Regional neuroanatomy

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References and images taken from:
• deLahunta and Glass: Veterinary Neuroanatomy and Clinical Neurology, 3rd edition, Saunders, 2009
• Thomson and Hahn: Veterinary Neuroanatomy: a clinical approach, Elsevier, 2012
• Uemura EE. Fundamentals of Canine Neuroanatomy and Neurophysiology, Wiley-Blackwell, 2015
New texts
Definitions

- **Nucleus** is a collection of nerve cell bodies in the **CNS**
- **Ganglion** is a collection of nerve cell bodies in the **PNS**
- **UMN** = upper motor neuron – nerve fibres of the motor system, confined to the **CNS**
- **LMN** = lower motor neuron – nerve fibres of the motor system, with cell bodies in the **CNS**, but majority of the nerve (axon) in the **PNS**, connecting with muscle at NMJ
- **Spinal cord segment** – section of spinal cord to which is attached a pair of dorsal roots and a pair of ventral roots
- **Intumescence** – enlarged region of spinal cord associated with limb innervation (cervical and lumbosacral intumescences)
- **Grey matter** – nerve cell bodies in the **CNS**
- **White matter** – myelinated nerve fibres (axons white because of high lipid content)
- **Tract** - group of neurons from dendrite to synapse, with same function e.g. vestibulospinal tract (CNS); name often tells origin and destination of tract
- **Nerve** group of axons in the periphery (e.g. C5 spinal n., radial n., oculomotor n.)
- **Pathway** – two, or more, tracts in series conveying same neural information, e.g. proprioceptive pathway (PNS and CNS components) – see next slide
Pathway example

Conscious proprioception pathway

• Name of nerve 1?
• Name of tract 2 (spinal cord)?
• Name of tract 3 (brainstem)?
• Name of nucleus A?
• Name of nucleus B?
• Name of pathway termination C?
Functional divisions within the nervous system

- **Brain**
  - Brainstem, cerebellum, forebrain
- **Spinal cord**
  - Cervical, cervical intumescence, thoracolumbar, lumbosacral, caudal
- **PNS**
  - Spinal nerve e.g. C5 spinal nerve
  - Named nerve e.g. radial nerve
- **Somatic and autonomic nervous systems**
**PNS – Spinal nerve anatomy**

Nerve roots
- Sensory (afferent), dorsal attachment
- Motor (efferent), ventral attachment

Fig 12.3 Thomson and Hahn

Evans, fig 16-2
General rule limb innervation
- Cranial intumescence/plexus innervates cranial, proximal limb
- Caudal intumescence/plexus innervates caudal, distal limb
Spinal cord

**Grey matter**
- Central location
- Nerve cell bodies
- Divided into horns
  - Dorsal (sensory)
  - Ventral (motor)
  - Lateral (autonomic)

**White matter**
- Peripheral location
- Axons and myelin
- Funiculi based on nerve root attachment
  - Dorsal – afferent
  - Lateral – afferent, efferent to flexors
  - Ventral – efferent to extensors

Fig 4-5 Thomson and Hahn, legend on next slide

XS K9 thoracic spinal cord
<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>ID</th>
<th>Name</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>Propriospinal (spino-spinal)</td>
<td>I</td>
<td>Lateral corticospinal</td>
</tr>
<tr>
<td>B</td>
<td>Fasciculus gracilis</td>
<td>J</td>
<td>Lateral tectotegmentospinal</td>
</tr>
<tr>
<td>C</td>
<td>Fasciculus cuneatus</td>
<td>K</td>
<td>Medullary (lateral) reticulospinal</td>
</tr>
<tr>
<td>D</td>
<td>Dorsolateral fasciculus</td>
<td>L</td>
<td>Pontine (ventral) reticulospinal</td>
</tr>
<tr>
<td>E</td>
<td>Dorsal spinocerebellar</td>
<td>M</td>
<td>Lateral vestibulospinal</td>
</tr>
<tr>
<td>F</td>
<td>Ventral spinocerebellar</td>
<td>N</td>
<td>Tectospinal</td>
</tr>
<tr>
<td>G</td>
<td>Spinothalamic</td>
<td>O</td>
<td>Ventral corticospinal</td>
</tr>
<tr>
<td>H</td>
<td>Rubrospinal</td>
<td>P</td>
<td>Medial vestibulospinal and medial longitudinal fasciculus</td>
</tr>
</tbody>
</table>

Table legend for XS of spinal cord WM on previous slide.
The vestibulospinal tract runs in the ______________ funiculus.

