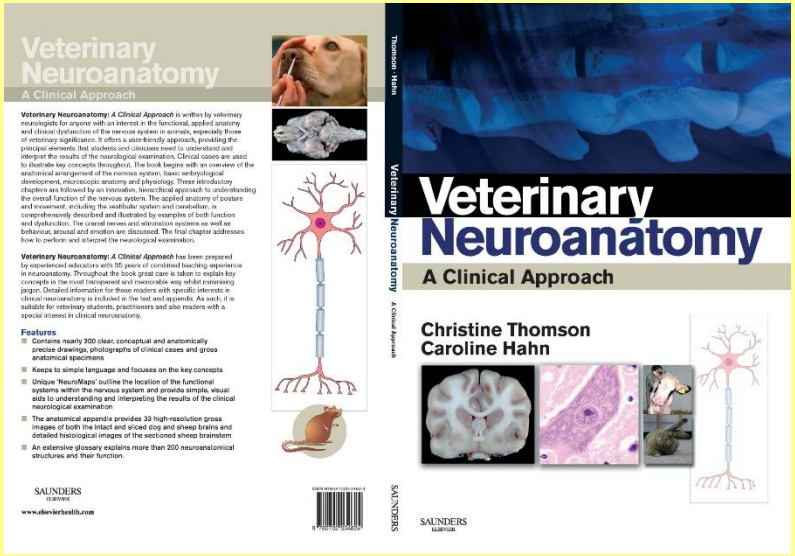
Regional neuroanatomy

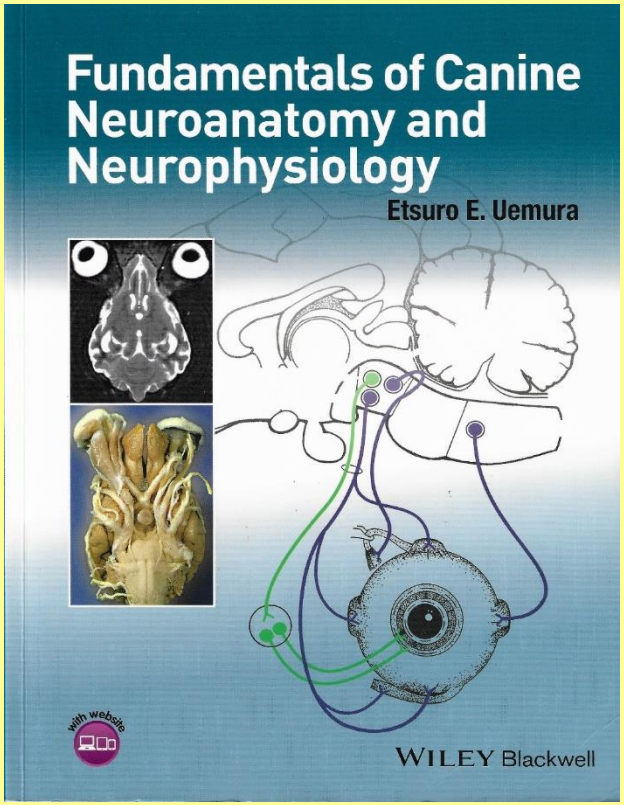
Chris Thomson
BVSc(Hons), Dip ACVIM (Neurol), Dip ECVN, PhD
Associate Professor Neurobiology,
Dept. of Vet. Med.,
University of Alaska, Fairbanks,
Alaska.

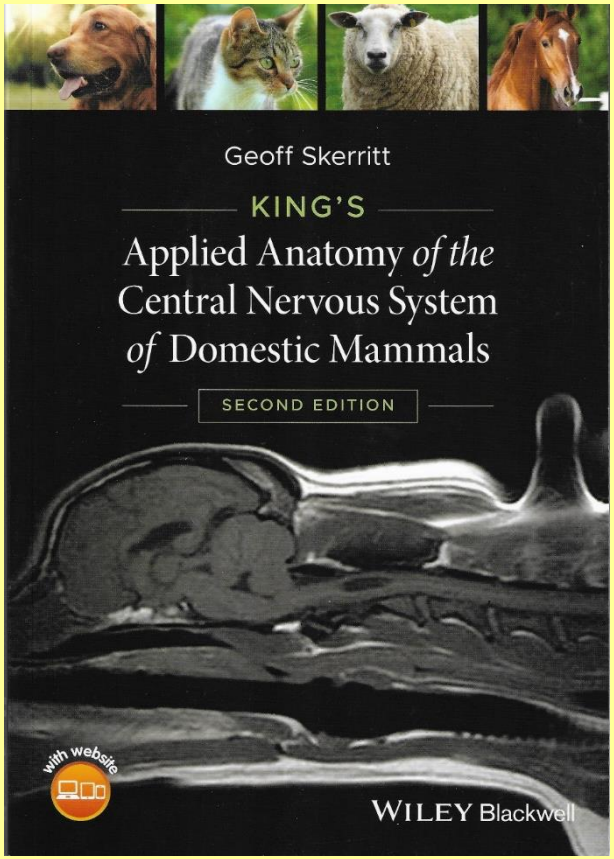
References and images taken from:

- deLahunta and Glass: Veterinary Neuroanatomy and Clinical Neurology, 3rd edition, Saunders, 2009
- Dyce: Textbook of veterinary anatomy, 4th edition, Saunders, 2010
- Evans HE. Miller's Anatomy of the Dog, 3rd Edition, Saunders, Philadelphia, 1993
- Gray's Anatomy. The Anatomical Basis of Clinical Practice, Ed Standring S. 39th Edition, Elsevier, Edinburgh, 2005
- Jenkins TW. Functional Mammalian Neuroanatomy. 2nd Edition, Lea & Febiger, Philadelphia, 1978
- King A.S. Physiological and clinical anatomy of the domestic animals /; v. 1. Central nervous system. Oxford; New York : Oxford University Press, 1987
- Thomson and Hahn: Veterinary Neuroanatomy: a clinical approach, Elsevier, 2012
- Uemura EE. Fundamentals of Canine Neuroanatomy and Neurophysiology, Wiley-Blackwell, 2015
- Vandevelde M, Higgins RJ, Oevermann A. Veterinary Neuropathology. Essentials of theory and practice, Wiley-Blackwell, 2012

New texts


Veterinary Neuroanatomy
A Clinical Approach
Veterinary Neuroanatomy: A Clinical Approach is written by veterinary neurologists for anyone with an interest in the functional, applied anatomy and clinical dysfunction of the nervous system in animals, especially those of veterinary significance. It offers a user-friendly approach, providing the principal elements that students and clinicians need to understand and interpret the results of the neurological examination. Clinical cases are used to illustrate key concepts throughout. The book begins with an overview of the anatomical arrangement of the nervous system, basic embryological development, microscopic anatomy and physiology. These introductory chapters are followed by an innovative, hierarchical approach to understanding the overall function of the nervous system. The applied anatomy of posture and movement, including the vestibular system and cerebellum, is comprehensively described and illustrated by examples of both function and dysfunction. The cranial nerves and elimination systems as well as behaviour, arousal and emotion are discussed. The final chapter addresses how to perform and interpret the neurological examination.
Veterinary Neuroanatomy: A Clinical Approach has been prepared by experienced educators with 55 years of combined teaching experience in neuroanatomy. Throughout the book great care is taken to explain key concepts in the most transparent and memorable way whilst minimising jargon. Detailed information for those readers with specific interests in clinical neuroanatomy is included in the text and appendix. As such, it is suitable for veterinary students, practitioners and also readers with a special interest in clinical neuroanatomy.
Features
Contains nearly 300 clear, conceptual and anatomically precise drawings, photographs of clinical cases and gross anatomical specimens
Keeps to simple language and focuses on the key concepts
Unique 'NeuroMaps' outline the location of the functional systems within the nervous system and provide simple, visual aids to understanding and interpreting the results of the clinical neurological examination
The anatomical appendix provides 33 high-resolution gross images of both the intact and sliced dog and sheep brains and detailed histological images of the sectioned sheep brainstem
An extensive glossary explains more than 200 neuroanatomical structures and their function.
SAUNDERS
www.elsevierhealth.com
Thomson · Hahn
Veterinary Neuroanatomy
A Clinical Approach
Christine Thomson
Caroline Hahn
SAUNDERS


