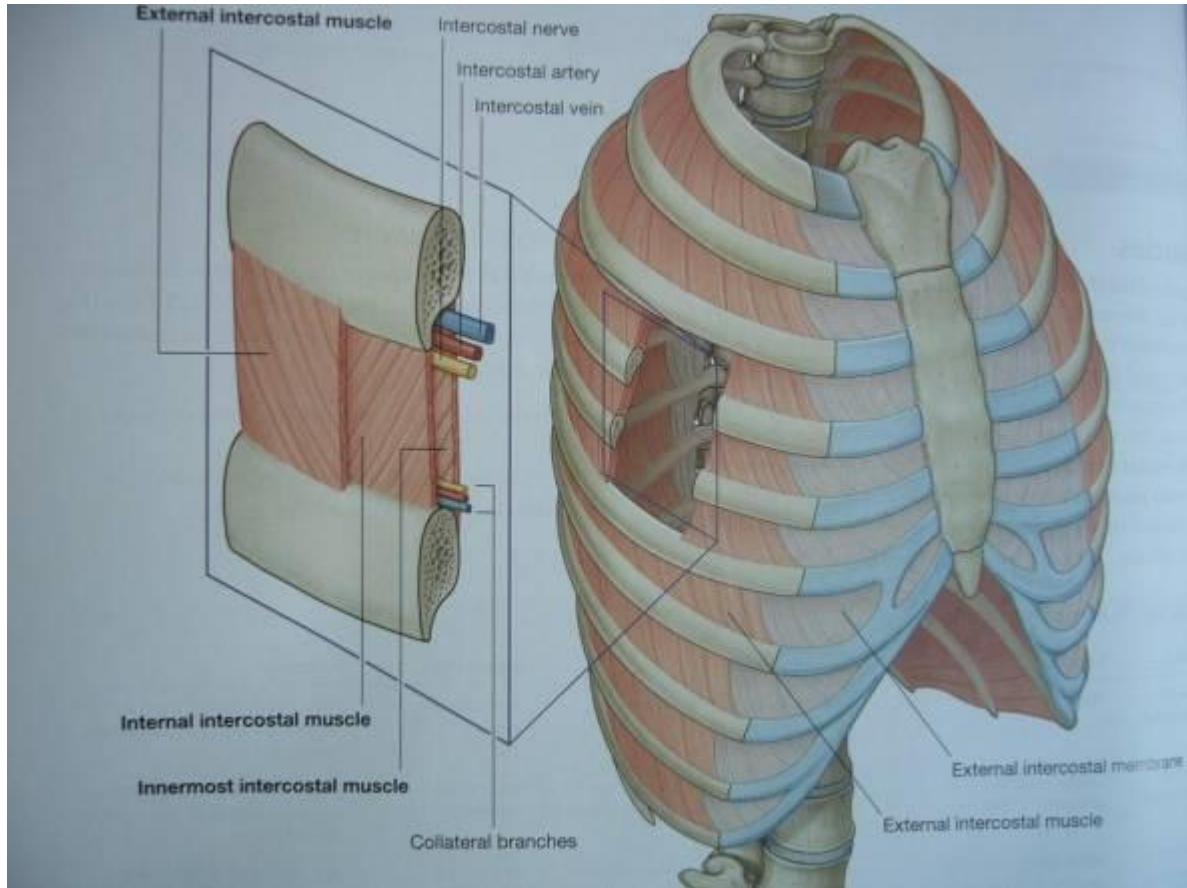


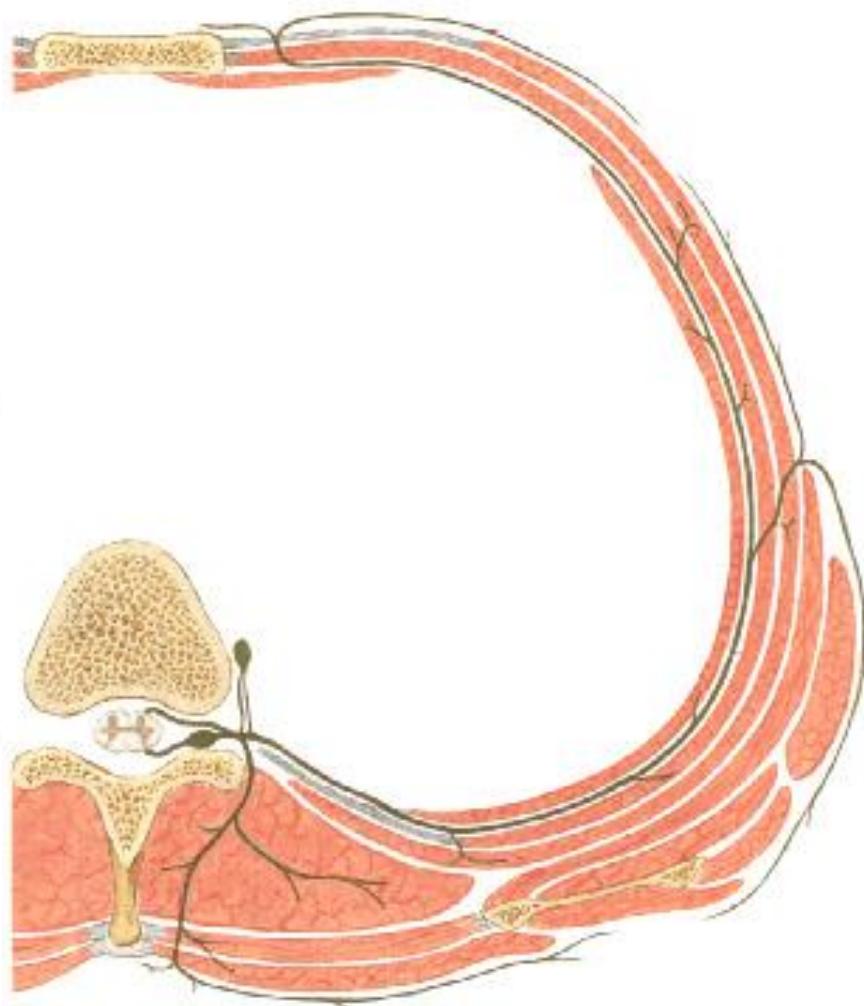
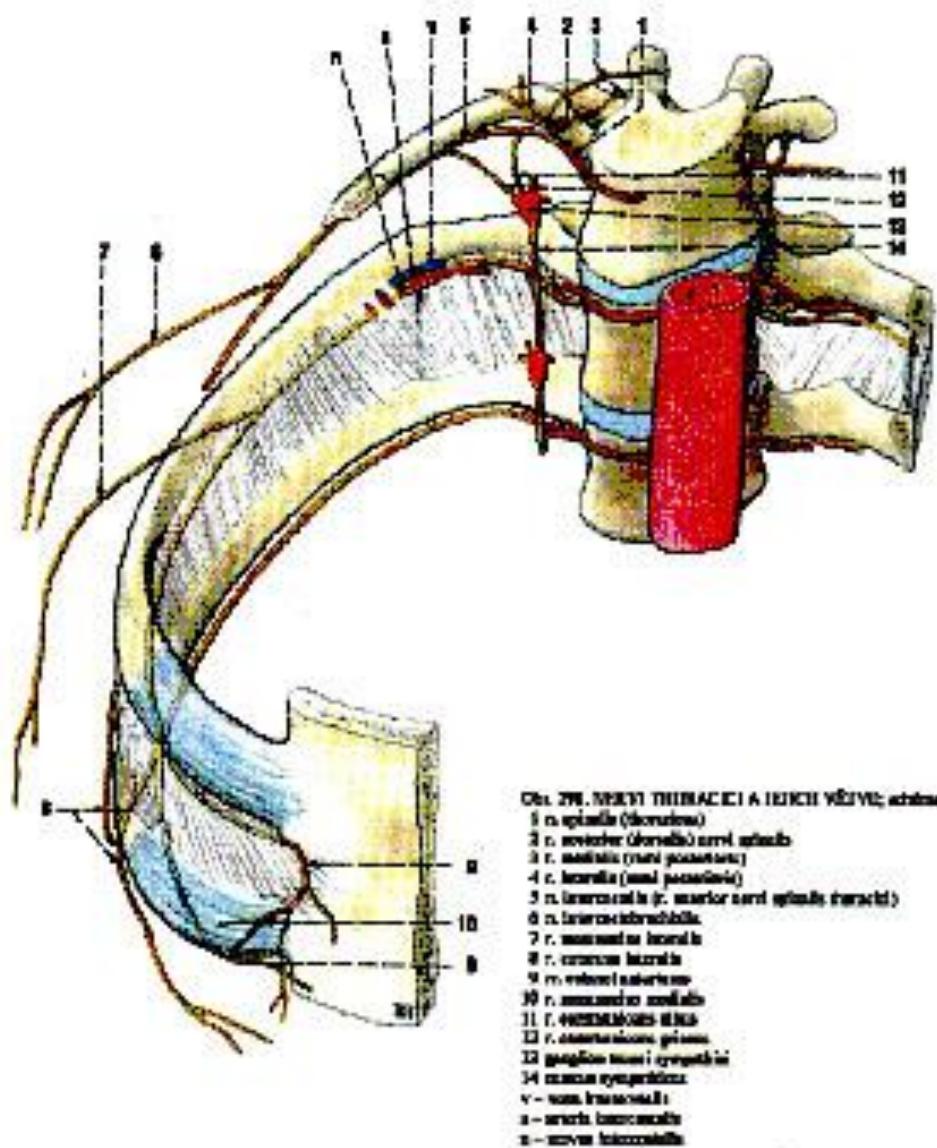
Innervation of the breast and location of the nerves at risk during breast cancer surgery. ICBN indicates intercostobrachial nerve (sensory only); II-VI, intercostal nerves 2 to 6, lateral cutaneous branches (sensory only); LPN, lateral pectoral nerve (mixed sensory and motor); LTN, long thoracic nerve (motor only); MCN, medial cutaneous nerve of the arm (sensory only); MPN, medial pectoral nerve (mixed sensory and motor); TDN, thoracodorsal nerve (motor only).
Reg Anesth Pain Med. 2014 Jun;in press. Neural Blockade for Persistent Pain After Breast Cancer Surgery. Wijayasinghe N et al



