

Central nervous system.

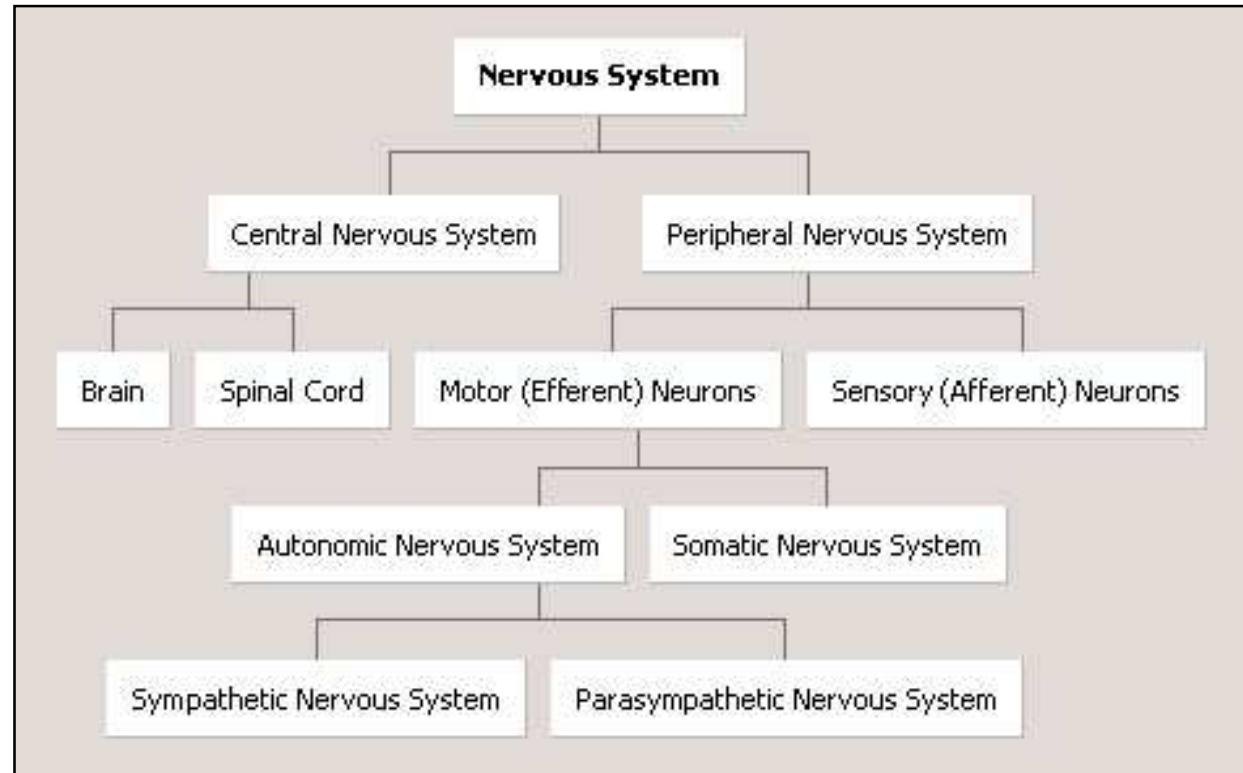
Spinal cord and spinal nerves

1. Central nervous system – gross subdivisions
2. Spinal cord – embryogenesis and external structure
3. Internal structure of the spinal cord
4. Grey matter – nuclei and laminae
5. White matter – nerve fiber tracts
6. Reflex apparatus of the spinal cord
7. Formation and general organization of the spinal nerves
8. Dorsal and ventral rami of the spinal nerves – plexuses





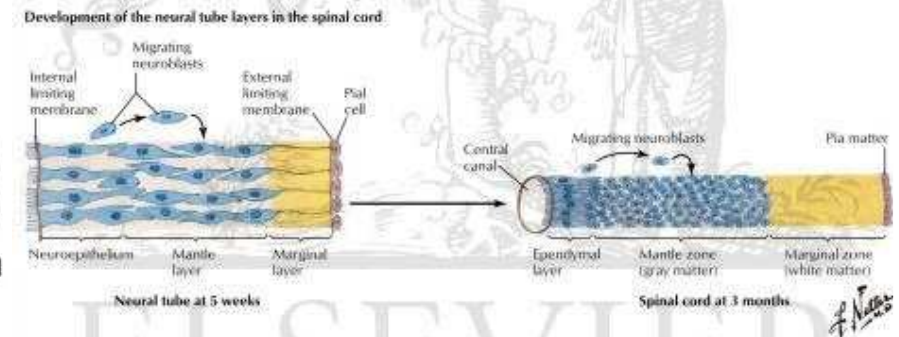
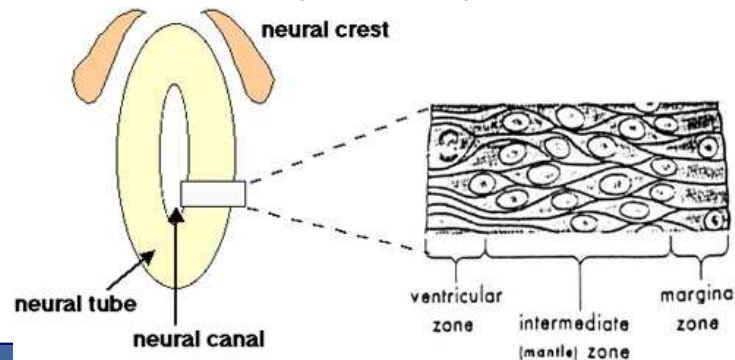
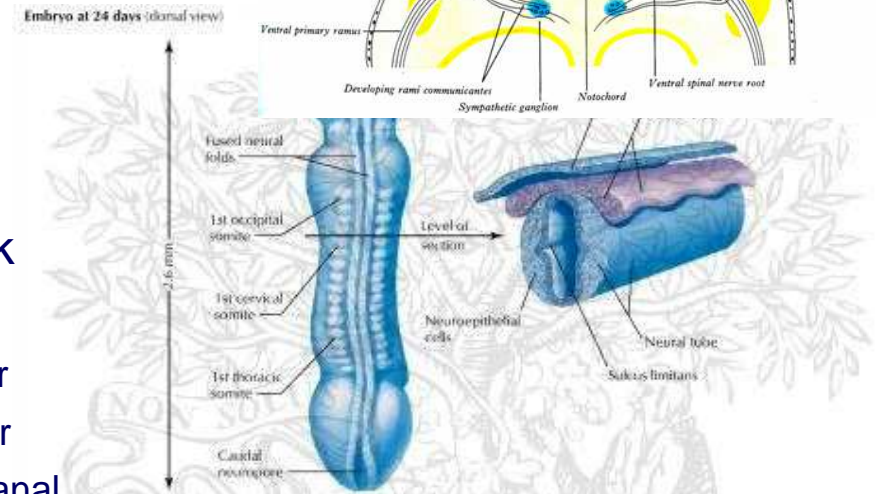
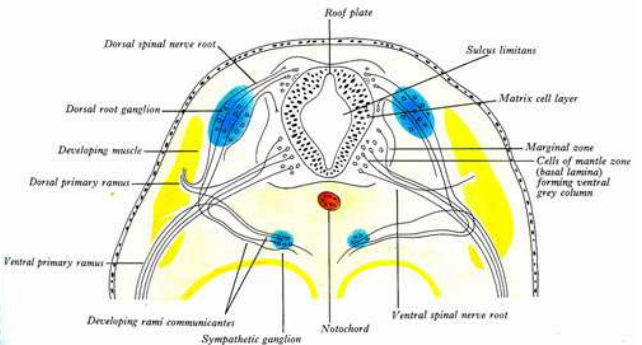
Classification of the nervous system





Embryogenesis of the spinal cord

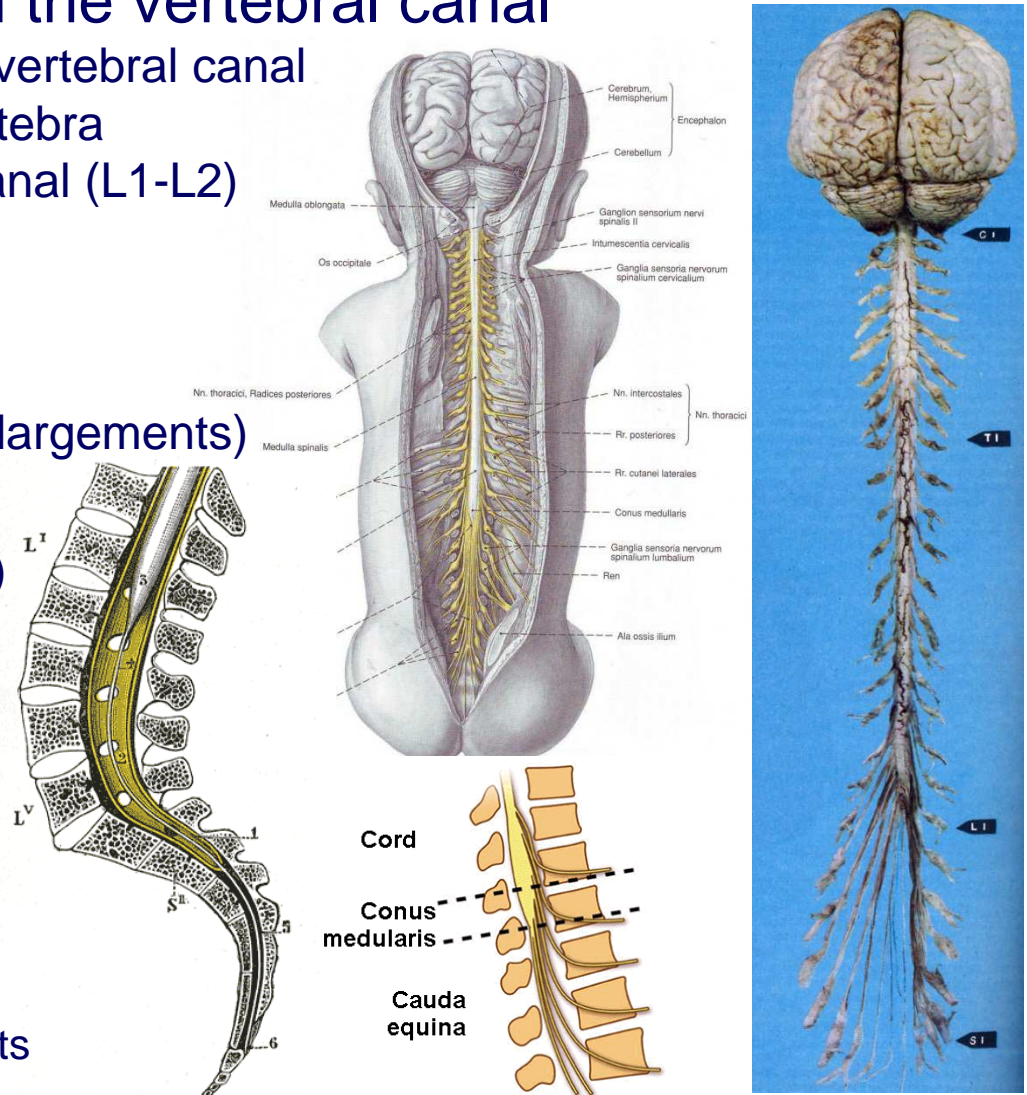
- origin: neuroectodermal
 - ✓ caudal part of the neural tube
- begin of formation: 3rd week
- developmental stages: *basal plate and alar plate*
 - ✓ neural plate
 - ✓ neural groove
 - ✓ neural tube
 - ✓ nerve crest
- closure of posterior neuropore: 4th week
- histogenesis – zones in the wall:
 - ✓ marginal layer ⇒ white matter
 - ✓ intermediate (mantle) layer ⇒ grey matter
 - ✓ ventricular (ependymal) layer ⇒ central canal





Topographic location, size and extent

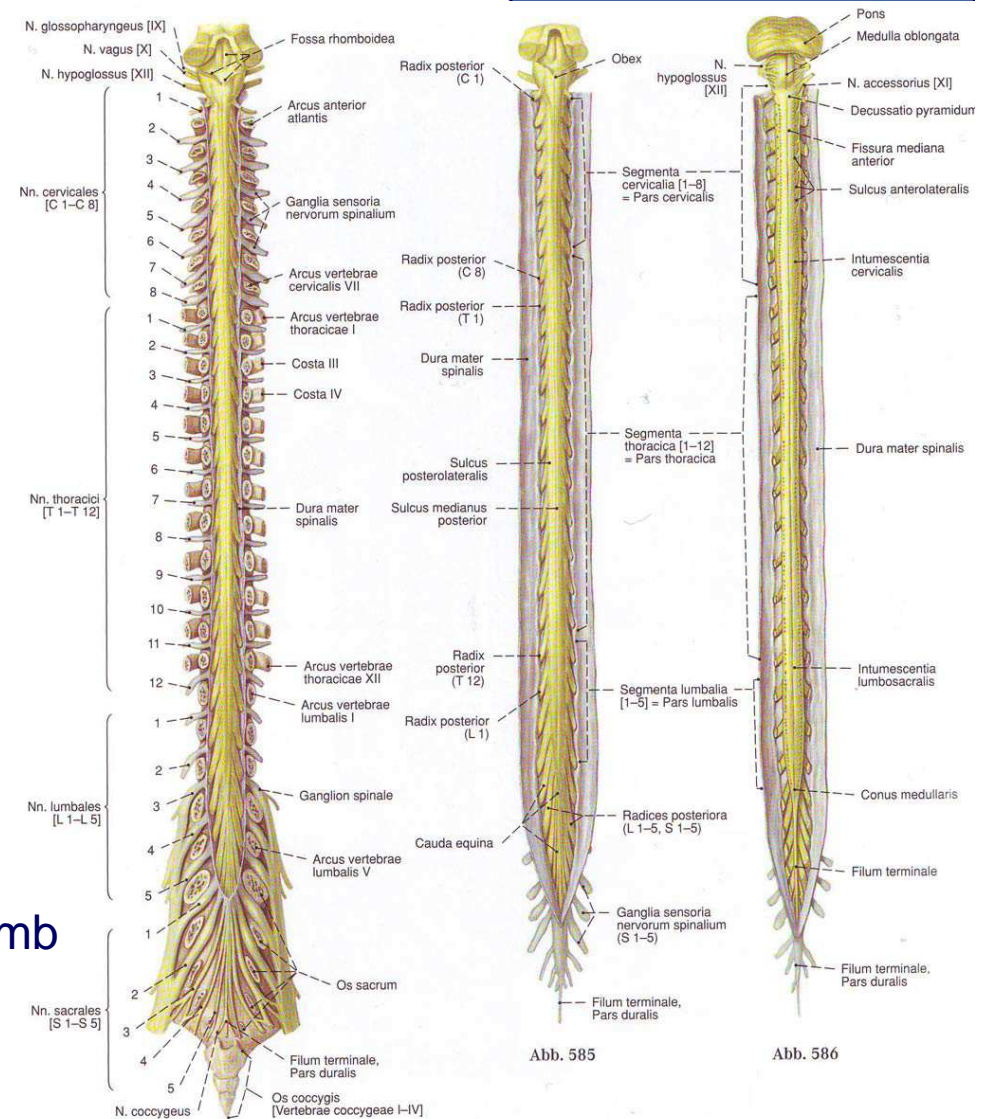
- topography and levels – in the vertebral canal
 - ✓ fetal life – the entire length of vertebral canal
 - ✓ at birth – near the level L3 vertebra
 - ✓ adult – upper $\frac{2}{3}$ of vertebral canal (L1-L2)
- average length:
 - ✓ ♂ – 45 cm long
 - ✓ ♀ – 42-43 cm
- diameter ~ 1-1.5 cm (out of enlargements)
- weight ~ 35 g (2% of the CNS)
- shape – round to oval (cylindrical)
- terminal part:
 - ✓ *conus medullaris*
 - ✓ *filum terminale internum* (cranial 15 cm) – S2
 - ✓ *filum terminale externum* (final 5 cm) – Co2
 - ✓ *cauda equina* – collection of lumbar and sacral spinal nerve roots





Macroscopic anatomy – enlargements

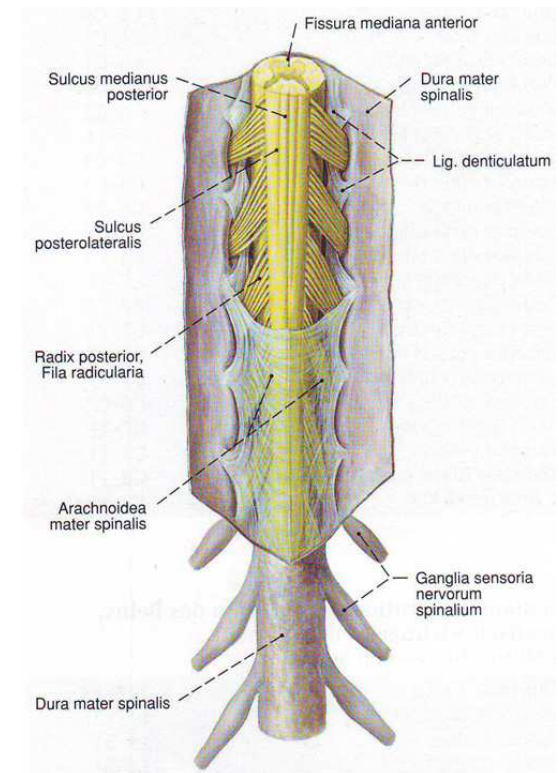
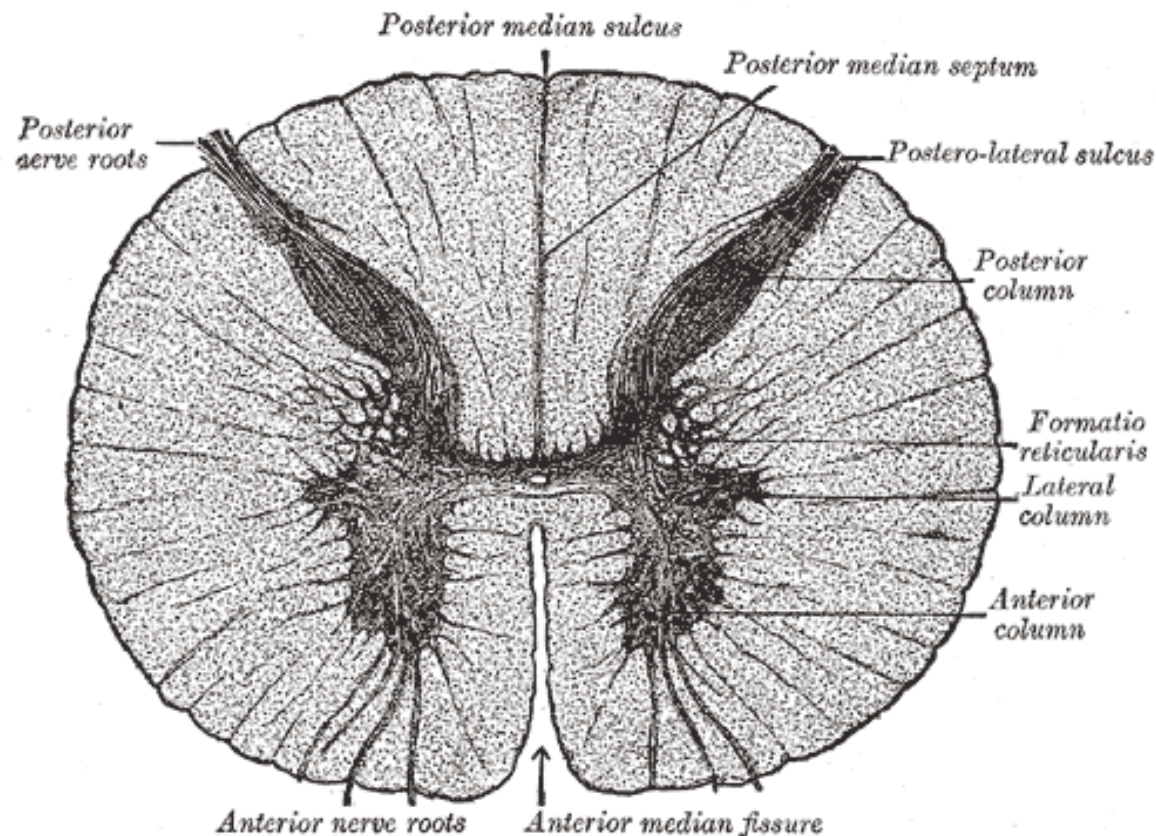
- cervical enlargement, *intumescentia cervicalis*:
 - ✓ spinal segments (C4-Th1)
 - ✓ vertebral levels (C4-Th1)
 - ✓ provides upper limb innervation (brachial plexus)
- lumbosacral enlargement, *intumescentia lumbosacralis*:
 - ✓ spinal segments (L2-S3)
 - ✓ vertebral levels (Th9-Th12)
 - ✓ segmental innervation of lower limb (lumbosacral plexus)