Fundamentals of Canine Neuroanatomy and Neurophysiology
Etsuro E. Uemura
with website
WILEY Blackwell


Geoff Skerritt
KING'S
Applied Anatomy of the Central Nervous System of Domestic Mammals
SECOND EDITION
with website
WILEY Blackwell

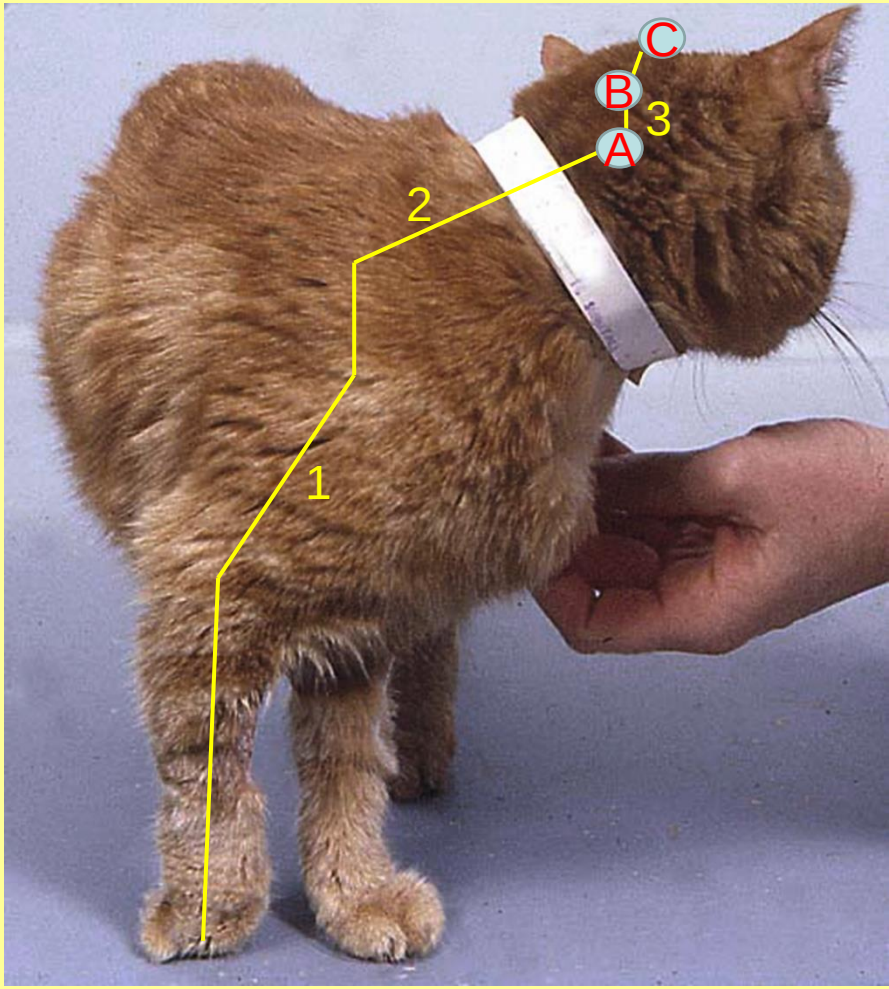
Definitions

- 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

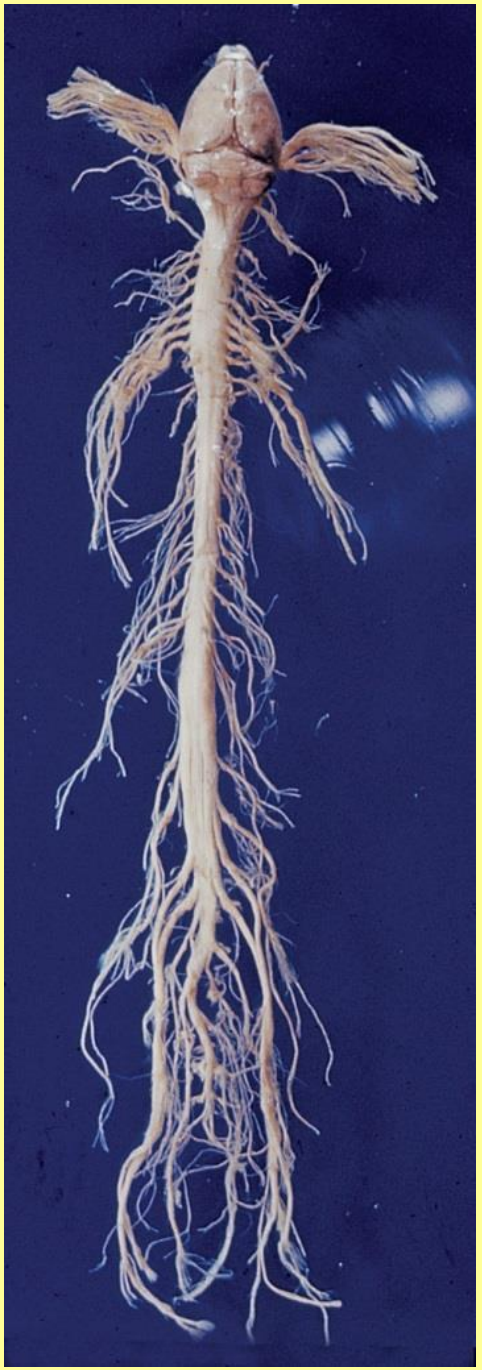
Conscious proprioception pathway

- 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



Rat nervous system, Courtesy of Dr. Anna Fails, CSU

PNS – Spinal nerve anatomy

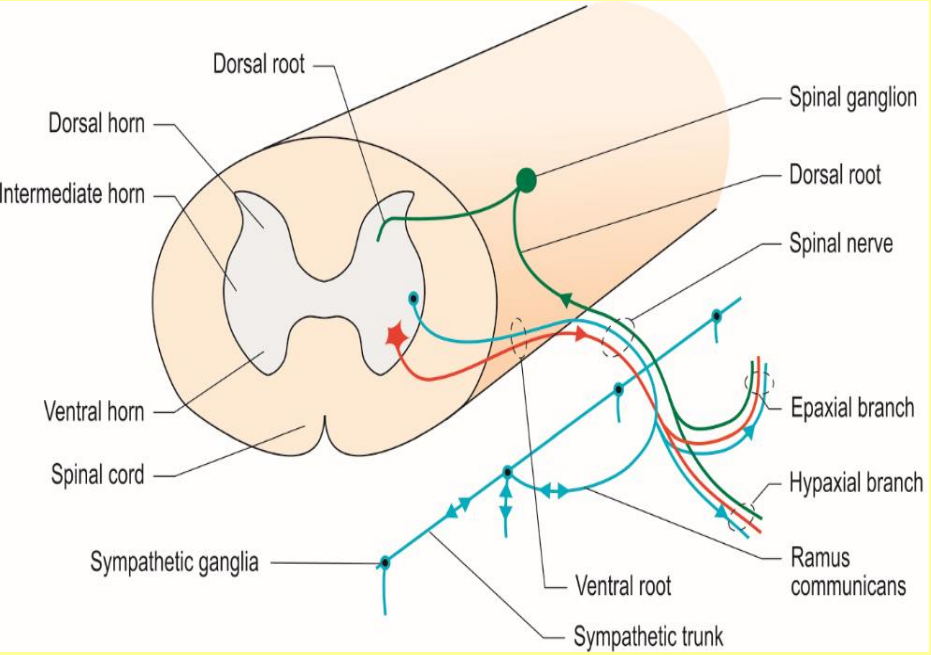
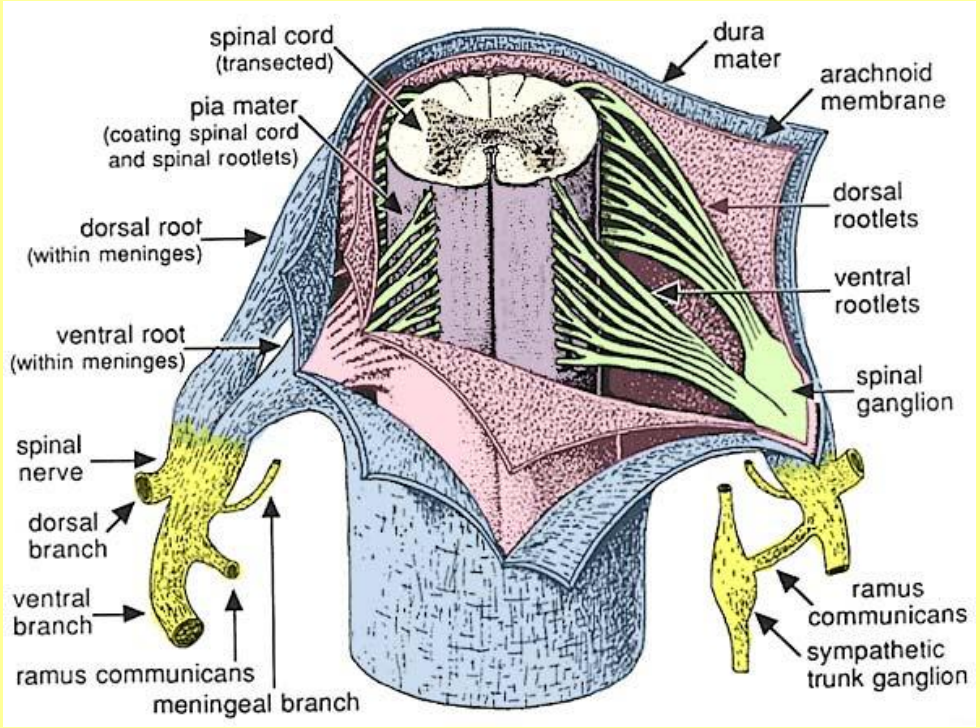