(Hint: what is the function of this tract?)
CNS – spinal cord

– Functional regions
  • Based on origin of limb innervation
  • e.g. dog?
– Species differences – number of segments
  • How many thoracic segments horse c/w cat?
  • No. spinal cord segments ≠ no. vertebrae
– Regional differences
  • Shape of grey and white matter (to follow)
Functional SC division based on limb innervation

Fig 1.2 Thomson and Hahn
Differentiating anatomical levels of spinal cord sections

- **Shape**
  - Cervical cord oval, thoracic is circular
- **Size**
  - Intumescence vs non-intumescence
- **WM:GM**
  - Cervical > lumbar
- **Shape of dorsal horn apex**
  - Cervical-pointed, thoracic-blunted, lumbar-rectangular
- **Size of ventral horn**
  - Intumescence vs non-intumescence
- **Cranial to T7**
  - Both fasciculus gracilis and cuneatus, and therefore dorsal intermediate sulcus
- **C1**
  - Pyramidal decussation,
  - Nucleus gracilis and cuneatus
- **Intermediate (lateral horn)**
  - T1-L3 segments
  - Sacral segments
- **Dorsal median fissure**
  - Lumbar and sacral
- **Caudal lumbar and sacral**
  - Cauda equina

From Dr. C. S. Bailey, UC Davis
Species difference number of vertebrae

<table>
<thead>
<tr>
<th>Animal</th>
<th>Cervical</th>
<th>Thoracic</th>
<th>Lumbar</th>
<th>Sacral</th>
<th>Caudal</th>
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<tbody>
<tr>
<td>Dog &amp; cat</td>
<td>7</td>
<td>13</td>
<td>7 (occas. 6)</td>
<td>3</td>
<td>20+</td>
</tr>
<tr>
<td>Horse</td>
<td>7</td>
<td>18</td>
<td>6</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>Ox</td>
<td>7</td>
<td>13</td>
<td>6</td>
<td>5</td>
<td>18-20</td>
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<tr>
<td>Sheep</td>
<td>7</td>
<td>13</td>
<td>6(7)</td>
<td>4</td>
<td>16-18</td>
</tr>
<tr>
<td>Goat</td>
<td>7</td>
<td>13</td>
<td>6(7)</td>
<td>5</td>
<td>16-18</td>
</tr>
<tr>
<td>Swine</td>
<td>7</td>
<td>14-15</td>
<td>6-7</td>
<td>4</td>
<td>20-23</td>
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<tr>
<td>Camelid</td>
<td>7</td>
<td>12</td>
<td>7</td>
<td>4</td>
<td>13-15</td>
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<tr>
<td>Bird</td>
<td>8-25</td>
<td>7 – four</td>
<td>Synsacrum – last 1-2</td>
<td>5-6 free</td>
<td>5-6 free</td>
</tr>
<tr>
<td></td>
<td></td>
<td>fuse to</td>
<td>thoracic, plus the</td>
<td>vertebrae,</td>
<td>vertebrae,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>form</td>
<td>lumbar, sacral and first</td>
<td>then</td>
<td>then</td>
</tr>
<tr>
<td></td>
<td></td>
<td>notarium</td>
<td>caudal vertebrae</td>
<td>pygostyle</td>
<td>pygostyle</td>
</tr>
</tbody>
</table>

Table 1.3, Thomson and Hahn
Functional regions of the brain

- Anatomical regions
  - Tel Di Mes Met My
- Functional regions
  - Brainstem
    - Myelencephalon
      - Medulla oblongata
    - Pons
      - ventral metencephalon
    - Mesencephalon
      - midbrain
  - Cerebellum
    - Dorsal metencephalon
  - Forebrain
    - Thalamic structures
      - Diencephalon
    - Cerebral hemispheres
      - Telencephalon
Functional NA of the brainstem

Fig 1.7 Thomson and Hahn

Fig 10.2 Thomson and Hahn
Brainstem function CNN and nuclei

- CNN III-XII and their nuclei
  - Sensory
    - CNN V, VII, VIII, IX, X,
    - Nuclei: solitary (VII, IX, X – visceral afferents from body, and taste), trigeminal sensory (V, VII, IX, X), vestibular, cochlear
  - LMN – CNN III-VII, IX-XII
    - Nuclei: oculomotor, trochlear, trigeminal, abducens facial, ambiguus (IX, X, XI to striated muscle), hypoglossal
  - Parasympathetic to head and body
    - CNN III, VII, IX, X
    - Nuclei: parasympathetic nucleus of III, VII, IX, X

- Sensory
  - Nuclei – gracilis, cuneatus (medial); lateral cuneate nucleus (cuneate and spinocerebellar)
  - Trapezoid nuclei (auditory pathway – trapezoid nuclei, lateral lemniscus)
  - Colliculi – rostral and caudal – auditory and visual grasp

