

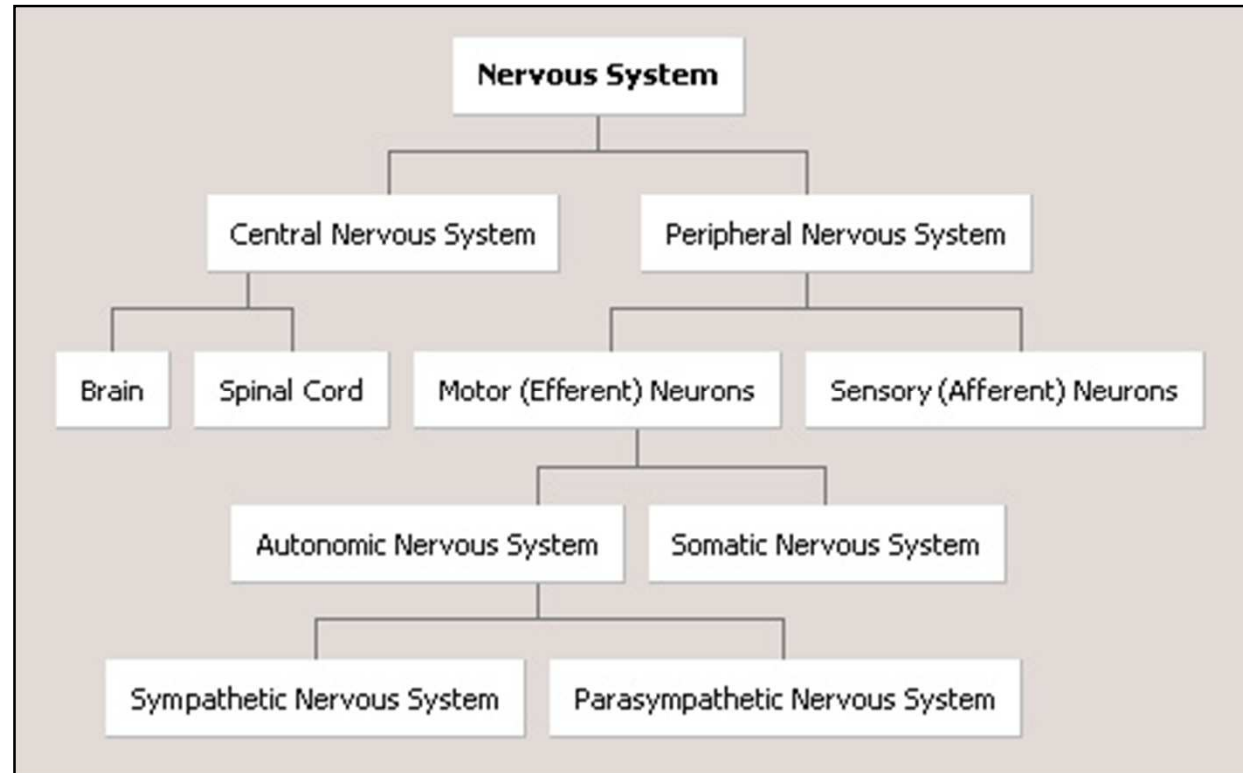
# Central nervous system. Spinal cord and spinal nerves

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





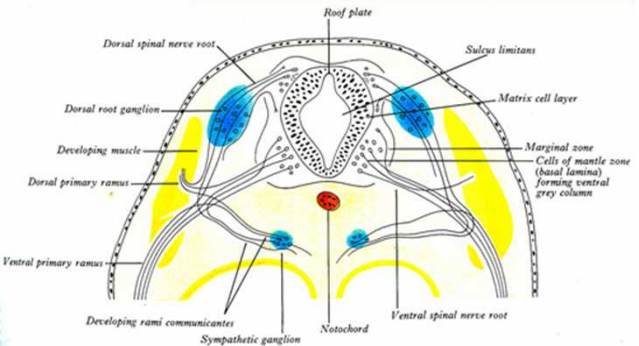
# Classification of the nervous system



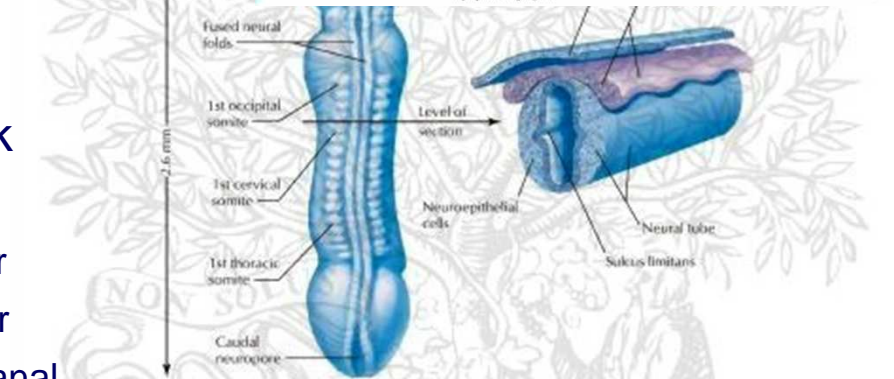


# Embryogenesis of the spinal cord

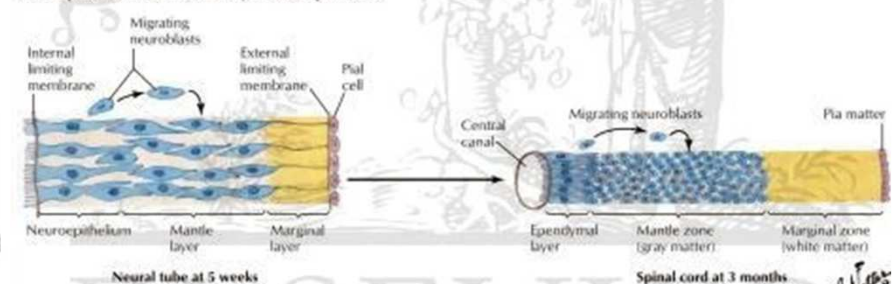
- origin: neuroectodermal
  - ✓ caudal part of the neural tube
- begin of formation: 3<sup>rd</sup> week
- developmental stages: *basal plate and alar plate*
  - ✓ neural plate
  - ✓ neural groove
  - ✓ neural tube
  - ✓ nerve crest
- closure of posterior neuropore: 4<sup>th</sup> week
- histogenesis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



Embryo at 24 days (dorsal view)

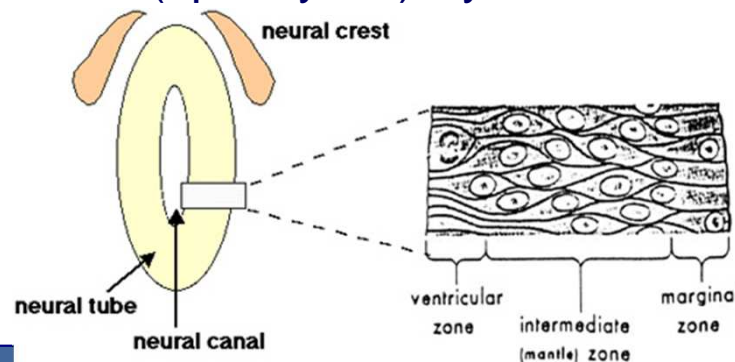


Development of the neural tube layers in the spinal cord



Neural tube at 5 weeks

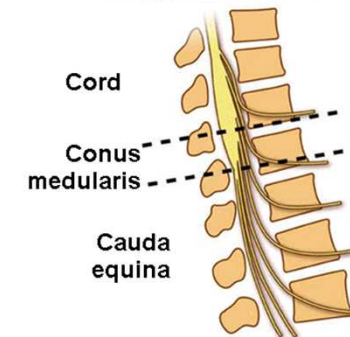
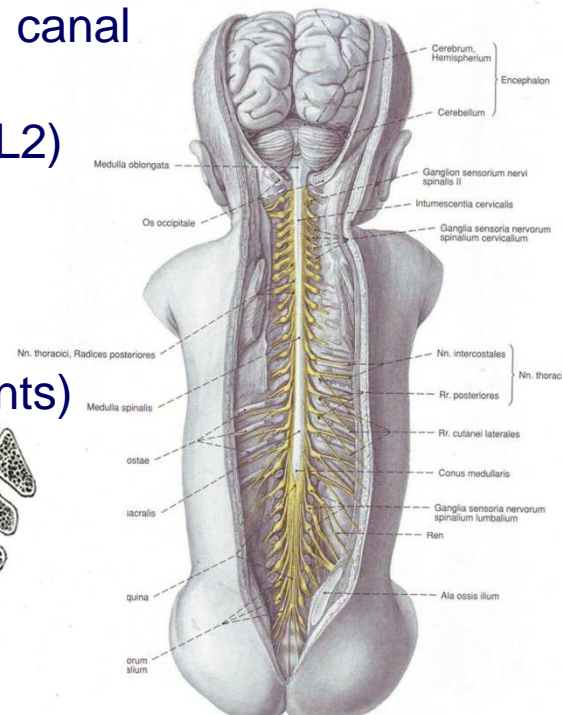
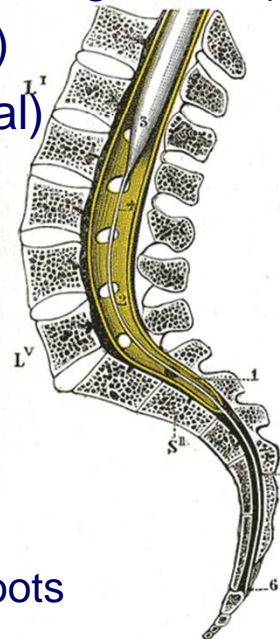
Spinal cord at 3 months





# Topographic location, size and extent

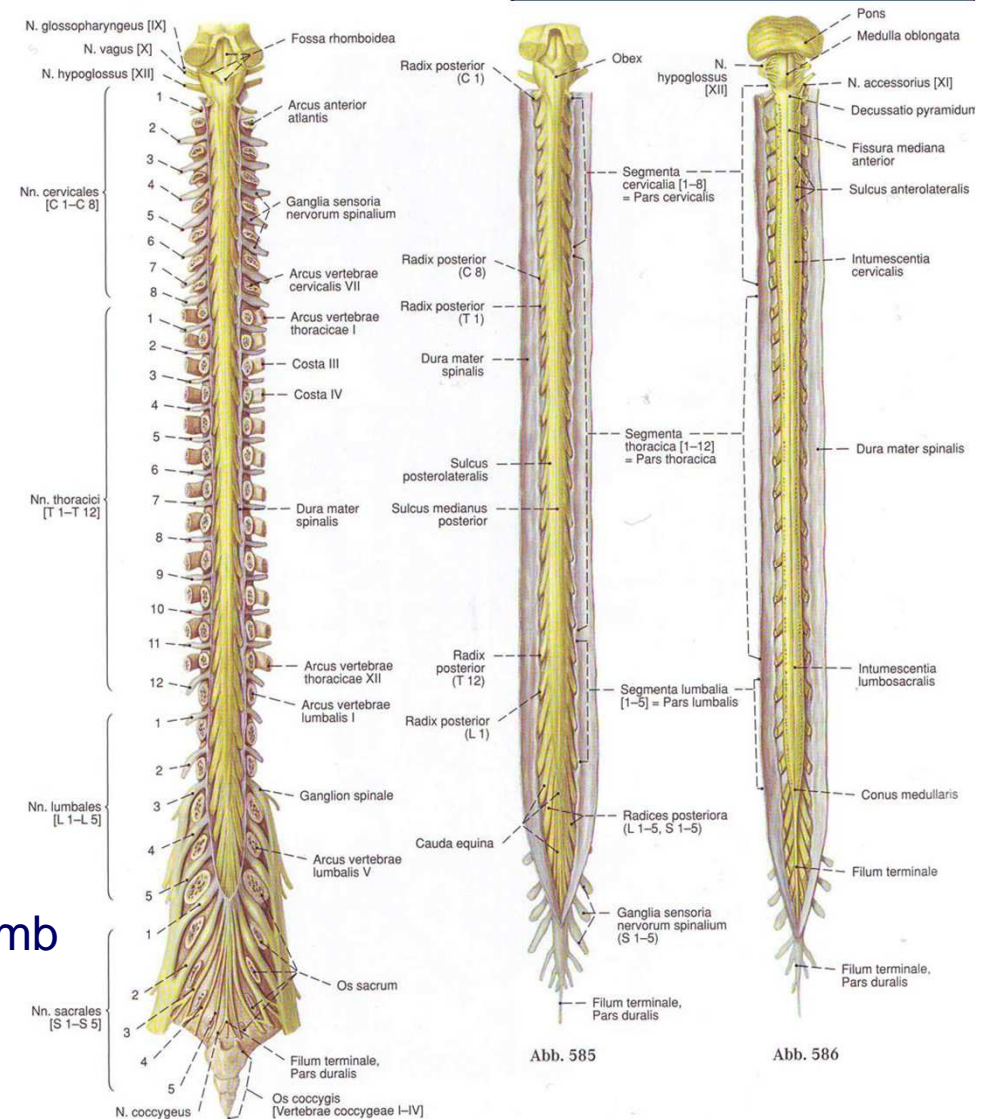
- topography and levels – in the vertebral canal
  - ✓ fetal life – the entire length of vertebral canal
  - ✓ at birth – near the level L3 vertebra
  - ✓ adult – upper  $\frac{2}{3}$  of vertebral canal (L1-L2)
- average length:
  - ✓ ♂ – 45 cm long
  - ✓ ♀ – 42-43 cm
- diameter ~ 1-1.5 cm (out of enlargements)
- 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

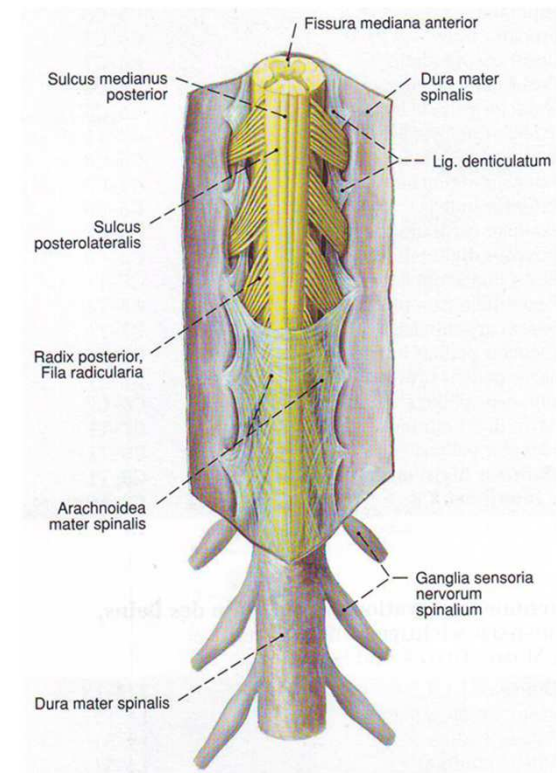
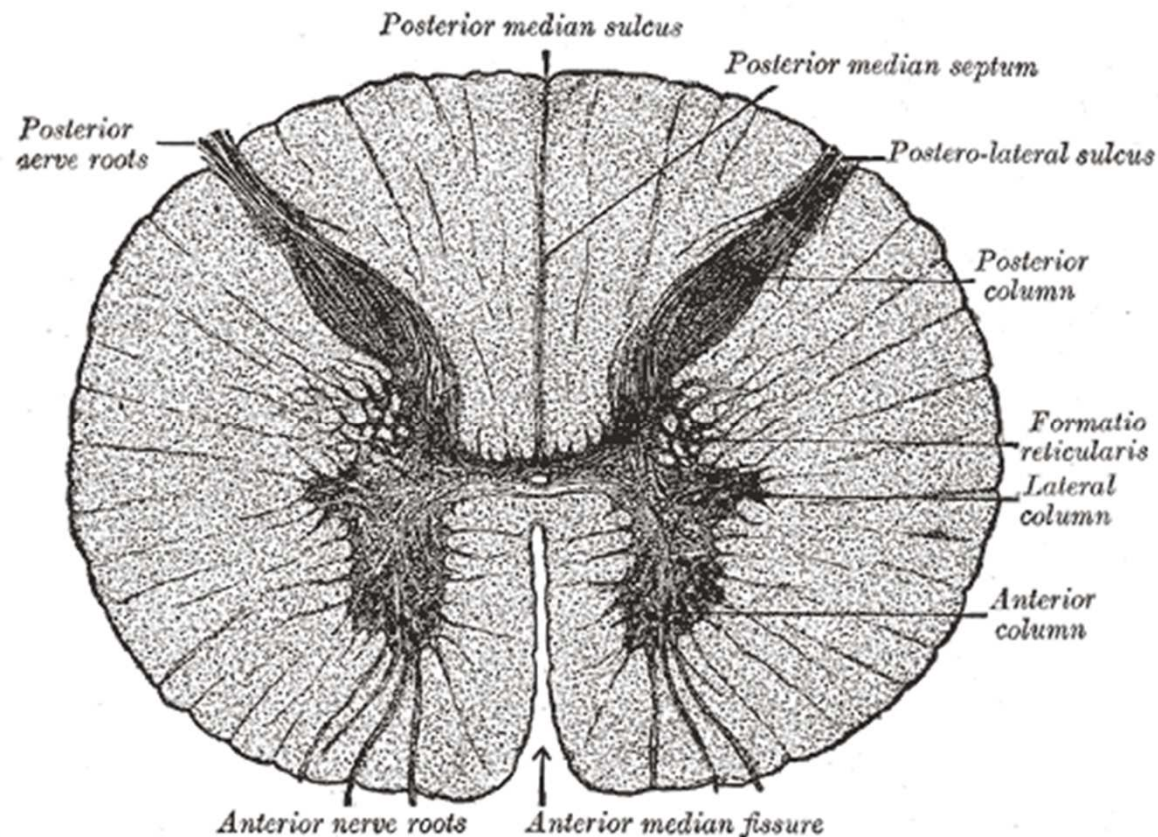
- cervical enlargement, *intumescentia cervicalis*:
  - ✓ spinal segments (C4-Th1)
  - ✓ vertebral levels (C4-Th1)
  - ✓ provides upper limb innervation (brachial plexus)
- lumbosacral enlargement, *intumescentia lumbosacralis*:
  - ✓ spinal segments (L2-S3)
  - ✓ vertebral levels (Th9-Th12)
  - ✓ segmental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