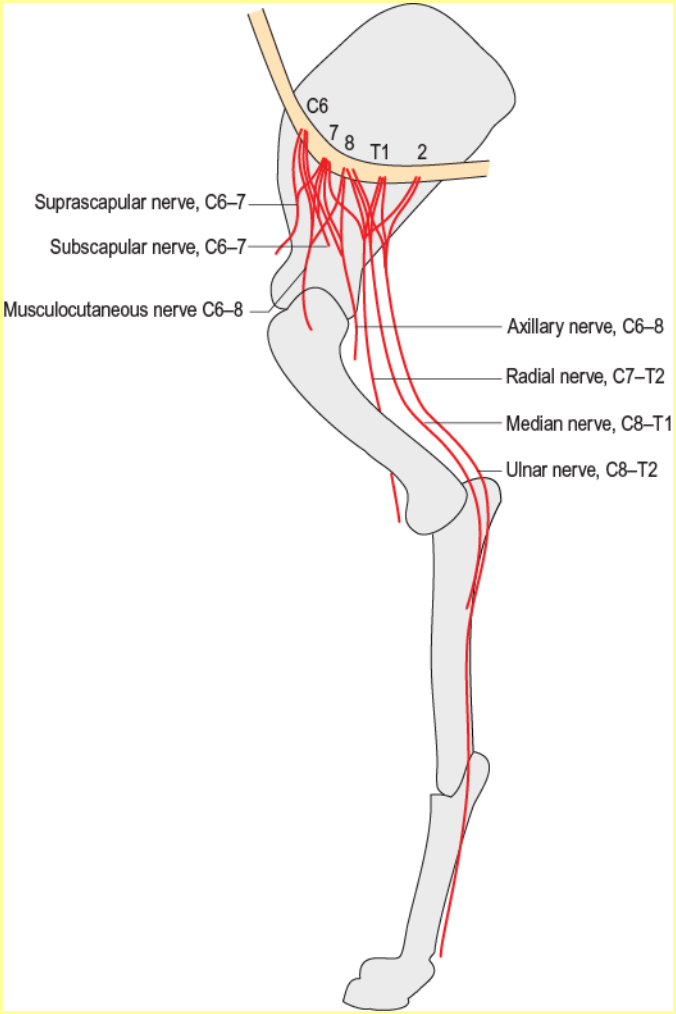
Fig 12.3 Thomson and Hahn



Evans, fig 16-2

Nerve roots

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



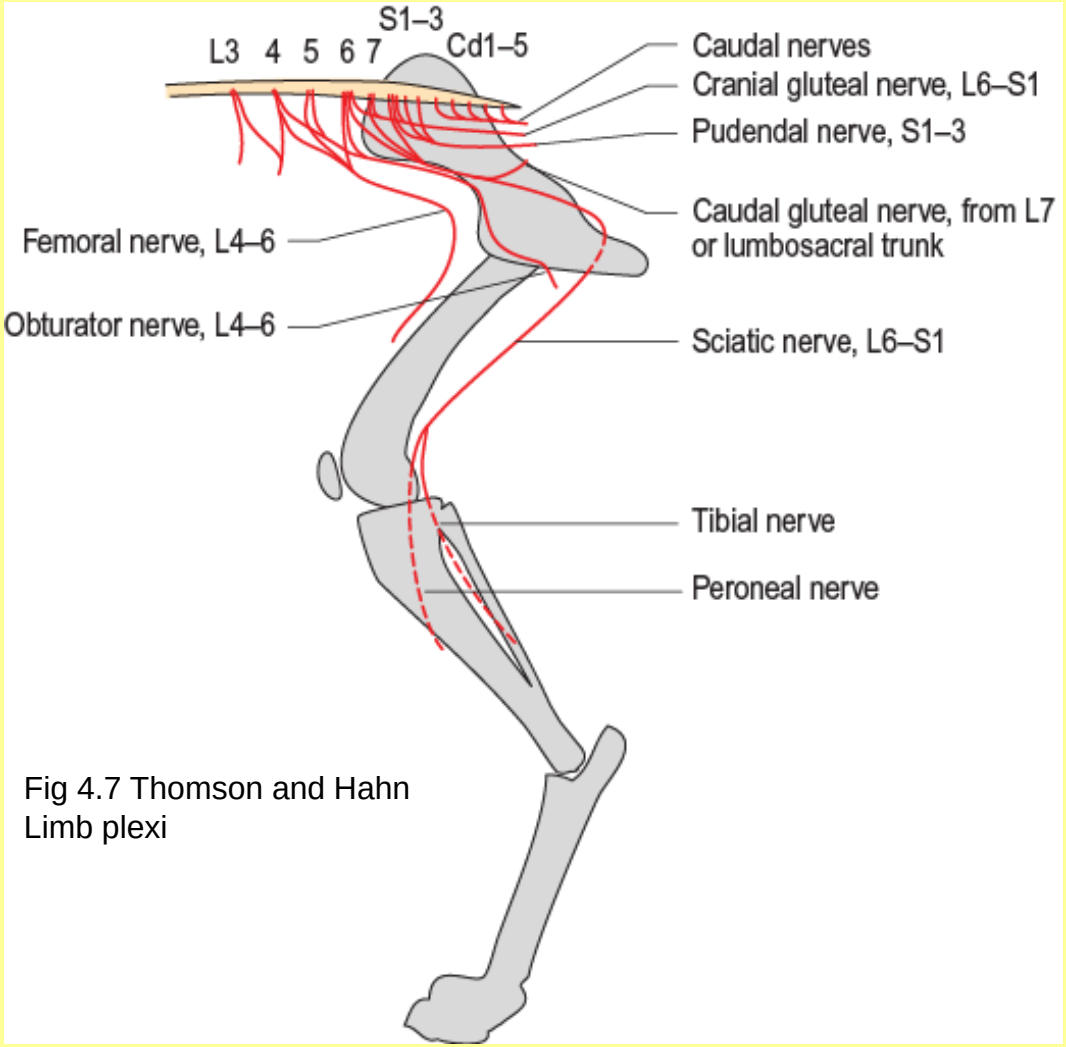


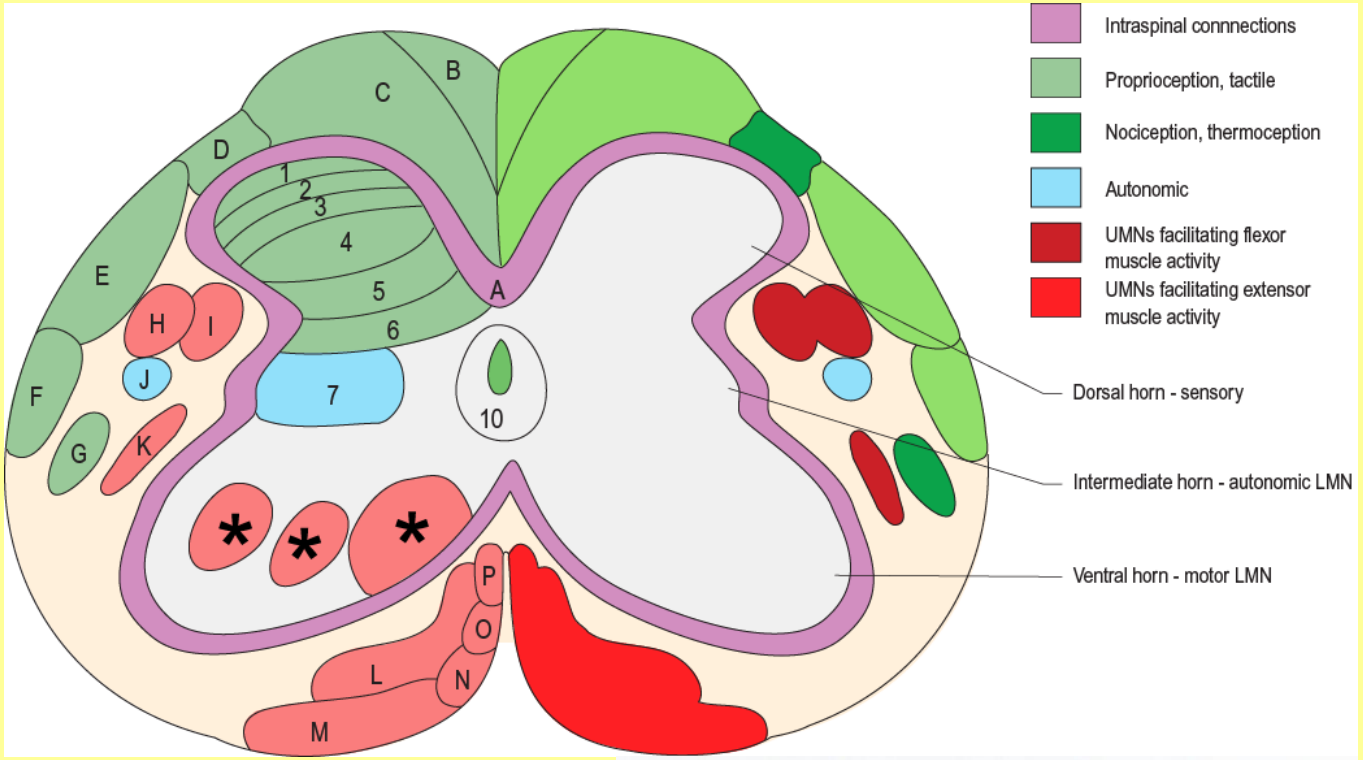
Fig 4.7 Thomson and Hahn
Limb plexi

General rule limb innervation

- Cranial intumescence/plexus innervates cranial, proximal limb
- Caudal intumescence/plexus innervates caudal, distal limb