External surface structure

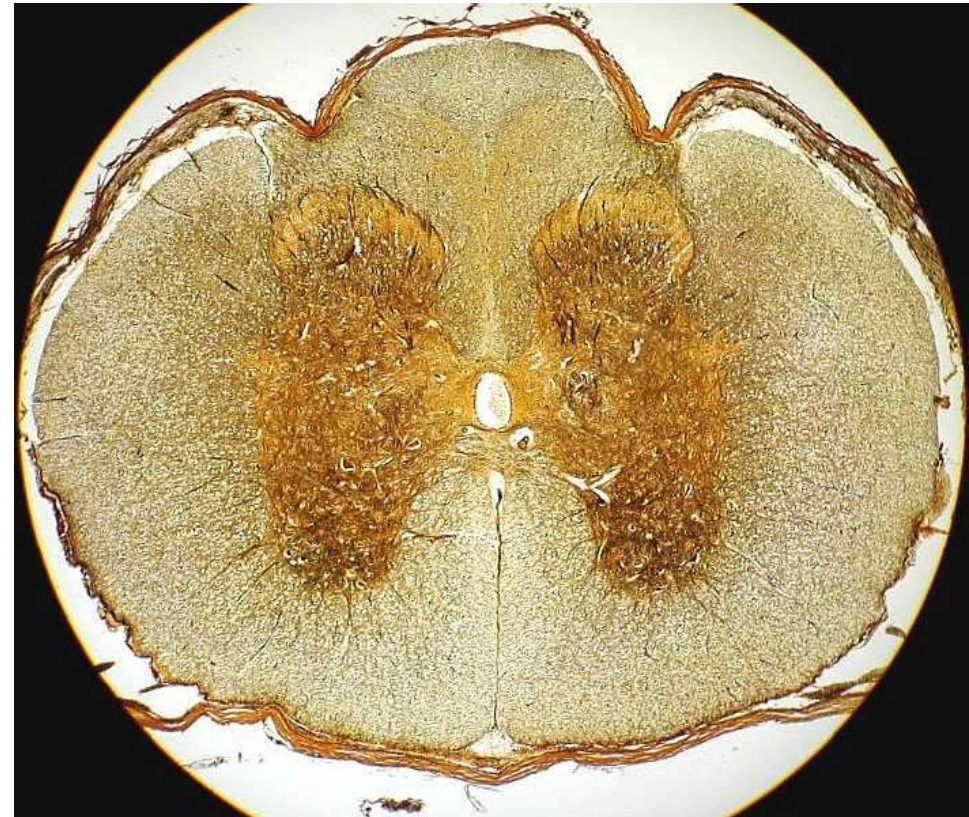
- **Two symmetrical halves:**
 - ✓ divided by two external longitudinal grooves:
 - a deeper anterior median fissure
 - a shallower posterior median sulcus (less prominent)
 - ✓ joined by a commissural band of nervous tissue





Anterior median fissure

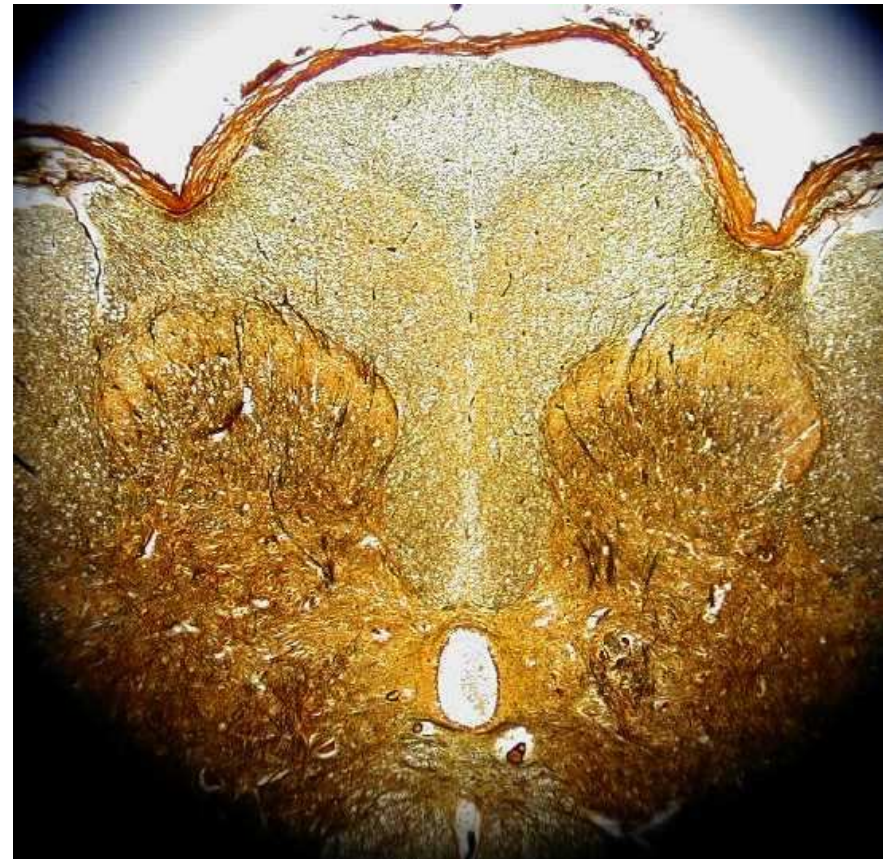
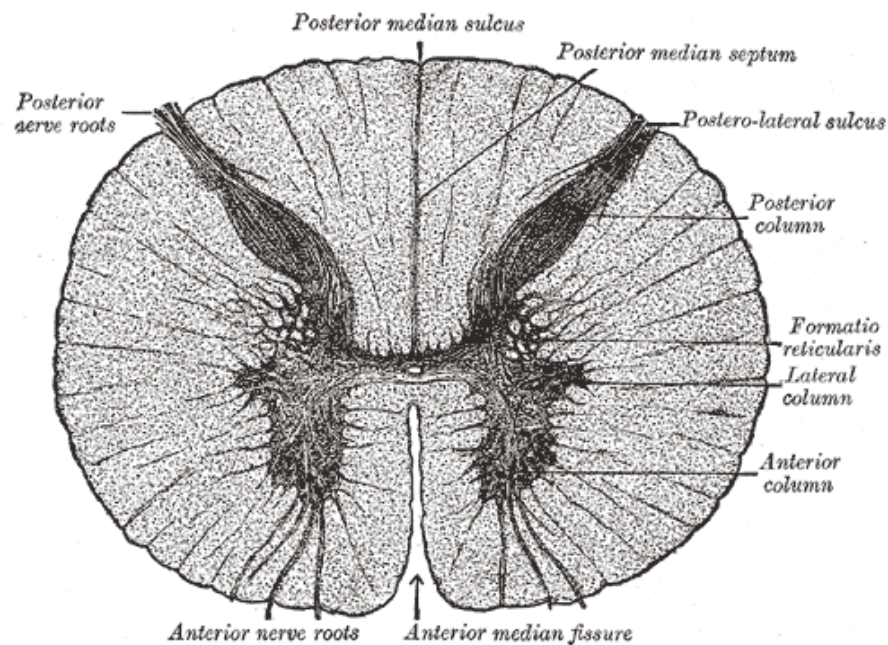
- average depth ~ 3 mm:
 - ✓ deeper at more caudal levels
- roof:
 - ✓ a reticulum of *pia mater*
- floor:
 - ✓ a lamina of nerve fibers, anterior white commissure
- anterior spinal artery
- anterolateral sulcus – ventral nerve root





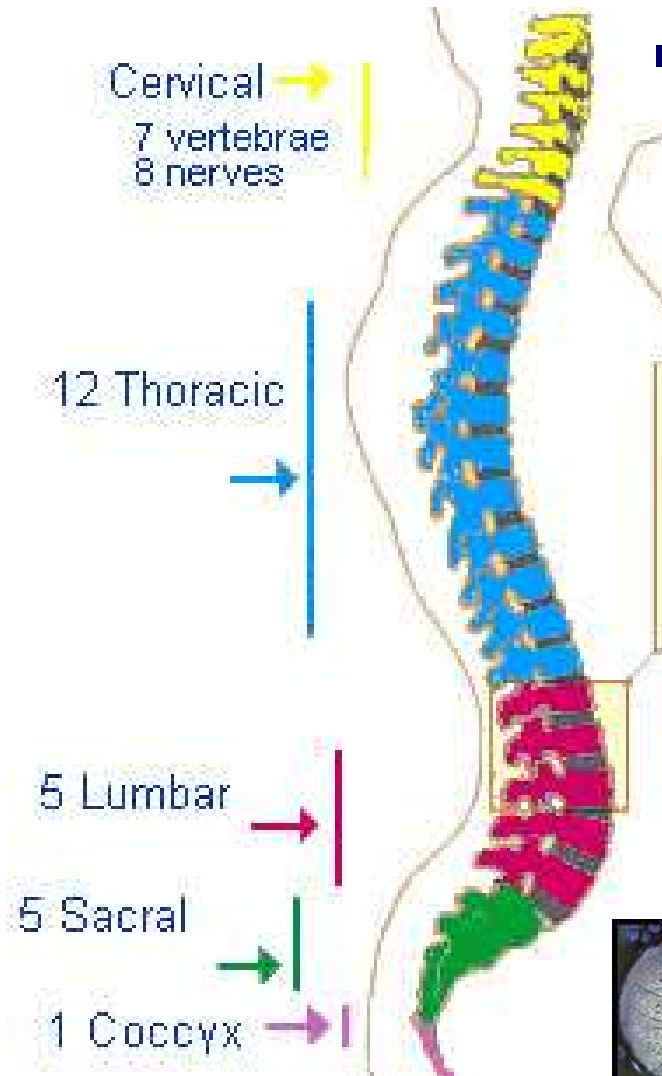
Posterior median septum

- average depth ~ 4-6 mm:
 - ✓ diminishing caudally
- neuroglial partition:
 - ✓ reaching the gray matter
- posterolateral sulcus – dorsal nerve root



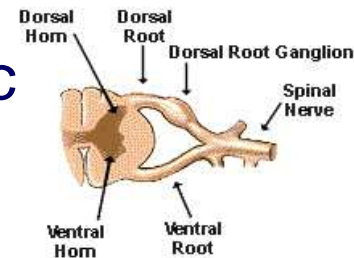


Segmental structure



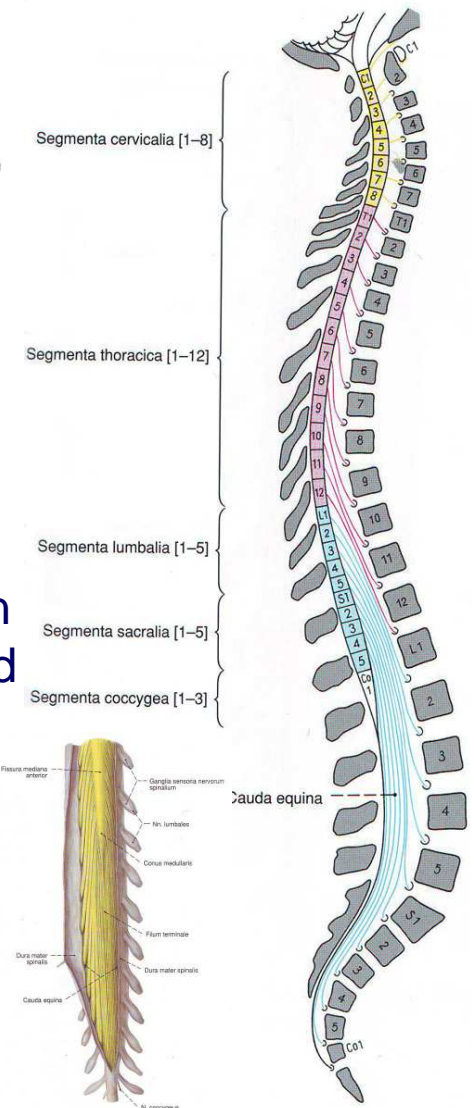
■ 31 segments:

- ✓ 8 cervical
- ✓ 12 thoracic
- ✓ 5 lumbar
- ✓ 5 sacral
- ✓ 1 coccygeal



■ segment ≠ vertebra:

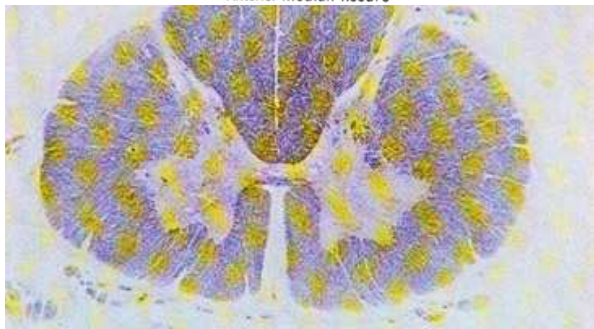
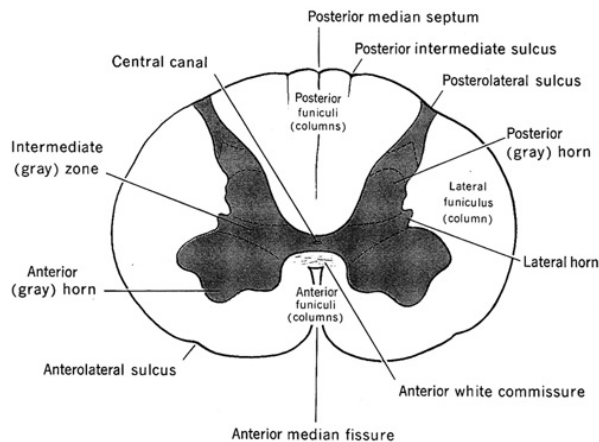
- ✓ growth of the vertebral column exceeds that of the spinal cord
- ✓ all segments terminate **above** level L1/L2 ⇒ *cauda equina*
- ✓ vary in diameter and length



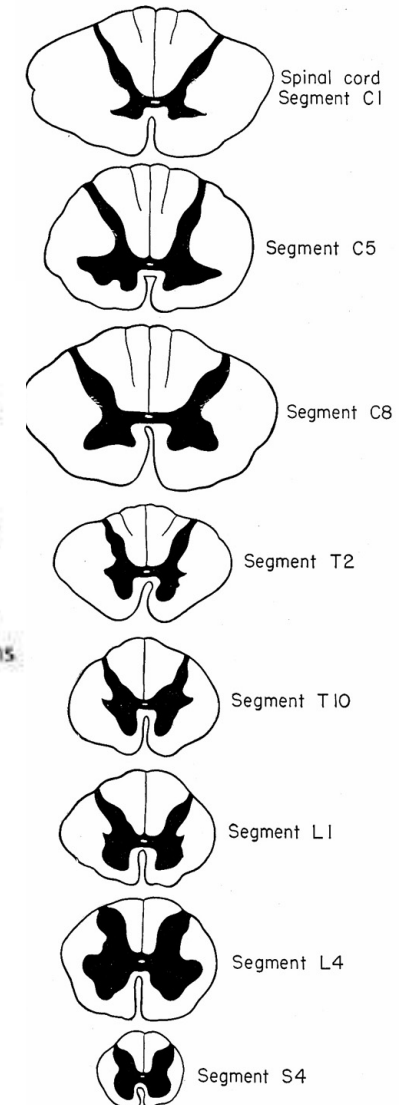
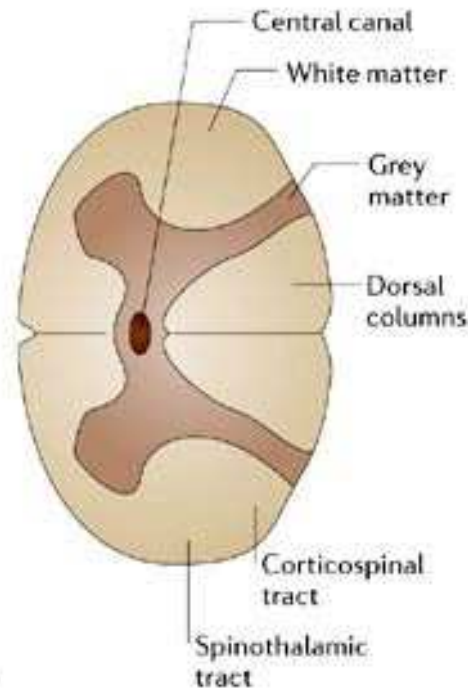
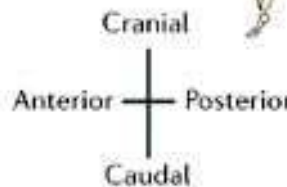
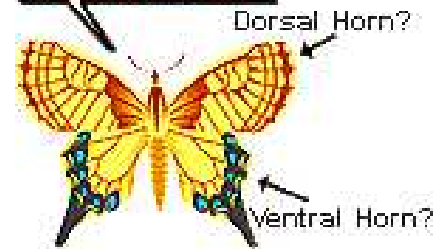


Internal structure of the spinal cord

- grey matter, *substantia grisea*
 - ✓ butterfly-like or H-shaped
- white matter, *substantia alba*
- vary in diameter and length at different levels



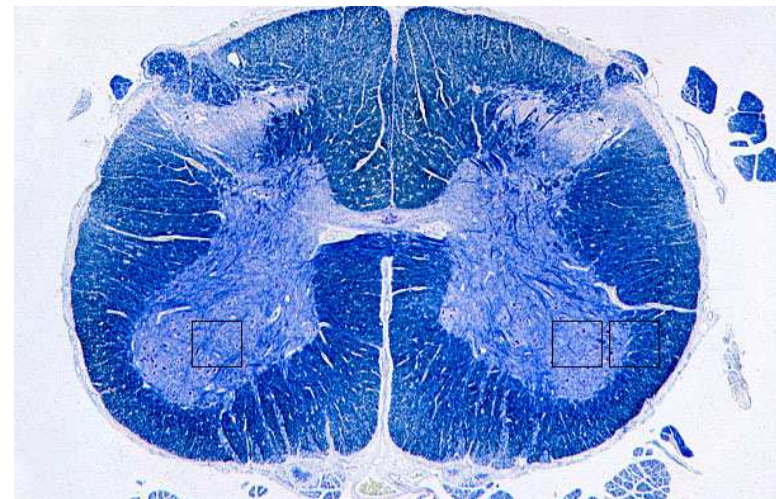
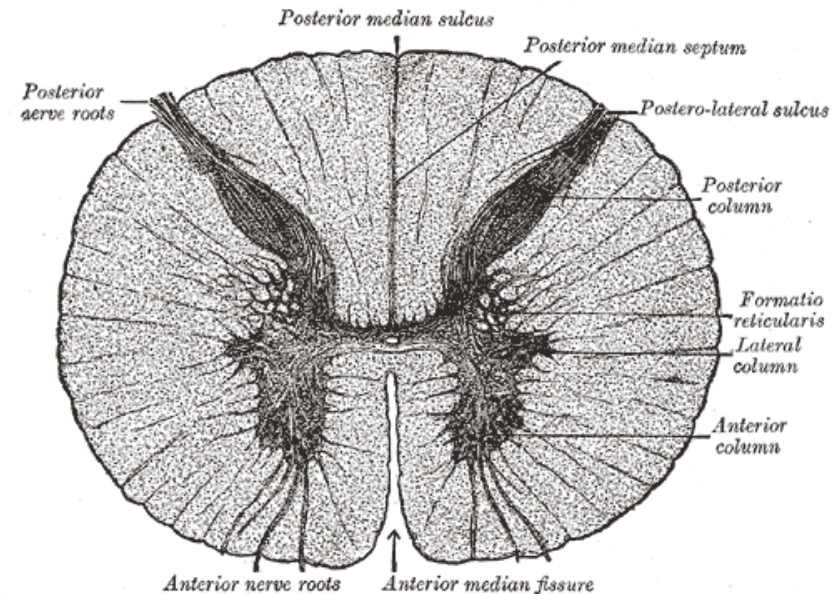
How do you like my dorsal and ventral horns?