# External surface structure

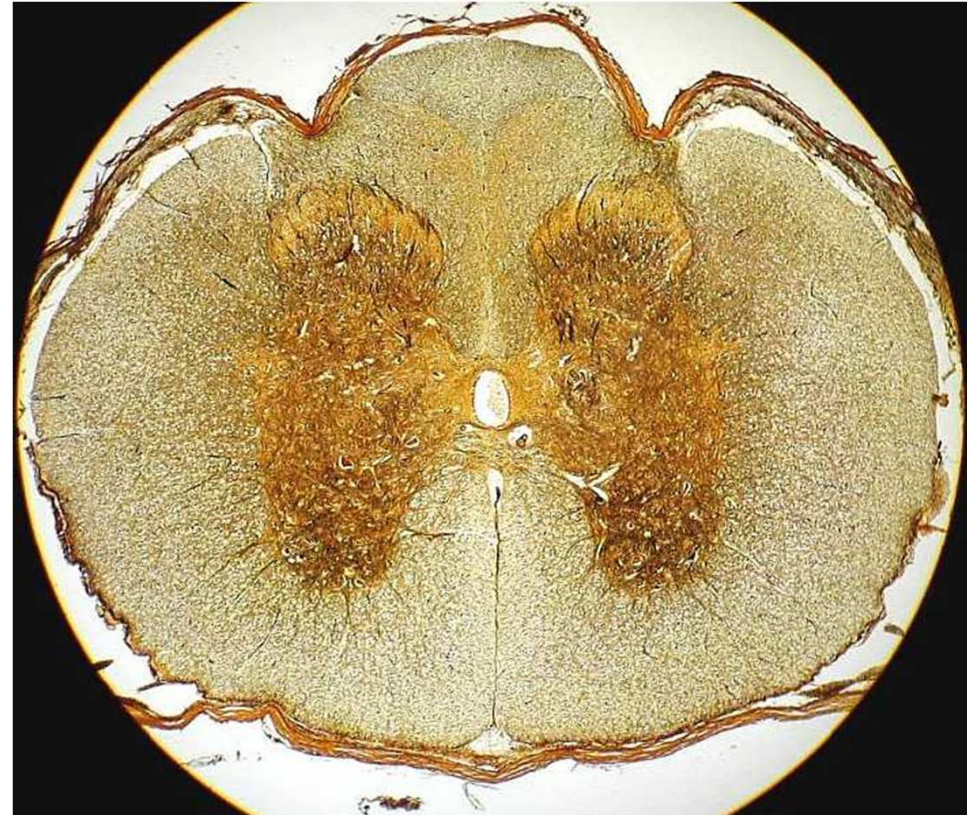
- **Two symmetrical halves:**
  - ✓ divided by two external longitudinal grooves:
    - a deeper anterior median fissure
    - a shallower posterior median sulcus (less prominent)
  - ✓ joined by a commissural band of nervous tissue





# Anterior median fissure

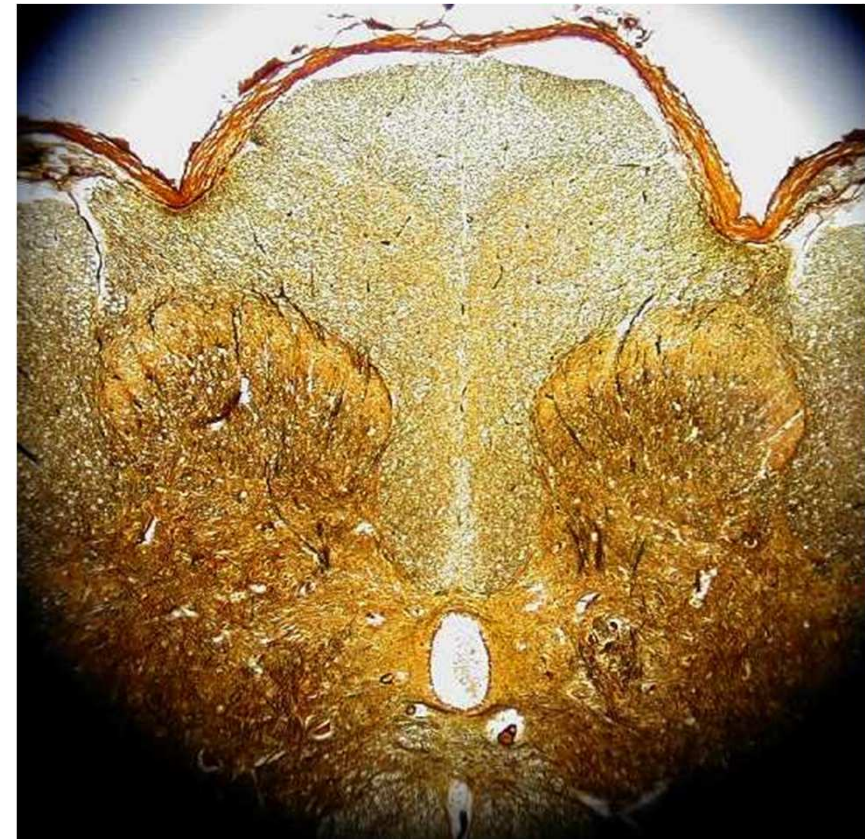
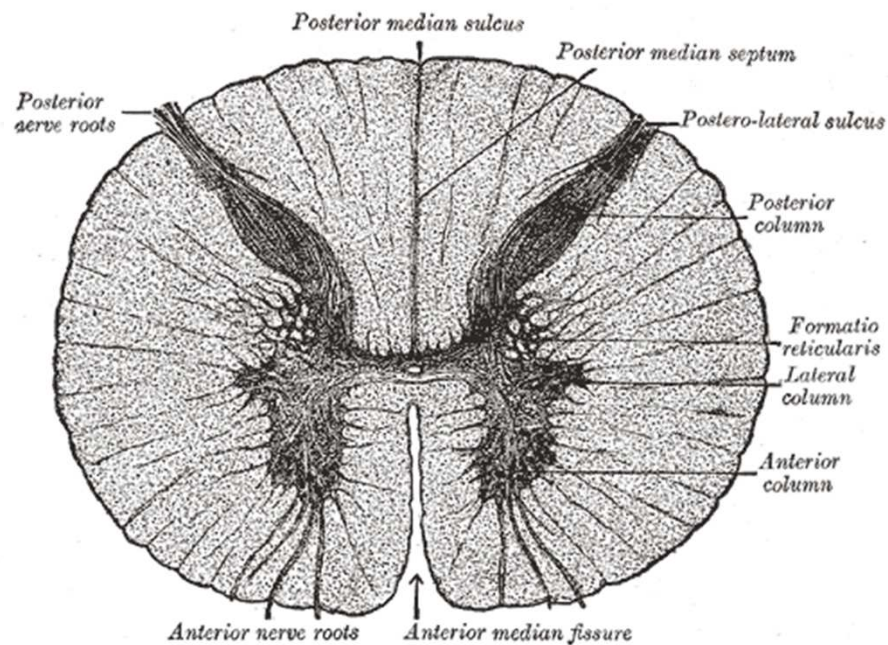
- average depth ~ 3 mm:
  - ✓ deeper at more caudal levels
- roof:
  - ✓ a reticulum of *pia mater*
- floor:
  - ✓ a lamina of nerve fibers, anterior white commissure
- anterior spinal artery
- anterolateral sulcus – ventral nerve root





# Posterior median septum

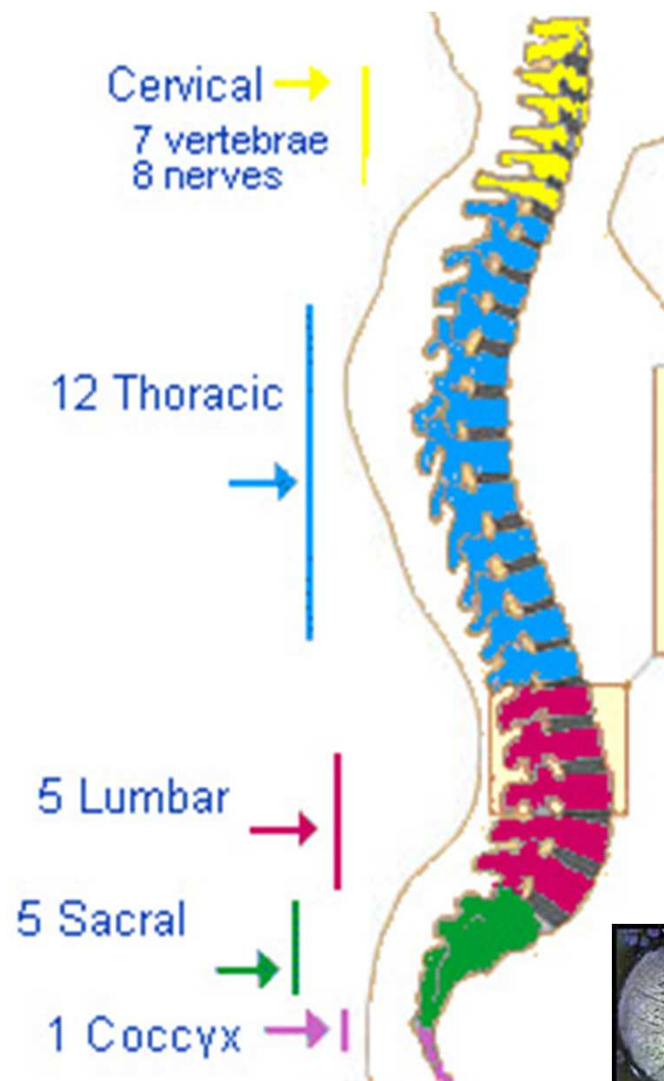
- average depth ~ 4-6 mm:
  - ✓ diminishing caudally
- neuroglial partition:
  - ✓ reaching the gray matter
- posterolateral sulcus – dorsal nerve root





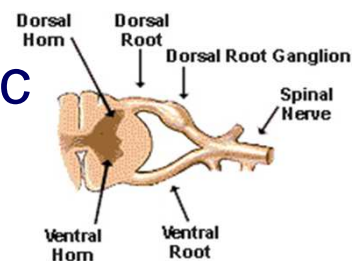


# Segmental structure



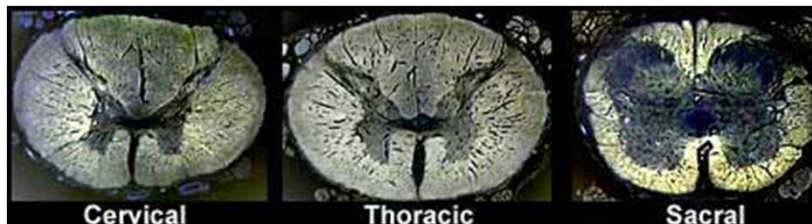
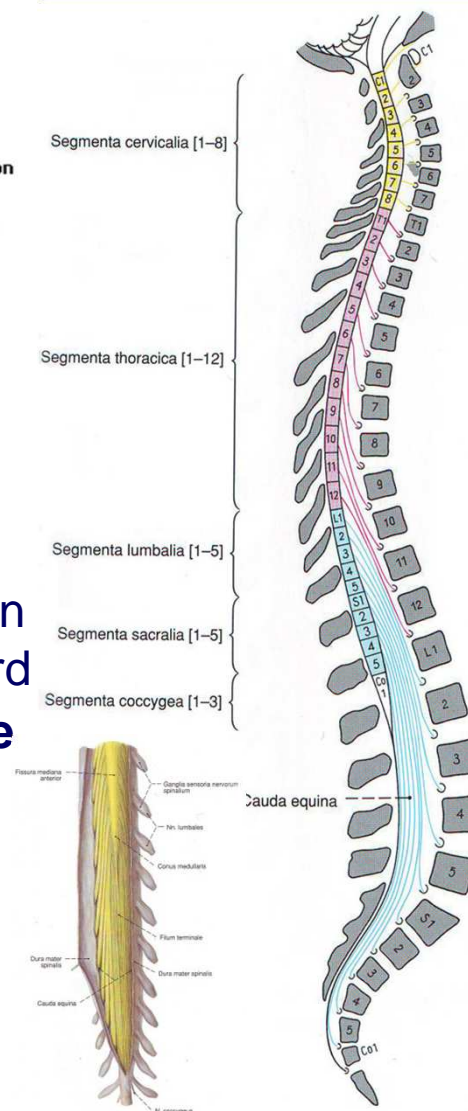
## ■ 31 segments:

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



## ■ segment ≠ vertebra:

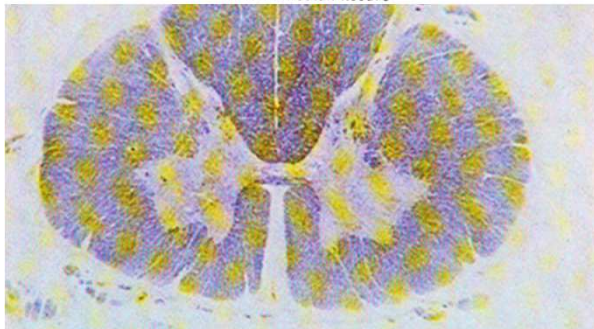
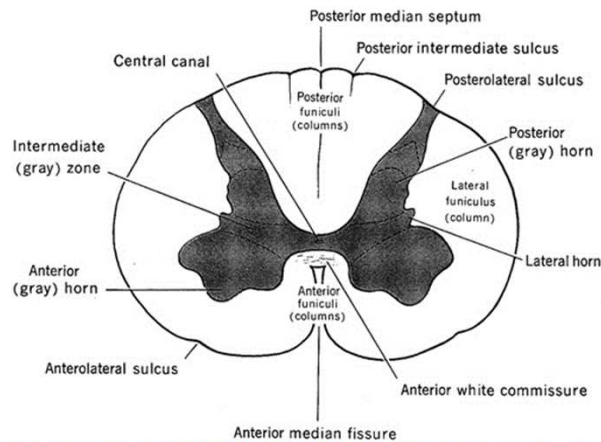
- ✓ growth of the vertebral column exceeds that of the spinal cord
- ✓ all segments terminate **above** level L1/L2 ⇒ *cauda equina*
- ✓ vary in diameter and length



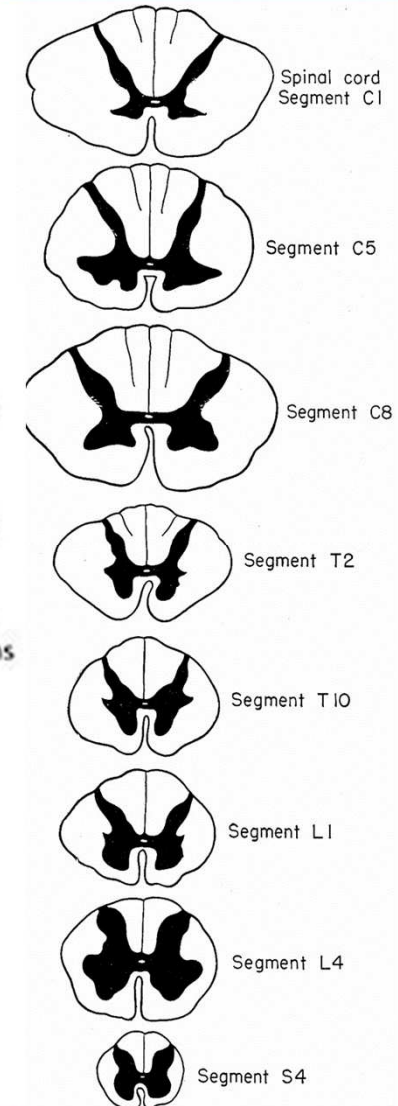
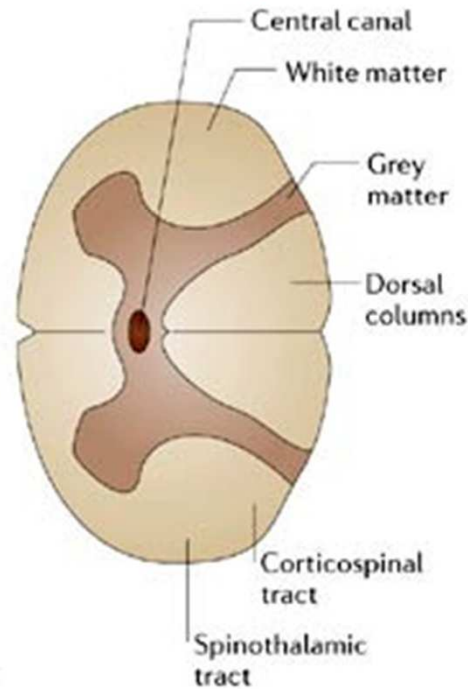
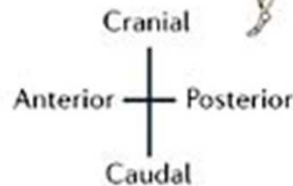
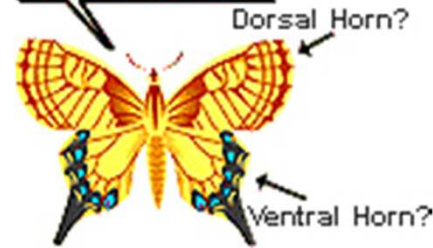


# Internal structure of the spinal cord

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



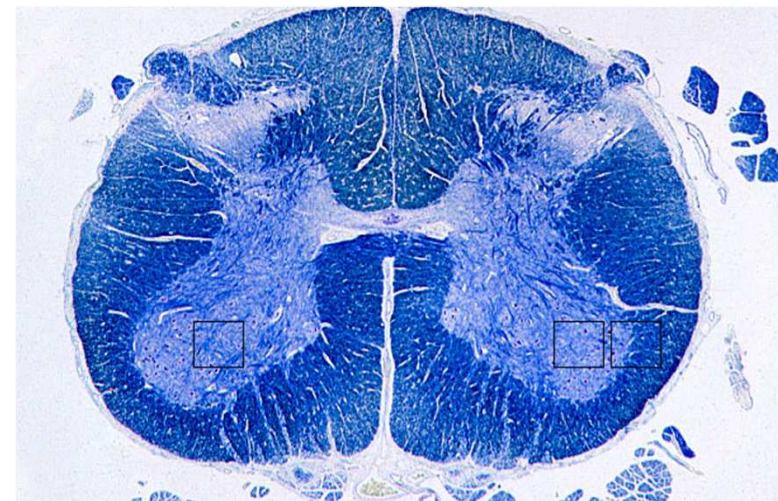
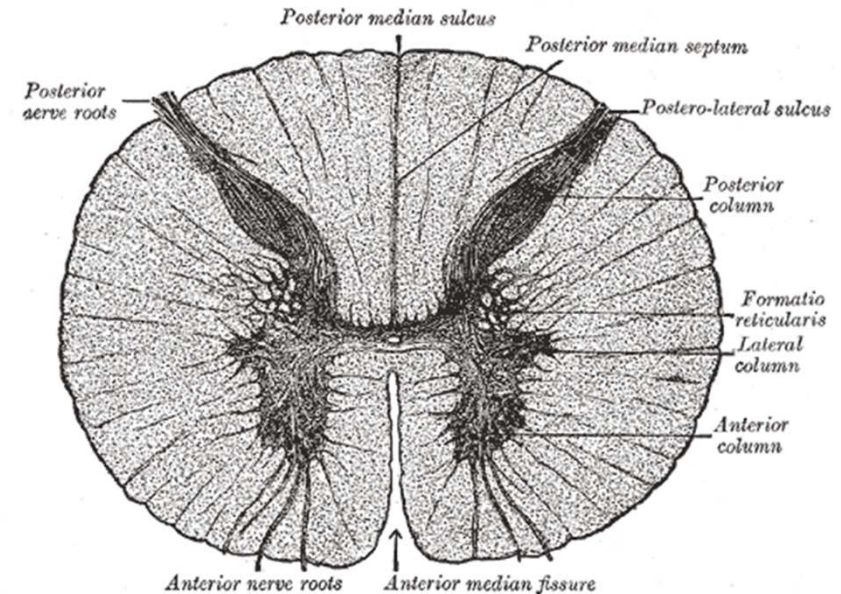
How do you like my dorsal and ventral horns?