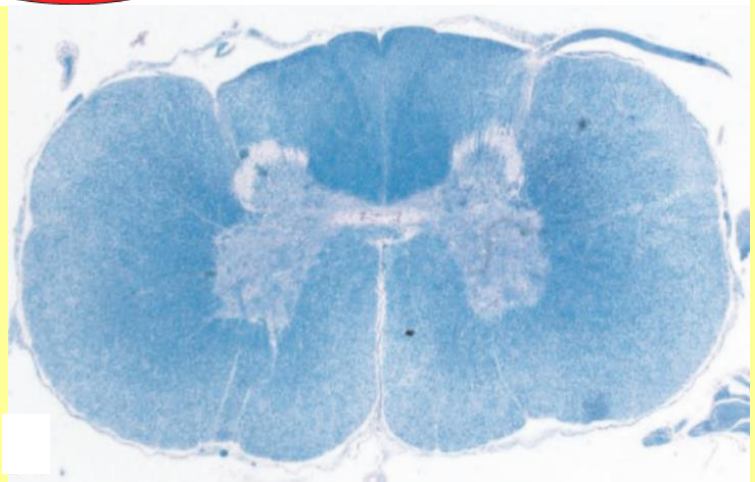
Spinal cord

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



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

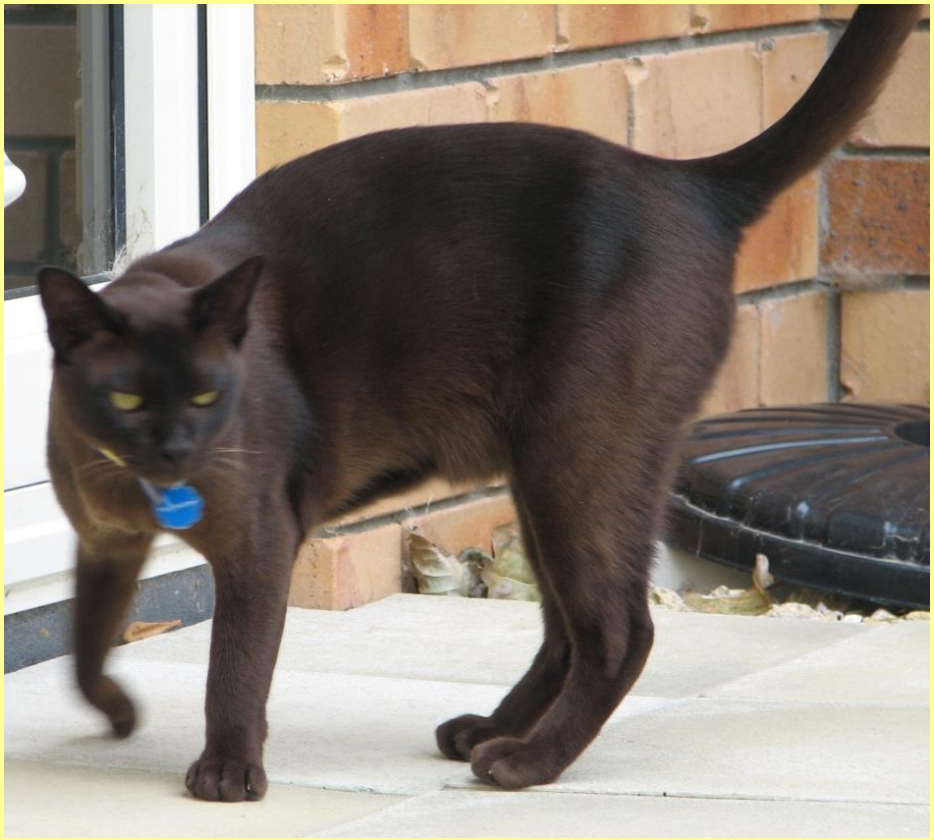
White matter
- Peripheral location
- Axons and myelin
- Funiculi based on nerve root attachment
  - Dorsal – afferent
  - Lateral – afferent, efferent to flexors
  - Ventral – efferent to extensors