- Motor
  - UMN semi automatic motor function and pattern generators
    - Posture, gait, breathing, chewing, swallowing, urination
    - Nuclei – red (rubrospinal), tectum (medial tectospinal – visual grasp; lateral tectotegmentospinal – sympathetic UMN to head), vestibular (vestibulospinal), reticular (reticulospinal – medullary and pontine = part of descending reticular formation)
  - Control circuits
    - Substantia nigra – mesencephalon, forebrain-basal nuclei circuits

- Mentation
  - Arousal – ARAS (ascending reticular activating system)

- Visceral control centres
  - Reticular formation (see ANS lecture)
    - respiratory, cardiovascular, vomiting centres, swallowing, coughing, micturition centre
Brainstem function – relays

- **Relay** (transmission neurons) and WM tracts
  - Rostrally directed
    - May synapse in or pass through the brainstem.
    - Sensory relay from limbs, trunk and head
      - Tactile – fasciculus cuneatus and gracilis, medial lemniscus
      - Thermal – spinothalamic,
      - Nociception – Spinocervicothalamic, spinoreticulothalamic
    - Proprioceptive relay from limbs, trunk and head
      - Nucleus gracilis and cuneatus, medial lemniscus
      - Spinocerebellar
      - Spinovestibular
  - Caudally directed
    - From forebrain motor areas via crus cerebri
      - Brainstem for CNN function (corticonuclear tracts)
      - Spinal cord for trunk and limb function (corticospinal tracts)
      - Cerebellum via pontine nuclei and transverse fibres of the pons (corticopontine tract)
      - Reticular formation (corticoreticular tract)
    - From midbrain
      - Inhibitory to nociception – periaqueductal grey matter (mesencephalon) and nucleus raphe magnus (myelencephalon) to spinal cord dorsal horn
  - Other
    - Olivary nucleus – relay from cerebrum and midbrain to cerebellum
    - Locus ceruleus – widespread to brain and SC, NAd inhibition of excitation
Cerebellum

- Dorsal metencephalon
  - Vermis - 10 lobules
  - Two hemispheres
  - Flocculonodular lobe

Fig 7.1 Thomson and Hahn
Fig A8 Thomson and Hahn
Grey matter
- Cortex – 3 layers
- Cerebellar nuclei
White matter
- Arbor vitae
- Lamina of the folia
- Cerebellar peduncles
Cerebellar peduncles

- Rostral
  - Primarily efferents to mid and forebrain
  - One afferent (Ventral SCT)
- Middle
  - Primarily corticopontine afferents
- Caudal
  - Spino and vestibulocerebellar afferents
  - Efferents to myelencephalon
  - Juxtarestiform body – efferents, including to vestibular nuclei
  - Restiform – spinal and brainstem connections

Fig 7.3B Thomson and Hahn
Parasagittal section
Functional NA of the cerebellum

Functional regions
- **Dark green**
  - Vestibulocerebellum
  - Vestibular function
- **Mid green**
  - Spinocerebellum
  - Trunk and limb movement
- **Light green**
  - Pontocerebellum
  - Skilled movement

Fig 7.4a Thomson and Hahn
Cerebellum rolled out flat, star on primary fissure
Functional zones
Species difference

Species specific structure
- Medial vs lateral portions
- Snakes c/w mammals c/w primates

Fig 7.4 Thomson and Hahn
Trout brain, dorsal aspect

Human head, horizontal section through brainstem and cerebellum,
Gray’s Anatomy, 39th edition, Fig 20.1, p 354,
Forebrain Anatomy

• Components
  – 1) Diencephalon
    • ‘…thalamic’ structures
    • 1 = interthalamic adhesion
  – 2) Telencephalon
    • Cerebral hemispheres

Dog brain, median section, MRI, T2
Diencephalon

- Components
  - Thalamus
    - with interthalamic adhesion *
  - Hypothalamus
  - Epithalamus – pineal gland
  - Subthalamus
  - Metathalamus
    - Geniculate nuclei (G)
      - Lateral and medial
      - vision and audition pathways
Diencephalon – Thalamus

- Functions – relay station
  - ‘post office’
  - 1) Direct cortical projection
    - National and international mail
      - All sensory systems except olfaction
        - Special senses, conscious proprioception, nociception,
  - 2) Local cortical connections
    - Local mail
      - Diencephalon <-> telencephalon interconnections
  - 3) Thalamic ascending reticular activating system (ARAS)
    - Blanket mail shots
      - Diffuse arousal of telencephalon
Clinical Signs of Thalamic Dysfunction

- Direct cortical projection
  - Sensory deficits
    - e.g. proprioceptive deficits, facial hypalgesia

- Local cortical connections
  - Seizures

- Thalamic reticular system
  - ARAS
  - Altered mentation
Diencephalon – Hypothalamus

• Nuclei
  – Supraoptic – ADH/vasopressin
  – Paraventricular – oxytocin
  – Suprachiasmatic – sleep/wake cycle
  – Ventromedial – appetite control

• Autonomic NS regulation
  – Temperature regulation

• Neurohypophysis
  – part of pituitary gland

On the MRI, which structure is the hypophysis?