# Grey matter, *substantia grisea*

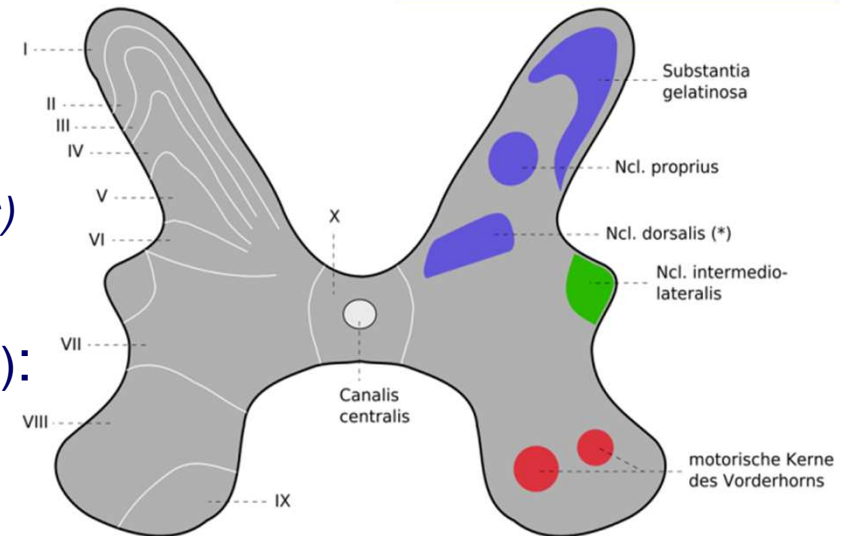
- composition:
  - ✓ neuronal perikarya
  - ✓ dendrites with their synapses
  - ✓ glial supporting cells
  - ✓ blood vessels
- anterior (ventral) column:
  - ✓ *cornu anterius (columna anterior)*
- posterior (dorsal) column:
  - ✓ *cornu posterius (columna posterior)*
- lateral column:
  - ✓ *cornu laterale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





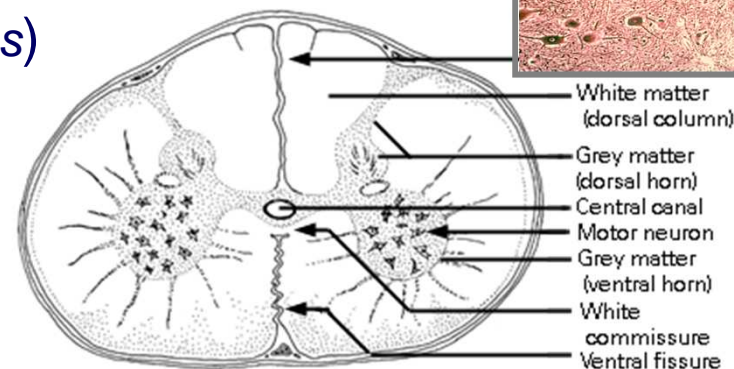
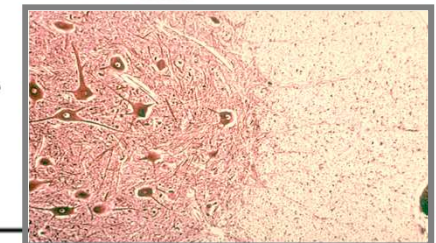
# General structure of the grey matter

- 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)



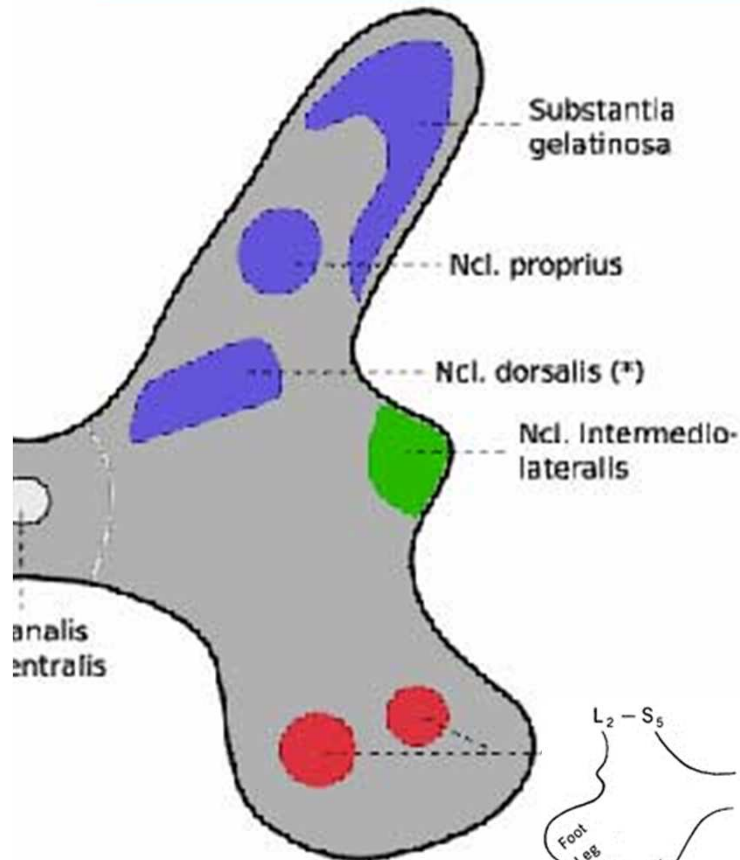
Schichtengliederung (Laminae)

\* auch Ncl. thoracicus posterior bzw. Stilling-Clarke



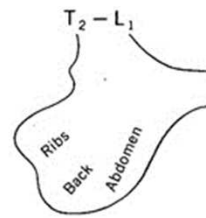


# Grey matter – nerve cell groups



lateral horn: 2 nuclei

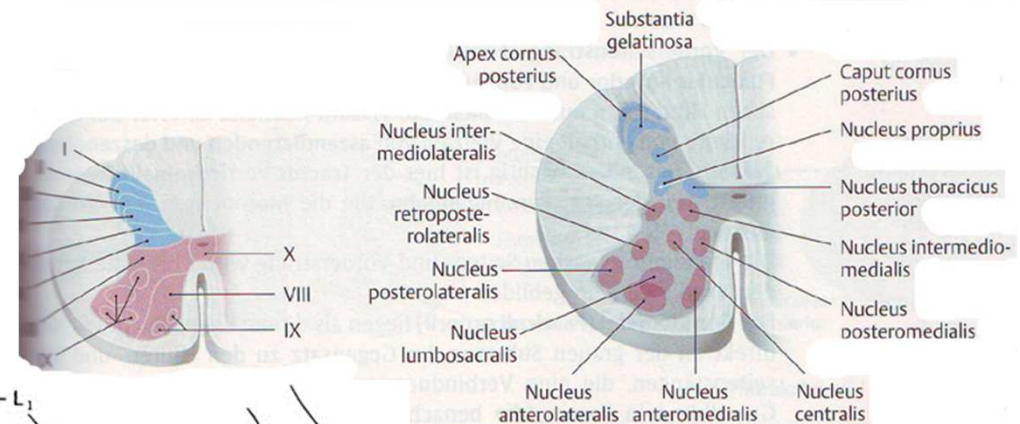
- ✓ sympathetic: intermediolateral nucleus (Th1-L2)
- ✓ parasympathetic: intermediomedial nucleus (S2-S4)
- ✓ spinal reticular nucleus



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



ventral horn: 5 nuclei

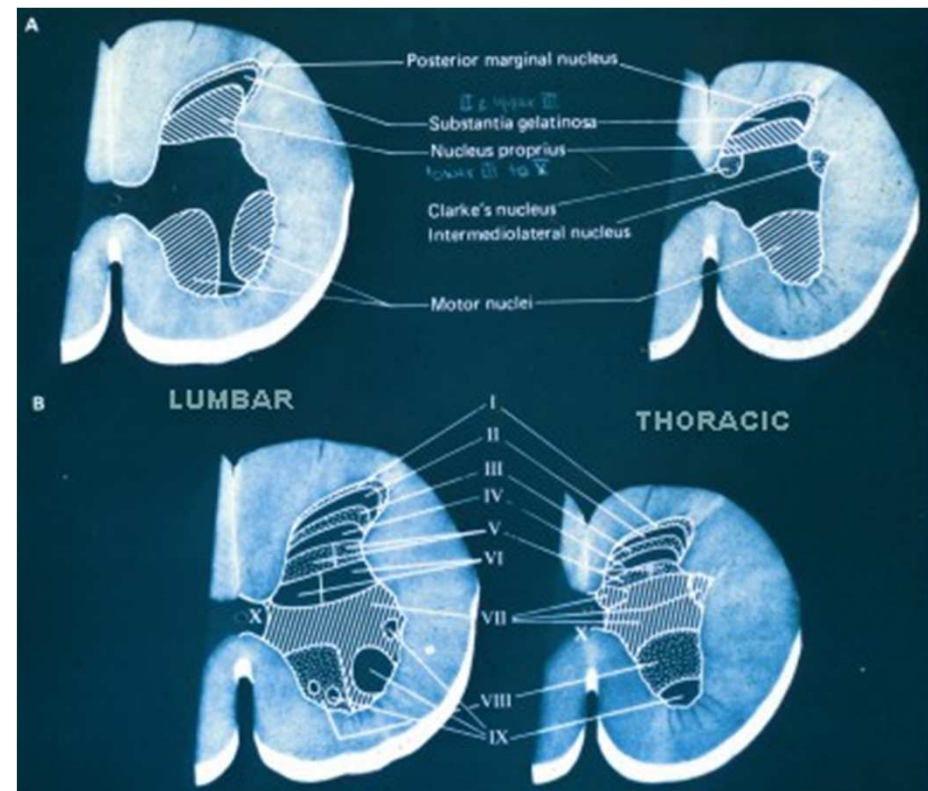
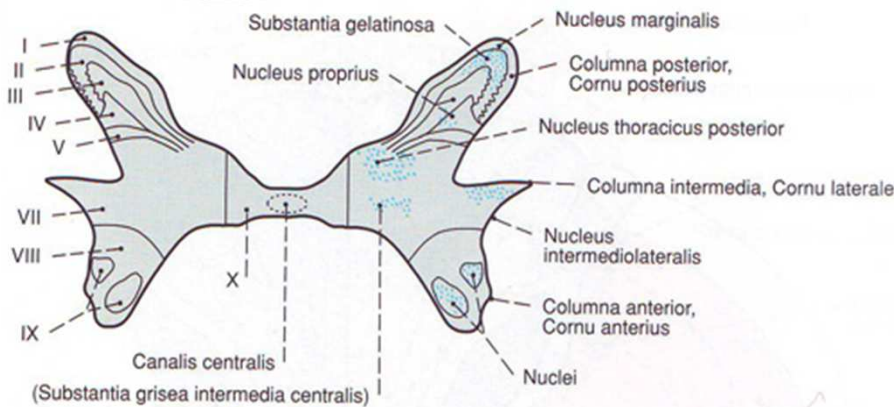
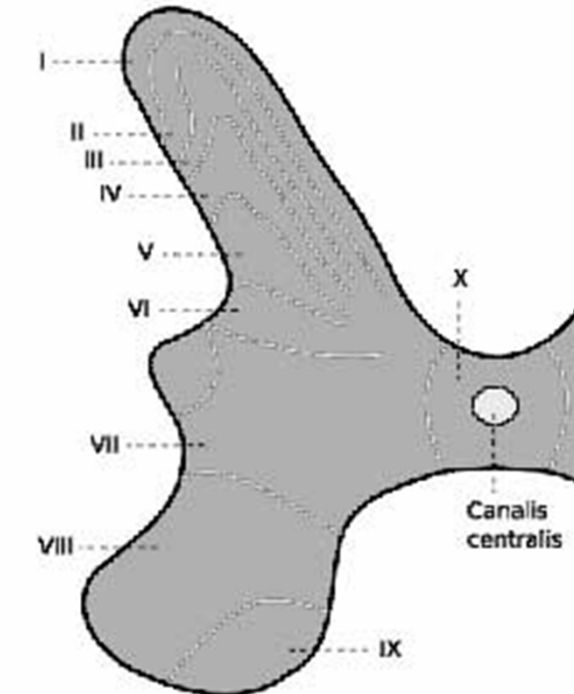
- ✓ medial group
  - ventromedial nucleus
  - dorsomedial nucleus
- ✓ lateral group
  - ventrolateral nucleus
  - central nucleus
  - dorsolateral nucleus



# Grey matter – laminar architecture

**10 distinct cellular laminae of Rexed:**

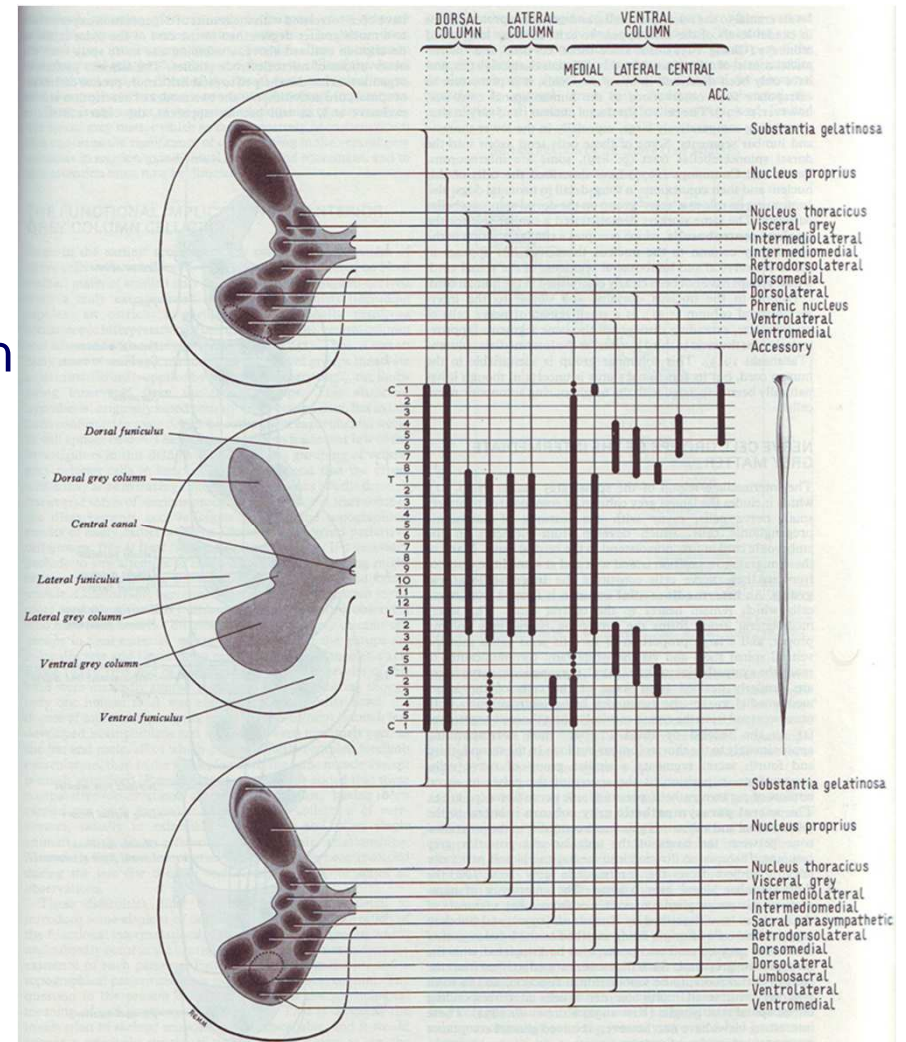
- ✓ I-VI: dorsal horn
- ✓ VII: intermediate zone and lateral horn
- ✓ VIII-IX: ventral horn
- ✓ X: central canal + substantia gelatinosa (of Rolando)