XS K9 thoracic spinal cord

ID	Name	ID	Name
A	Propriospinal (spino-spinal)	I	Lateral corticospinal
B	Fasciculus gracilis	J	Lateral tectotegmentospinal
C	Fasciculus cuneatus	K	Medullary (lateral) reticulospinal
D	Dorsolateral fasciculus	L	Pontine (ventral) reticulospinal
E	Dorsal spinocerebellar	M	Lateral vestibulospinal
F	Ventral spinocerebellar	N	Tectospinal
G	Spinothalamic	O	Ventral corticospinal
H	Rubrospinal	P	Medial vestibulospinal and medial longitudinal fasciculus

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)

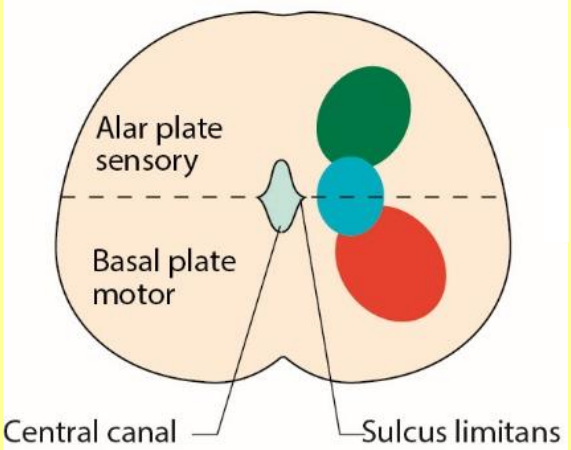


Fig 1.7 Thomson and Hahn

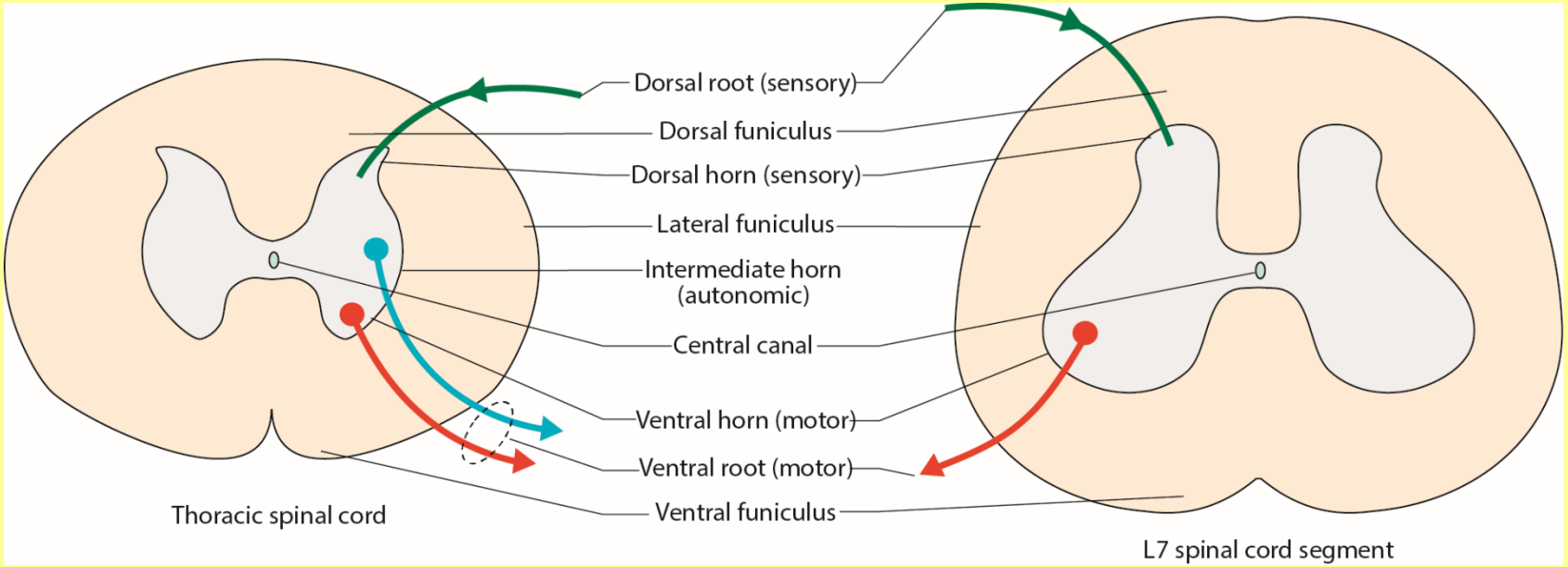
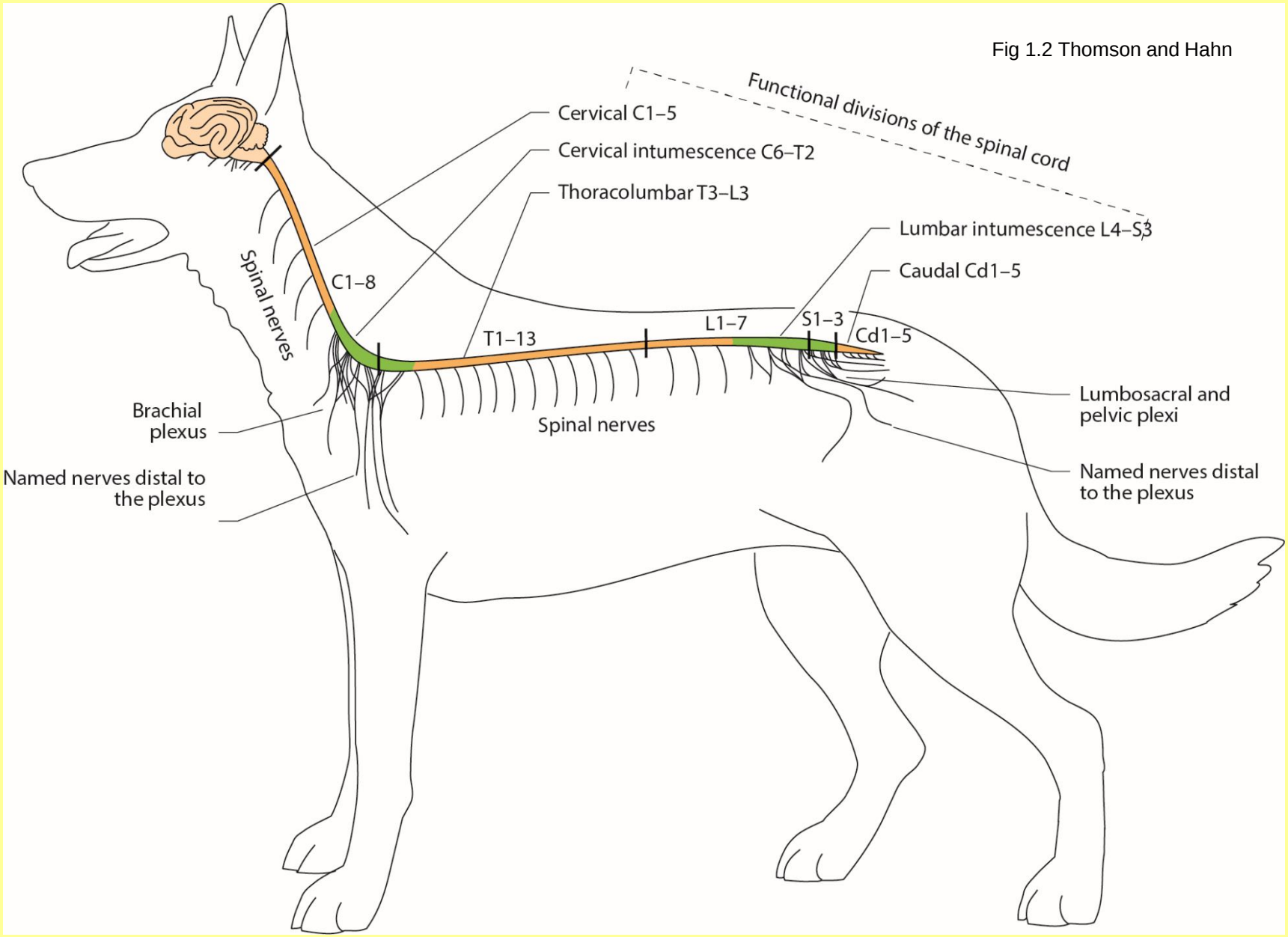