Spatium intercostale

V
A
N



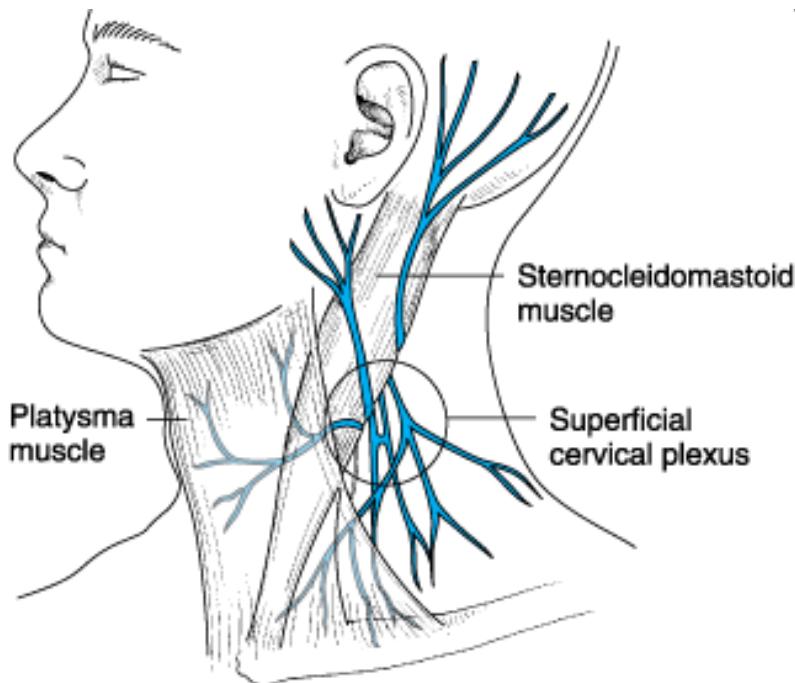


Regional anesthesia

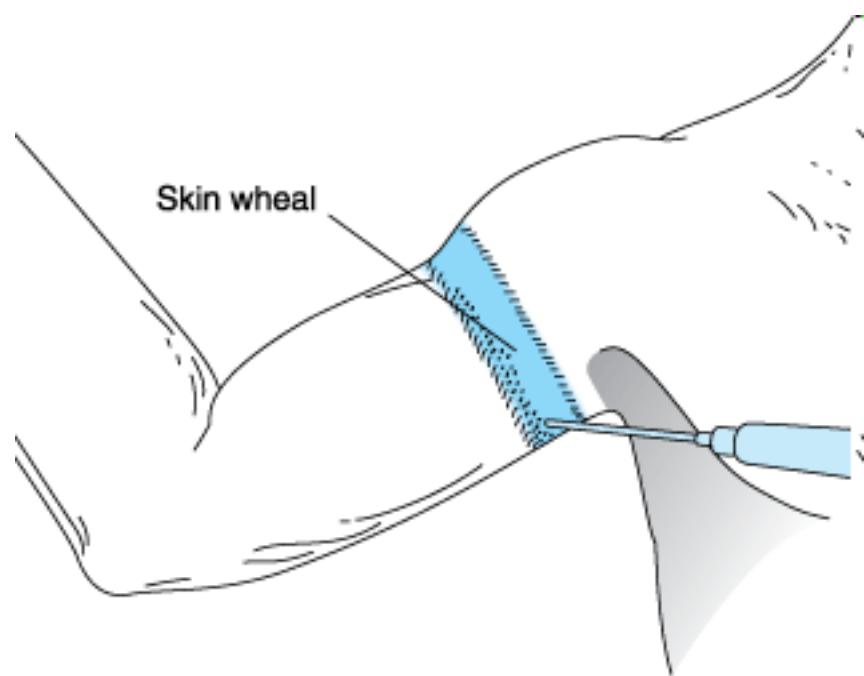
Superficial block of plexus cervicalis (1)

Bloc of nn. Intercostobrachiales (2)

(2) in application of air tourniquet for upper limb



Copyright ©2006 by The McGraw-Hill Companies, Inc.
All rights reserved.



Copyright ©2006 by The McGraw-Hill Companies, Inc.
All rights reserved.

Palsy of intercostal nerves

- irritation → pain in the intercostal spaces (e.g. herpes zoster living in ganglion spinale)
- peritoneal irritation – reflexory contraction of abdominal muscle wall = défense musculaire (e.g.= peritonitis)

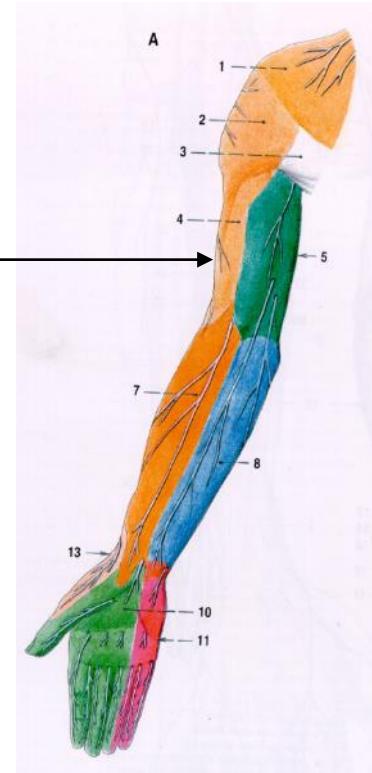


Reflexes of abdomen

| | |
|-------------|--------|
| Epigastric | T7-8 |
| Mezogastric | T9-10 |
| Hypogastric | T11-12 |