# Grey matter – functional organization

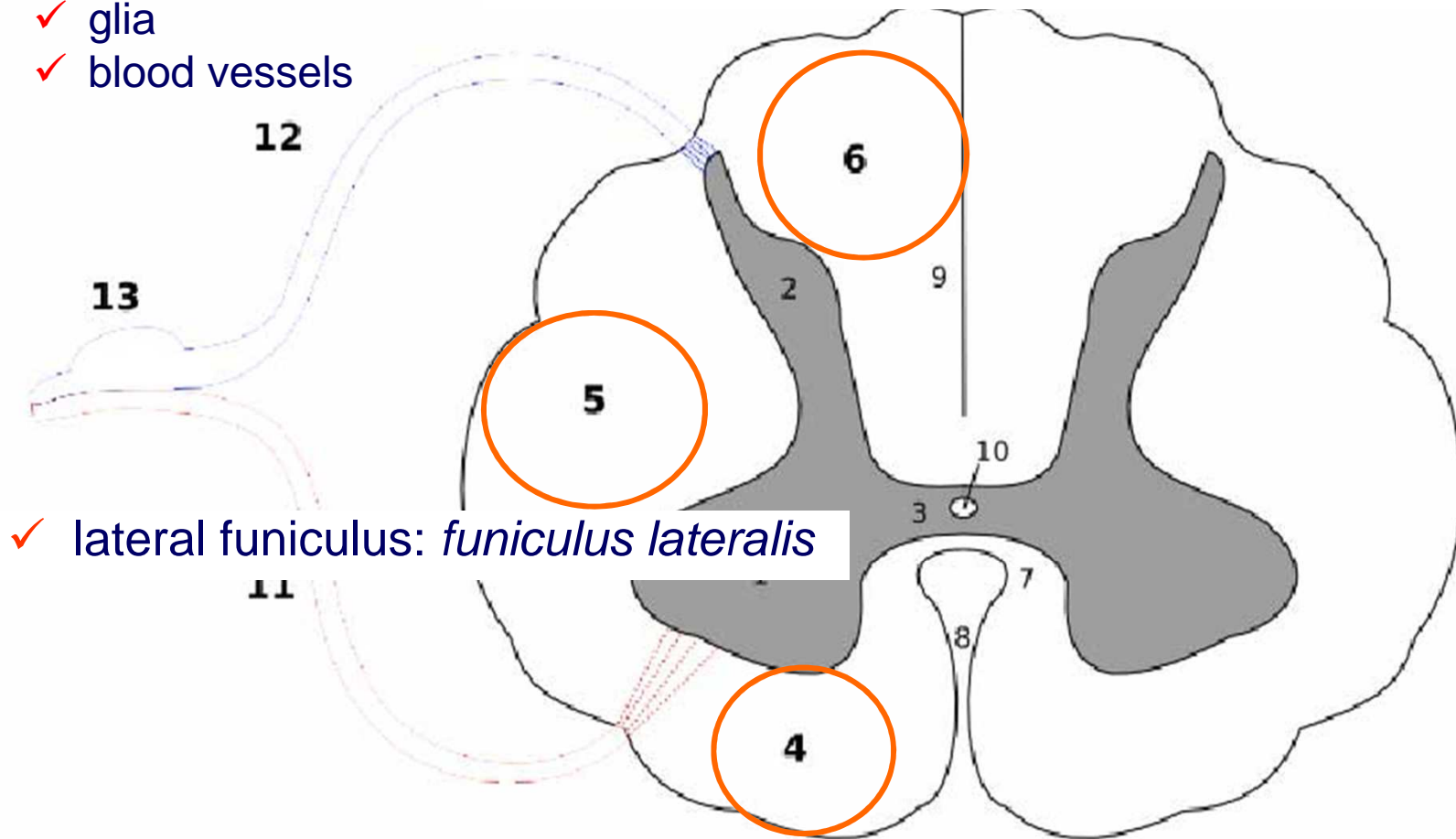
- different sensations – different neurons (the law of Bell and Magendie)
- the theory of nerve components:
- dorsal horn mediates sensation
  - ✓ general somatic afferents
  - ✓ general visceral afferents (GVA)
- ventral horn mediates motor function
  - ✓ general somatic efferents (GSE) for the ventral 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*

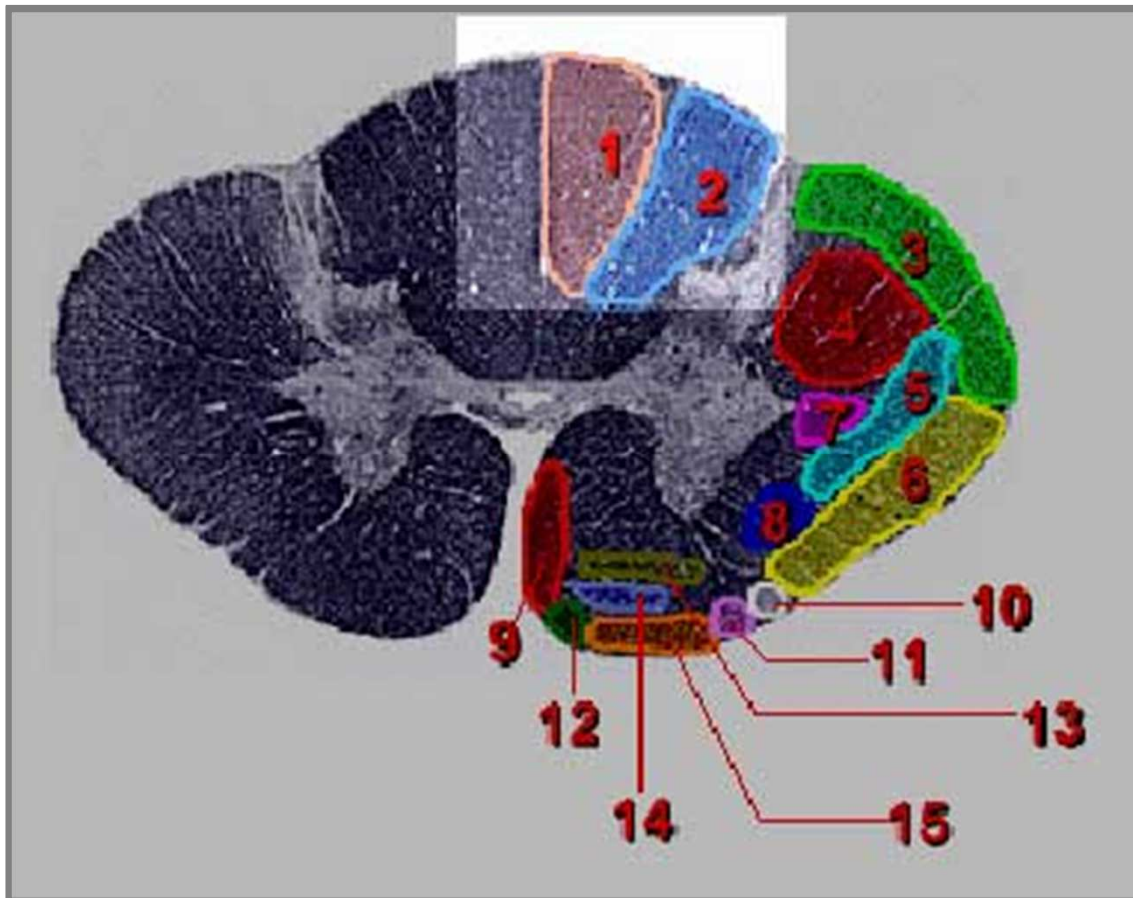
✓ anterior funiculus: *funiculus ventralis (anterior)*





# Dorsal column tracts

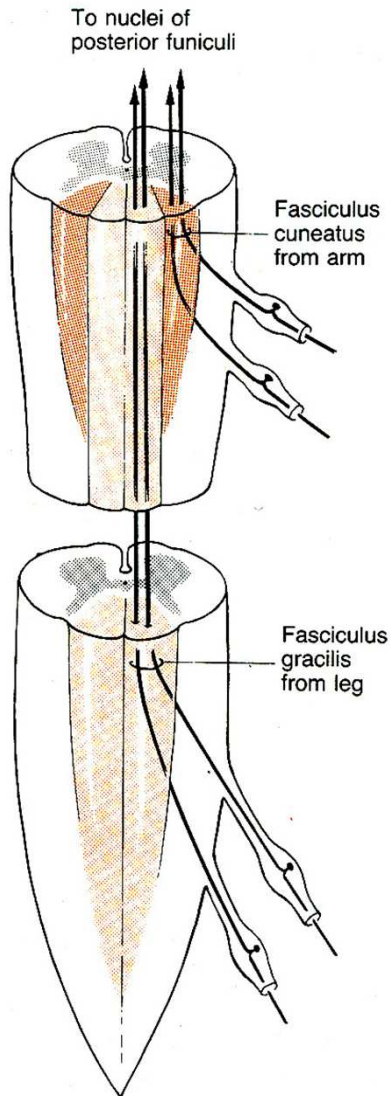
- Ascending pathways:
  1. *Fasciculus gracilis* (of Goll)
  2. *Fasciculus cuneatus* (of Burdach)



- 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

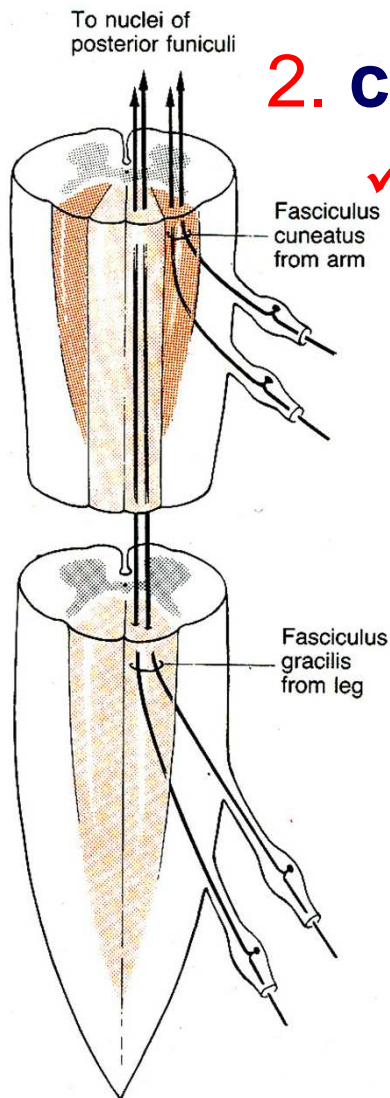
✓ medial part of the posterior funiculus



- ✓ 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

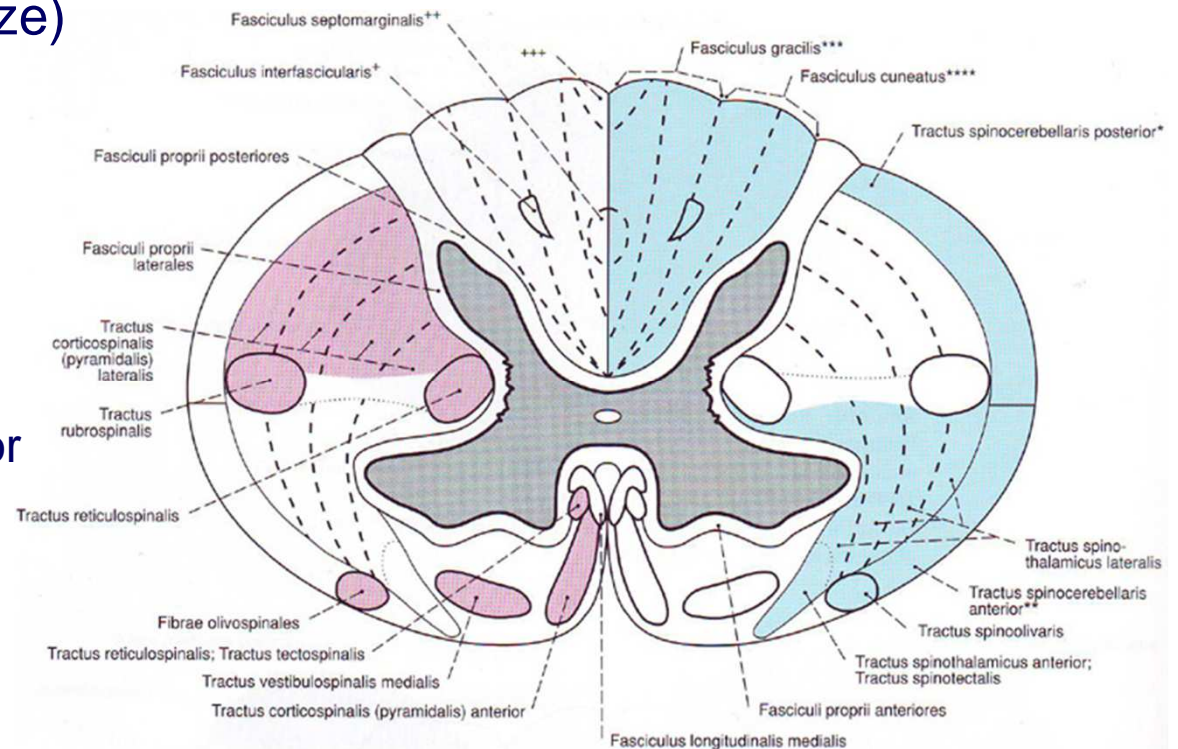


- ✓ first appear at about **Th6**
- ✓ contains long ascending branches of the **upper six thoracic and all cervical** dorsal roots
- ✓ **deep sensitivity (proprioception)** from the upper part of the trunk and from the arm
- ✓ **superficial sensitivity** – touch, pressure and vibration
- ✓ interruption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



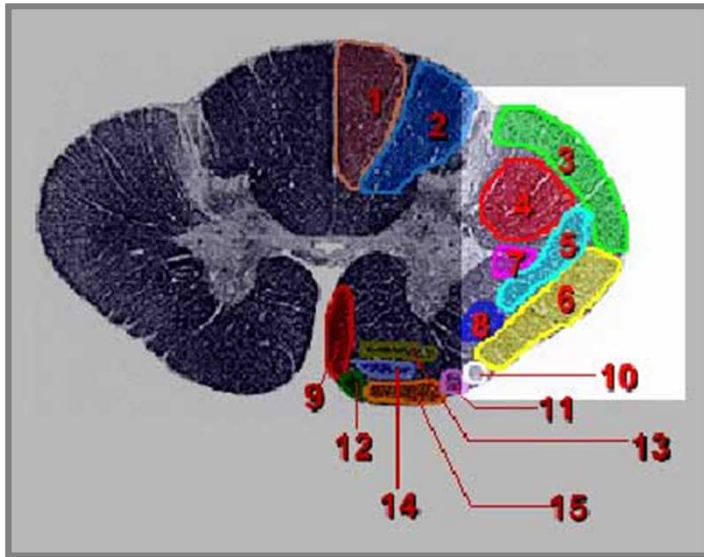
# Posterior funiculus

- 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:

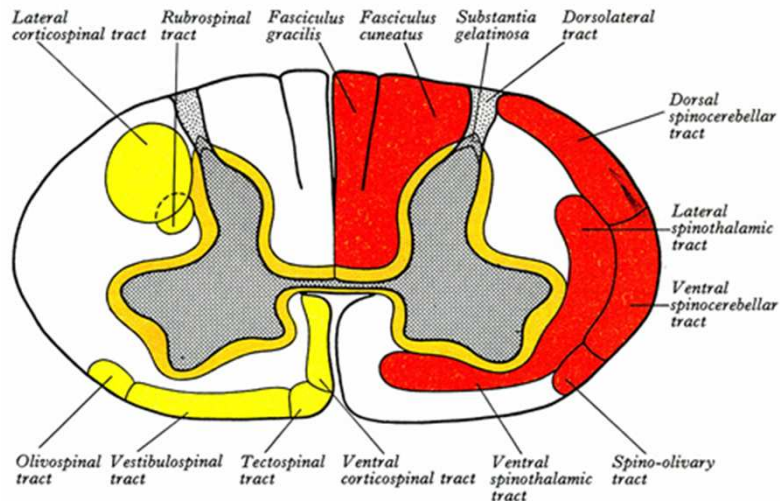
1. Dorsal spinocerebellar tract (of Flechsig)
2. Ventral spinocerebellar tract (of Gowers)
3. Lateral spinothalamic tract (of Eninger)
4. Spinotectal tract
5. Spino-olivary tract
6. Spinoreticular fibers
7. Dorsolateral tract (of Lissauer)

## ■ Descending tracts:

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

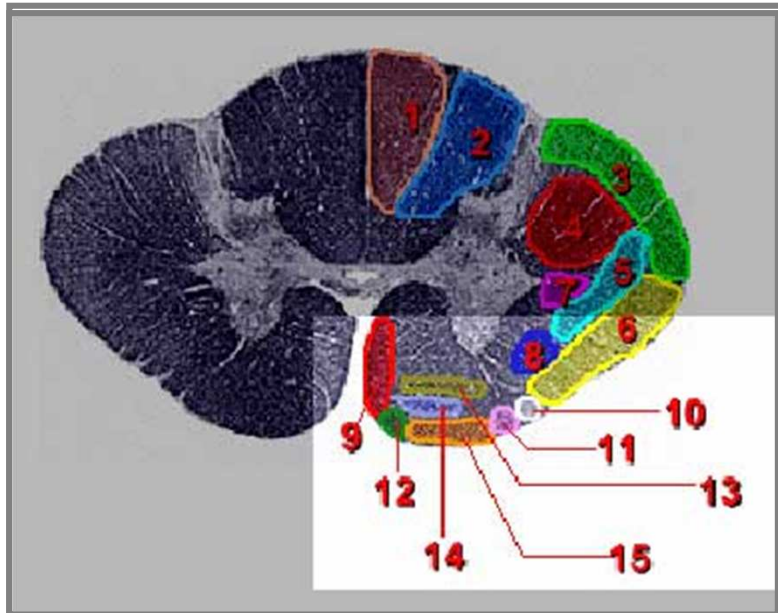
## ■ Intersegmental tracts:

1. Lateral intersegmental tract





# Anterior funiculus



## ■ Ascending tracts:

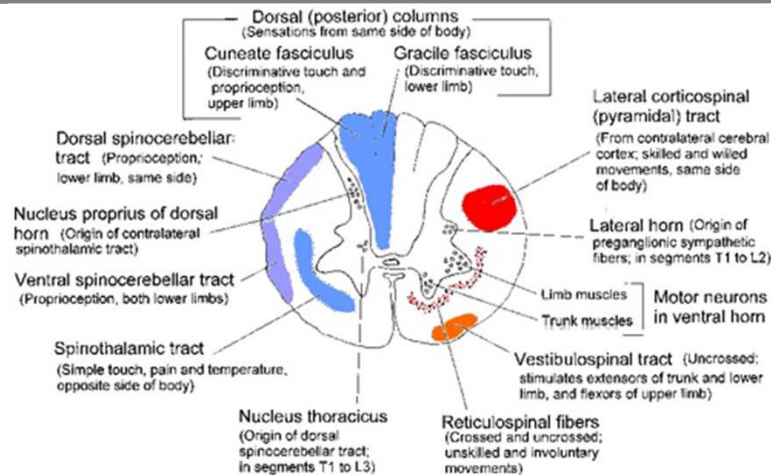
1. Anterior spinothalamic tract

## ■ Descending tracts:

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

## ■ Intersegmental tracts:

1. Anterior intersegmental tract

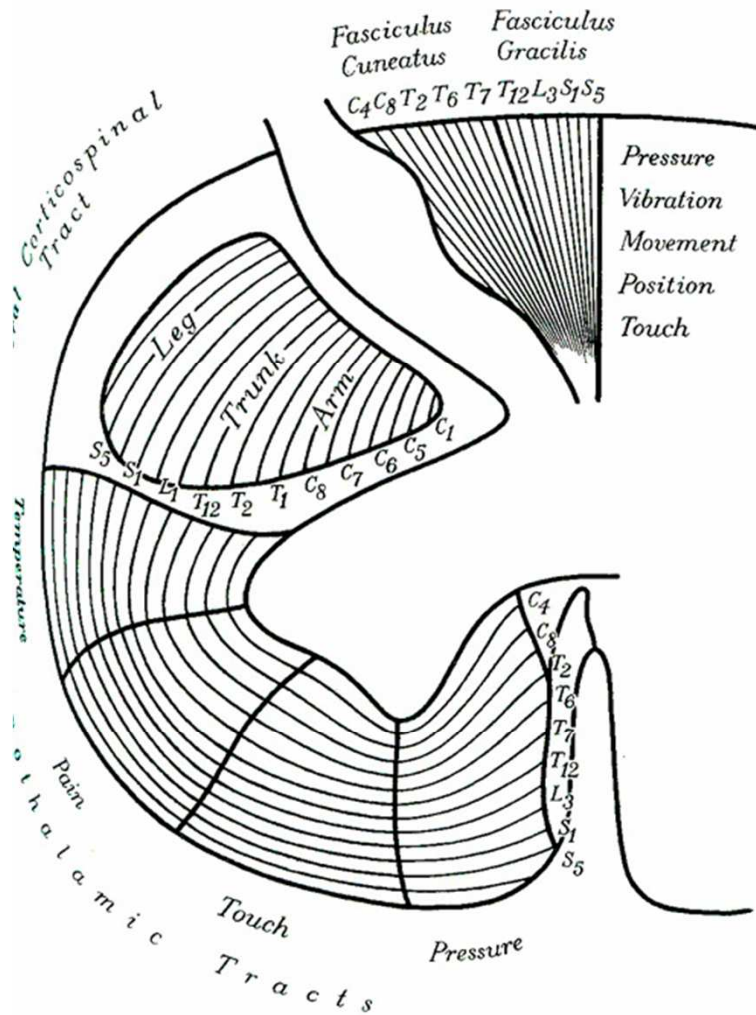




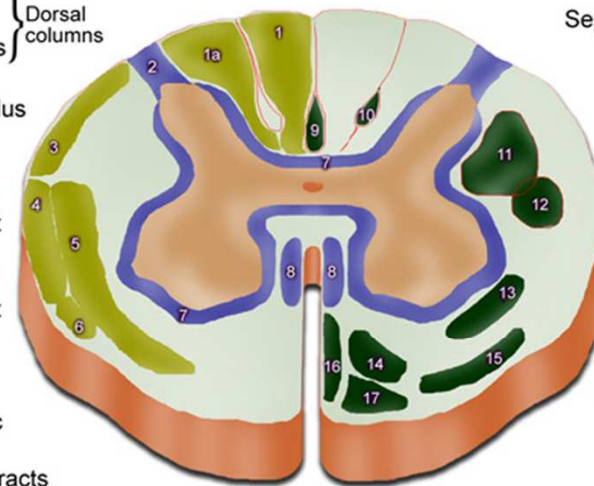
# Functional topography of pathways

## Posterior (dorsal funiculi) columns:

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



- 1 Fasciculus gracilis
- 1a Fasciculus cuneatus
- 2 Dorsolateral fasciculus or tract of Lissauer
- 3 Posterior or dorsal spinocerebellar tract
- 4 Anterior or ventral spinocerebellar tract
- 5 Spinothalamic, spinoreticular, spinomesencephalic (spinotectal), and spinohypothalamic tracts
- 6 Spinoolivary tract
- 7 Fasciculi proprii
- 8 Medial longitudinal or sulcomarginal fasciculi



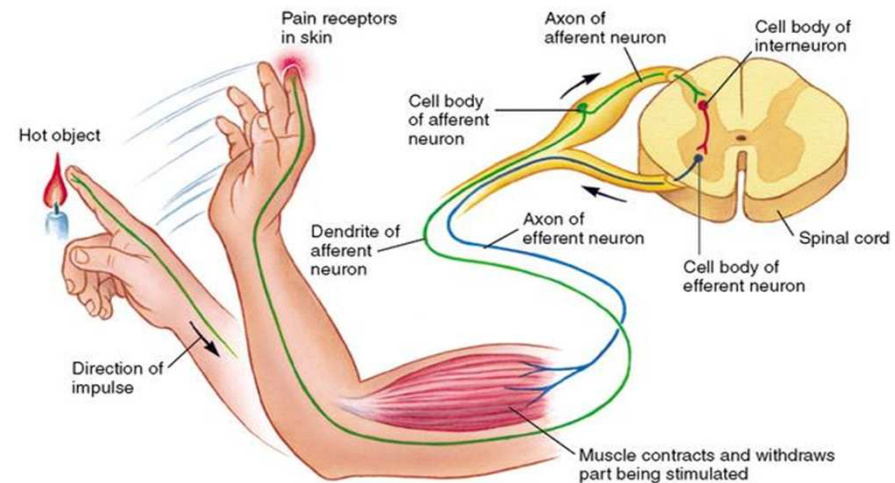
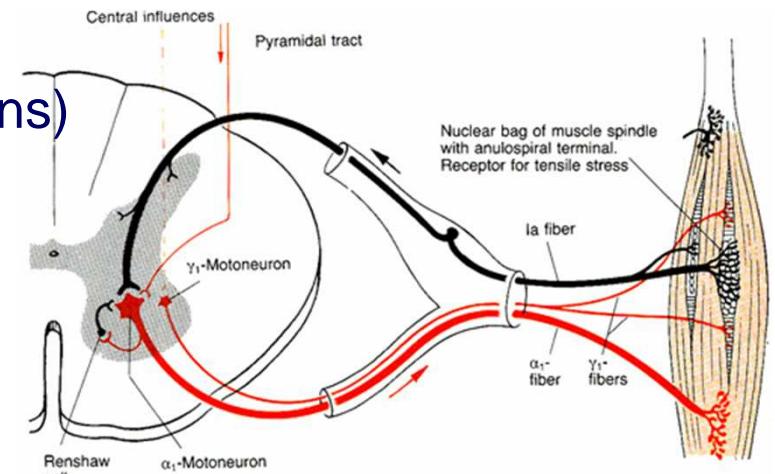
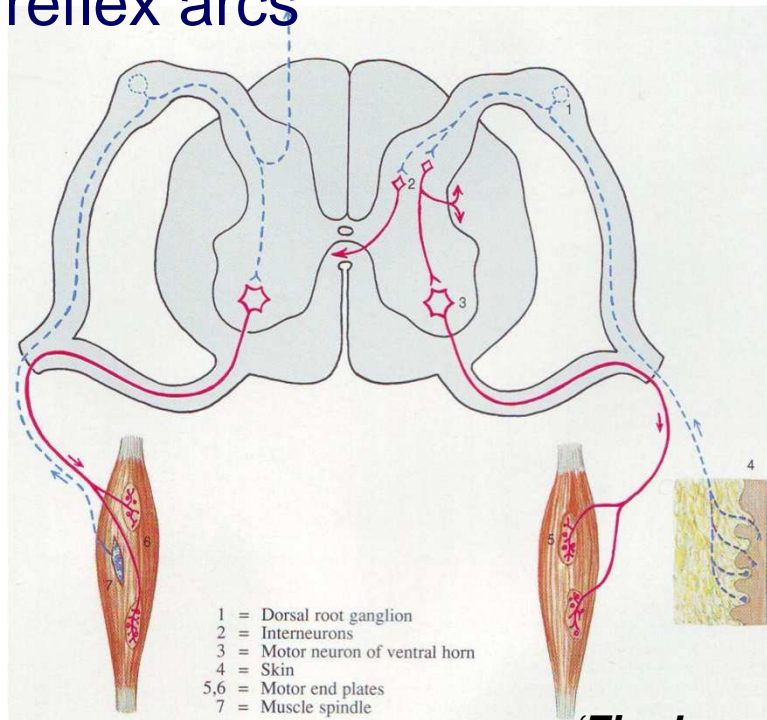
- 9 Septomarginal fasciculus
- 10 Interfascicular or semilunar fasciculus
- 11 Lateral corticospinal or pyramidal
- 12 Rubrospinal tract
- 13 Medullary or lateral reticulospinal tract
- 14 Pontoreticulospinal or medial reticulospinal tract
- 15 Vestibulospinal tract
- 16 Anterior or ventral corticospinal tract
- 17 Tectospinal tract

- Ascending tracts
- Descending tracts
- Bidirectional tracts



# 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

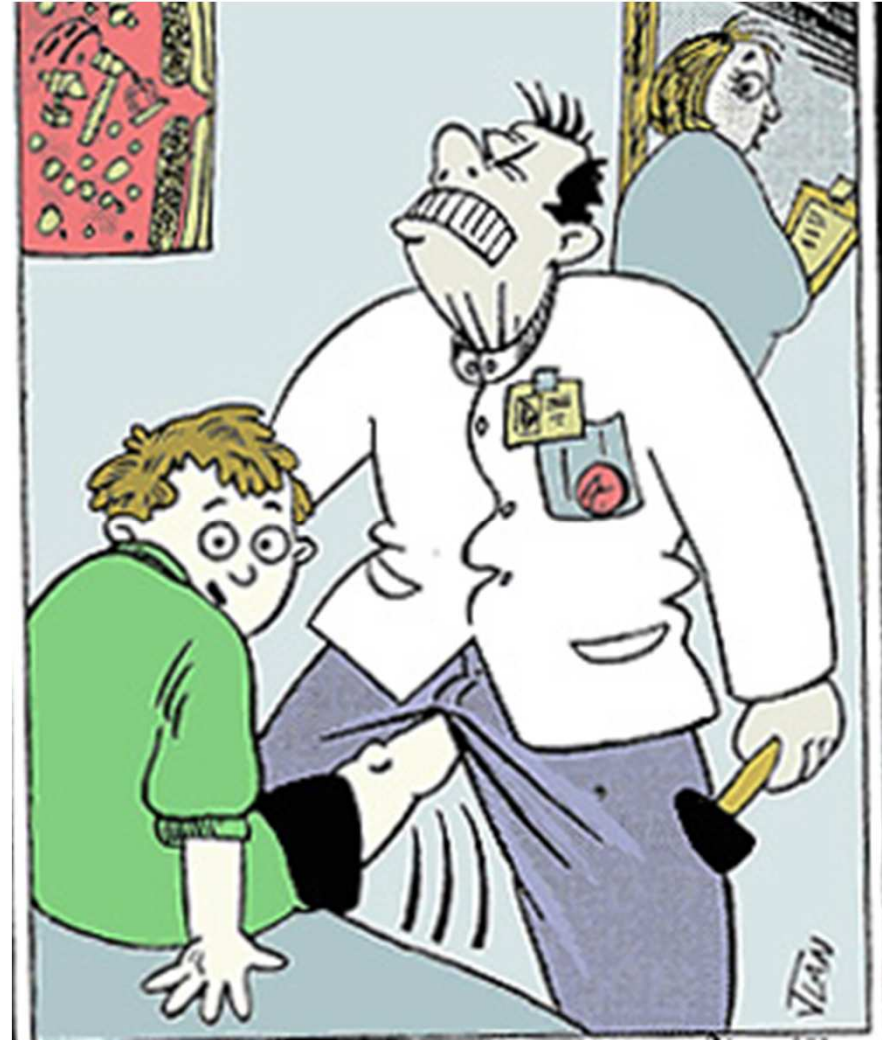


**'Final common path(way)' (of Sherrington)**





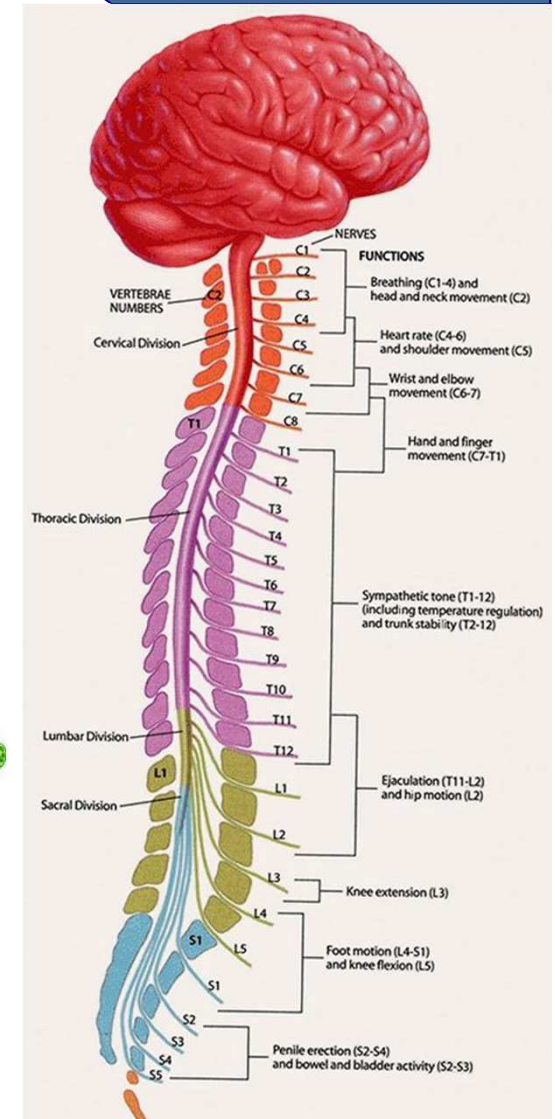
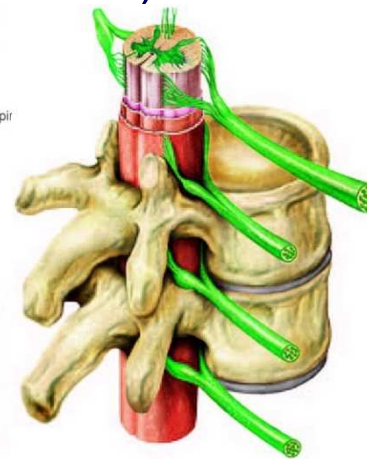
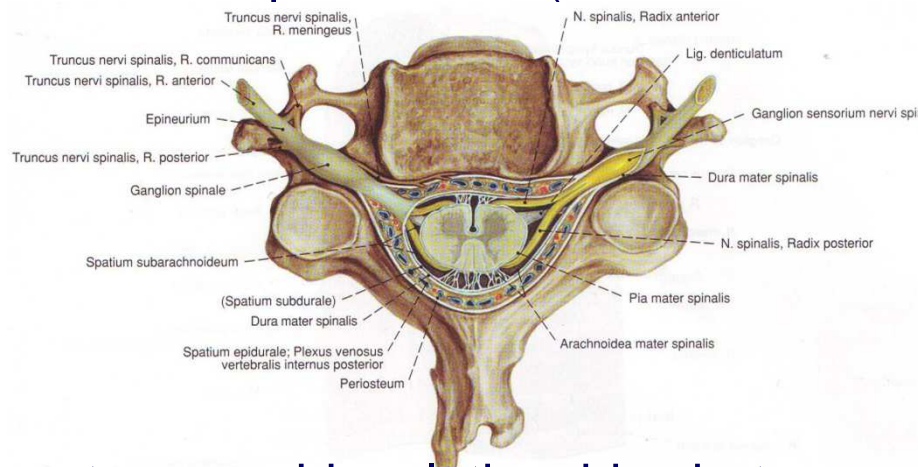
# Patellar Reflex Testing