Fig 1.5 Thomson and Hahn



Functional SC division based on limb innervation

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

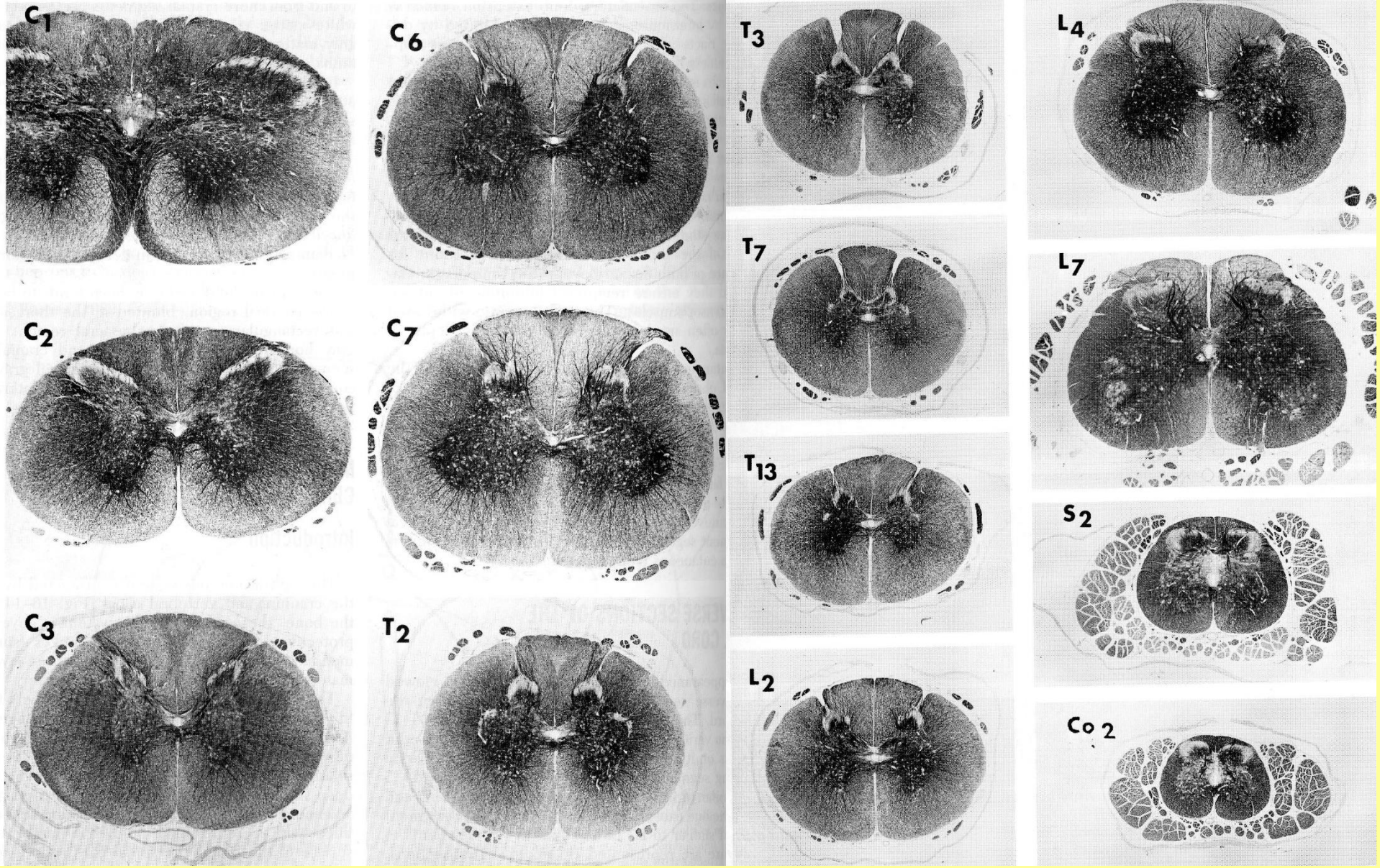


Fig 16-13 Evans

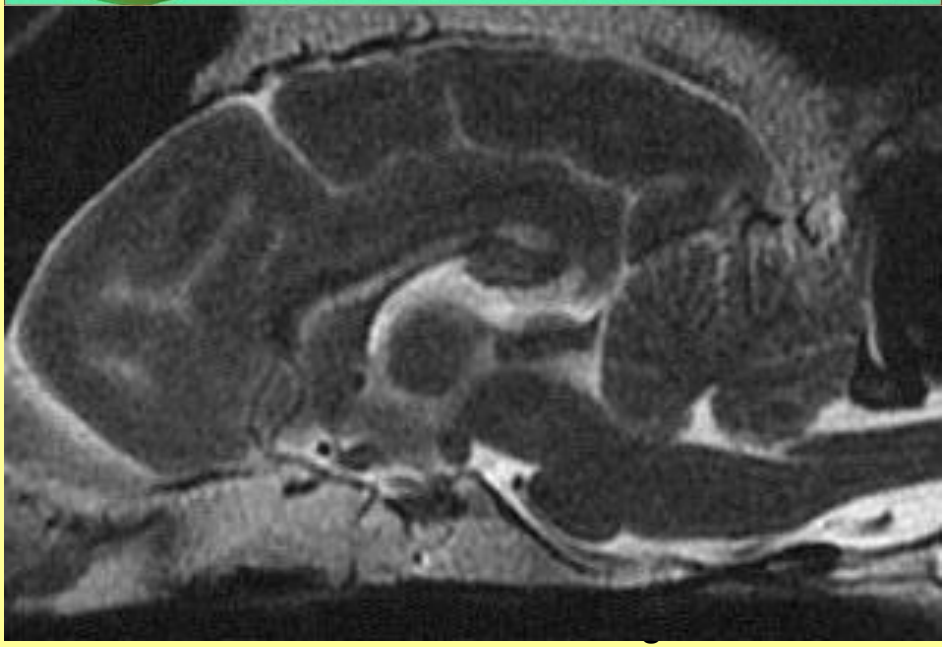
Species difference number of vertebrae

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

Table 1.3, Thomson and Hahn

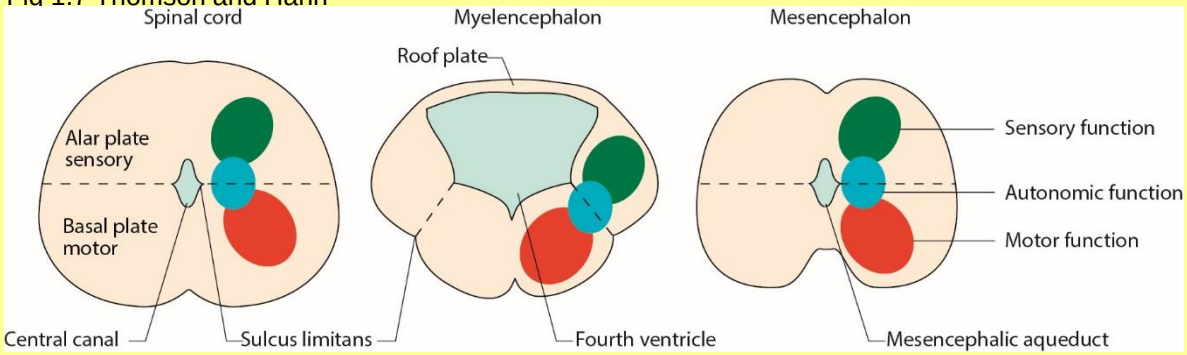
Functional regions of the brain

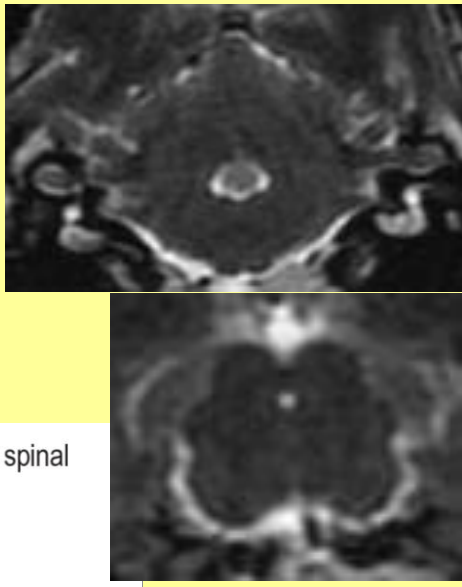
- Anatomical regions
  - Tel Di Mes Met My
- Functional regions
  - Brainstem
    - Myelencephalon
      - Medulla oblongata
    - Pons
      - ventral metencephalon
    - Mesencephalon
      - midbrain
  - Cerebellum
    - Dorsal metencephalon
  - Forebrain
    - Thalamic structures
      - Diencephalon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