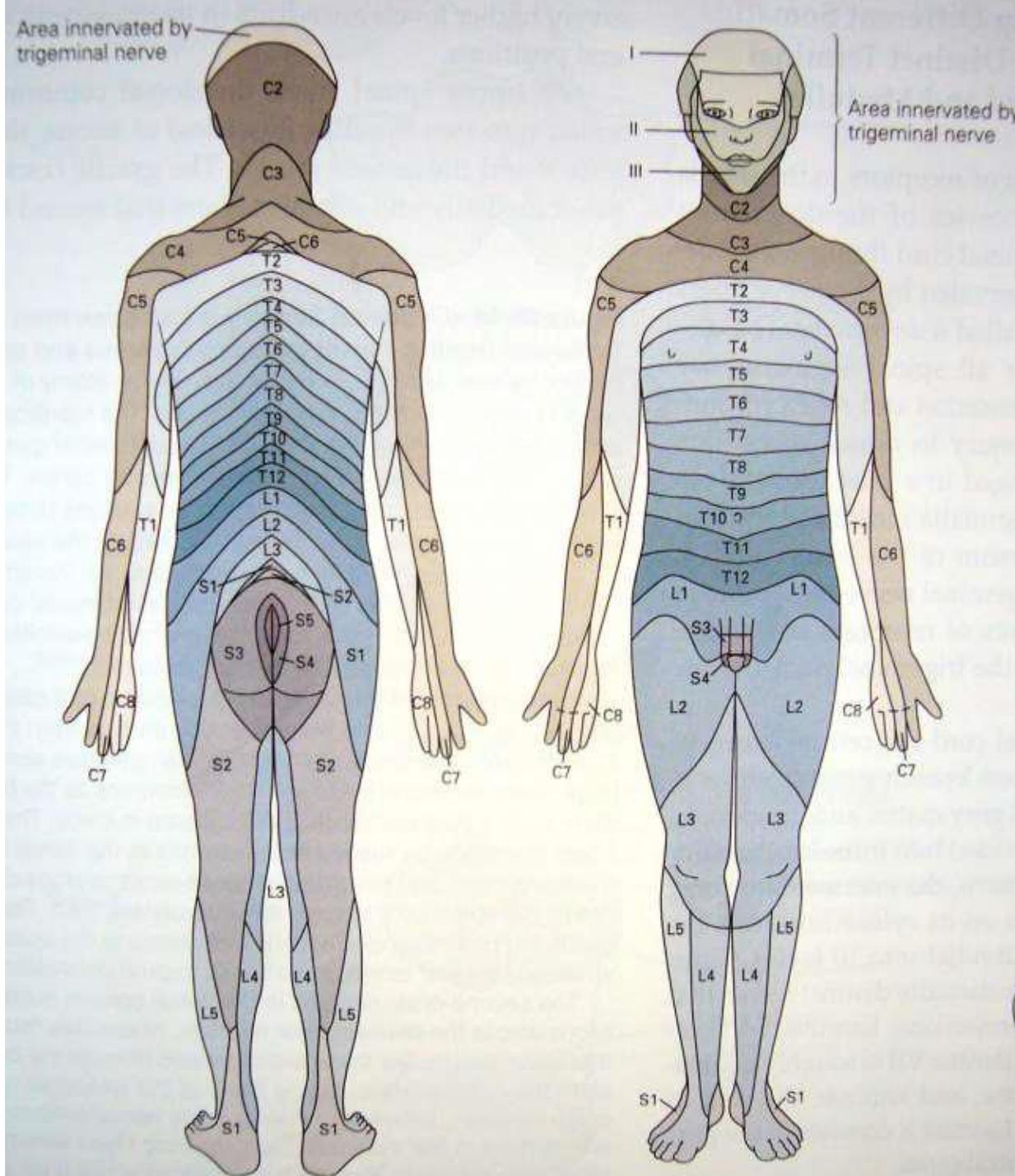
Somatosensory skin innervation

- area radicularis (dermatome)
 - area of skin supplied by one **spinal** nerve
(= by one **spinal segment**)
- area nervina —
 - area of skin supplied by **one peripheral nerve**
- area radicularis visceralis
 - area of internal organ supplied by viscerosensory nerves of one spinal segment
- *Head's (reflex) zone*
 - segmental projection of sensitivity from organs to skin