Dog brain, median section
Telencephalon

- Definitions
  - Cerebrum, cerebral hemisphere, cerebral cortex
- Sulci and gyri
  - Species difference
  - Lissencephalic
    - Lagomorphs and rodents c/w most domestic spp.
- Longitudinal fissure + falx cerebri
- Transverse fissure + tentorium cerebelli

Equine, dog, rabbit, and bird (B) brains dorsal aspect; Thomson & Hahn 1-8
Telencephalon

- **Lobes**
  - **Frontal**
    - Motor cortex (skilled)
    - Somatosensory cortex
  - **Parietal**
    - Cognition
  - **Temporal**
    - Memory,
    - Audition, vestibular
    - Taste
  - **Occipital**
    - Vision
  - **Piriform**
    - Rhinencephalon
    - Olfaction

Thomson and Hahn, 1.10

Functional areas of the forebrain Jenkins 16-10
Functional areas of telencephalon

Thomson and Hahn, 1.11, dog and cat brains

Motor cortex – learned / skilled motor function
c/w brainstem motor nuclei – semi-automatic motor function
Telencephalon: white matter

- **WM Fibre types**
  - **1) Commissural** – connecting the hemispheres
    - Corpus callosum – cerebrum interconnection
    - Rostral – olfactory and limbic system connections
    - Hippocampal
    - Caudal
  - **2) Association fibres**
    - Corticocortical, ipsilateral
    - Short – b/w gyri
    - Long – b/w lobes
  - **3) Projection fibres**
    - Corticopetal (afferent)
    - Corticofugal (efferent)
    - Internal capsule – corticofugal

Dog brain, Thomson and Hahn 1.13

Dog brain, Thomson and Hahn 1.12
Telencephalon – GM

- Superficial GM
  - Cerebral cortex
- Deep GM
  1) Basal nuclei
     - GM + WM = corpus striatum
     - Primary connections with cerebral cortex
  2) Hippocampus
     - Part of the limbic system
     - Behaviour, learning, memory
  3) Septal nuclei
     - Behaviour (sexual and aggressive)
Telencephalon – Basal Nuclei

• Function
  – Storage of motor patterns / rituals
  – Modify learned motor activity
    • Planning
    • Regulation
    • Execution
  – Neostriatum
    • Caudate and putamen nuclei
    • Inhibitory influence
    • Lesions → hyperactivity and hypertonus
      – Obstinate progression = head pressing
    • Hyperkinaesias?
  – Paleostriatum
    • Globus pallidus
    • Facilitatory influence
    • Lesions → hypoactivity and hypotonus

www.pawfun.com/
Cerebral peduncles c/w crus cerebri

Cerebral peduncles
• tegmentum (reticular, CNN and red nuclei), substantia nigra and crus cerebri

Crus cerebri
• efferents from cortex
  • Corticopontine, corticonuclear, corticospinal tracts
Forebrain functions 1

- Diencephalon
  - Connections
    - Sensory (rostrally directed)
    - Skilled motor (caudally directed)
  - Autonomic functions
    - Temperature, hormonal, ANS control
  - ARAS – mentation

- Telencephalon
  - Neocortex (neopallium)
    - Projection areas (primary receiving)
      - Somatosensory – from body (soma)
        » Exteroceptors
        » Proprioceptors – tactile
        » Interoceptors – visceral
    - Special senses
      - Vision, audition, balance, olfaction
    - Association areas
      - Processing afferent information
      - e.g. cognition – parietal lobe
    - Motor (skilled)
  - Archicortex (archipallium)
    - Limbic system
      - behavior, memory, emotion
  - Paleocortex (paleopallium)
    - Ventral to lateral rhinal sulcus
    - Rhinencephalon – olfaction
  - (Allocortex – archi + paleocortex)
  - Basal nuclei
    - Modification of motor function
**Blood-brain barrier**

**Components?**

**Absent**
- choroid plexus, hypophysis, pineal gland, area postrema

**How do substances get into the CNS?**
- Diffusion – Gases
- Molecular transporters
  - e.g. glucose, amino acids

**Blood-CSF barrier**
- Fenestrated endothelium
- Basement membrane
- Ependymal cells with tight junctions

Diseases often lead to leaky vasculature