Grey matter, *substantia grisea*

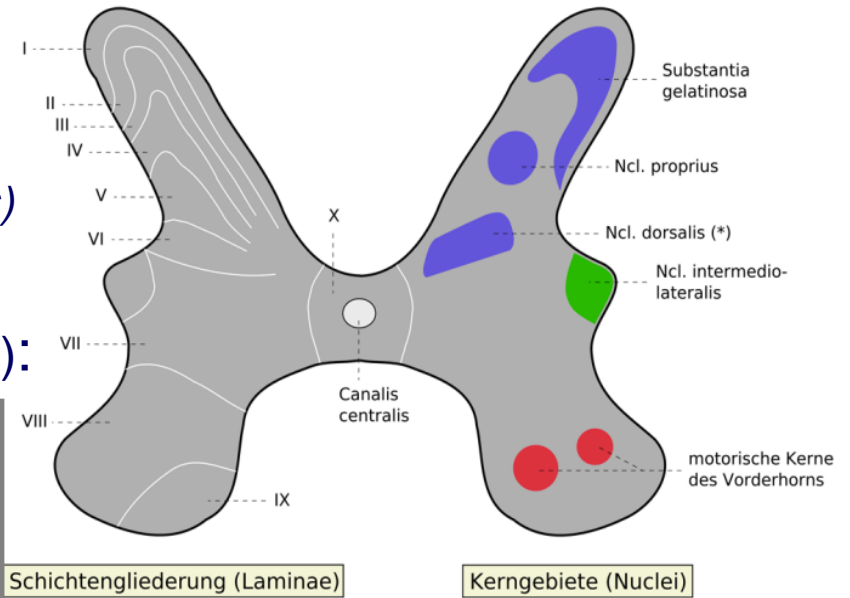
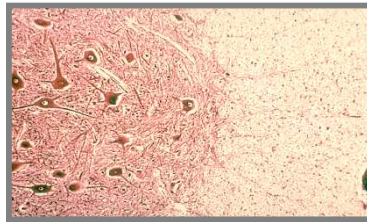
- composition:
 - ✓ neuronal perikarya
 - ✓ dendrites with their synapses
 - ✓ glial supporting cells
 - ✓ blood vessels
- anterior (ventral) column:
 - ✓ *cornu anterius (columna anterior)*
- posterior (dorsal) column:
 - ✓ *cornu posterius (columna posterior)*
- lateral column:
 - ✓ *cornu laterale – Th1-L2; S2-S4 (columna intermedia)*
- central canal:
 - ✓ *canalis centralis* ⇔ *liquor cerebrospinalis*
 - ✓ *substantia gelatinosa centralis*
- grey commissure:
 - ✓ *commissura grisea*



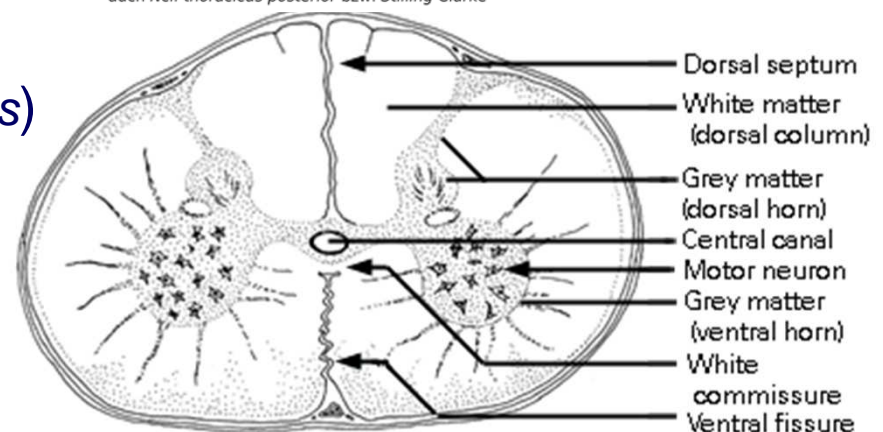


General structure of the grey matter

- posterior column (dorsal horn):
 - ✓ apex, caput, cervix, basis
 - ✓ projection neurons (*neurocyti funiculares*) and interneurons (*neurocyti interni*)
- lateral column (intermediolateral horn):
 - ✓ visceromotor neurons
 - parasympathetic
 - sympathetic
- anterior column (ventral horn):
 - ✓ motor neurons (*neurocyti radicales*)
 - large alpha motoneurons (ACh)
 - small gamma motoneurons (ACh)
 - Renshaw cells (Gly) (inhibitory interneurons)

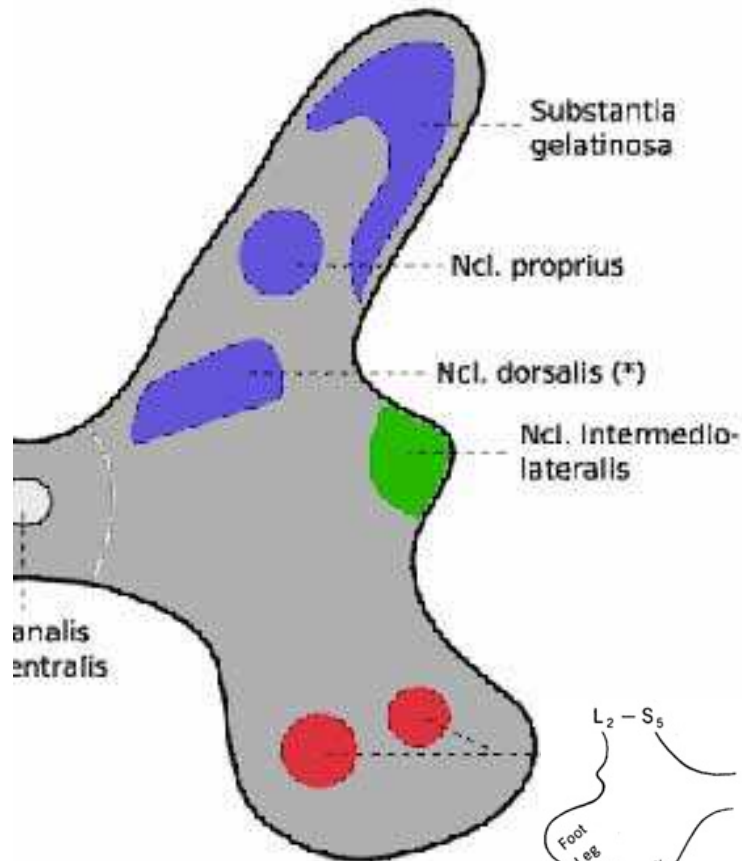


* auch Ncl. thoracicus posterior bzw. Stilling-Clarke





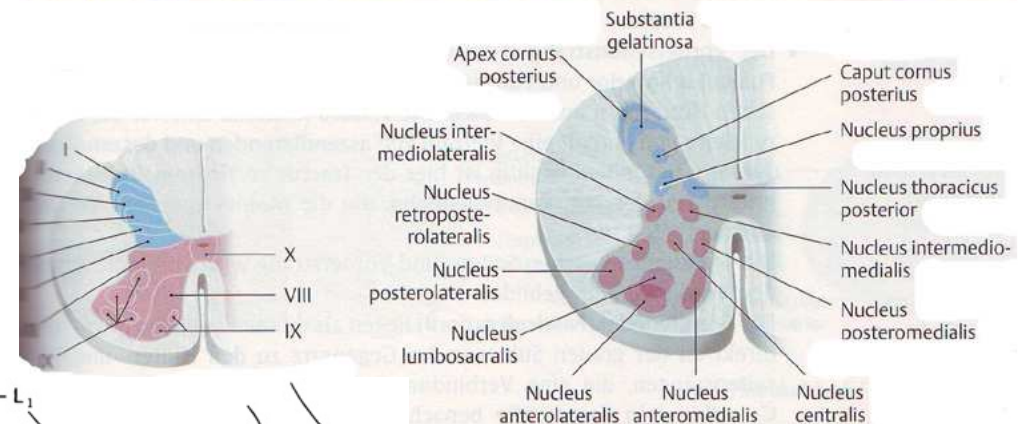
Grey matter – nerve cell groups



dorsal horn: 4 nuclei

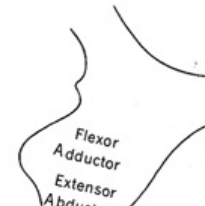
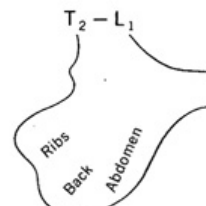
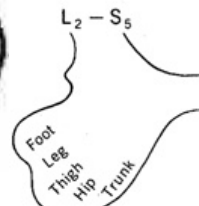
- ✓ dorsomarginal nucleus (*zona spongiosa*)
- ✓ *substantia gelatinosa* of Rolando
- ✓ *nucleus proprius* ⇒ receive pain impulses
- ✓ *nucleus dorsalis (thoracicus)* of Clarke-Stilling

1.3 Feinbau der grauen Substanz



lateral horn: 2 nuclei

- ✓ sympathetic: intermediolateral nucleus (Th1-L2)
- ✓ parasympathetic: intermediomedial nucleus (S2-S4)
- ✓ spinal reticular nucleus



ventral horn: 5 nuclei

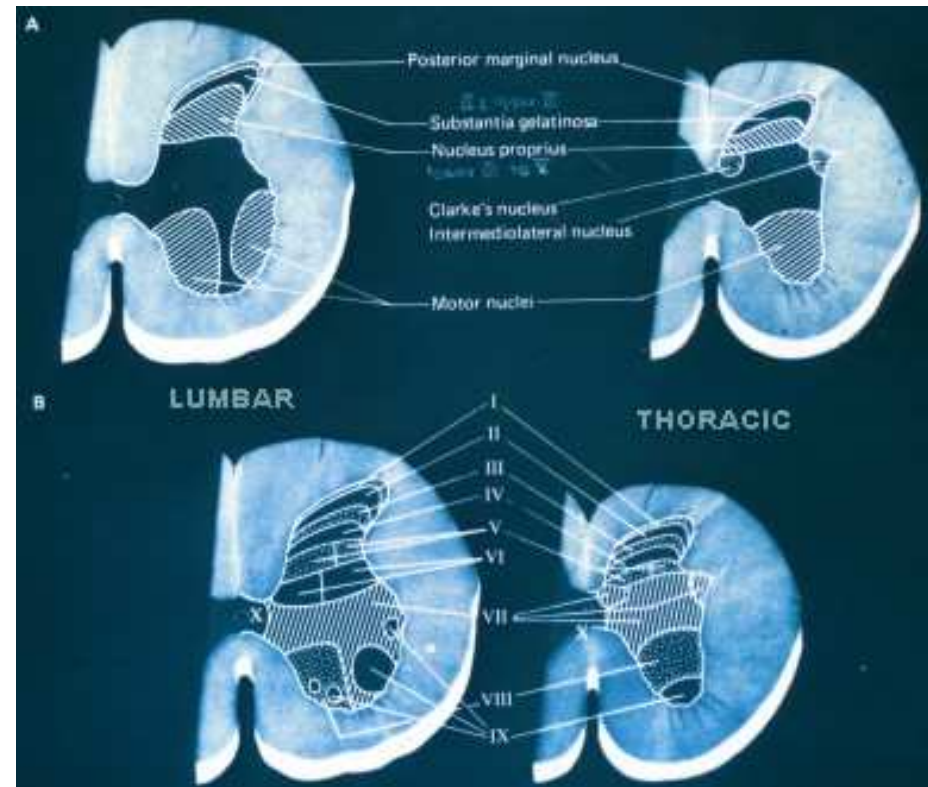
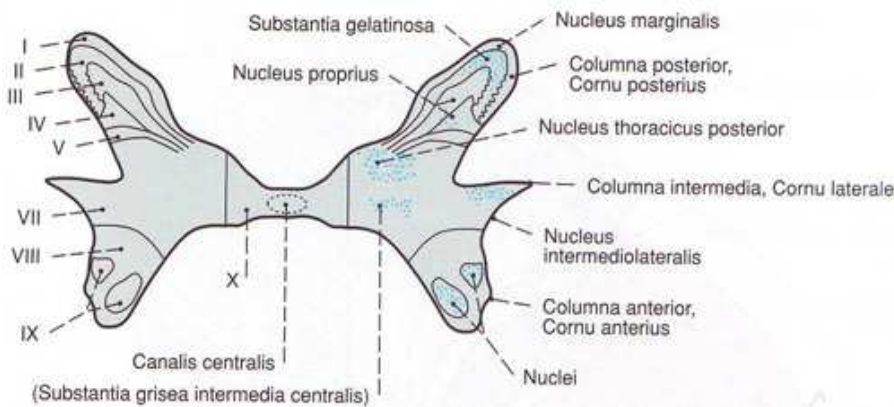
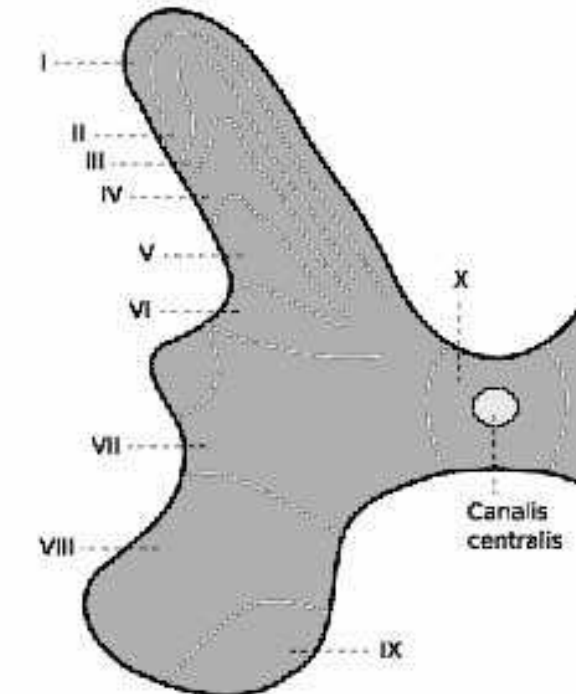
- ✓ medial group
 - ventromedial nucleus
 - dorsomedial nucleus
- ✓ lateral group
 - ventrolateral nucleus
 - central nucleus
 - dorsolateral nucleus



Grey matter – laminar architecture

10 distinct cellular laminae of Rexed:

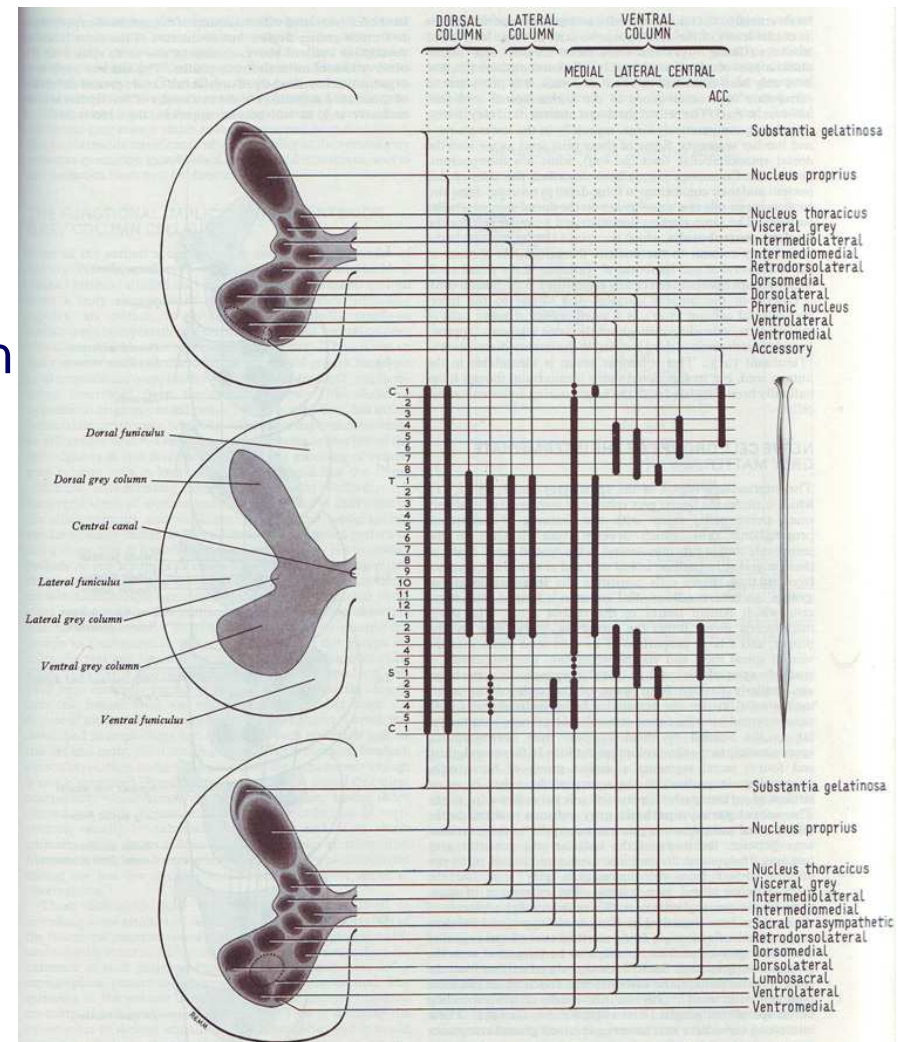
- ✓ I-VI: dorsal horn
- ✓ VII: intermediate zone and lateral horn
- ✓ VIII-IX: ventral horn
- ✓ X: central canal + substantia gelatinosa (of Rolando)





Grey matter – functional organization

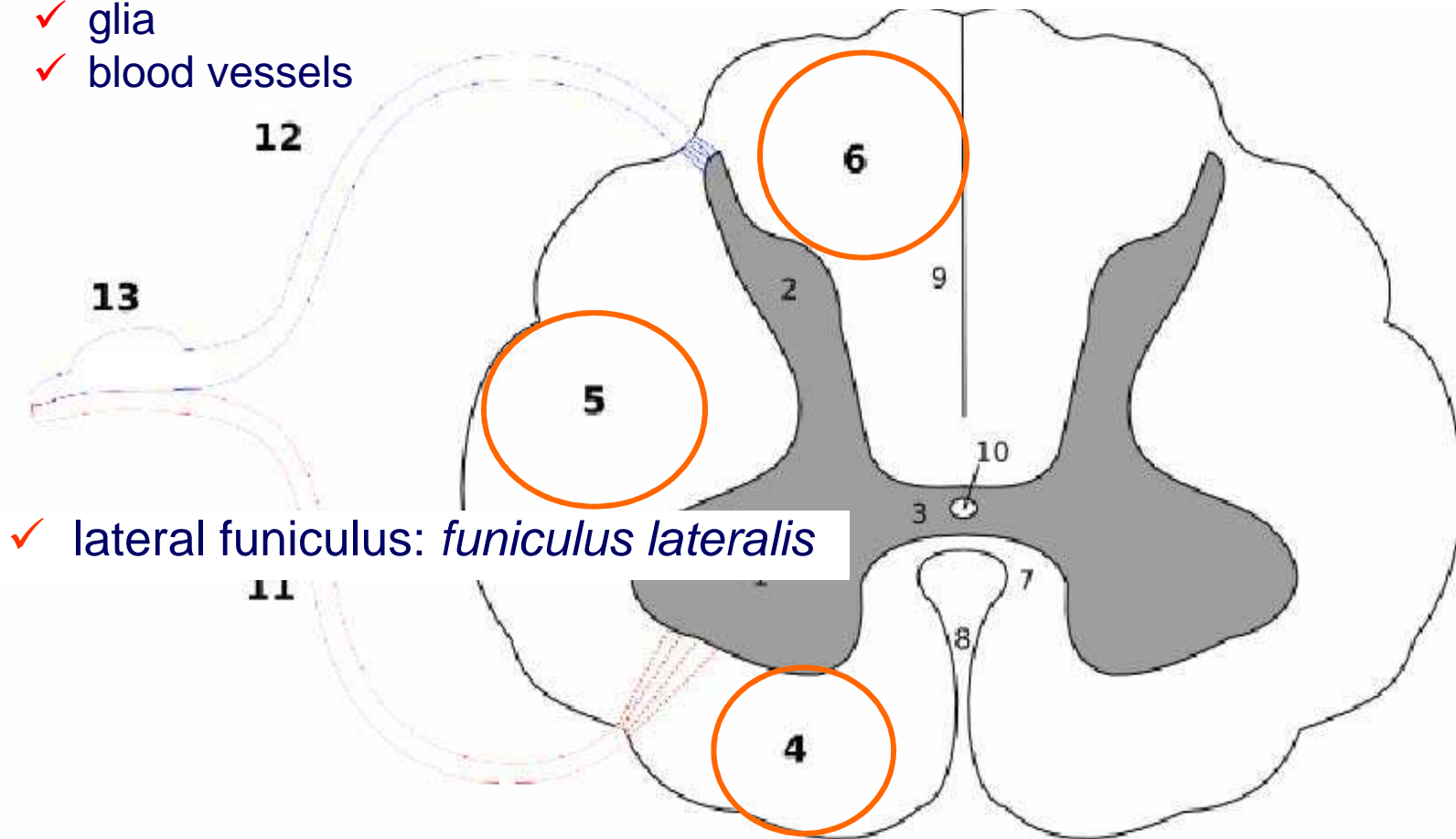
- different sensations – different neurons (the law of Bell and Magendie)
- the theory of nerve components:
- dorsal horn mediates sensation
 - ✓ general somatic afferents
 - ✓ general visceral afferents (GVA)
- ventral horn mediates motor function
 - ✓ general somatic efferents (GSE) for the ventral roots
- intermediate horn
 - ✓ receives GVA axons
 - ✓ originates GVE axons
- the perikarya in various nuclei differ in size, shape and connections
- nuclear groups in grey columns vary in longitudinal extent





White matter composition

- composition:
 - ✓ nerve fibers
 - ✓ glia
 - ✓ blood vessels
- 3 columns (funiculi) – ascending and descending tracts
 - ✓ posterior funiculus: *funiculus dorsalis (posterior)*