Dermatomes

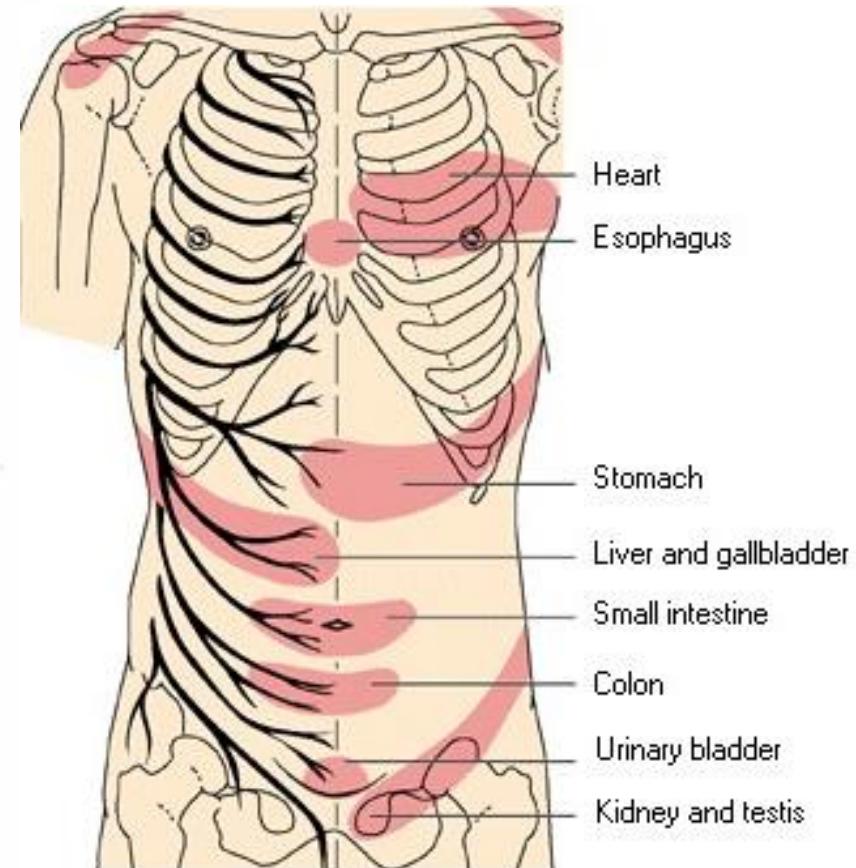
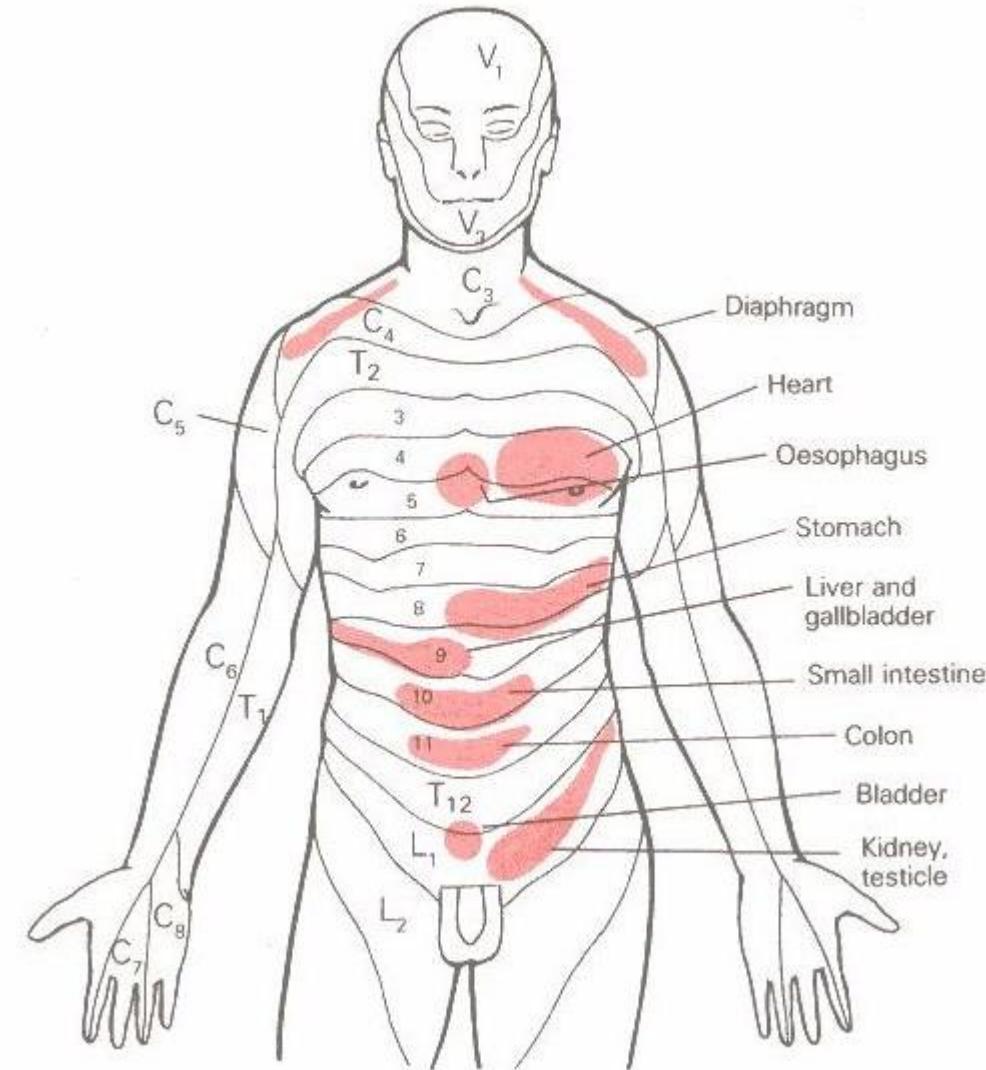
- area of skin supplied by **one spinal nerve** (= by one spinal segment)



