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

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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 ⅔ 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 suclus – ventral nerve root**
Posterior median septum

- average depth ~ 4-6 mm:
  - diminishing caudally
- neuroglial partition:
  - reaching the gray matter
- posterolateral suclus – 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
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 comissure:**
  - *comissura 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 radiculares)*
    - large alpha motoneurons  *(ACh)*
    - small gamma motoneurons  *(ACh)*
    - Renshaw cells  *(Gly)*
      - (inhibitory interneurons)
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

ventral horn: 5 nuclei
✓ medial group
  ➢ ventromedial nucleus
  ➢ dorsomedial nucleus
✓ lateral group
  ➢ ventrolateral nucleus
  ➢ central nucleus
  ➢ dorsolateral nucleus

lateral horn: 2 nuclei
✓ sympathetic: intermediolateral nucleus (Th1-L2)
✓ parasympathetic: intermediomedial nucleus (S2-S4)
✓ spinal reticular nucleus
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

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Longitudinal extent of the nuclei 15
White matter composition

- composition:
  - 3 columns (funiculi) – ascending and descending tracts
  - nerve fibers
  - glia
  - blood vessels
  - 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 fascilulus, semilunar tract (comma tract of Schultz)
     - 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. Interstitiospinal tract
  6. Solitarius spinal 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
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
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*
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
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

Cutaneous Innervation of Upper Limb
Anterior (Palmar) View

Radial nerve
Inferior lateral cutaneous nerve of arm (C5, 6)

Lateral cutaneous nerve of forearm (C5, 6, 7)
(Terminal part of musculocutaneous nerve)

Superficial branch (C8, 7, 8)

Median nerve
Palmar branch (C8, 7, 8)
Palmar digital branches (C8, 7, 8)

Ulnar nerve
Palmar branch (C8, T1)
Palmar digital branches (C8, T1)

Proper palmar digital branches of ulnar nerve (C8, T1)

Ulnar and radial hand and other digits of 4th digit as shown

Intercostobrachial nerve (T2) and medial cutaneous nerve of arm (C8, T1, 2)

Medial cutaneous nerve of forearm (C8, T1)

Medial cutaneous nerve of arm (C8, T1)

Posterior cutaneous nerve of arm (C5, 6, 7, 8)

Posterior cutaneous nerve of forearm (C5, 6, 7, 8)

Posterior cutaneous nerve of arm (C5, 6, 7, 8)

Axillary nerve
Superior lateral cutaneous nerve of arm (C5, 6)

Supraclavicular nerves (from cervical plexus — C3, 4)

Cutaneous Innervation of Upper Limb
Posterior (Dorsal) view

Radial nerve
Posterior cutaneous nerve of arm (C5, 6, 7, 8)

Median nerve
Superficial branch and dorsal digital branches of ulnar nerve (C8, T1)

Proper palmar digital branches of ulnar nerve (C8, T1)

Dorsal branch and dorsal digital branches of ulnar nerve (C8, T1)

Lateral cutaneous nerve of forearm (C5, 6, 7, 8, terminal part of musculocutaneous nerve)
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*
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

Thank you...