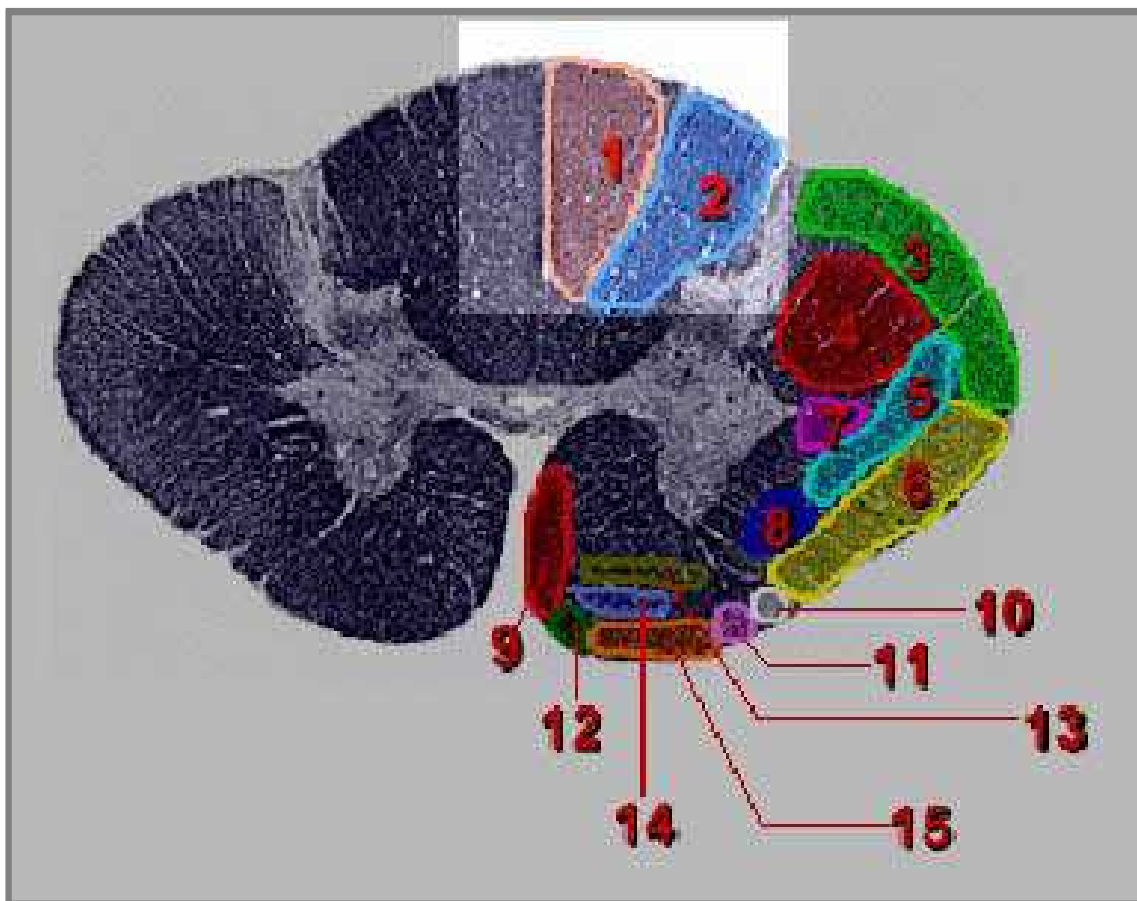
✓ lateral funiculus: *funiculus lateralis*

✓ anterior funiculus: *funiculus ventralis (anterior)*



Dorsal column tracts

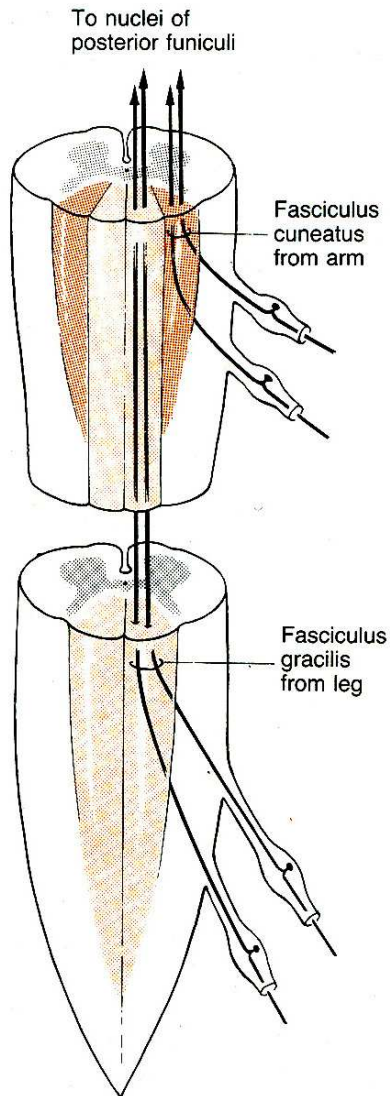
- Ascending pathways:
 1. *Fasciculus gracilis* (of Goll)
 2. *Fasciculus cuneatus* (of Burdach)



- Descending pathways:
 1. *Fasciculus interfascicularis, s. semilunaris* (of Schultze) = Interfascicular fasciculus
 2. *Fasciculus septomarginalis* (of Flechsig)



Fasciculus gracilis



1. gracile fascicle, synonym: Goll's column

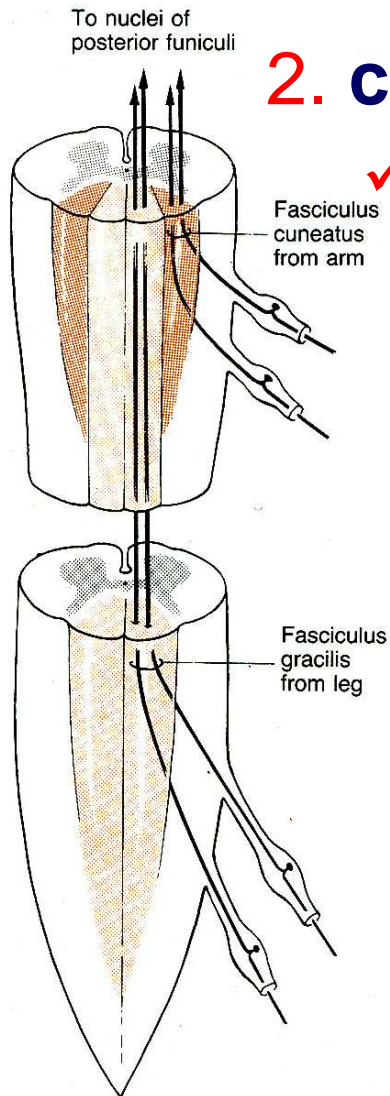
✓ medial part of the posterior funiculus



- ✓ present at **all spinal levels**
- ✓ terminates somatotopically upon the nucleus gracilis
- ✓ subserves **superficial sensitivity (discriminative modalities) and deep sensitivity (kinesthesia)** from the lower part of the trunk and from the leg
- ✓ interruption of this tract causes
 - loss of position sense resulting in posterior column '**sensory ataxia**'

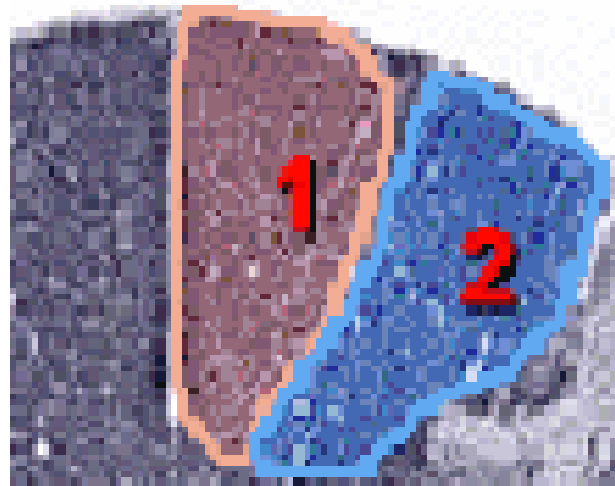


Fasciculus cuneatus



2. cuneate fascicle, synonym: Burdach's column

✓ lateral part of the posterior funiculus

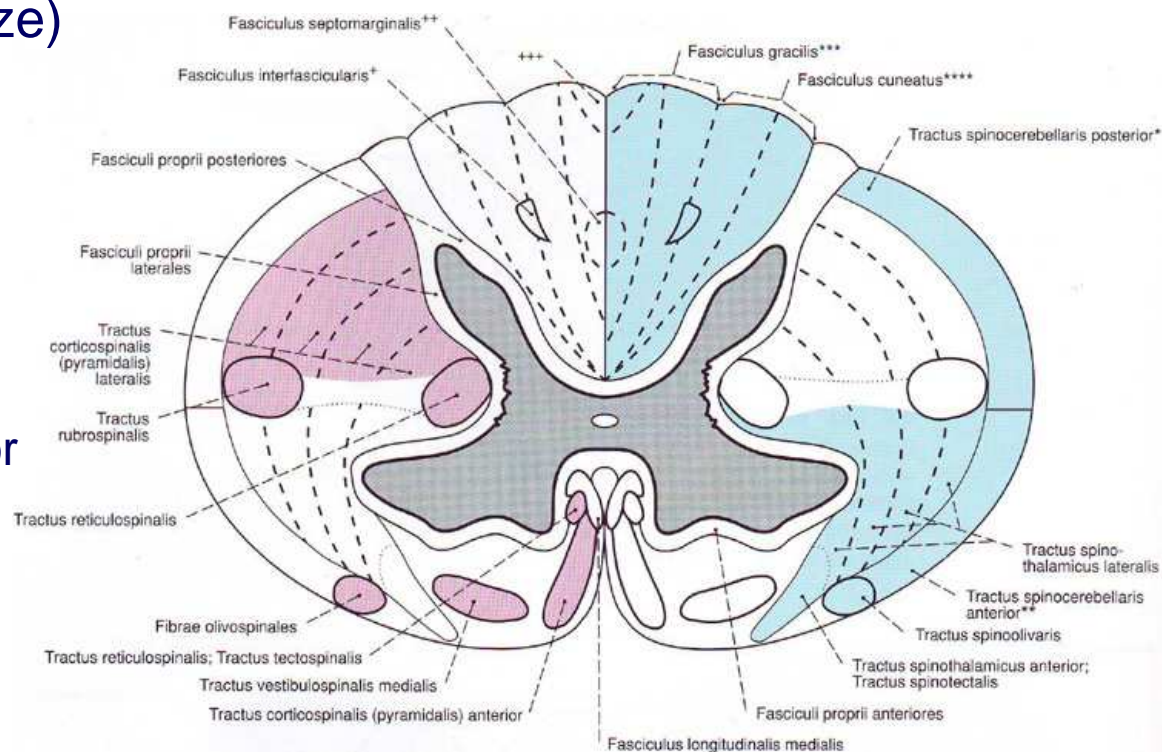


- ✓ first appear at about **Th6**
- ✓ contains long ascending branches of the **upper six thoracic and all cervical** dorsal roots
- ✓ **deep sensitivity (proprioception)** from the upper part of the trunk and from the arm
- ✓ **superficial sensitivity** – touch, pressure and vibration
- ✓ interruption of this tract causes
 - loss of position sense resulting in 'sensory ataxia'



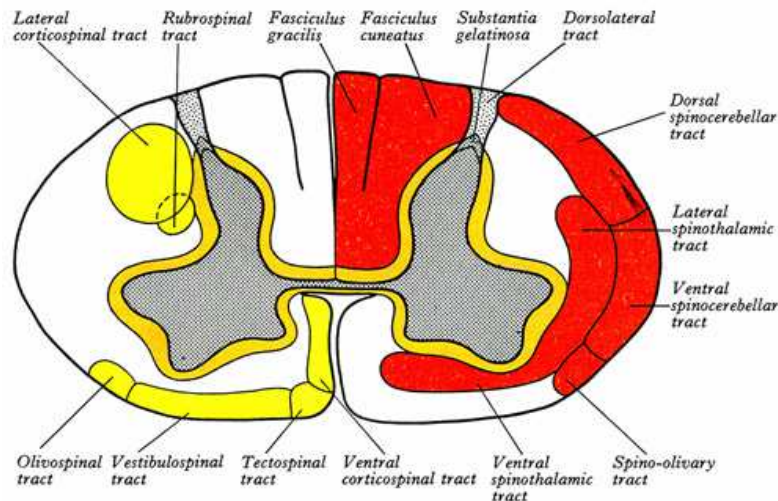
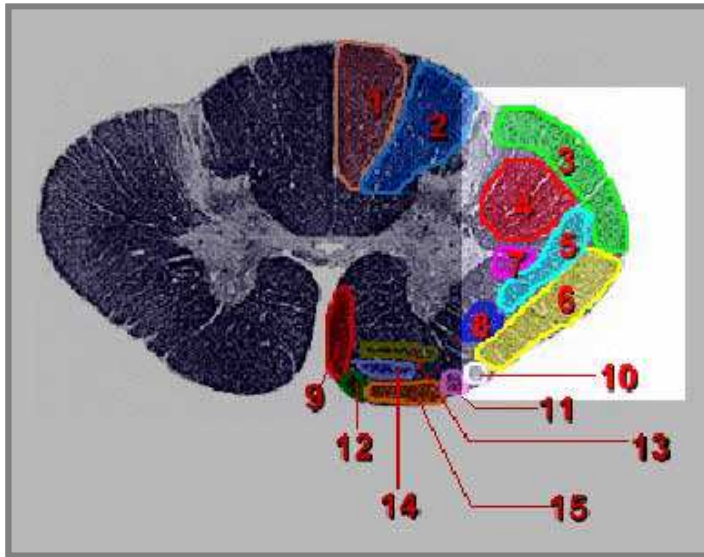
Posterior funiculus

- Descending tracts:
 1. Interfascicular fasciculus, semilunar tract (comma tract of Schultze)
 - ✓ in the medial part of the cuneate tract
 - ✓ extending through cervical and upper thoracic levels
 2. Septomarginal tract (oval field of Flechsig)
 - ✓ bordering the posterior median septum
 - ✓ in lower thoracic segments
 - ✓ propriospinal fibers
- Intersegmental tracts:
 - ✓ Posterior intersegmental tract





Lateral funiculus



■ Ascending tracts:

1. Dorsal spinocerebellar tract (of Flechsig)
2. Ventral spinocerebellar tract (of Gowers)
3. Lateral spinothalamic tract (of Edinger)
4. Spinotectal tract
5. Spino-olivary tract
6. Spinoreticular fibers
7. Dorsolateral tract (of Lissauer)

■ Descending tracts:

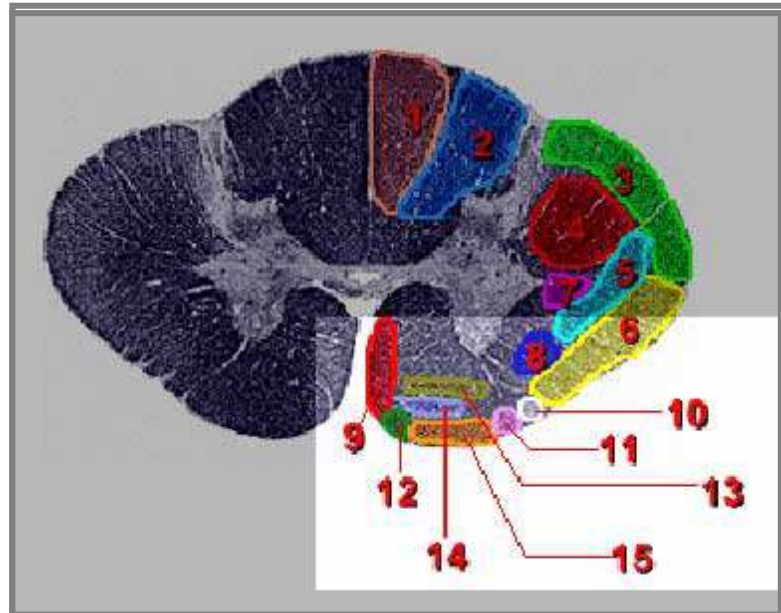
1. Lateral corticospinal tract
2. Rubrospinal tract
3. Tectospinal tract
4. Lateral reticulospinal tract
5. Olivospinal tract (of Helweg) – only in animals

■ Intersegmental tracts:

1. Lateral intersegmental tract



Anterior funiculus



■ Ascending tracts:

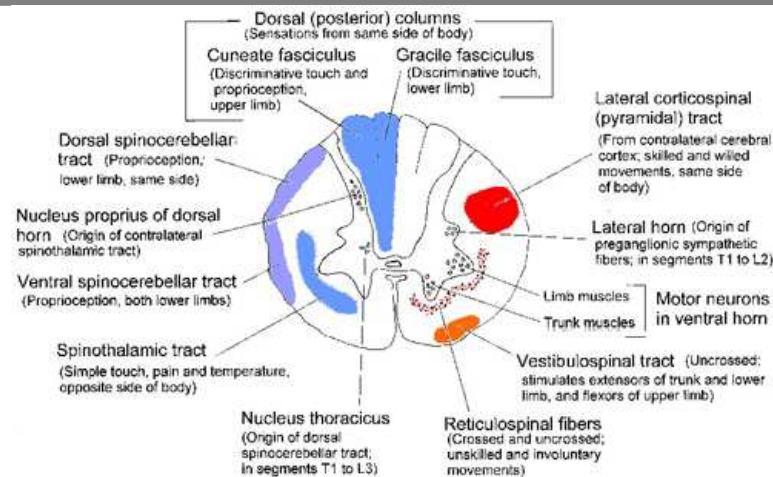
1. Anterior spinothalamic tract

■ Descending tracts:

1. Anterior corticospinal tract (bundle of Türk)
2. Reticulospinal tract
3. Vestibulospinal tract (medial and lateral)
4. Medial longitudinal fasciculus
5. Interstitospinal tract
6. Solitariospinal tract (of Cajal)

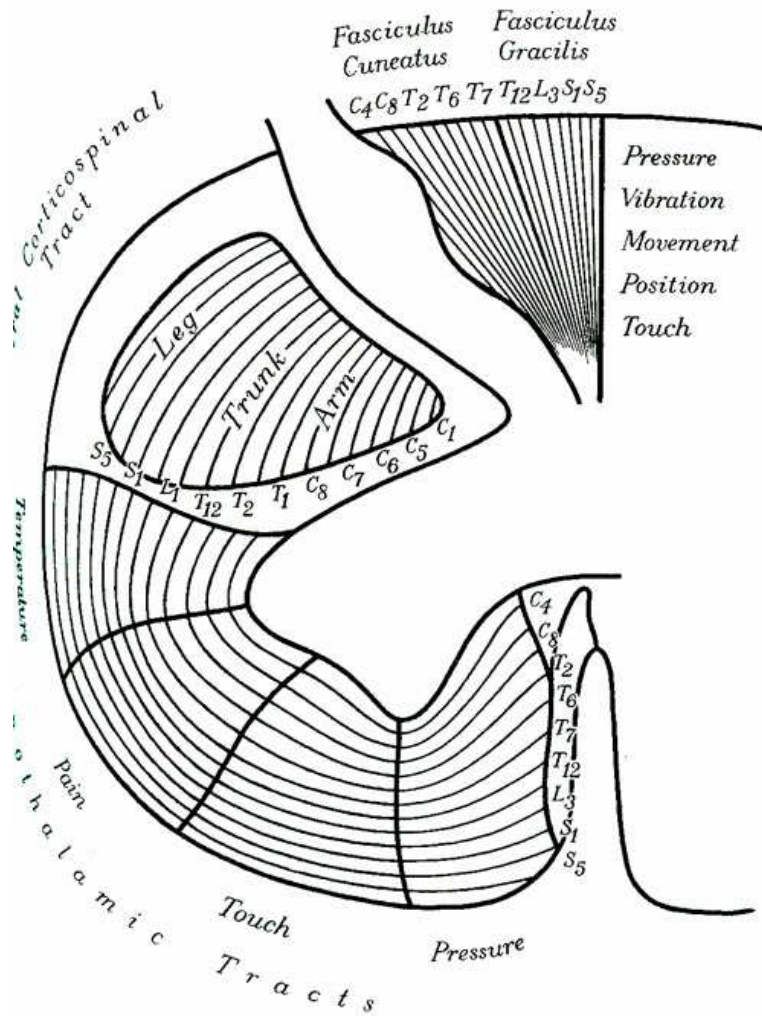
■ Intersegmental tracts:

1. Anterior intersegmental tract



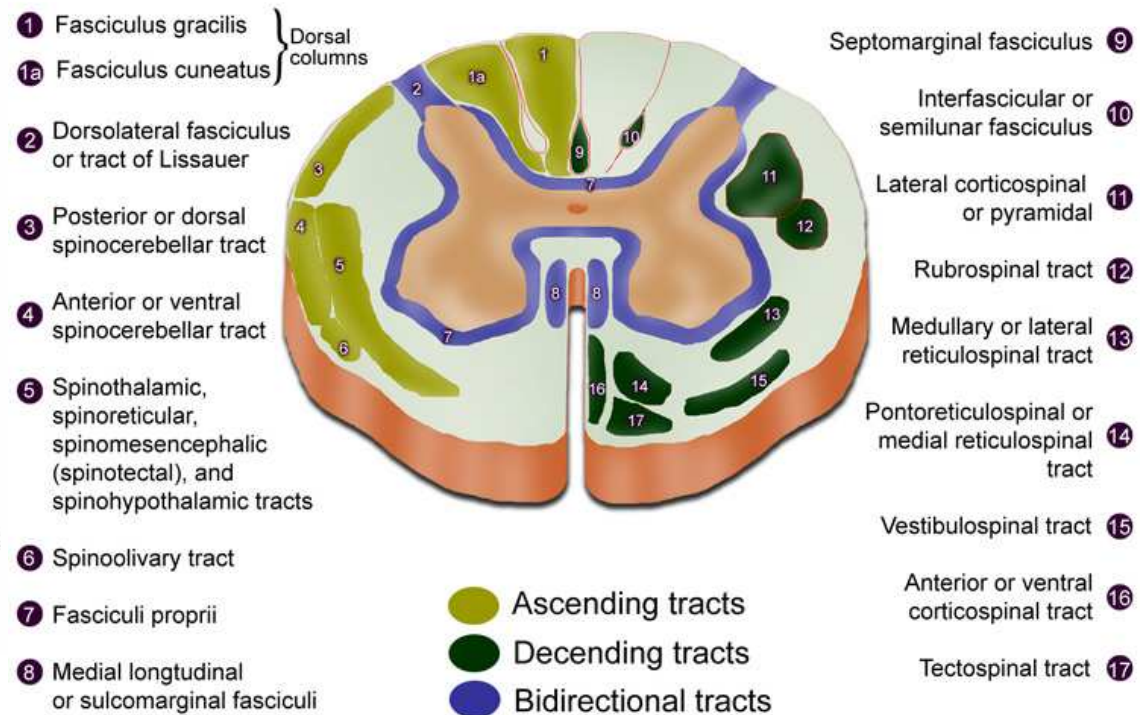


Functional topography of pathways



Posterior (dorsal funiculi) columns:

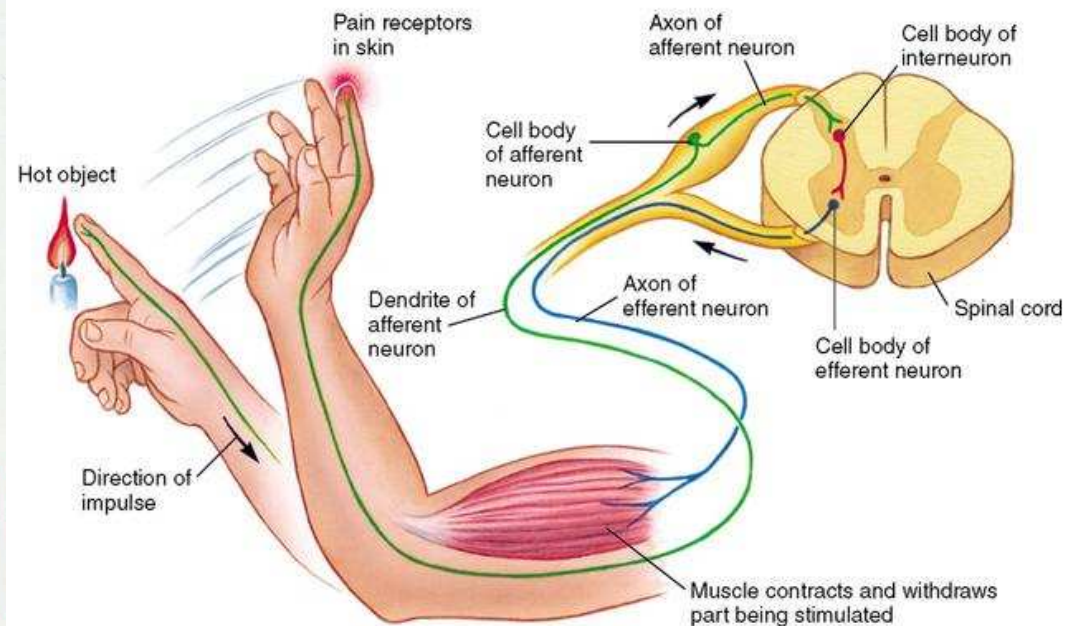
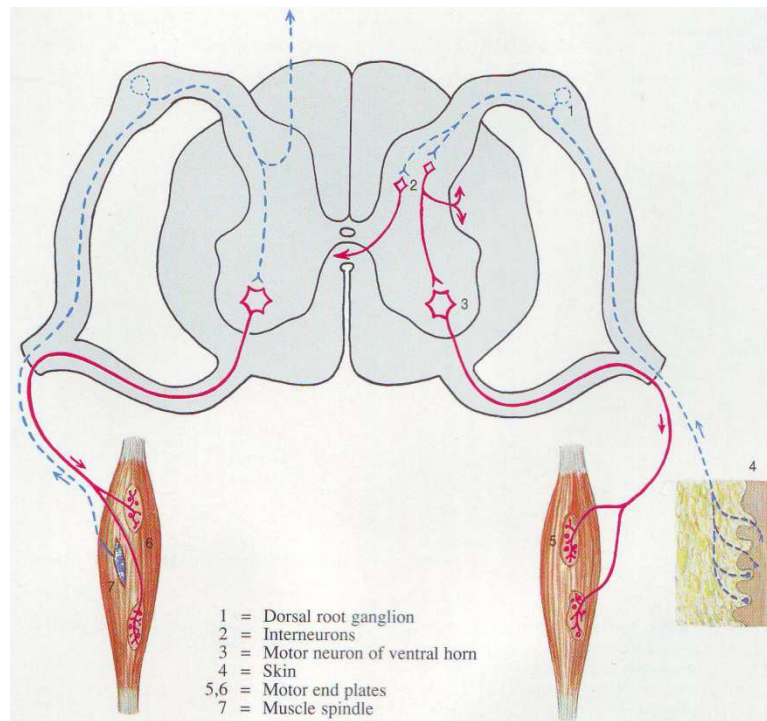
- ✓ proprioception (position sense)
- ✓ vibratory sense
- ✓ discriminative touch





Reflex arcs of the spinal cord

- reflex arc – the neural pathway that mediates a reflex action
- two types of reflex arcs:
 - ✓ autonomic reflex arc (affecting inner organs)
 - ✓ somatic reflex arc (affecting muscles)
- monosynaptic vs. polysynaptic reflex arcs

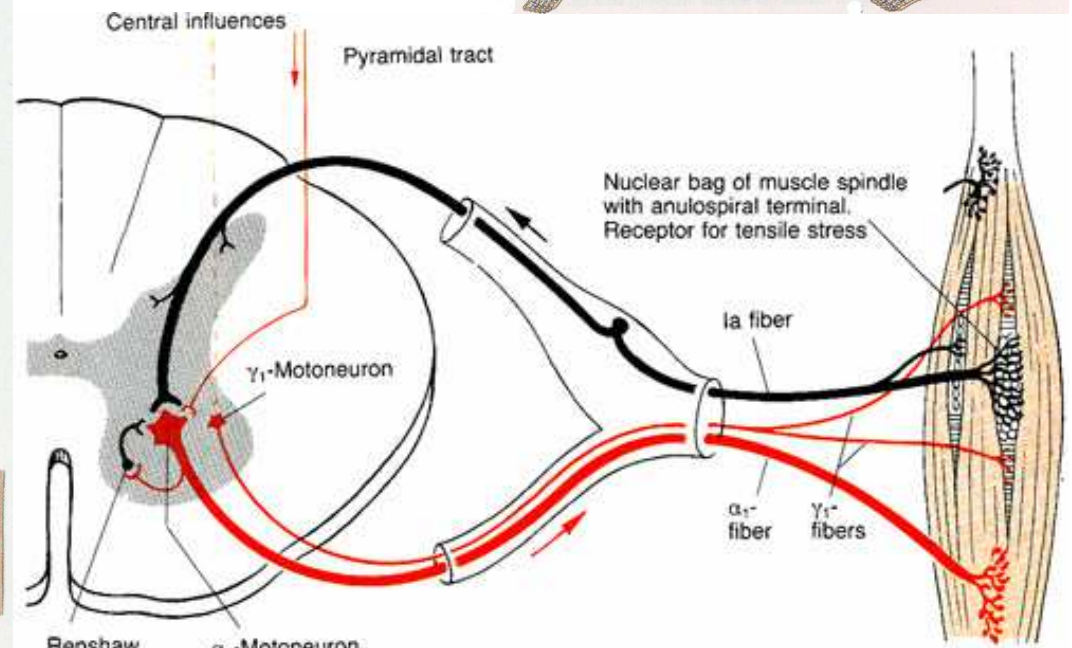
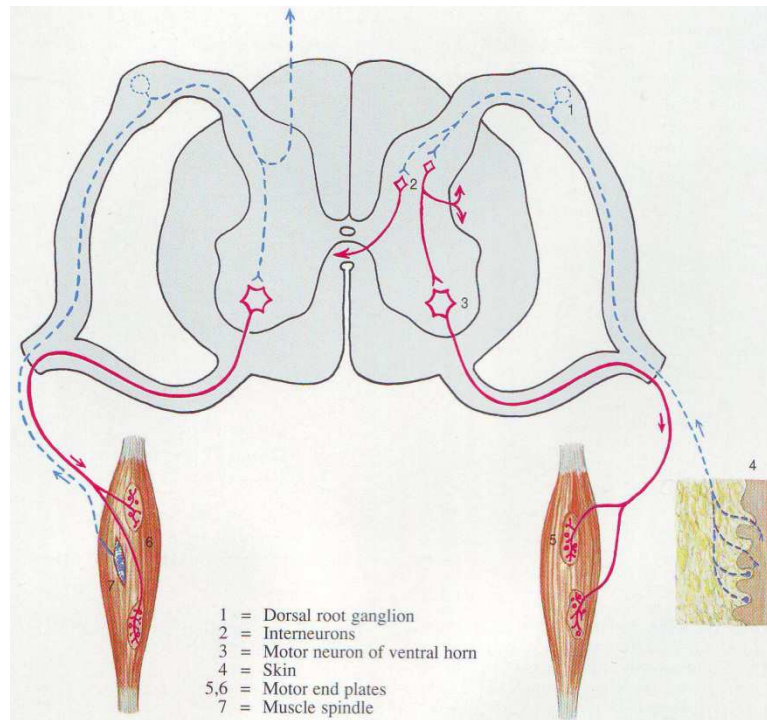
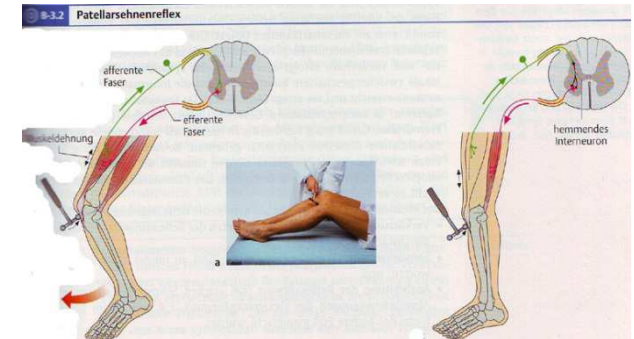


'Final common path(way)' (of Sherrington)



Reflex arcs of the spinal cord

- reflex arc – the neural pathway that mediates a reflex action
- two types of reflex arcs:
 - ✓ autonomic reflex arc (affecting inner organs)
 - ✓ somatic reflex arc (affecting muscles)
- monosynaptic vs. polysynaptic reflex arcs



'Final common path(way)' (of Sherrington)



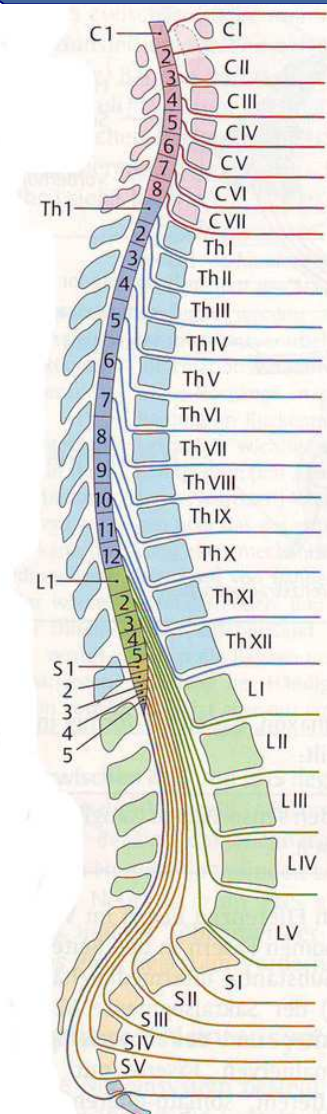
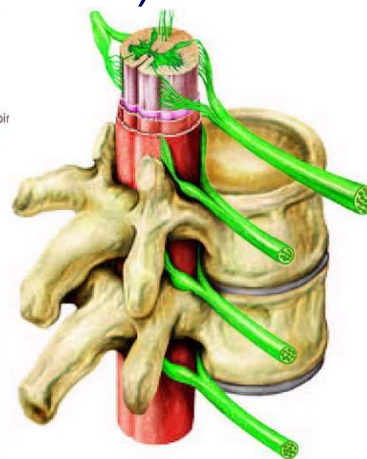
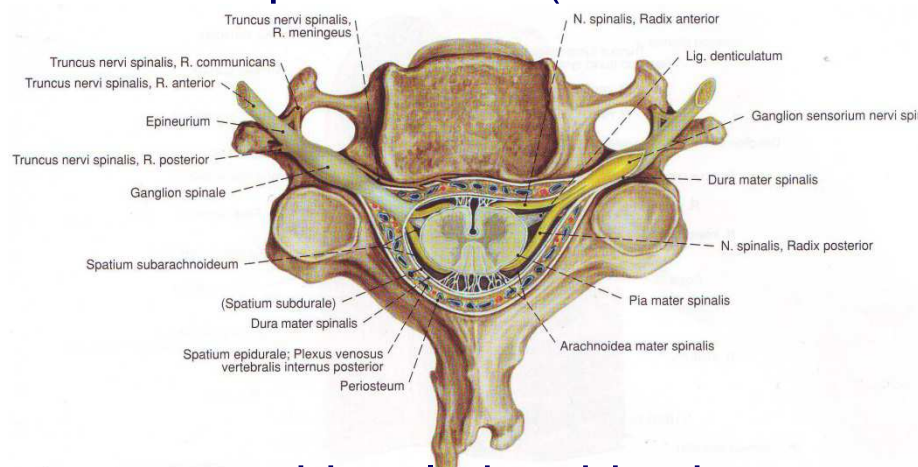
Patellar Reflex Testing





General organization of the spinal nerves

- 31 pairs of segmentally arranged nerves:
 - ✓ 8 cervical – C1-C8
 - ✓ 12 thoracic – Th1-Th12
 - ✓ 5 lumbar – L1-L5
 - ✓ 5 sacral – S1-S5
 - ✓ 1 coccygeal – Co1
- corresponds to a pair of embryonic somites
- emerges through the intervertebral foramen
- mixed spinal nerve (common nerve trunk)

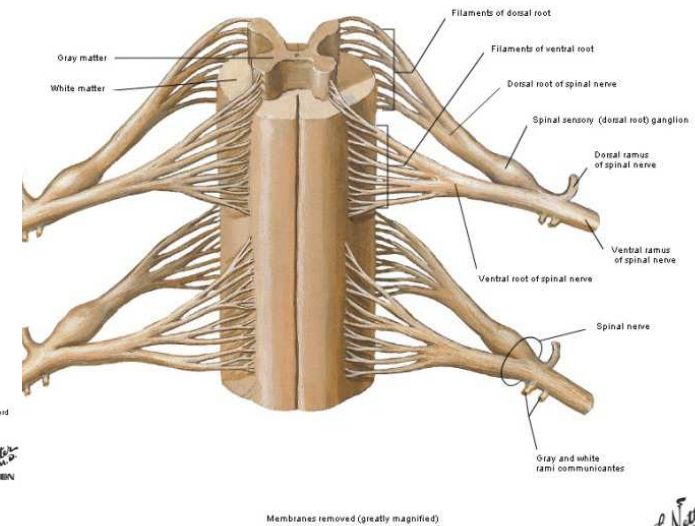
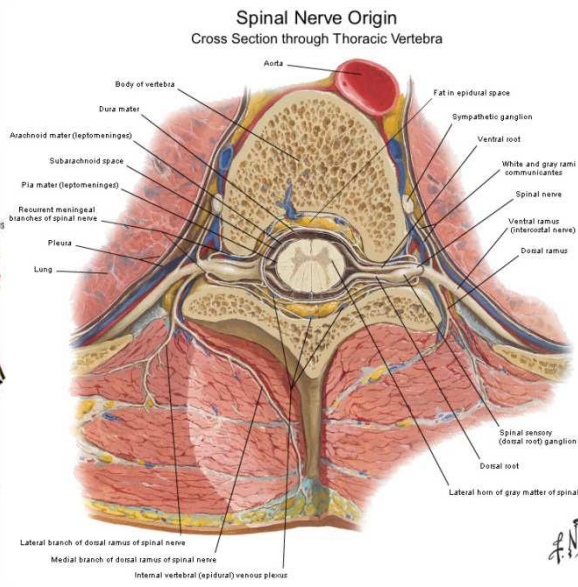
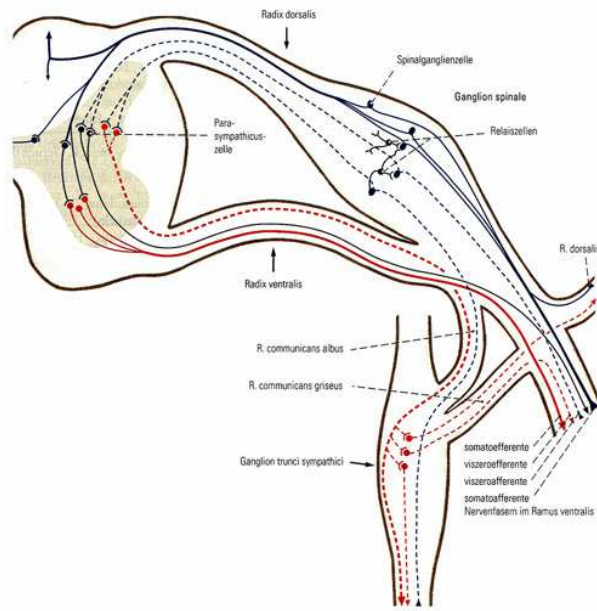
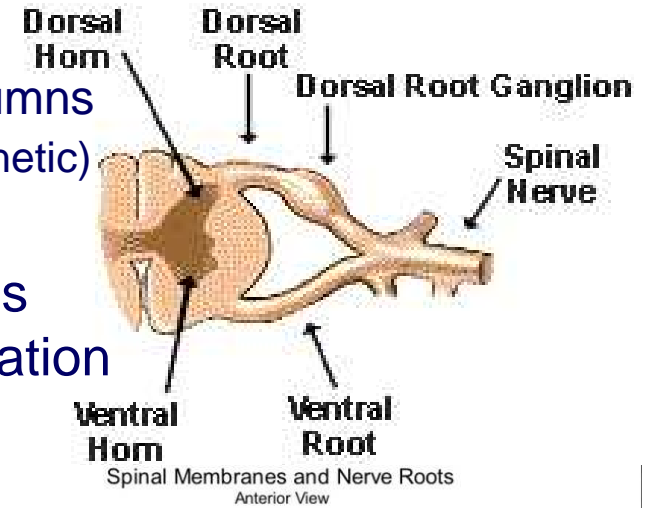


- topographic relationships between spinal nerves, segments and vertebrae



Spinal nerve formation

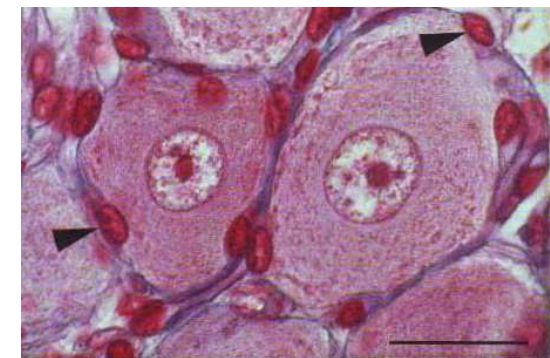
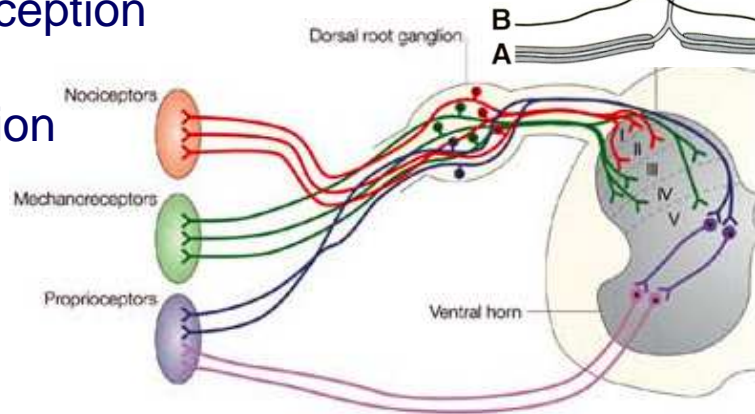
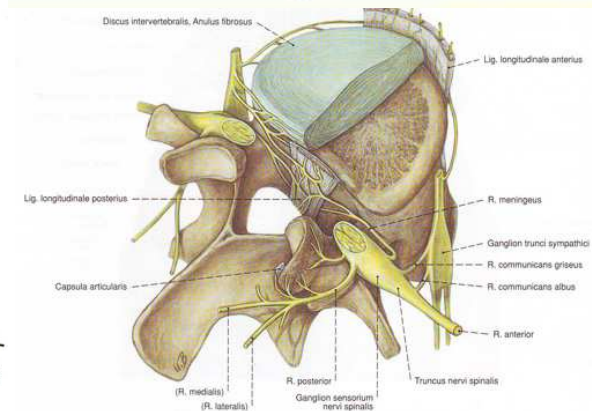
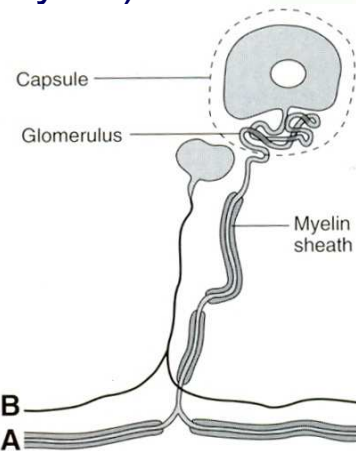
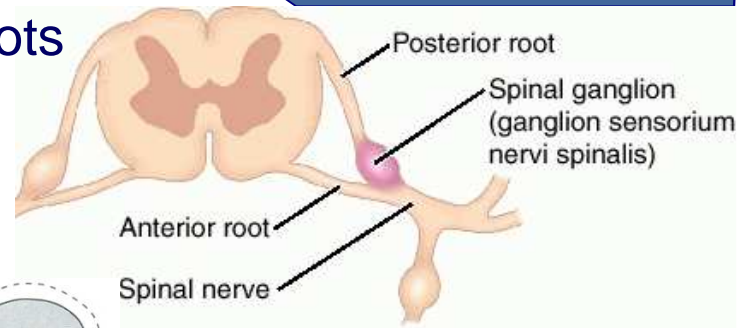
- ventral (motor) root:
 - ✓ axons of neurons in anterior and lateral grey columns
 - ✓ motor and autonomic (sympathetic and parasympathetic)
- dorsal (sensory) root:
 - ✓ central processes of the dorsal ganglion cells
 - ✓ convey somatic and visceral sensory information