# 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)

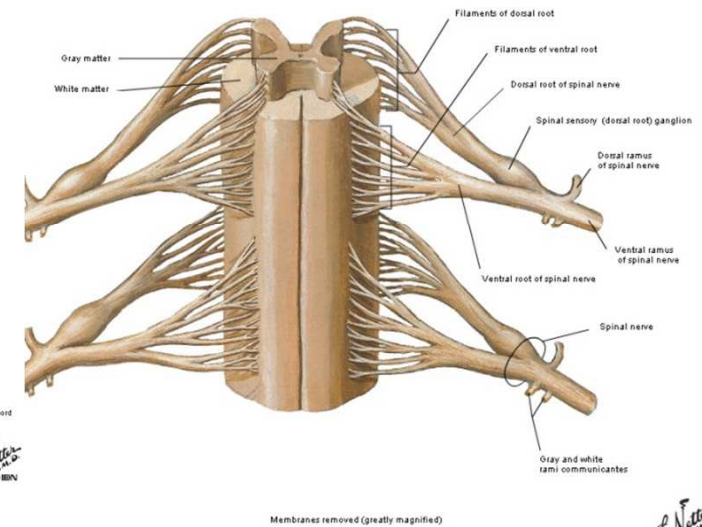
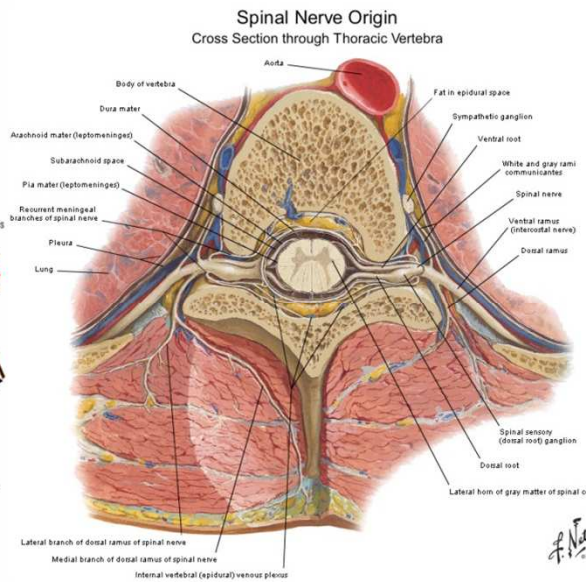
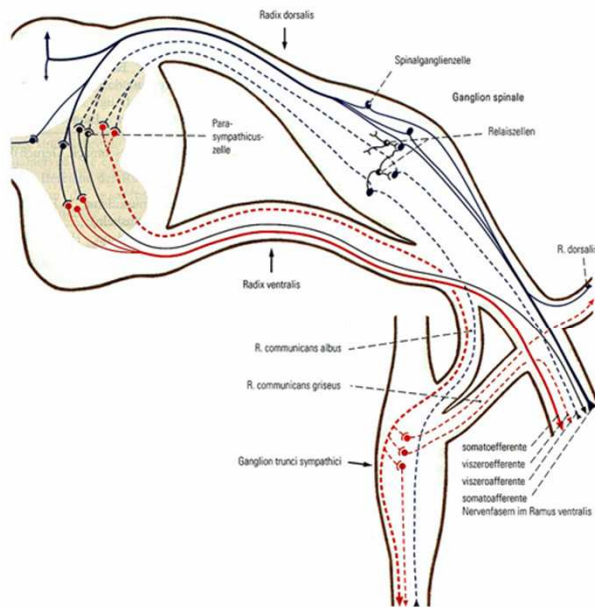
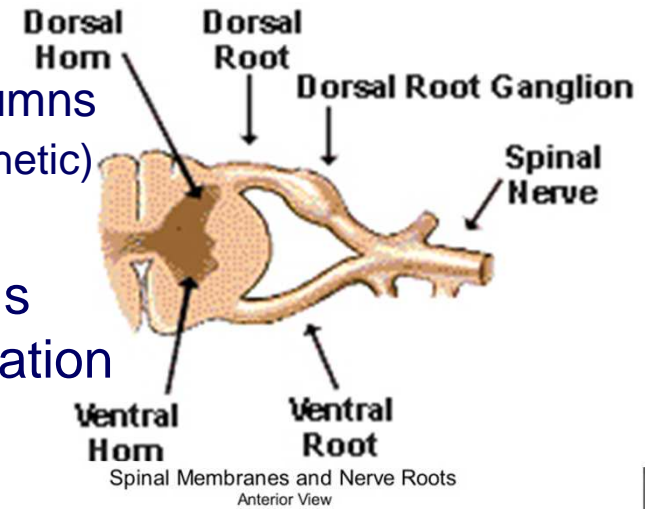


- topographic relationships between spinal nerves, segments and vertebrae



# Spinal nerve formation

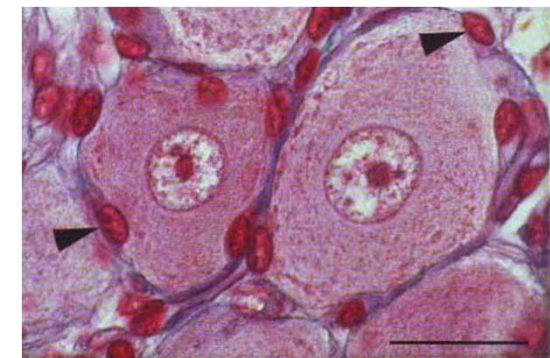
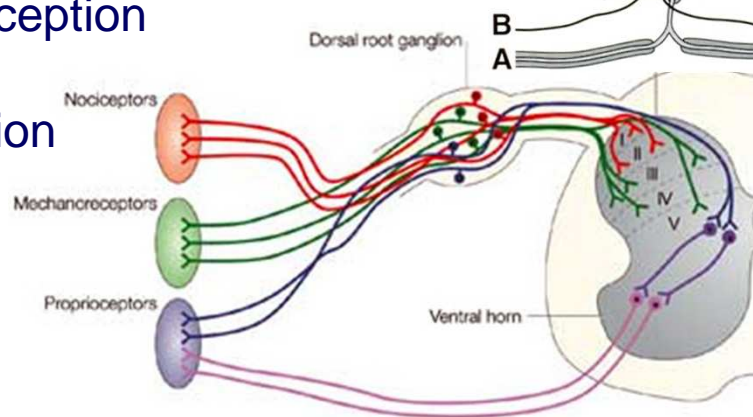
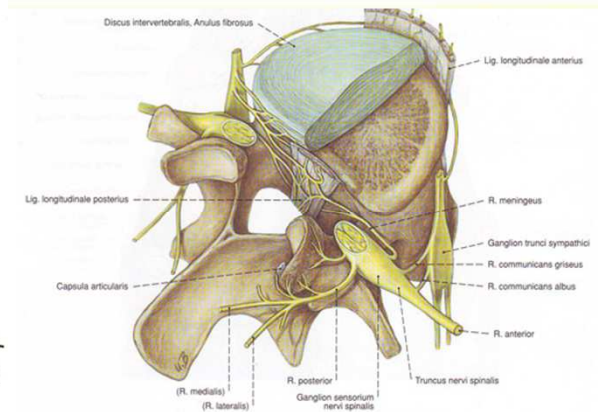
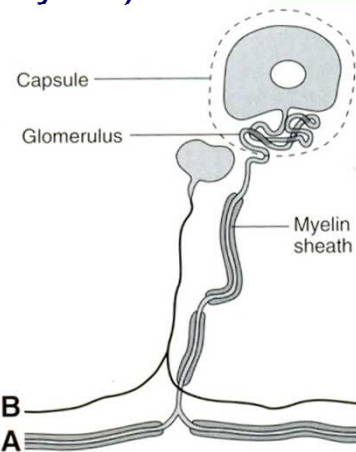
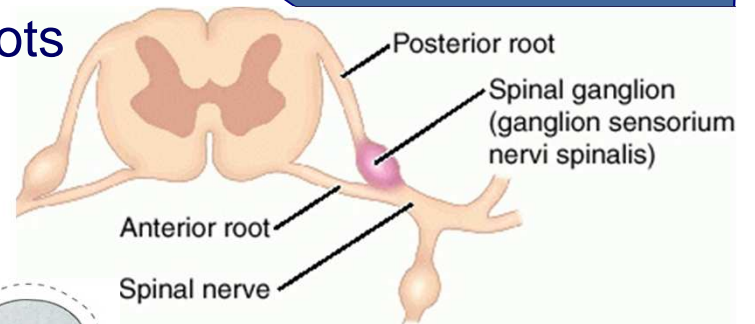
- ventral (motor) root:
  - ✓ axons of neurons in anterior and lateral grey columns
  - ✓ motor and autonomic (sympathetic and parasympathetic)
- dorsal (sensory) root:
  - ✓ central processes of the dorsal ganglion cells
  - ✓ convey somatic and visceral sensory information





# Spinal ganglion

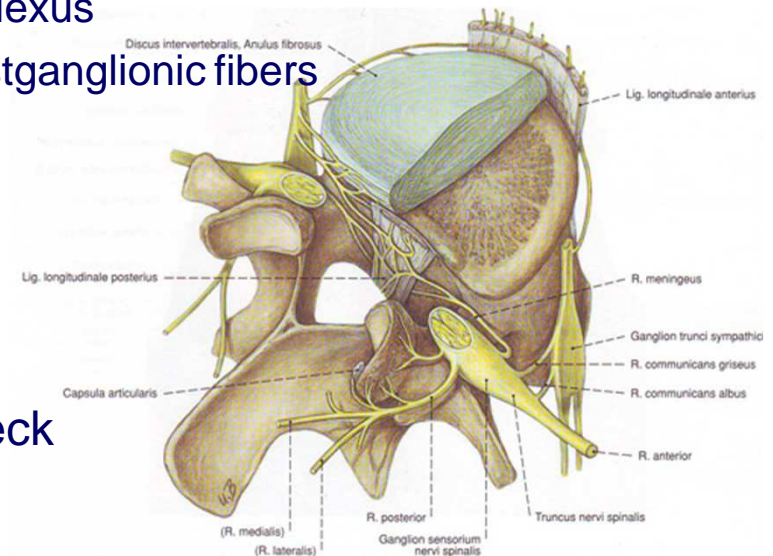
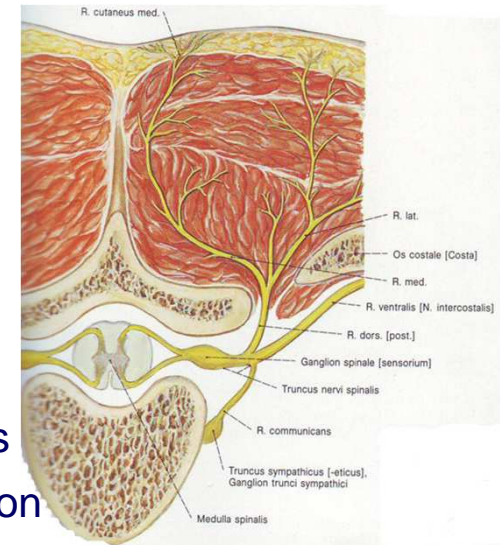
- spindle-shaped aggregations on the dorsal roots – **dorsal root ganglion**
  - ✓ (pseudo)unipolar neurons – ovoid or spherical (primary afferent neurons)
  - ✓ satellite cells (capsular cells, amphicytes)
  - ✓ Schwann cells and blood vessels
- embryonic origin – neural crest cells
- location – in 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

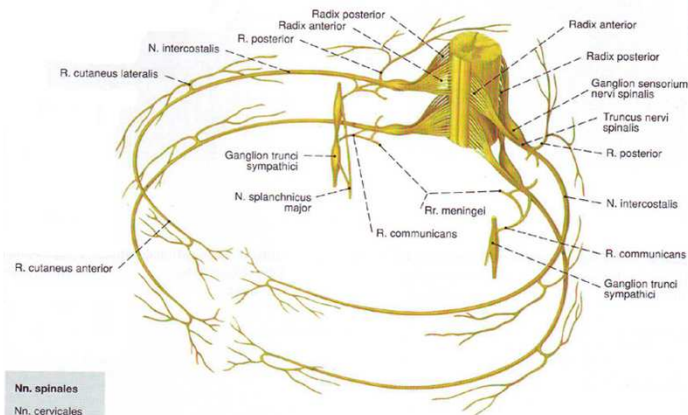
- divide into medial and lateral branches (exception C1)
- have a typical segmental distribution
- cervical dorsal rami:
  - ✓ suboccipital nerve (C1) – purely motor
  - ✓ greater occipital nerve (C2) – mixed
  - ✓ C3 medial cutaneous branch, third occipital nerve
- thoracic dorsal rami:
  - ✓ Th1-Th6 – 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



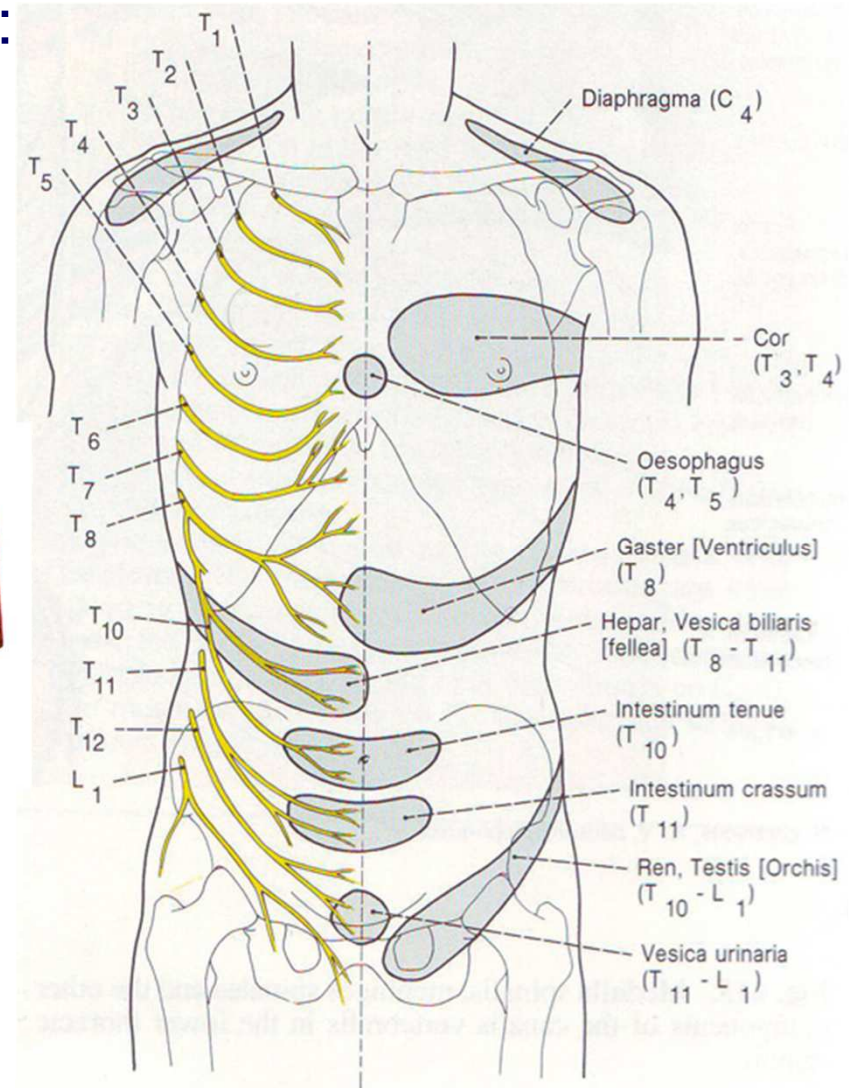
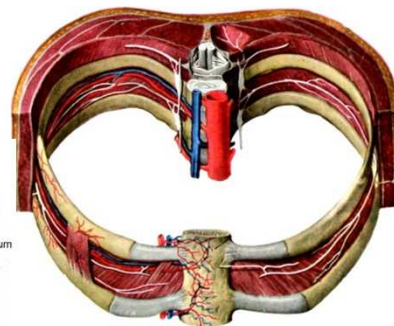


# Ventral rami of the spinal nerves

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



Nn. spinales  
Nn. cervicales  
Nn. thoracici  
Nn. lumbales  
Nn. sacrales  
N. coccygeus





# Cervical plexus, *plexus cervicalis*

- Formation and segmental origin:

- ✓ ventral rami of C1-C4 nerves

- Branches:

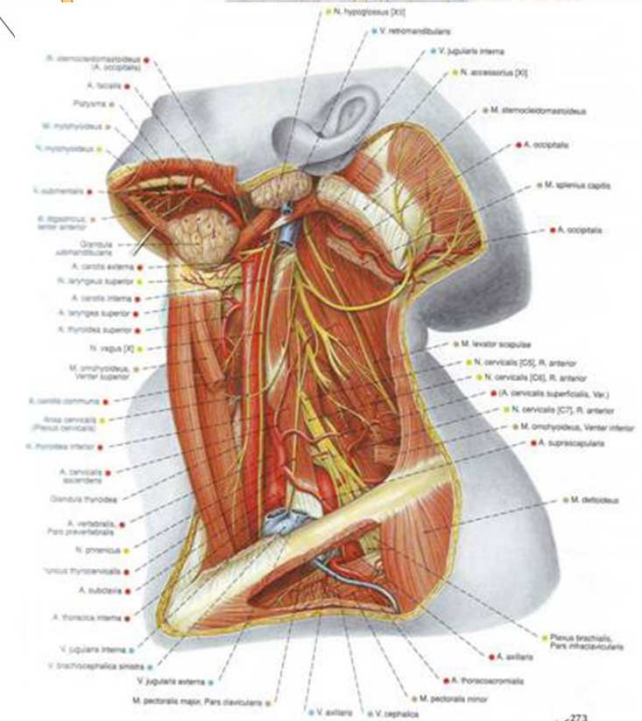
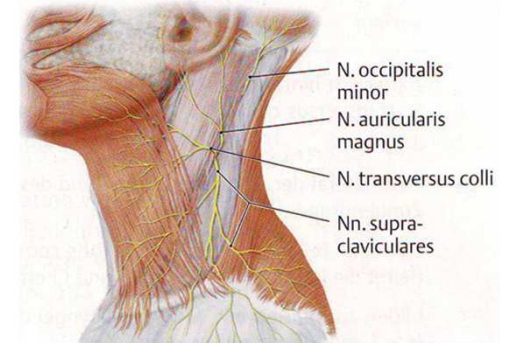
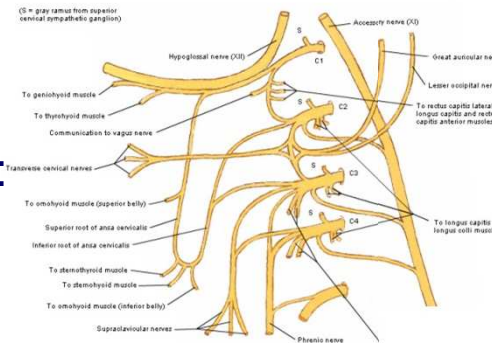
- ✓ superficial (sensory) branches:

- 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

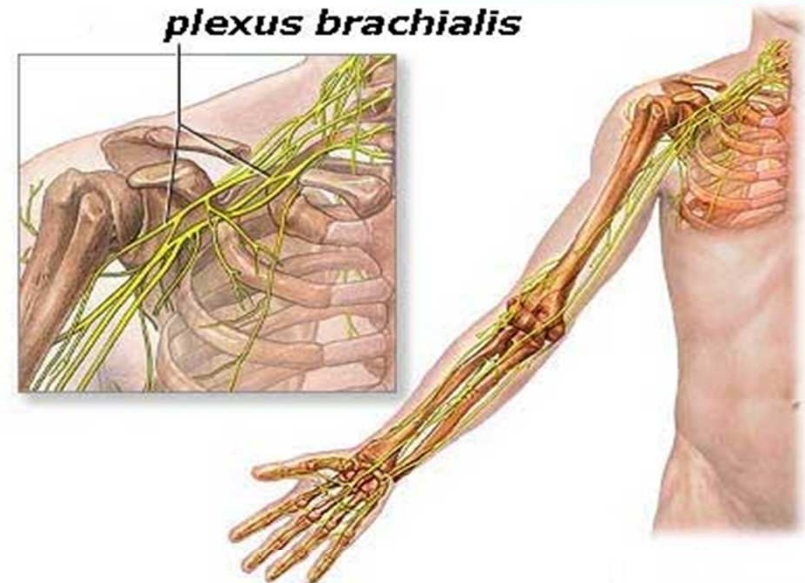




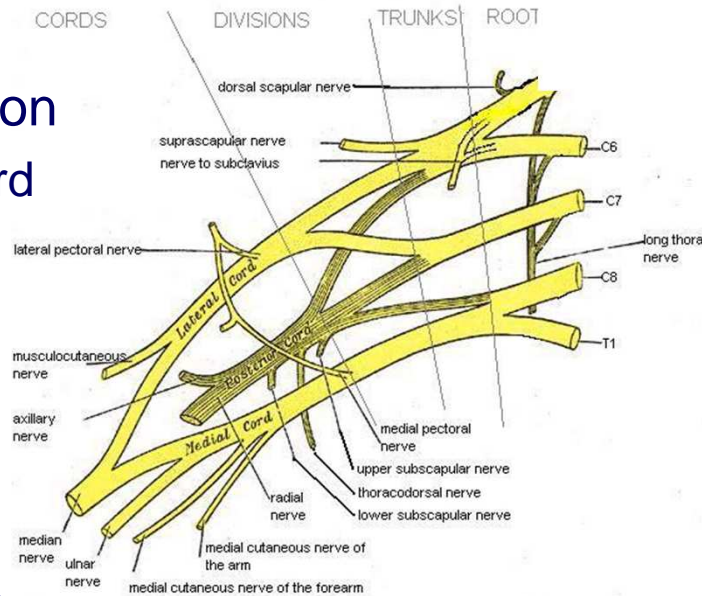


# Brachial plexus, *plexus brachialis*

- 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 Radial Median Axillary Ulnar
C6				
C7	Middle	Post.	Posterior	
C8				
T1	Lower	Ant.	Medial	



# Brachial plexus, *plexus brachialis*

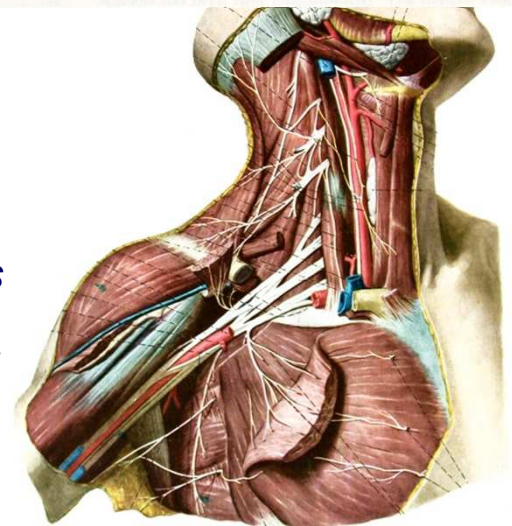
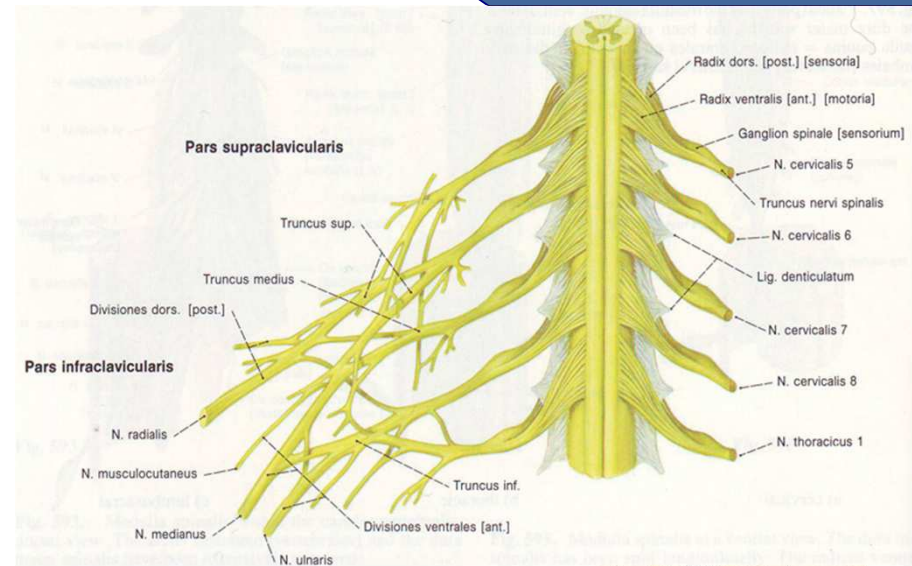
## ■ Main branches:

### ✓ 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*



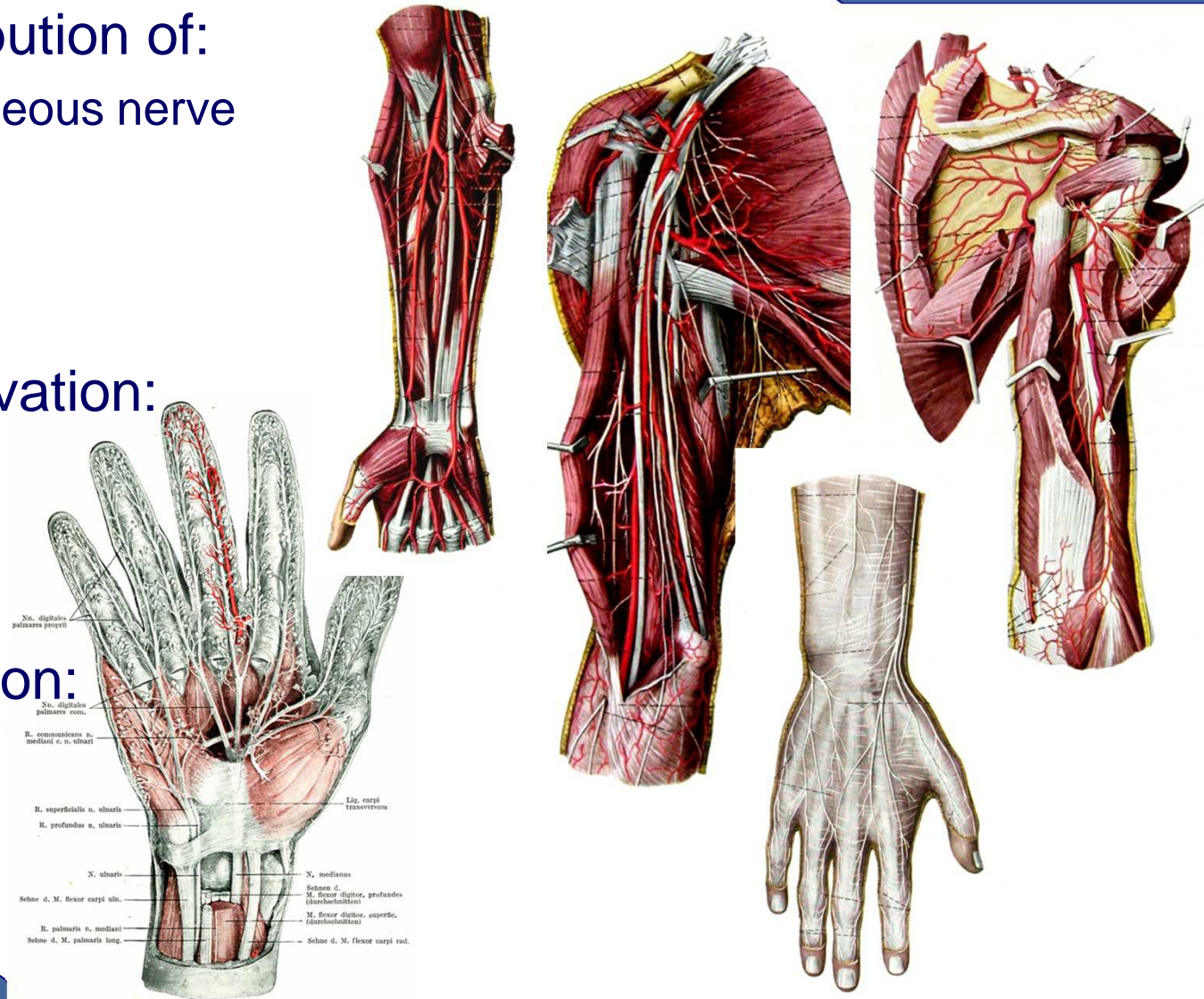


# Brachial plexus, *plexus brachialis*

- 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

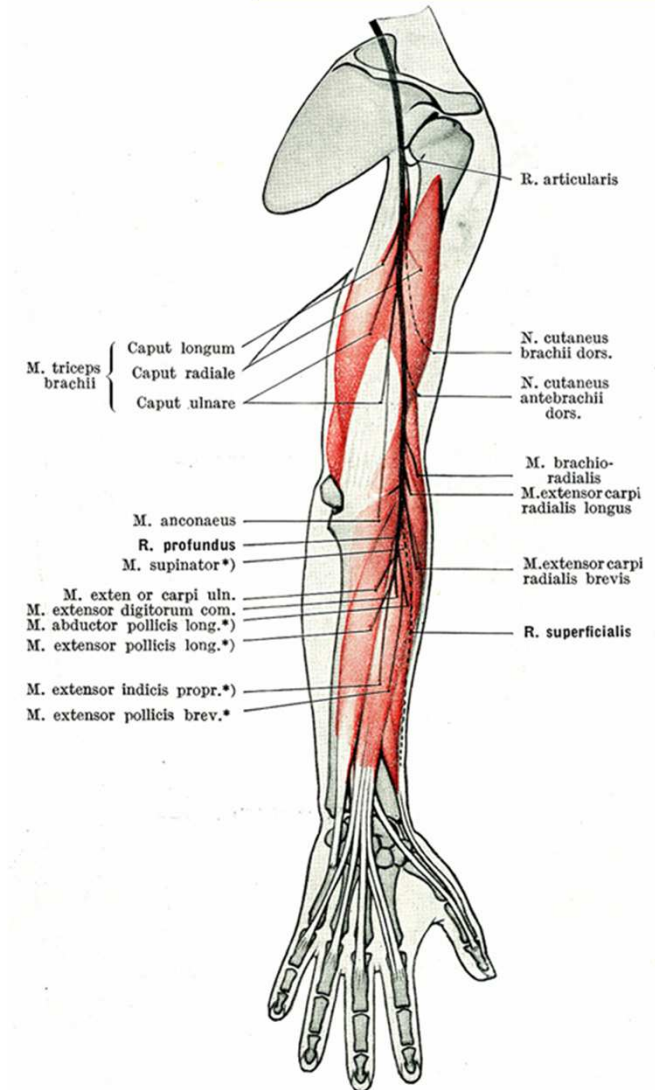
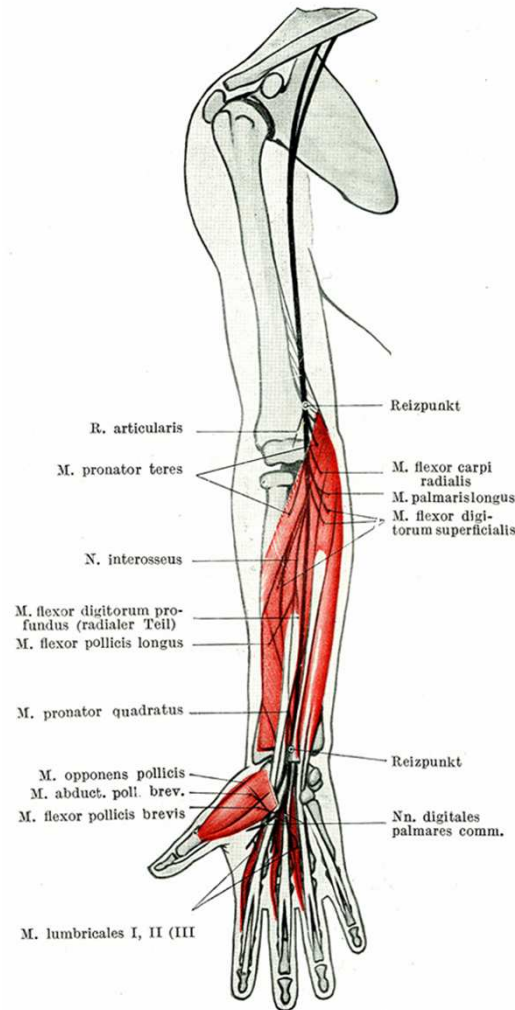
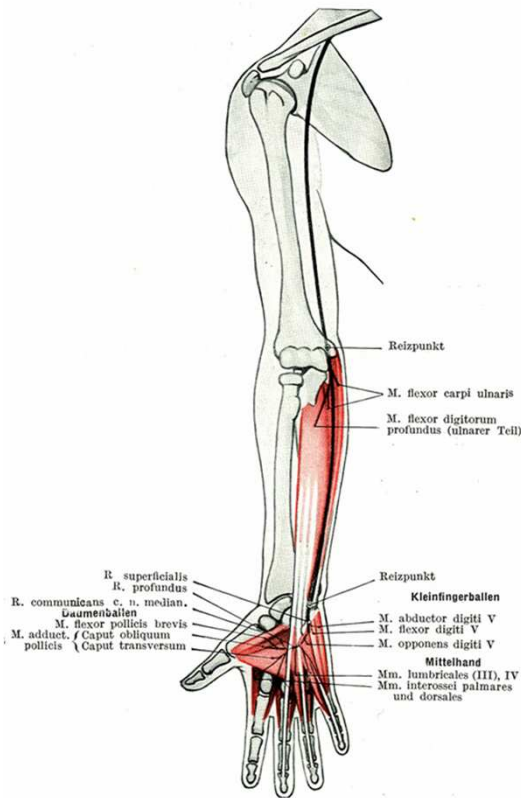