Functional NA of the brainstem

Fig 1.7 Thomson and Hahn





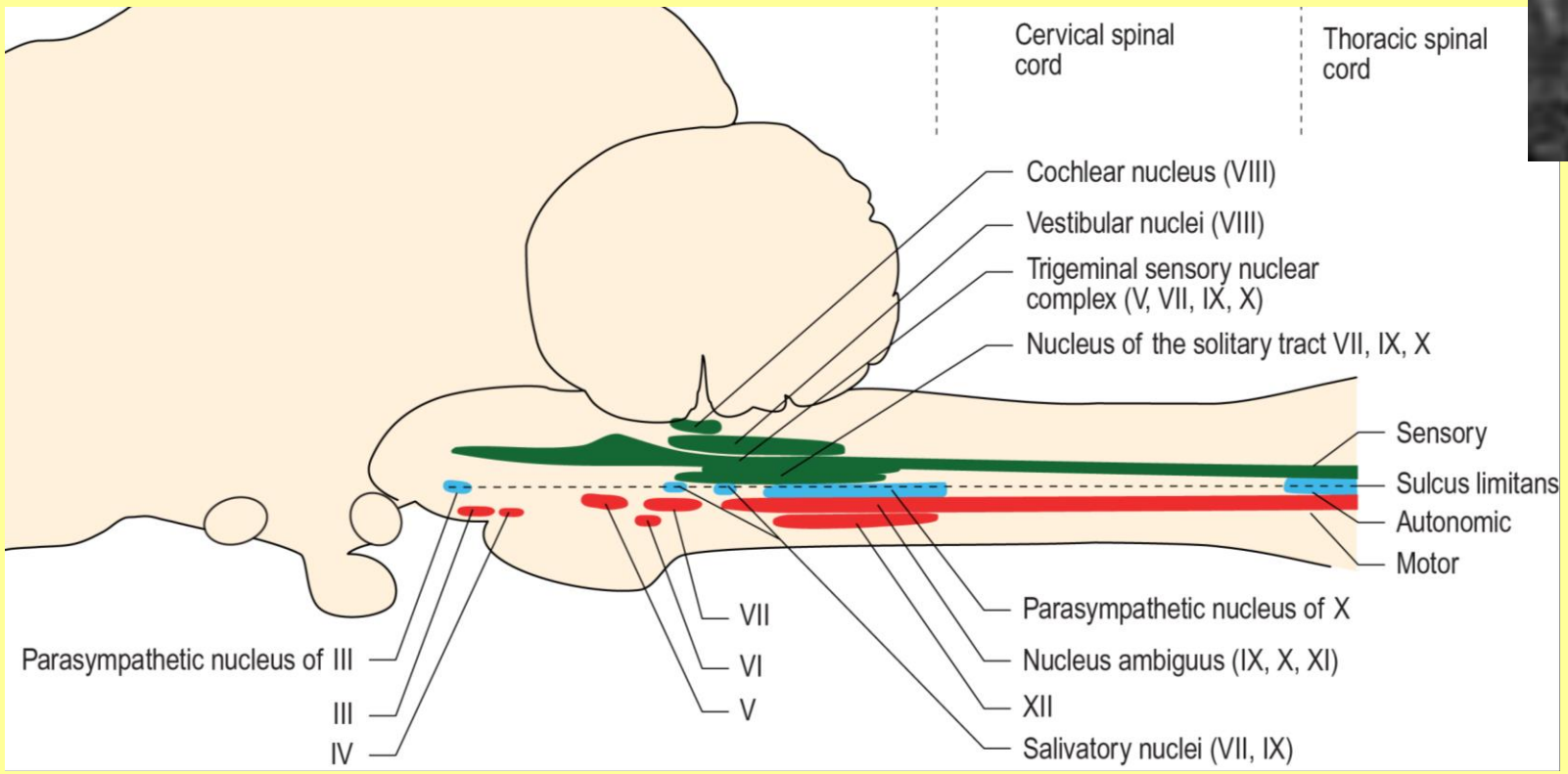


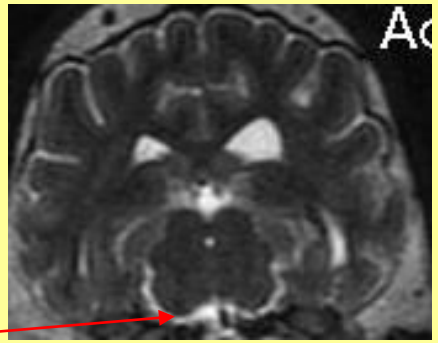
Fig 10.2 Thomson and Hahn

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

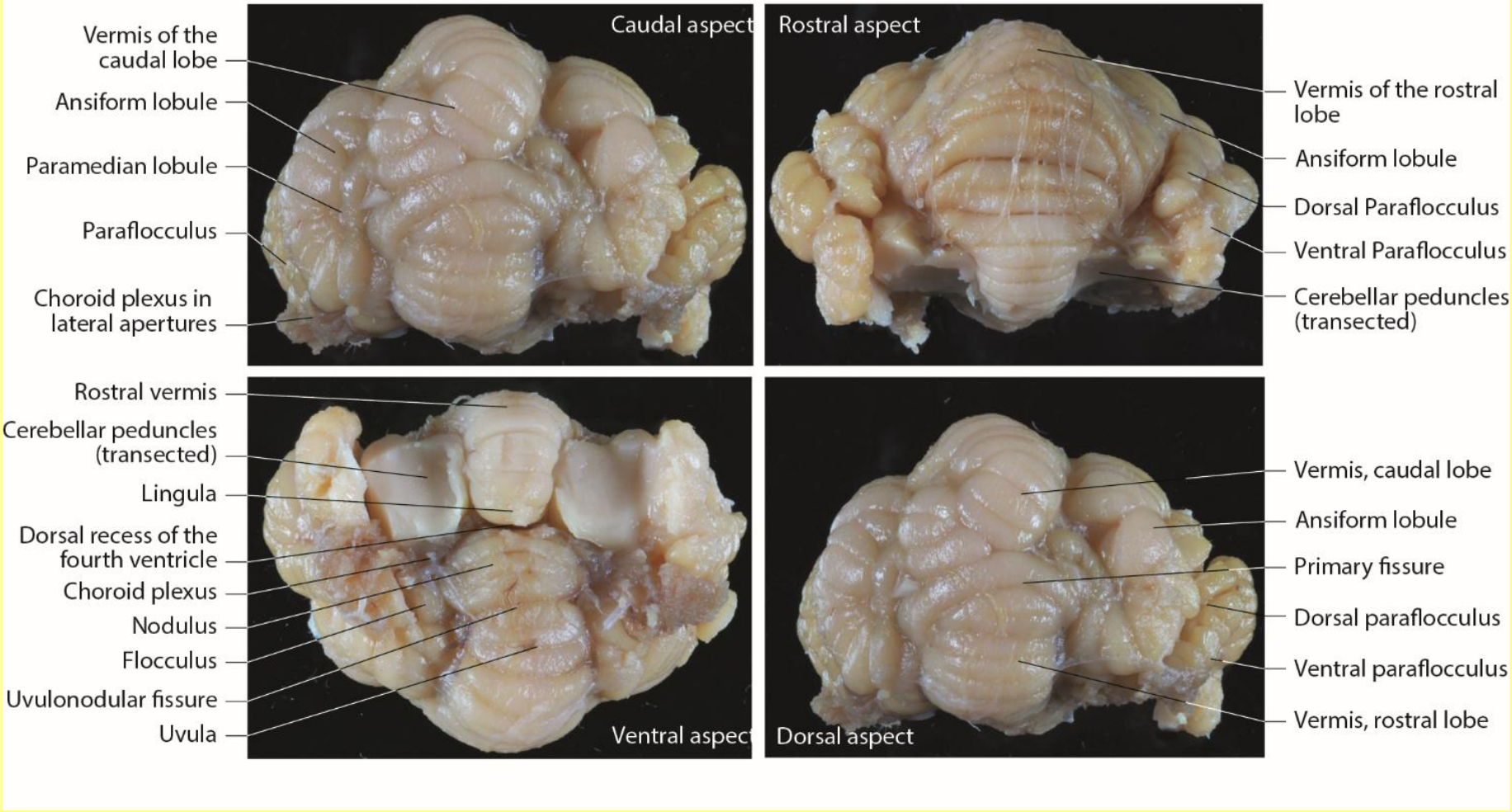
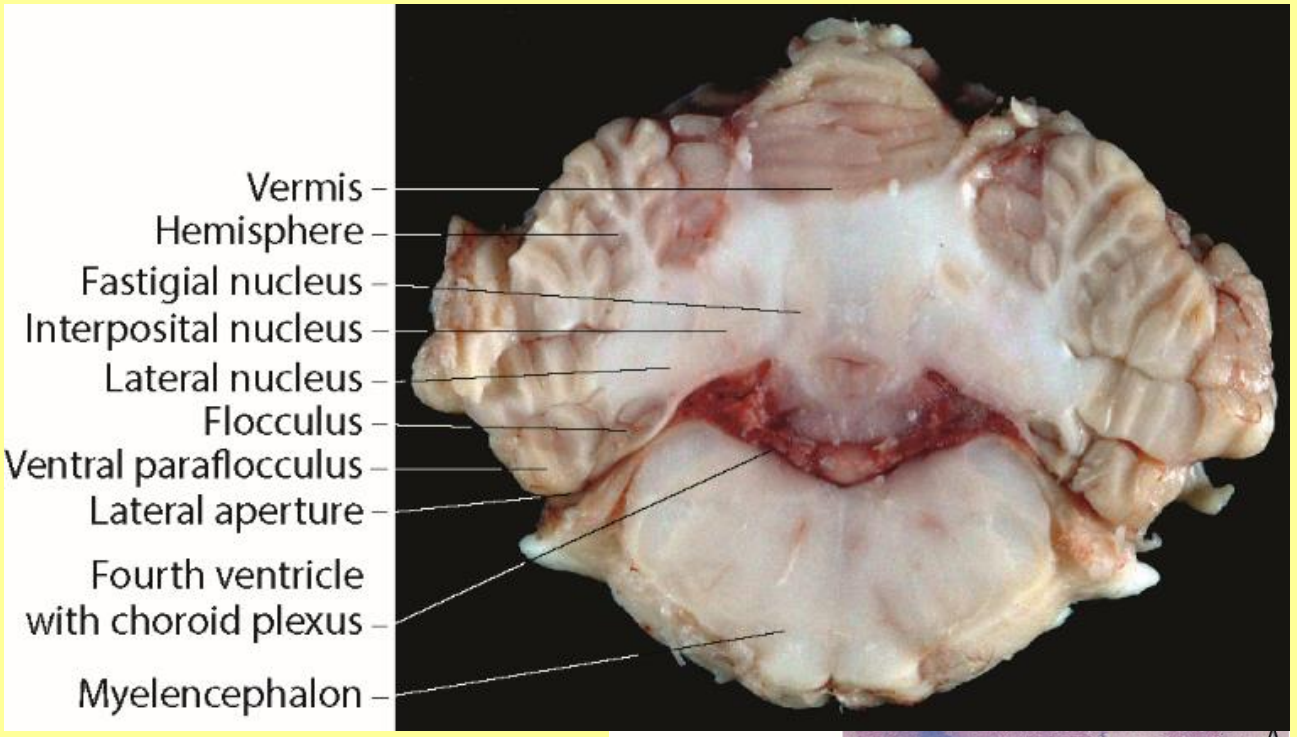