Spinal ganglion

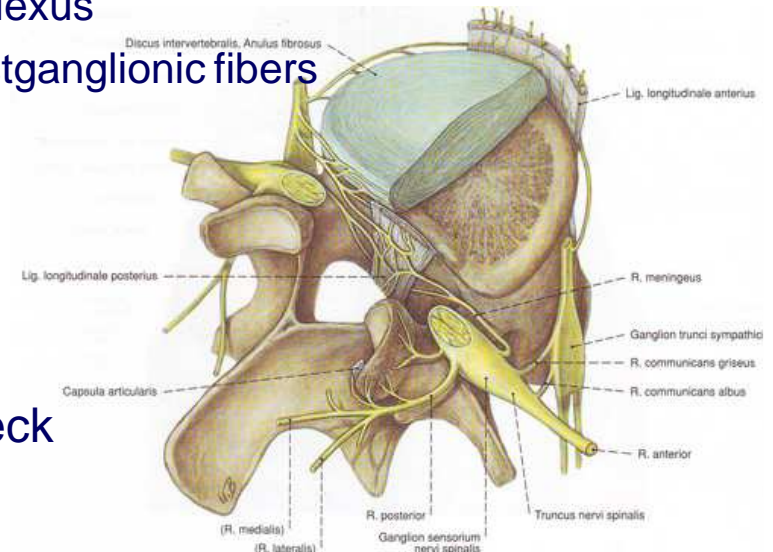
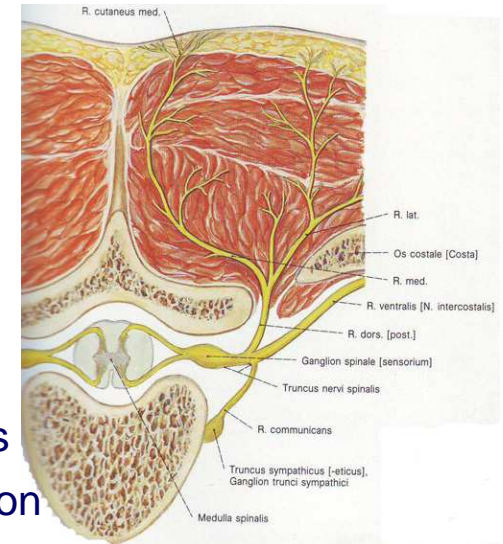
- spindle-shaped aggregations on the dorsal roots – **dorsal root ganglion**
 - ✓ (pseudo)unipolar neurons – ovoid or spherical (primary afferent neurons)
 - ✓ satellite cells (capsular cells, amphicytes)
 - ✓ Schwann cells and blood vessels
- embryonic origin – neural crest cells
- location – in intervertebral foramina
- axons (afferents) – proximal and distal processes
- functional modalities:
 - ✓ mechanoreception
 - ✓ nociception
 - ✓ proprioception





Spinal nerve trunks

- Spinal nerve functional components:
 - ✓ somatic components – efferent and afferent fibers
 - ✓ visceral components – sympathetic or parasympathetic
- Spinal nerve branches:
 - ✓ meningeal branch – at all vertebral levels (recurrent meningeal nerve)
 - ✓ white ramus communicans – myelinated preganglionic fibers
 - all thoracic and L1-L2 to corresponding sympathetic ganglion
 - S2-S4 nerves to the parasympathetic pelvic plexus
 - ✓ grey ramus communicans – unmyelinated postganglionic fibers
 - from paravertebral sympathetic ganglia
 - ✓ ventral (anterior) ramus – thicker
 - ventrolateral muscles
 - skin of the trunk and extremities
 - ✓ dorsal (posterior) ramus – thinner
 - intrinsic dorsal muscles of the back and neck
 - overlying skin from vertex to coccyx





Dorsal rami of the spinal nerves

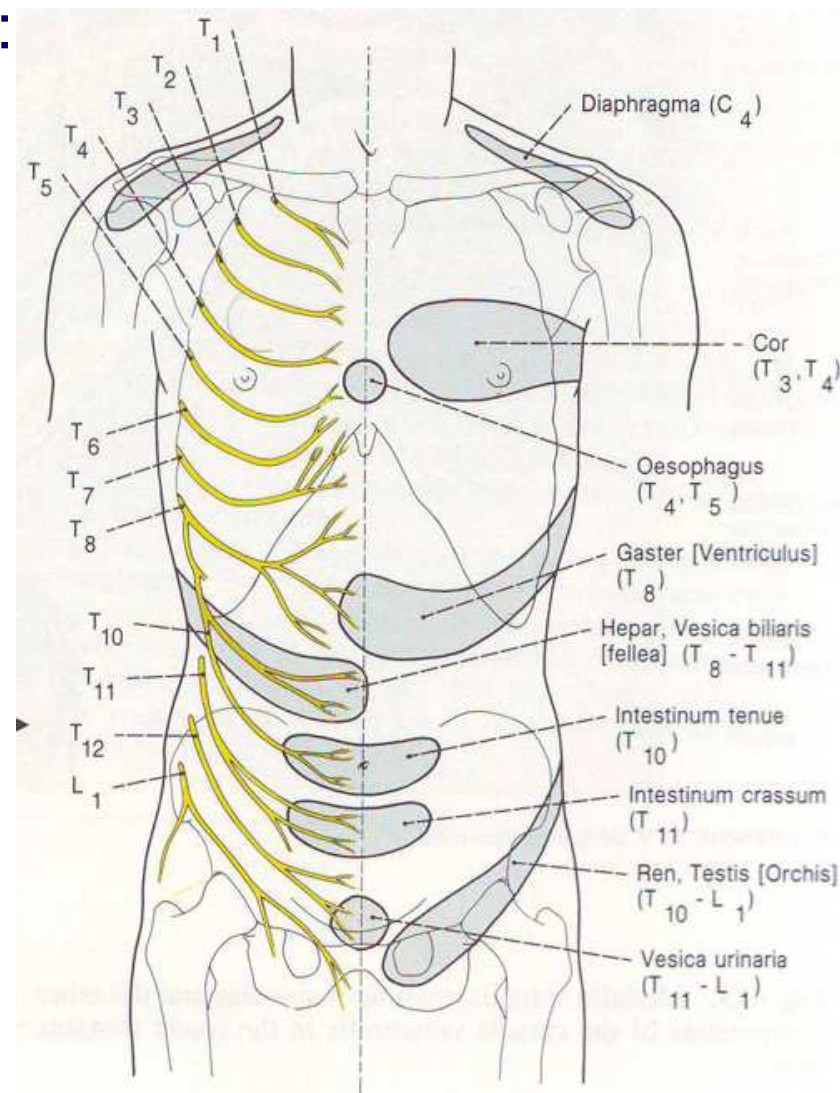
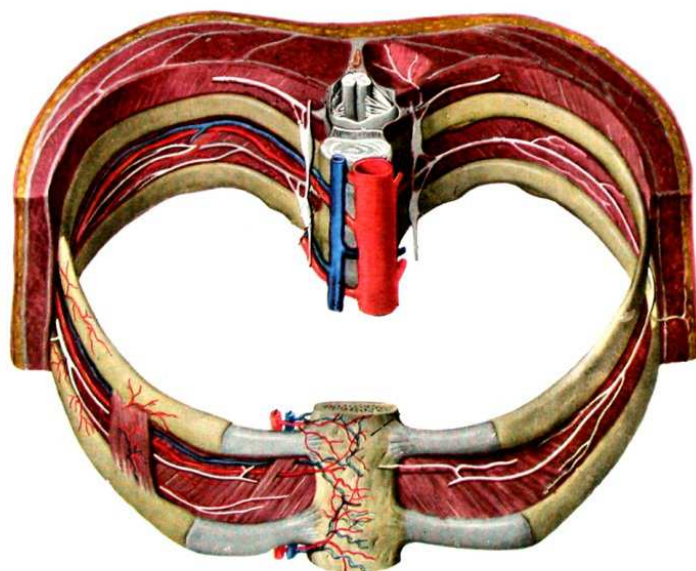
- divide into medial and lateral branches (exception C1)
- have a typical segmental distribution
- cervical dorsal rami:
 - ✓ suboccipital nerve (C1) – purely motor
 - ✓ greater occipital nerve (C2) – mixed
 - ✓ C3 medial cutaneous branch, third occipital nerve
- thoracic dorsal rami:
 - ✓ Th1-Th6 – medial (mixed) and lateral (motor) branch
 - ✓ Th7-Th12 – medial (motor) and lateral (mixed)
- lumbar dorsal rami:
 - ✓ L1-L3 lateral cutaneous branches – superior clunial nerves
- sacral dorsal rami:
 - ✓ S1-S3 lateral cutaneous branches – medial clunial nerves





Ventral rami of the spinal nerves

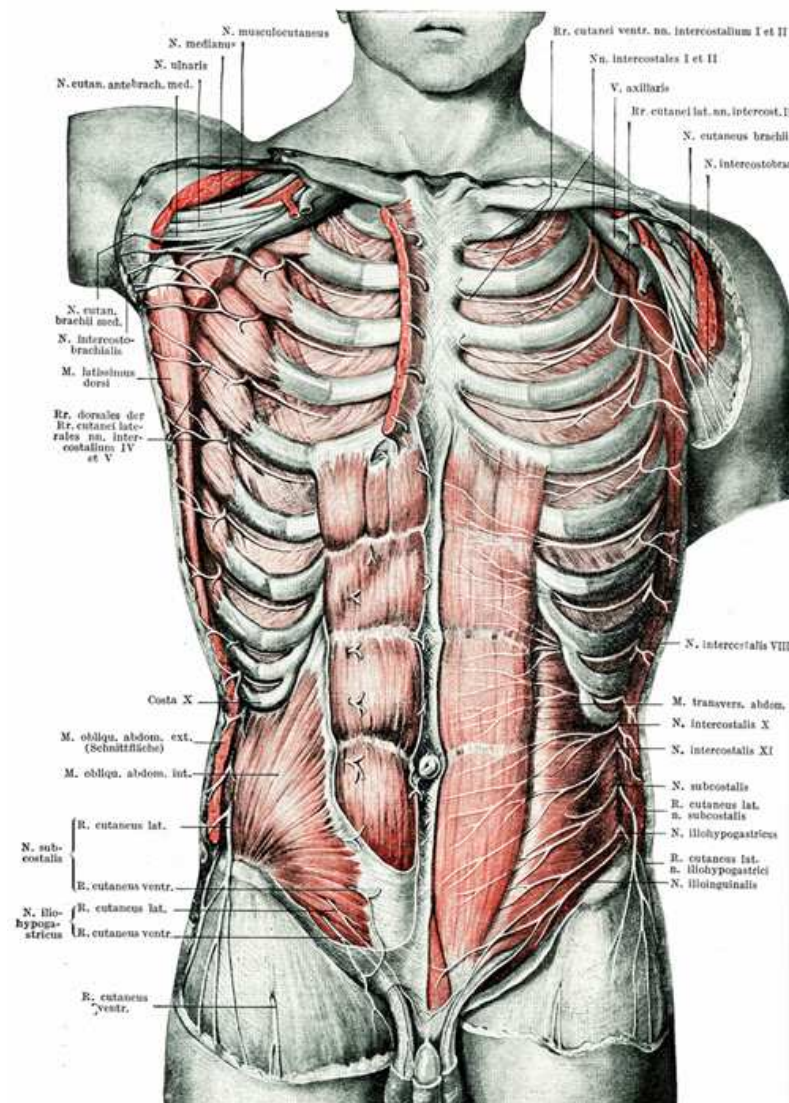
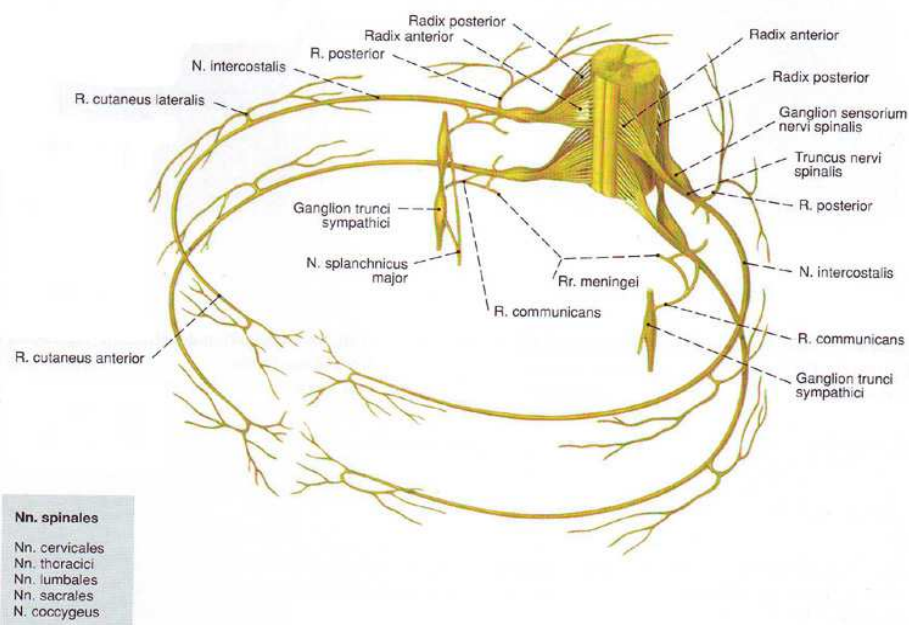
- Thoracic ventral rami – 12 pairs:
 - ✓ segmental distribution – **intercostal nerves**
 - ✓ Th12 – subcostal nerve
 - ✓ anterior cutaneous branches
 - ✓ lateral cutaneous branches





Ventral rami of the spinal nerves

- Thoracic ventral rami – 12 pairs:
 - ✓ segmental distribution – **intercostal nerves**
 - ✓ Th12 – subcostal nerve
 - ✓ anterior cutaneous branches
 - ✓ lateral cutaneous branches





Cervical plexus, *plexus cervicalis*

- Formation and segmental origin:

- ✓ ventral rami of C1-C4 nerves

- Branches:

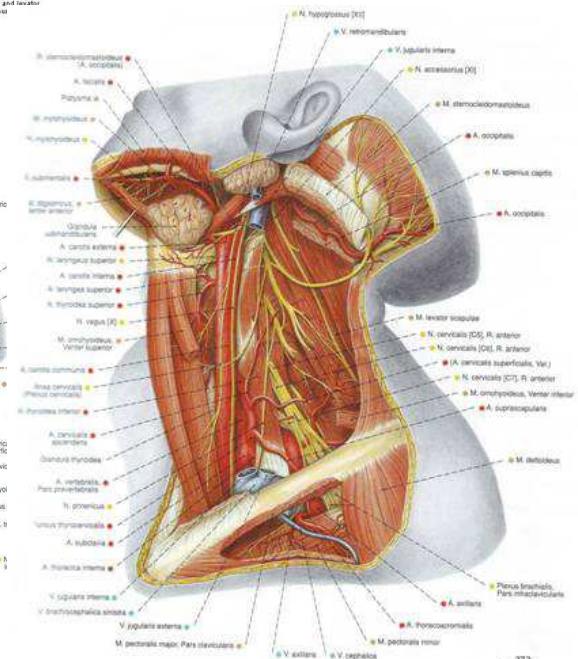
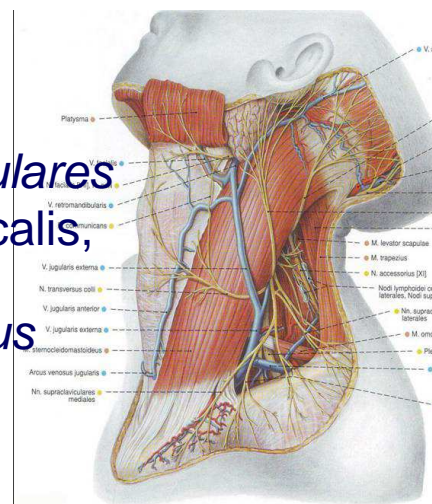
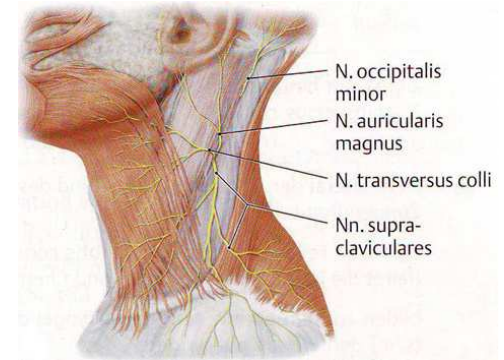
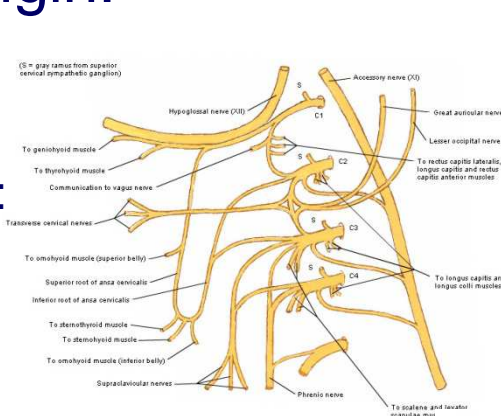
- ✓ superficial (sensory) branches:

- lesser occipital nerve, *n. occipitalis minor*
- great auricular nerve, *n. auricularis magnus*
- transverse colli nerve, *n. transversus colli*
- supraclavicular nerves, *nn. supraclaviculares*

- ✓ deep (motor) branches:

- muscular branches, *rr. musculares*
- inferior root of the ansa cervicalis, *radix inferior ansae cervicalis*
- trapezius root, *ramus trapezius*
- sternocleidomastoid root, *r. sternocleidomastoideus*
- phrenic nerve, *n. phrenicus*

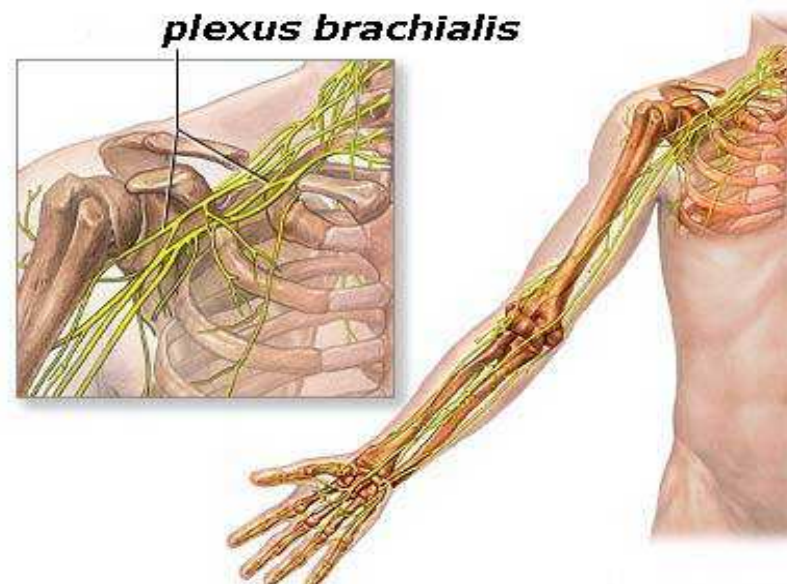
Cervical Plexus Schema



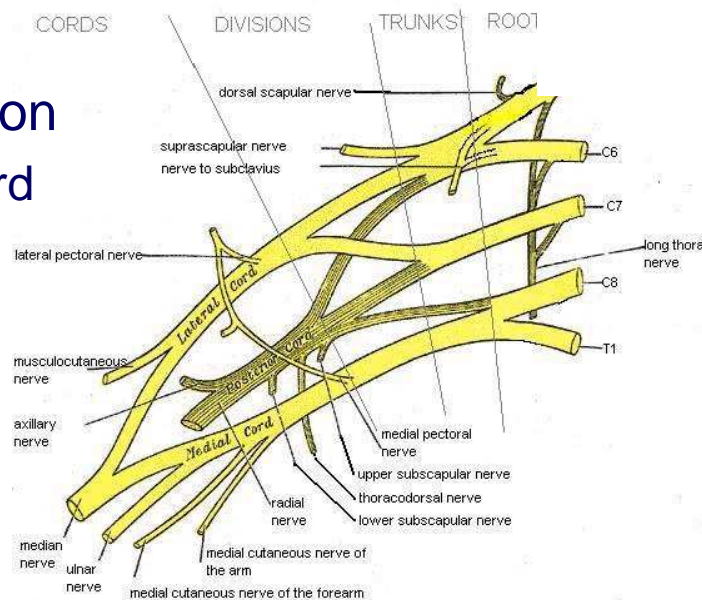


Brachial plexus, *plexus brachialis*

- Formation and segmental origin:
 - ✓ ventral rami of C5-C8, Th1 nerves
- Three primary trunks:
 - ✓ superior (upper) trunk – C5-C6
 - ✓ middle trunk – C7
 - ✓ inferior (lower) trunk – C8-Th1