Head's zones

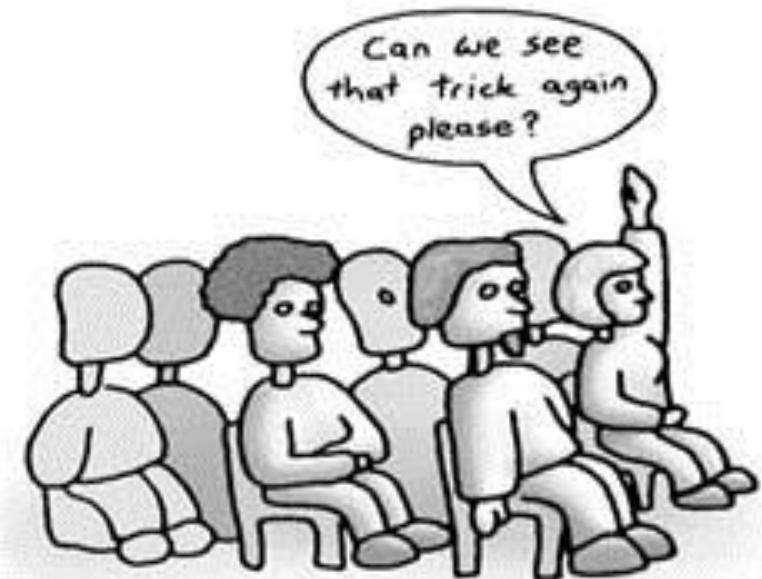


Sir Henry Head (1861-1940)

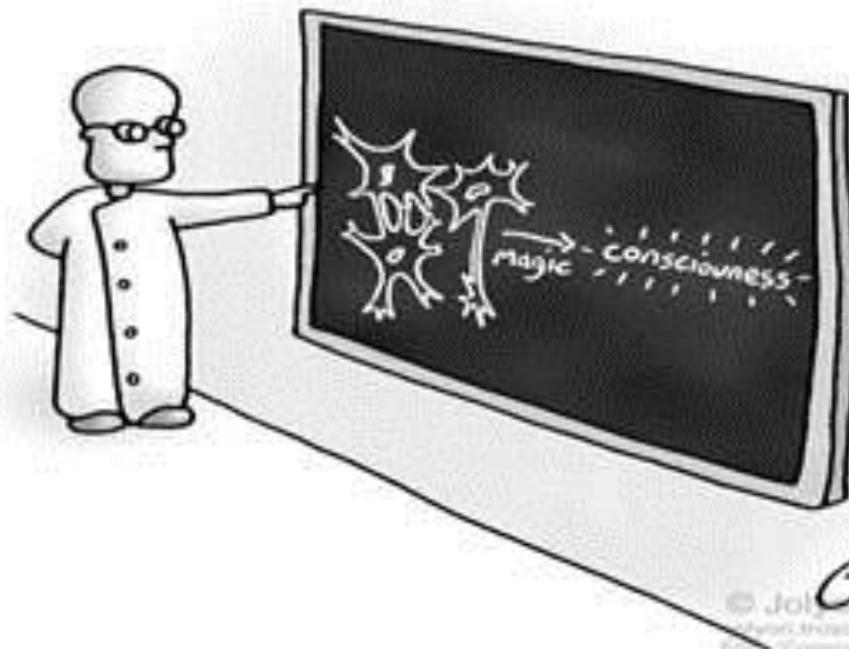


Head's zone

- diaphragm (C3–C5)
- lungs (T2–T5)
- heart (C8–T4)
- oesophagus (T4–T8)
- gonads (T10–T11)
- stomach (T6–T9)
- liver + gallbladder (T7–T9)
- intestine (T8–L2)
- appendix (T11–T12)
- pancreas (T7–T9)
- kidneys (T10–L1)



Can we see
that trick again
please?



© Jolijn Troscianko
troscianko@xs4all.nl
Foto: 'Consciousness' © Blauwevogel