# Muscle innervation of the upper limb

## ■ Muscular branches of:

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



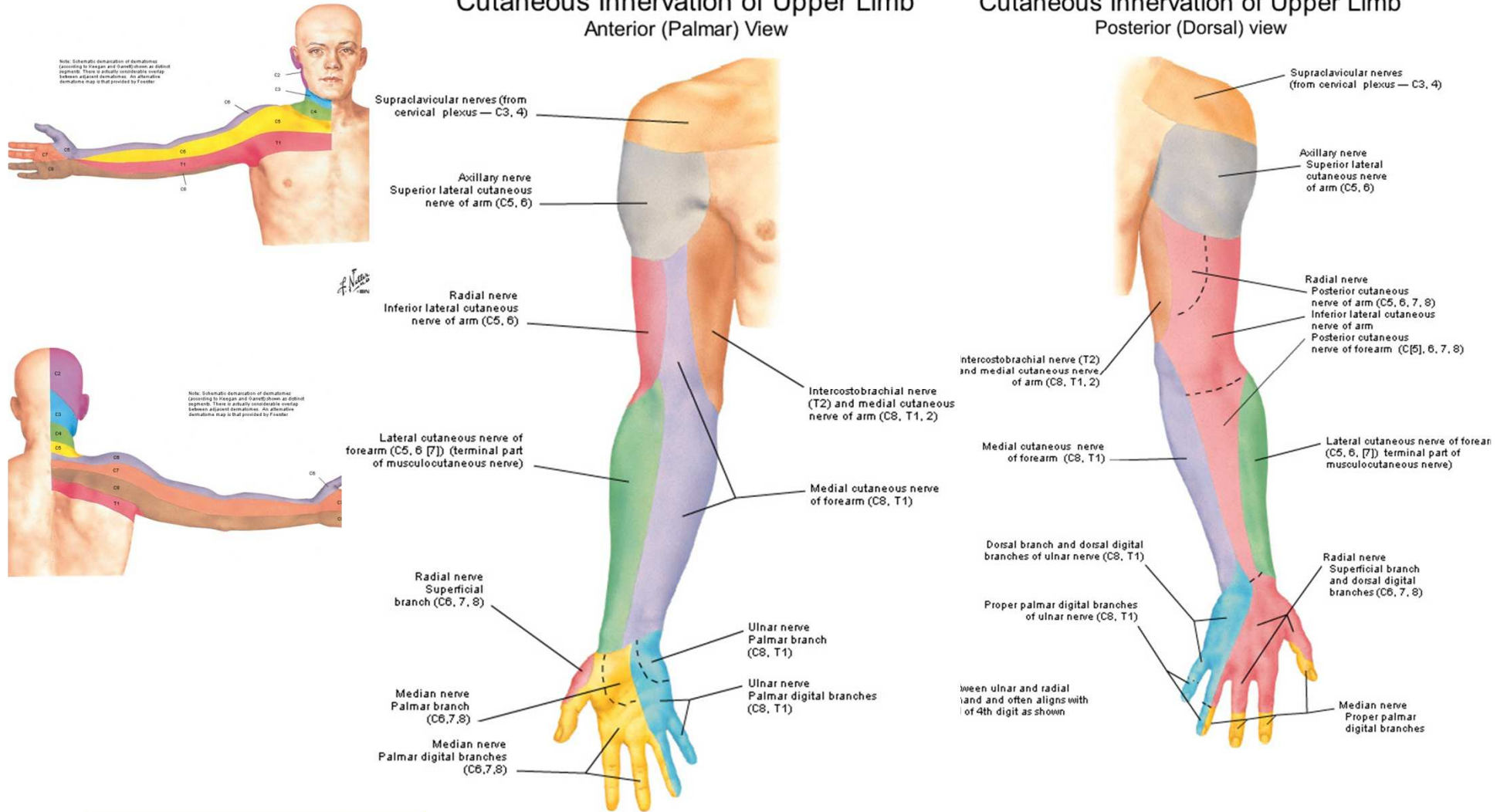


# Cutaneous innervation of the upper limb

Dermatomes of Upper Limb

## Cutaneous Innervation of Upper Limb Anterior (Palmar) View

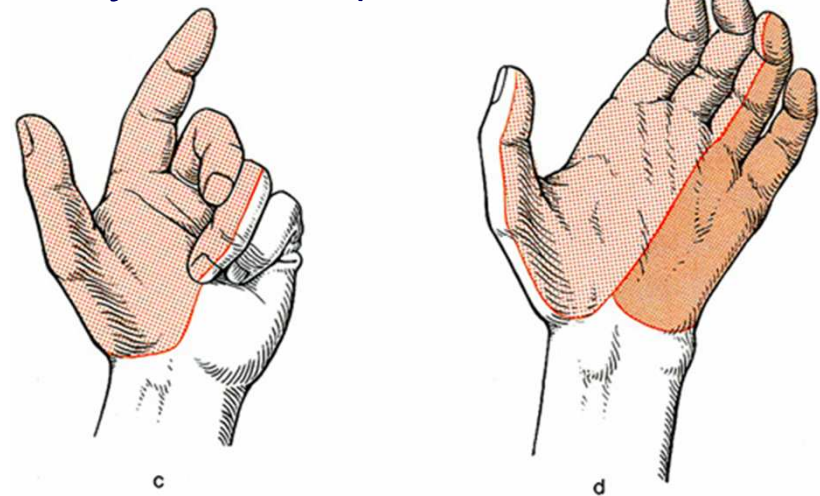
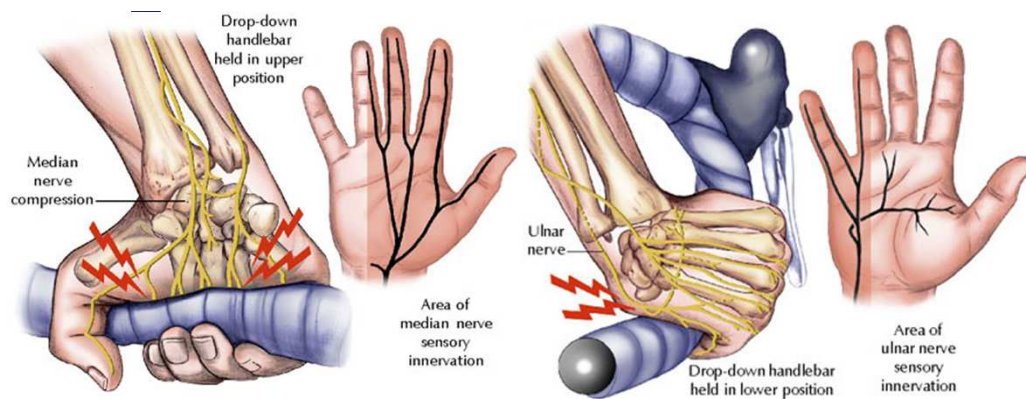
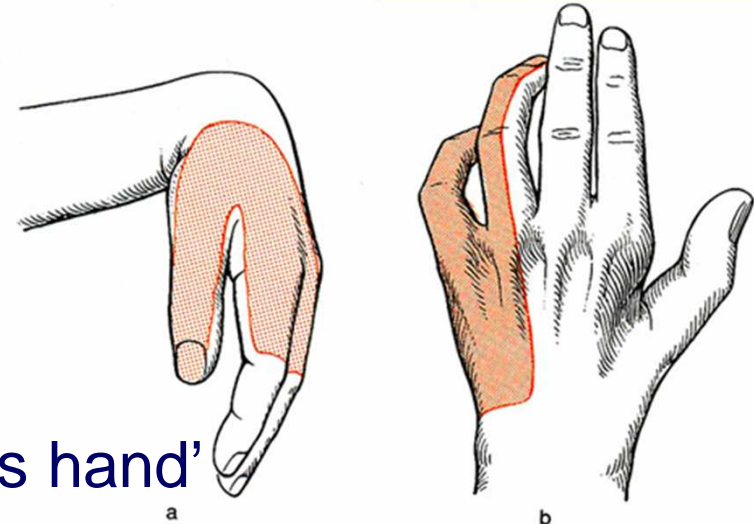
## Cutaneous Innervation of Upper Limb Posterior (Dorsal) view





# Peripheral neuropathies

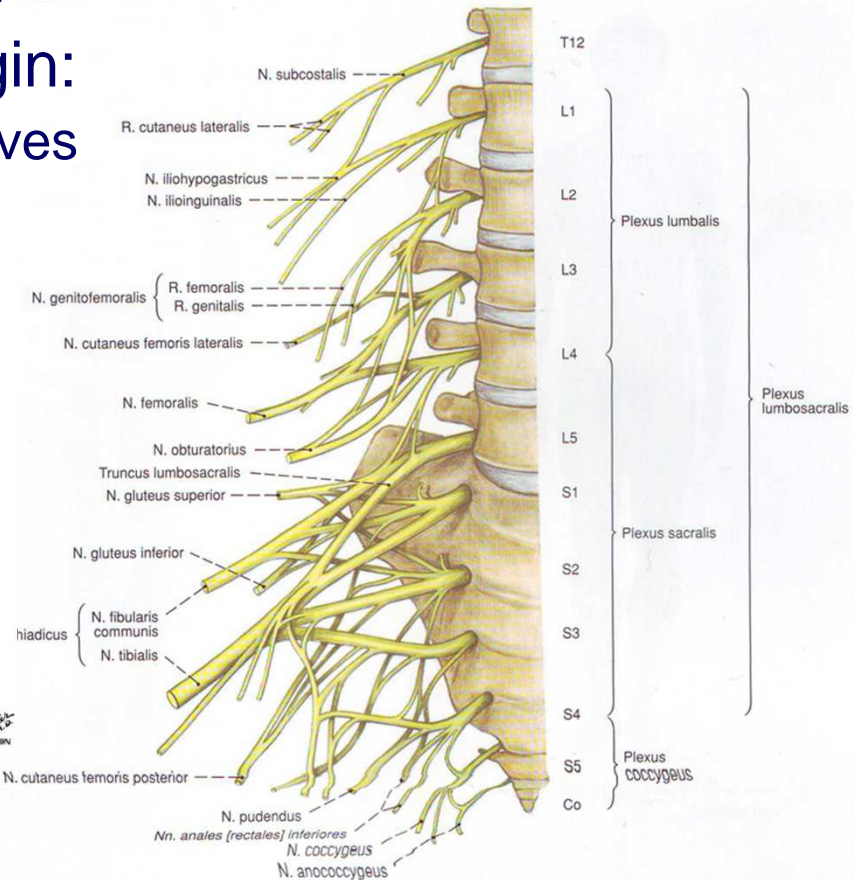
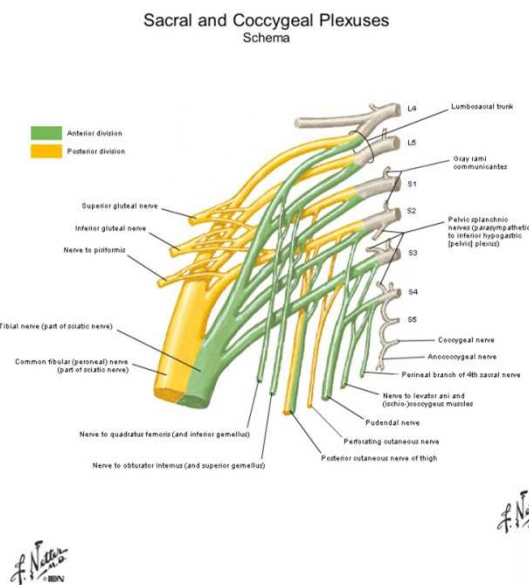
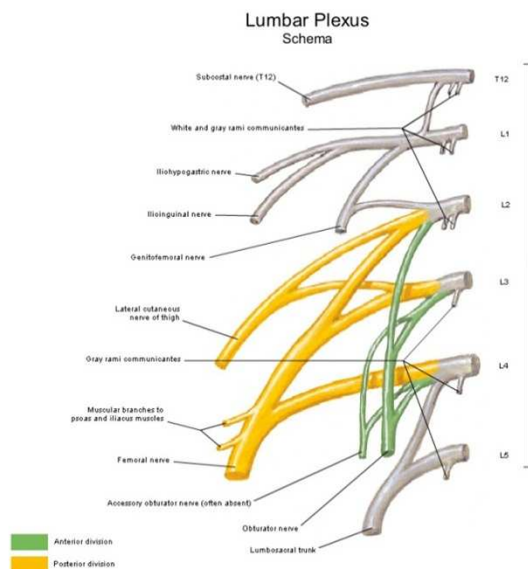
- Radial nerve palsy, wrist drop (Saturday night palsy)
- Ulnar nerve palsy, 'claw hand' handlebar palsy – cyclist's hands
- Median nerve palsy, 'accoucheur's hand' median neuropathy (Carpal tunnel syndrome)





# 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

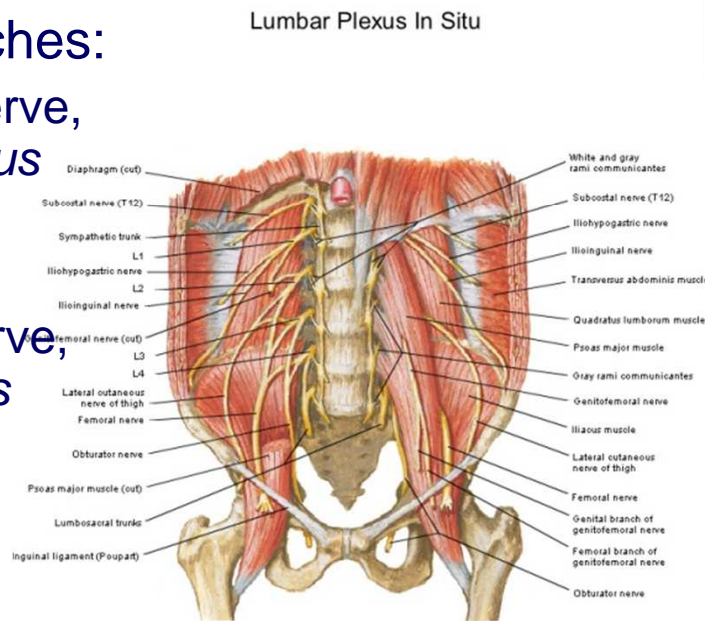
- Coccygeal plexus, *plexus coccygeus*:
  - ✓ ventral rami of S5, Co1



# 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*

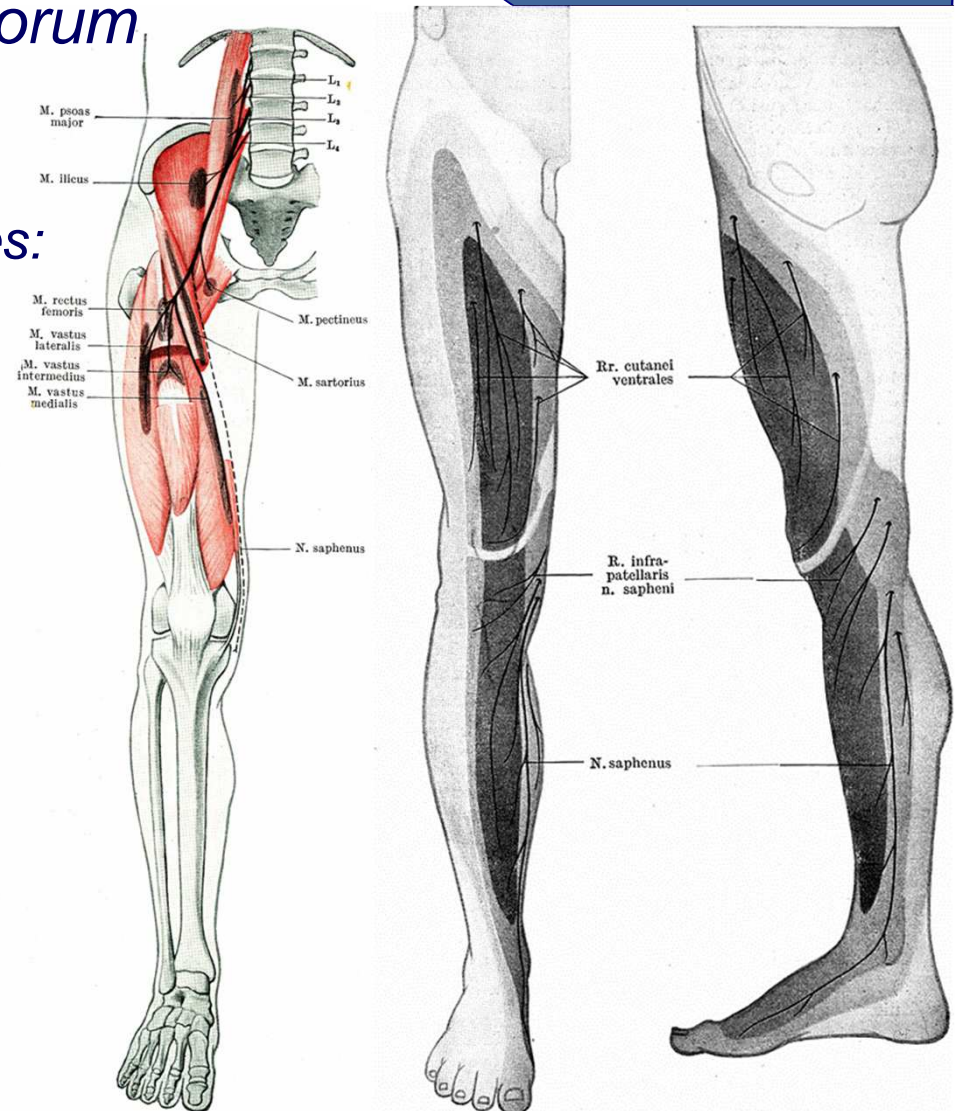
- branches – L2-L4:

✓ 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:

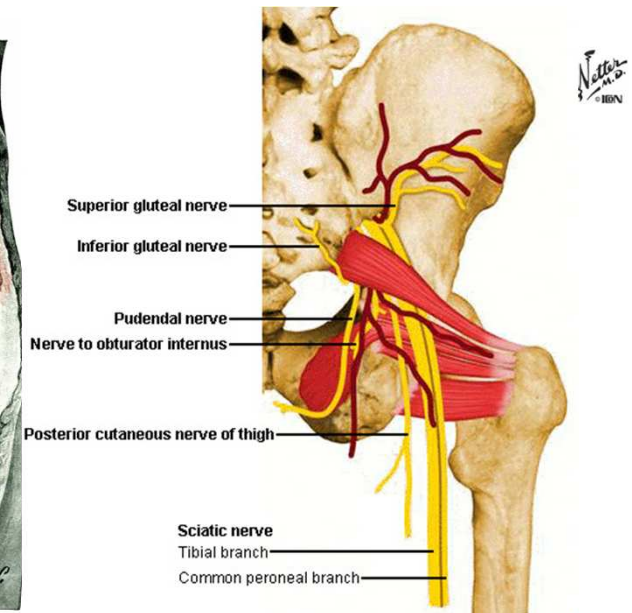
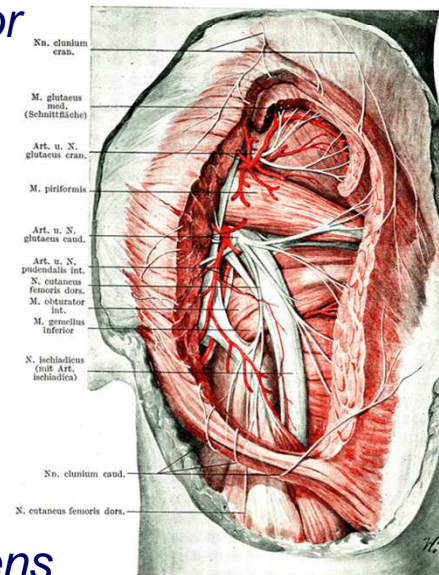
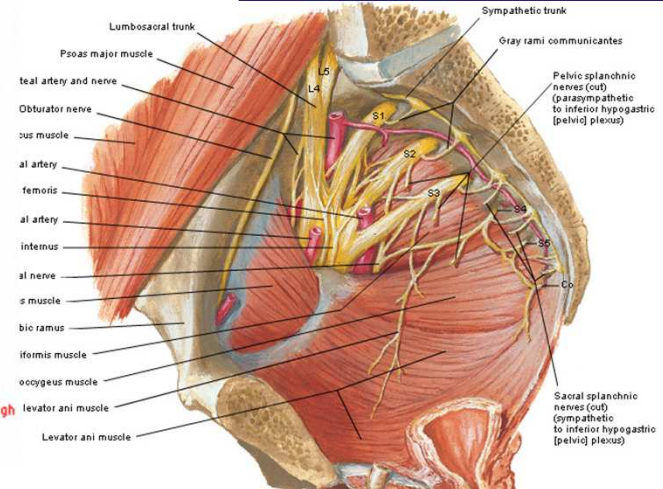
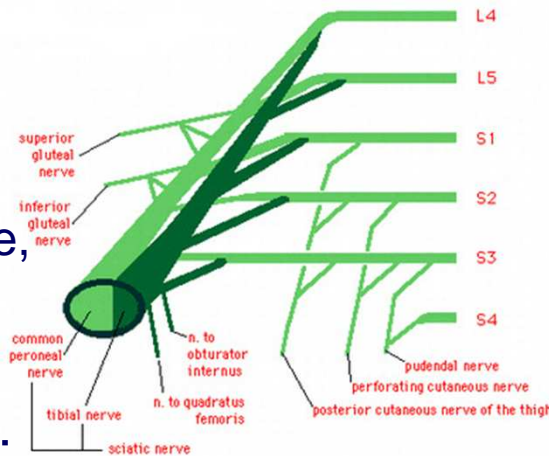
- posterior femoral cutaneous nerve  
*n. cutaneus femoris posterior*

### ✓ sensorimotor branches:

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

### ✓ visceral branch:

- pelvic splanchnic nerve, *nervus erigens*







# Saturday night palsy



*Thank you...*