- Divisions:
 - ✓ posterior division
 - posterior cord
 - ✓ anterior
 - lateral cord
 - medial cord



VENTRAL RAMI	TRUNKS	DIVISIONS	CORDS	MAIN BRANCHES
C5	Upper	Ant.	Lateral	Musculo-cutaneous
C6				
C7	Middle	Post.	Posterior	Radial
C8				
T1	Lower	Ant.	Medial	Axillary
				Ulnar



Brachial plexus, *plexus brachialis*

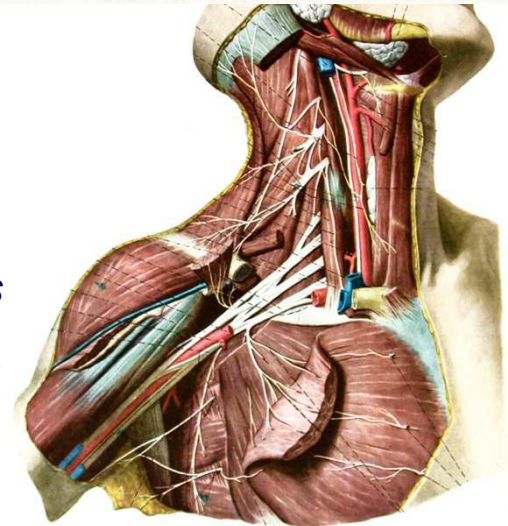
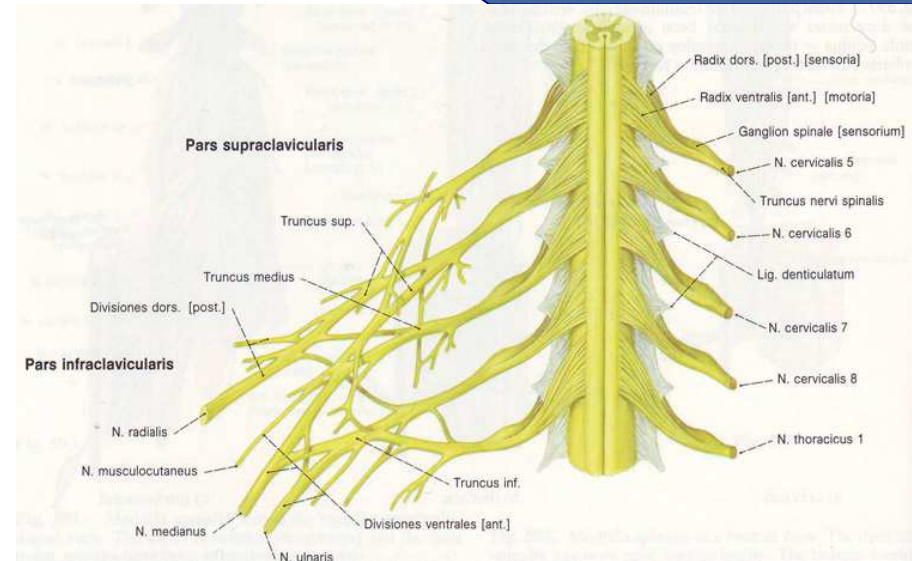
■ Main branches:

✓ supraclavicular part:

- dorsal scapular nerve, *n. dorsalis scapulae*
- long thoracic nerve, *n. thoracicus longus*
- nerve to the subclavius, *n. subclavius*
- suprascapular nerve, *n. suprascapularis*

✓ infraclavicular part:

- lateral cord, *fasciculus lateralis*:
 - musculocutaneous nerve, *n. musculocutaneus*
 - lateral root of median, *radix lateralis n. mediani*
- medial cord, *fasciculus medialis*:
 - medial root of median, *radix medialis n. mediani*
 - ulnar nerve, *n. ulnaris*
 - medial cutaneous of arm, *n. cutaneus brachii medialis*
 - medial cutaneous of forearm, *n. cutaneus antebrachii medialis*
- posterior cord, *fasciculus posterior*:
 - axillary nerve, *n. axillaris*
 - radial nerve, *n. radialis*





Brachial plexus, *plexus brachialis*

- Brachial distribution of:

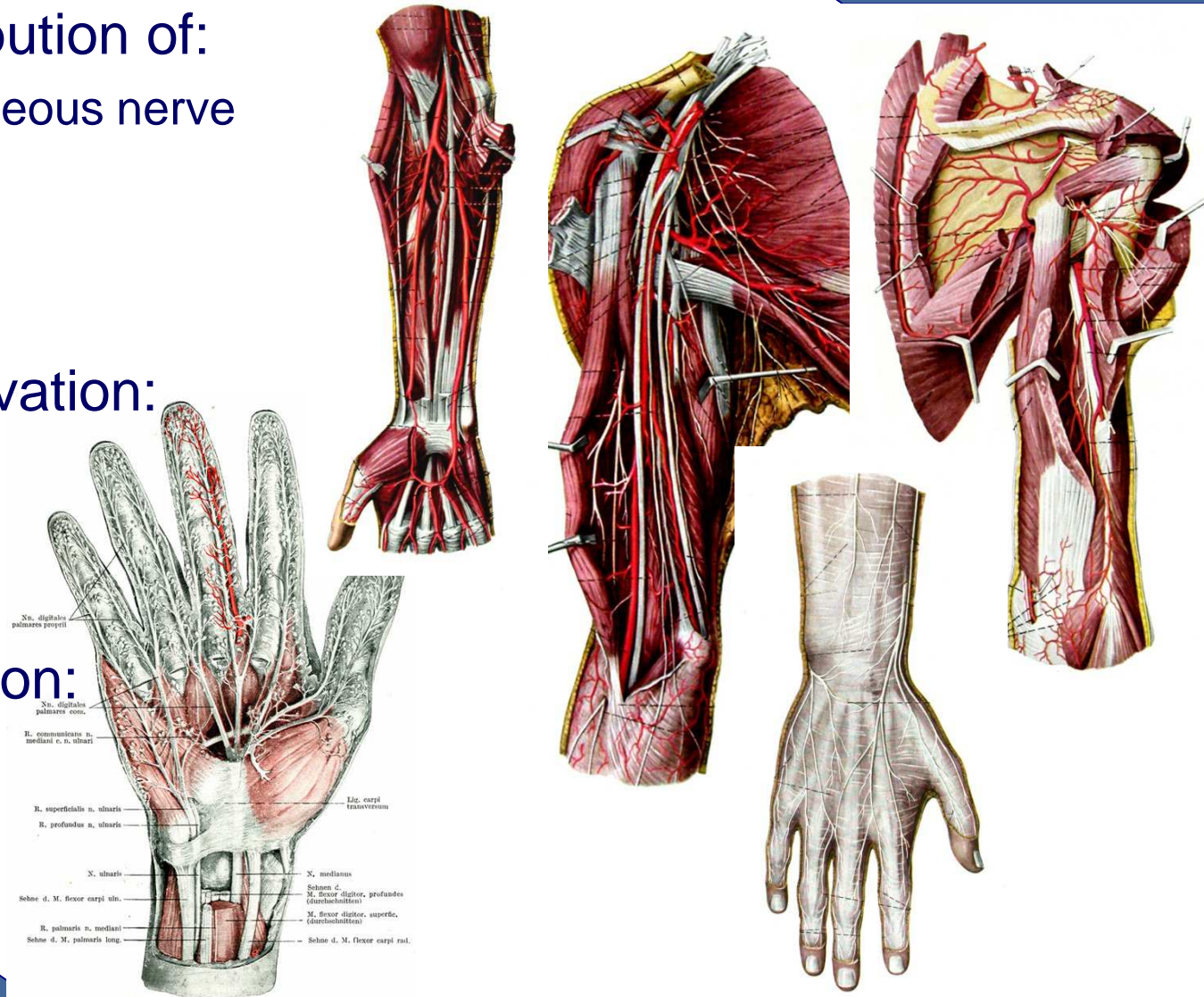
- ✓ musculocutaneous nerve
- ✓ median nerve
- ✓ ulnar nerve
- ✓ radial nerve

- Forearm innervation:

- ✓ median nerve
- ✓ ulnar nerve
- ✓ radial nerve

- Hand innervation:

- ✓ median nerve
- ✓ ulnar nerve

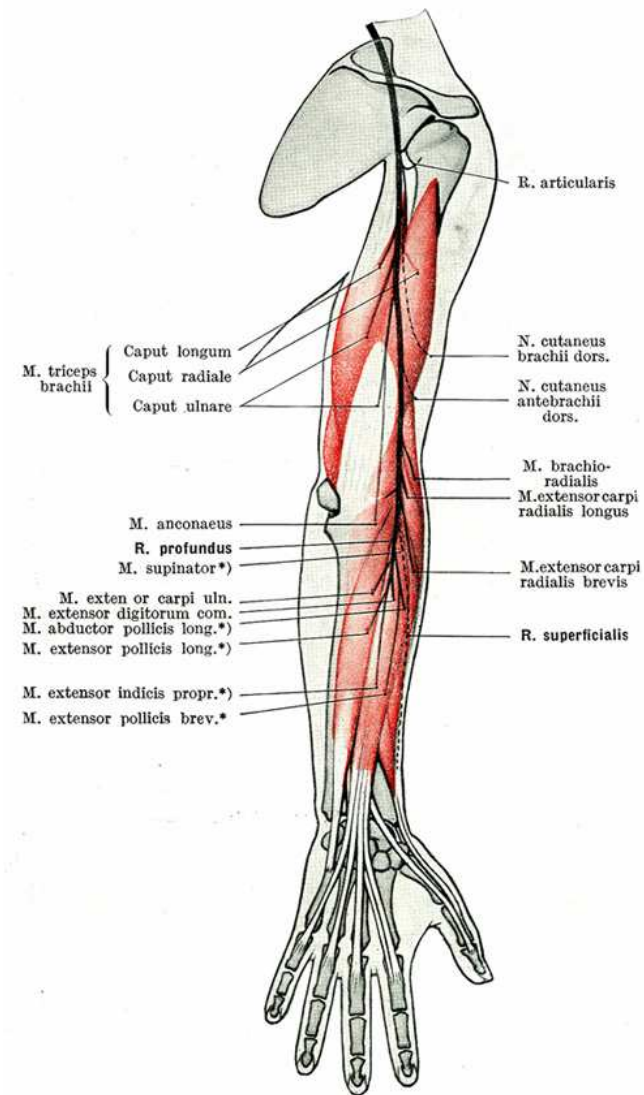
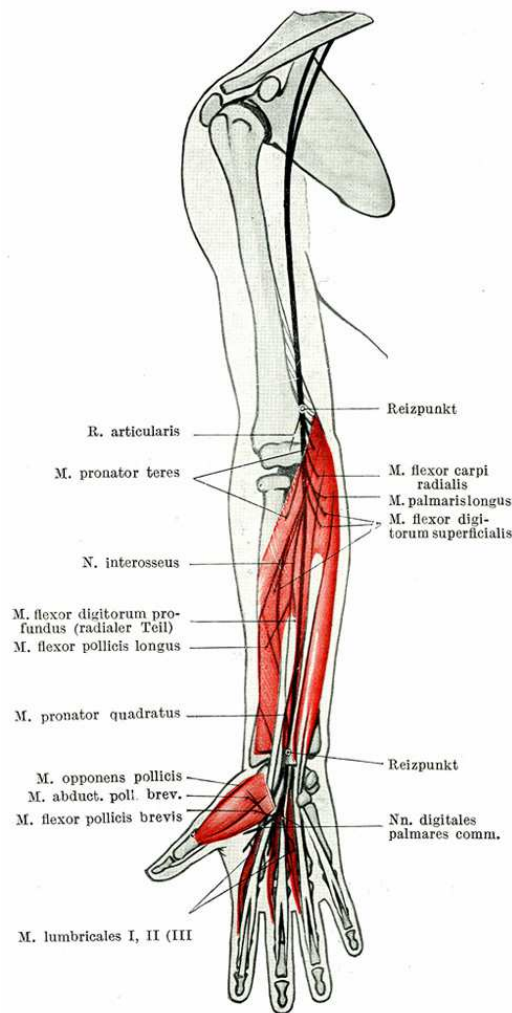
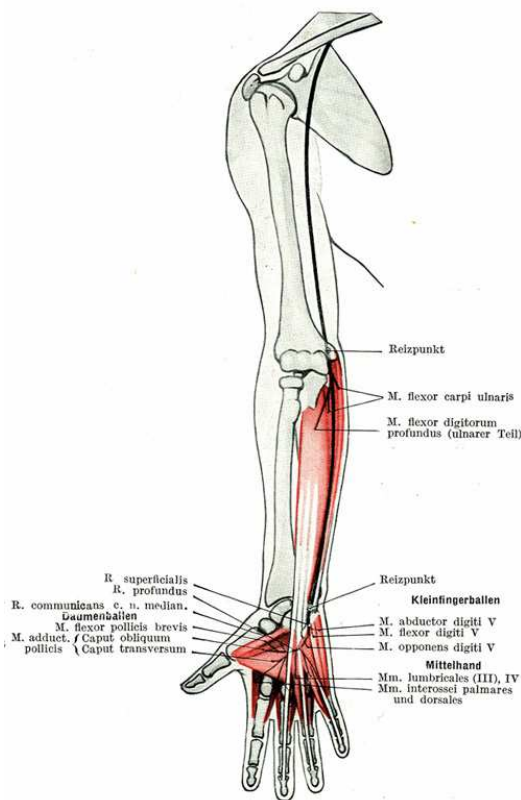




Muscle innervation of the upper limb

■ Muscular branches of:

- ✓ median nerve
- ✓ ulnar nerve
- ✓ radial nerve



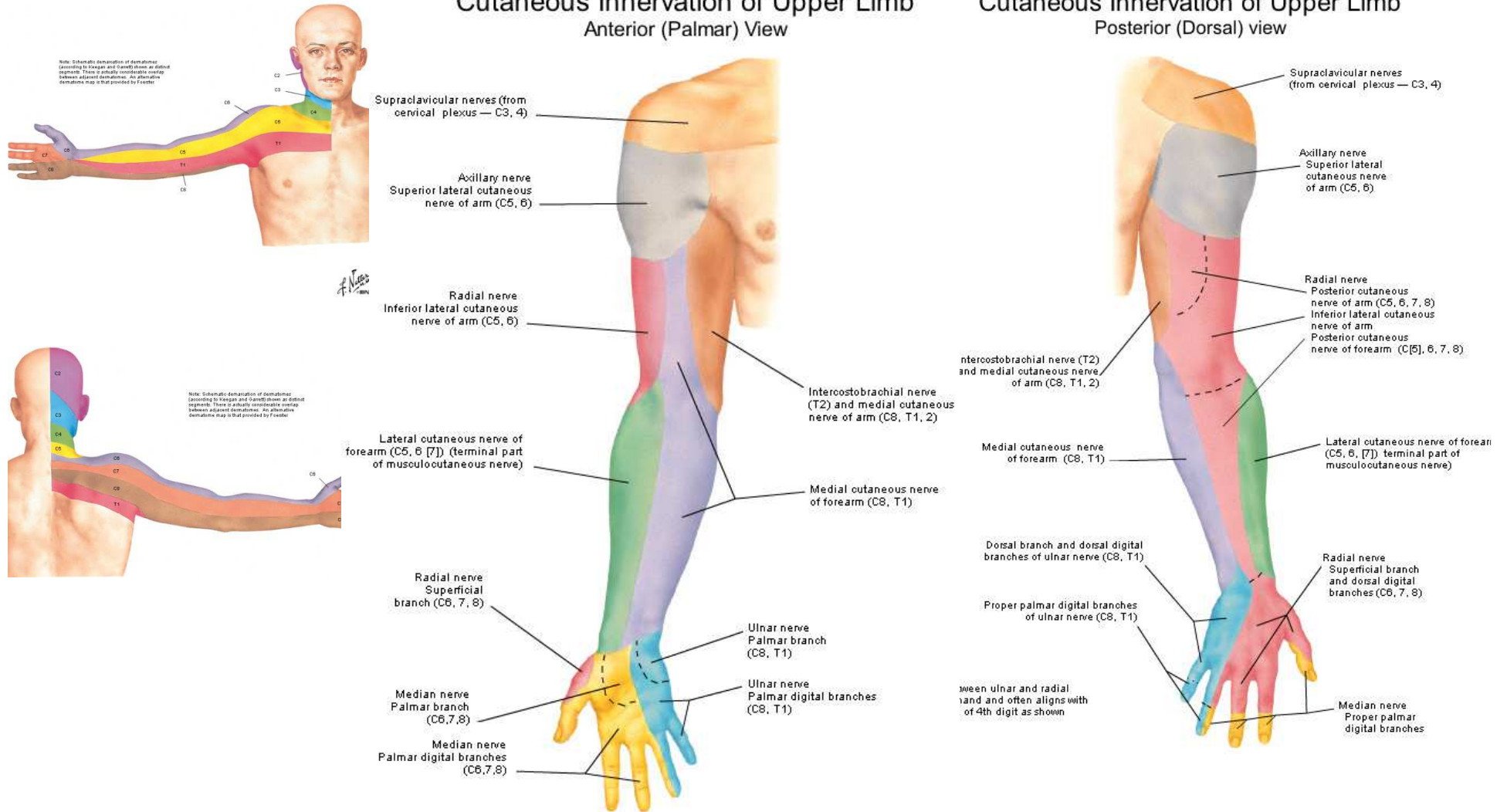


Cutaneous innervation of the upper limb

Dermatomes of Upper Limb

Cutaneous Innervation of Upper Limb Anterior (Palmar) View

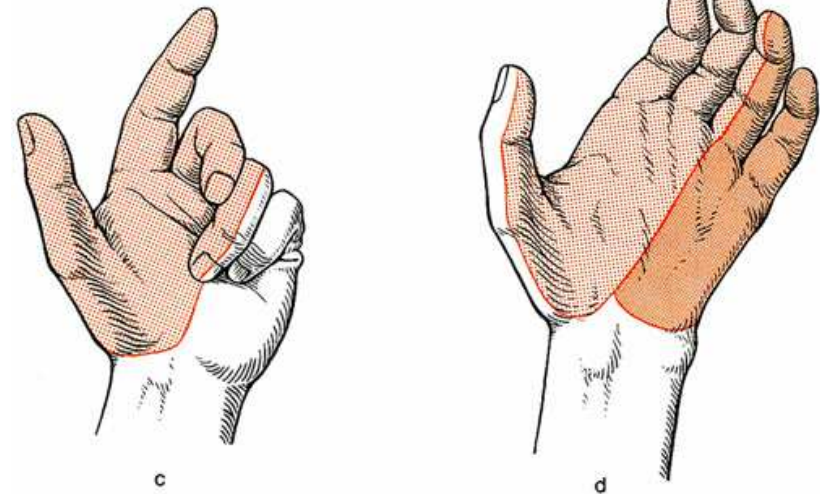
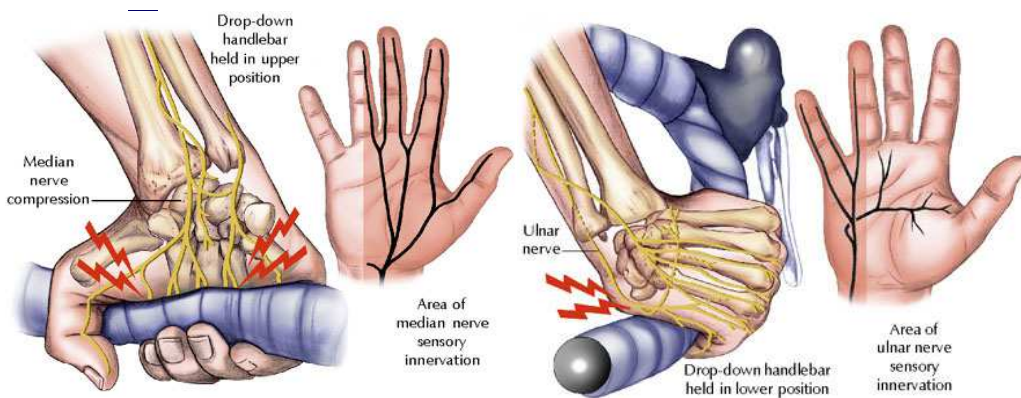
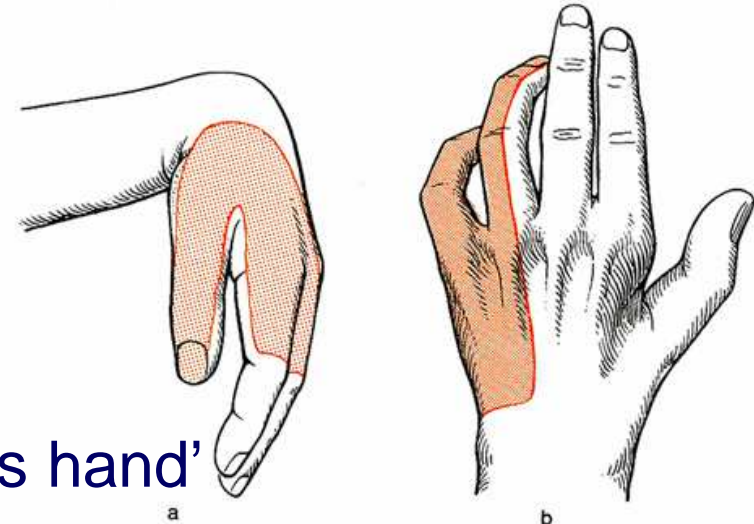
Cutaneous Innervation of Upper Limb Posterior (Dorsal) view





Peripheral neuropathies

- Radial nerve palsy, wrist drop (Saturday night palsy)
- Ulnar nerve palsy, 'claw hand' handlebar palsy – cyclist's hands
- Median nerve palsy, 'accoucheur's hand' median neuropathy (Carpal tunnel syndrome)



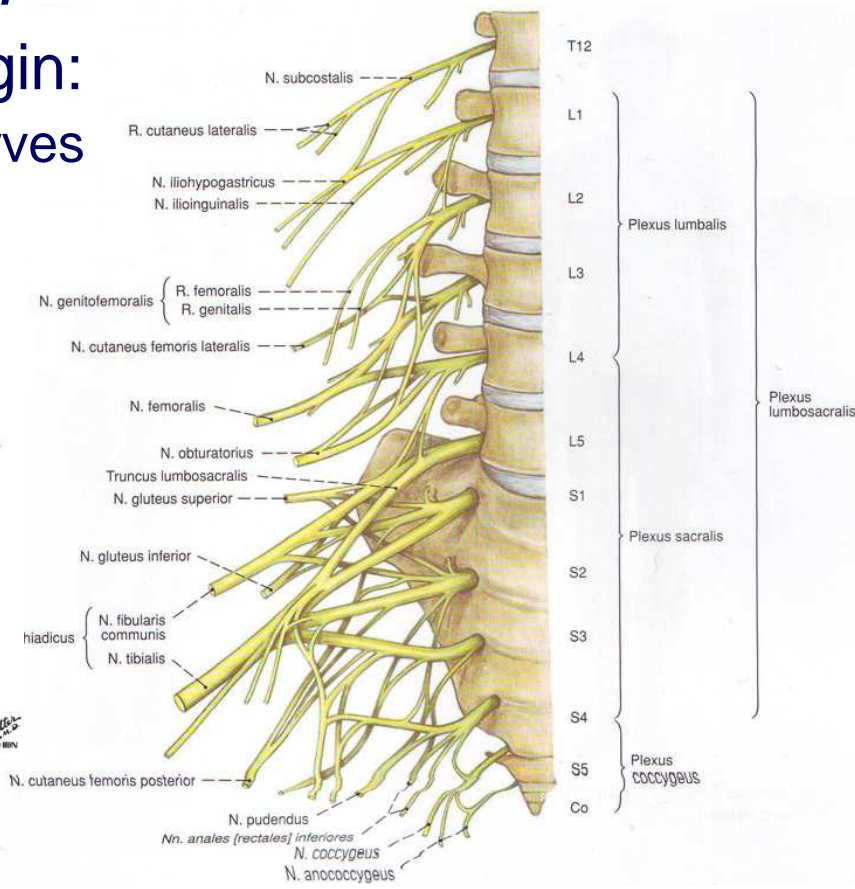
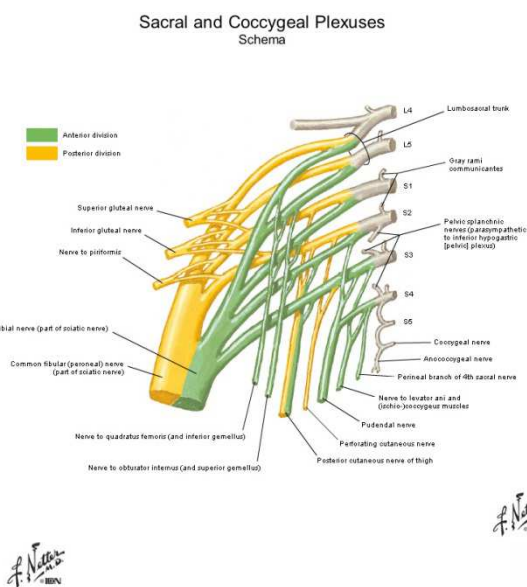
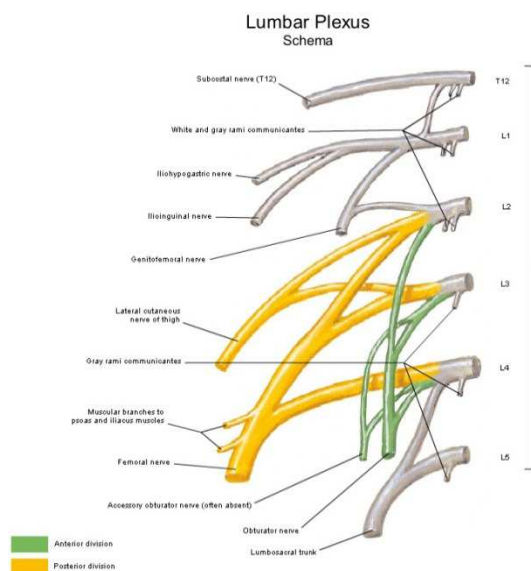


Lumbosacral plexus, *plexus lumbosacralis*

- Lumbar plexus, *plexus lumbalis*:

- ✓ formation and segmental origin:

- ventral rami of Th12, L1-L4 nerves



- Sacral plexus, *plexus sacralis*:

- ✓ formation and segmental origin:

- ventral rami of L5, S1-S5, Co1 nerves

- Coccygeal plexus, *plexus coccygeus*:

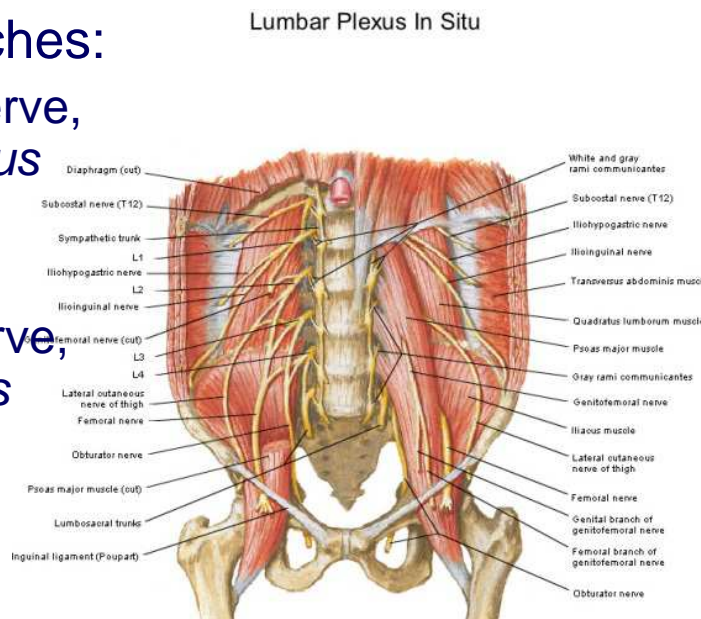
- ✓ ventral rami of S5, Co1



Lumbar plexus, *plexus lumbalis*

■ Branches:

- ✓ muscular branches,
rr. musculares
- ✓ purely sensory branch:
 - lateral femoral cutaneous nerve,
n. cutaneus femoris lateralis
- ✓ sensorimotor branches:
 - iliohypogastric nerve,
n. iliohypogastricus
 - ilioinguinal nerve,
n. ilioinguinalis
 - genitofemoral nerve,
n. genitofemoralis
 - obturator nerve,
n. obturatorius
 - femoral nerve,
n. femoralis



F. Netter
M.D.
1889



Femoral nerve, *n. femoralis*

- passes through *lacuna musculorum*

- branches – L2-L4:

- ✓ muscular branches, *rr. musculares*:

- iliopsoas

- pectineus

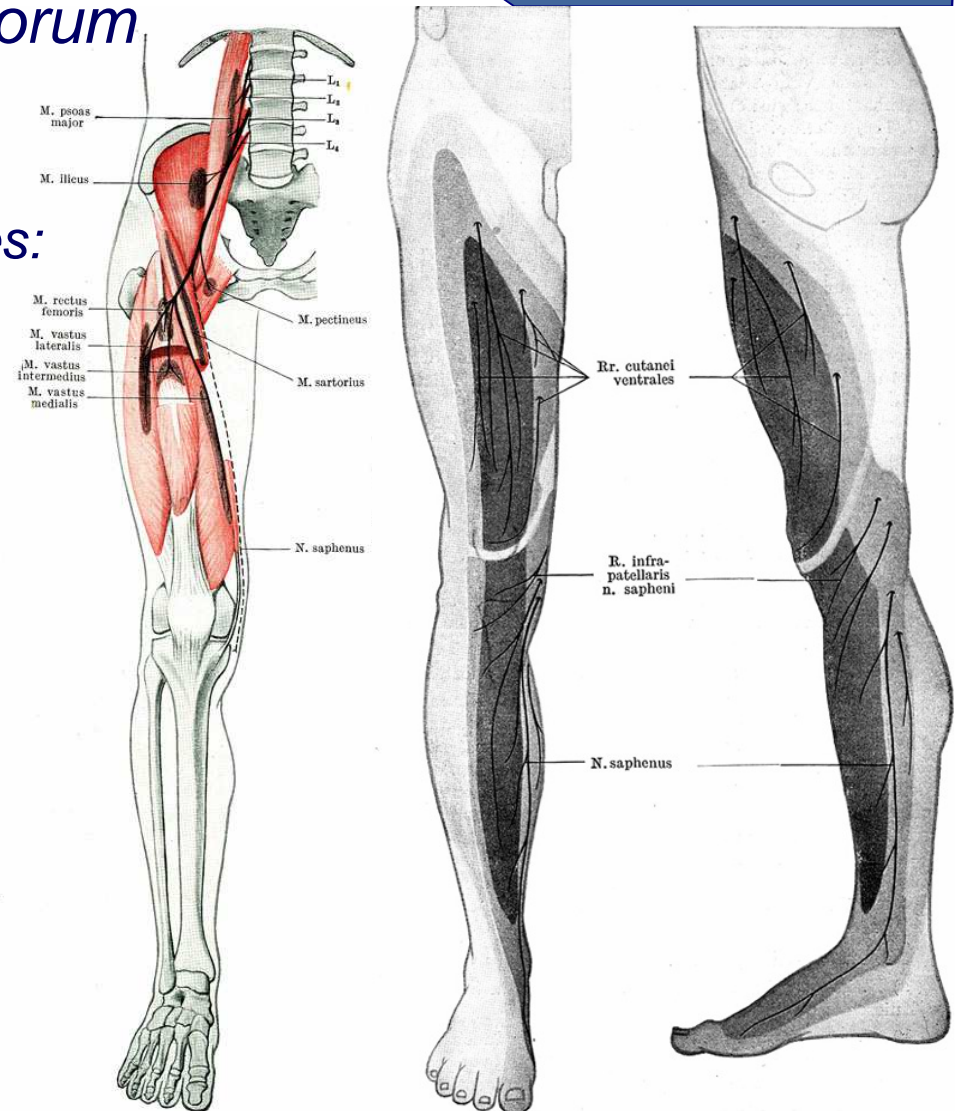
- sartorius

- extensor muscles of the knee –
quadriceps femoris

- ✓ sensory branches:

- anterior femoral cutaneous nerve

- saphenous nerve





Sacral plexus, *plexus sacralis*

Branches:

✓ motor branches:

- muscular branches, *rr. musculares*
- superior gluteal nerve, *n. gluteus superior*
- inferior gluteal nerve, *n. gluteus inferior*

✓ purely sensory branch:

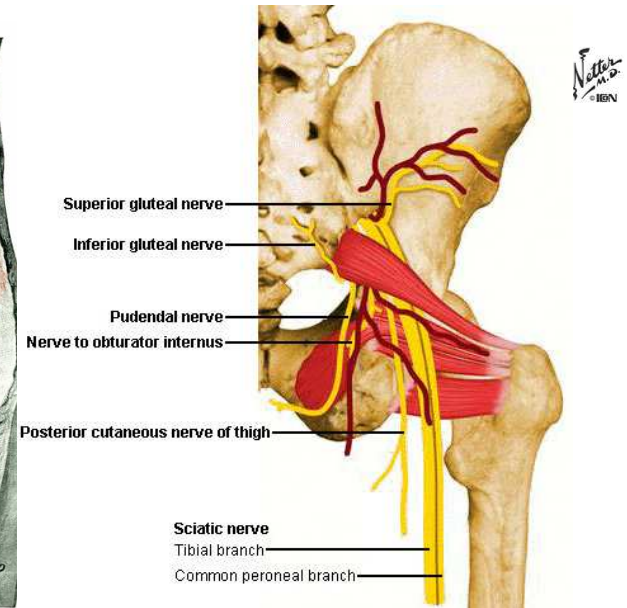
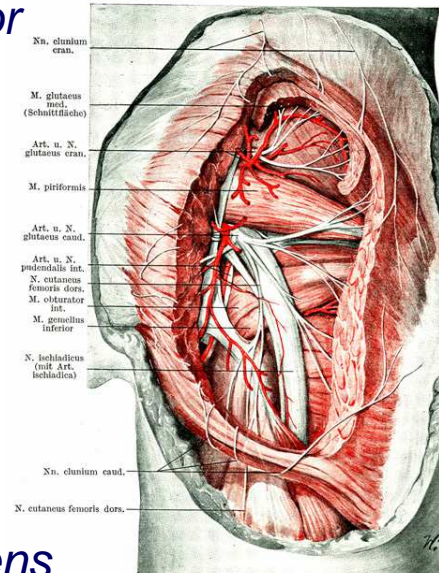
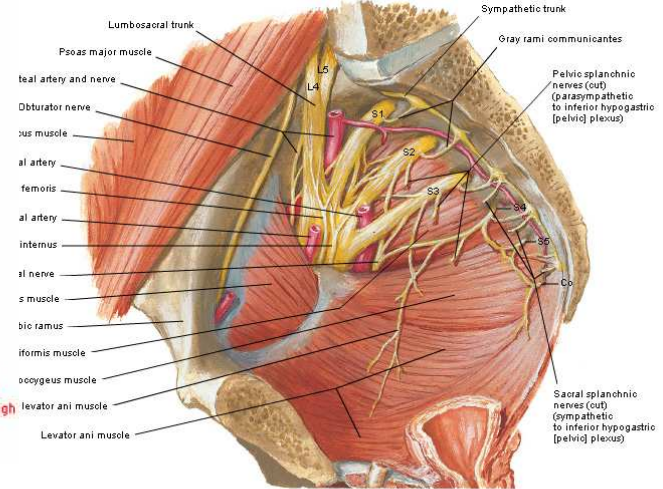
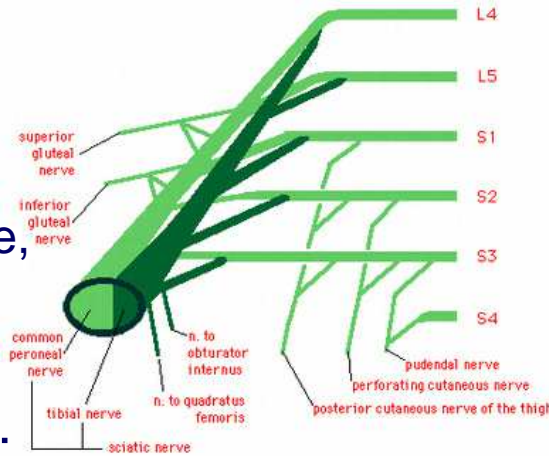
- posterior femoral cutaneous nerve, *n. cutaneus femoris posterior*

✓ sensorimotor branches:

- pudendal nerve, *n. pudendus*
- coccygeal nerve, *n. coccygeus*
- sciatic nerve, *n. ischiadicus*

✓ visceral branch:

- pelvic splanchnic nerve, *nervus erigens*





Sciatic nerve, *n. ischiadicus*

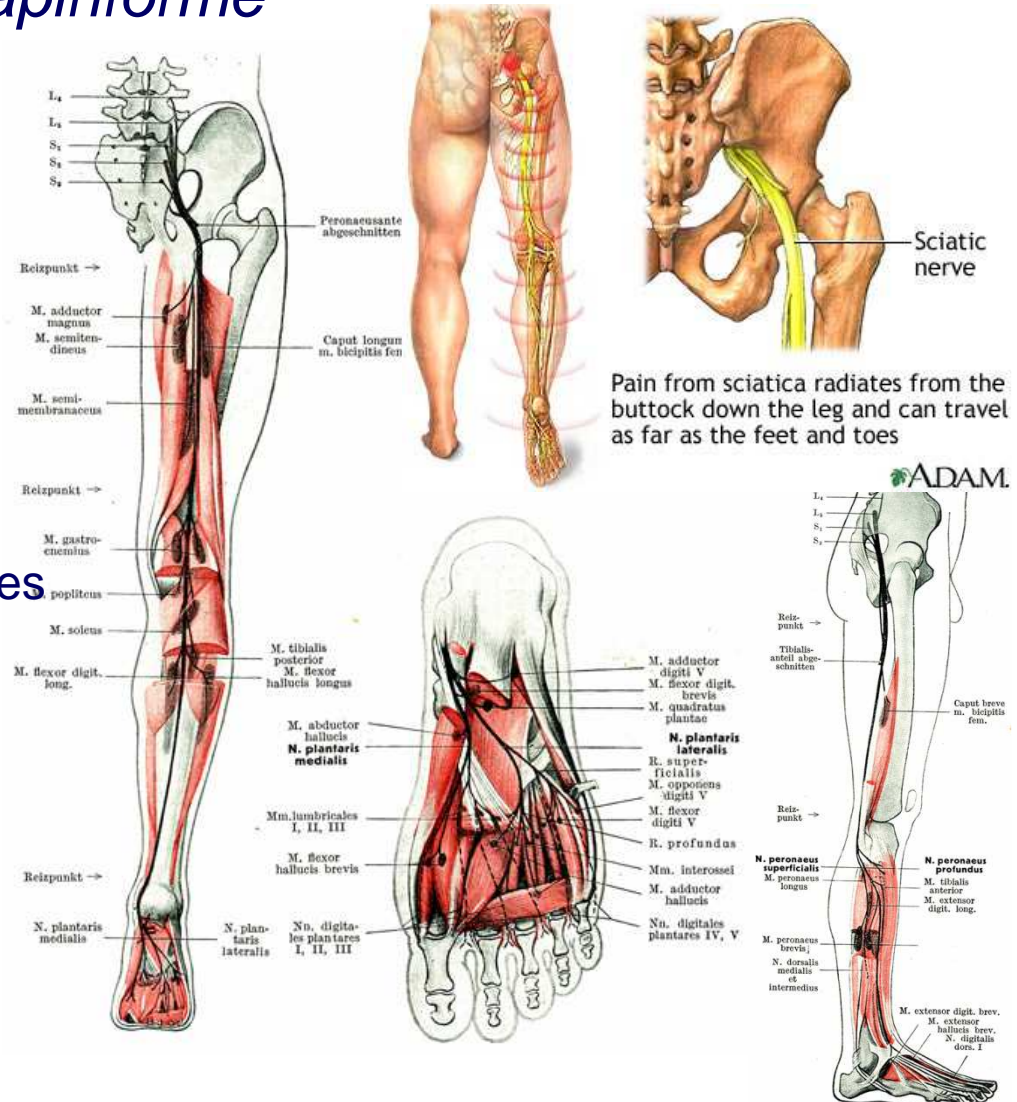
- passes through *foramen infrapiriforme*
- Main branches:

- ✓ tibial nerve, *n. tibialis*:

- articular branches
 - muscular branches
 - sural nerve
 - medial and lateral calcaneal
 - medial and lateral plantar nerves

- ✓ common peroneal nerve, *n. peroneus communis*:

- superficial peroneal nerve (musculocutaneous)
 - deep peroneal nerve (anterior tibial nerve)





Saturday night palsy



= park bench paralysis



radial nerve area of sensory loss



Wrist drop in low radial nerve lesion. Saturday night palsy in high nerve lesion



Thank you...