Fig A8 Thomson and Hahn

Figs 7.2 and 7.6, Thomson and Hahn



- Grey matter
  - Cortex – 3 layers
  - Cerebellar nuclei
- White matter
  - Arbor vitae
  - Lamina of the folia
  - Cerebellar peduncles

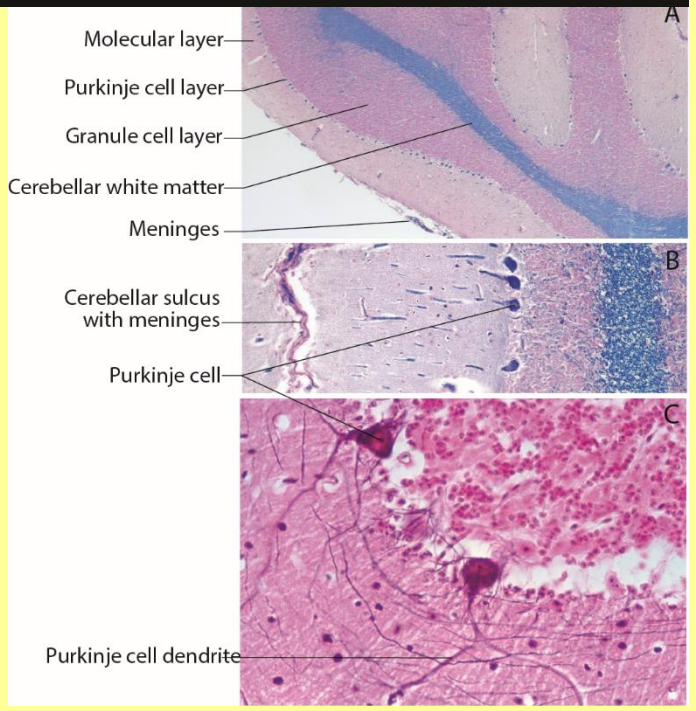


Fig 7.6, Thomson and Hahn

Cerebellar peduncles

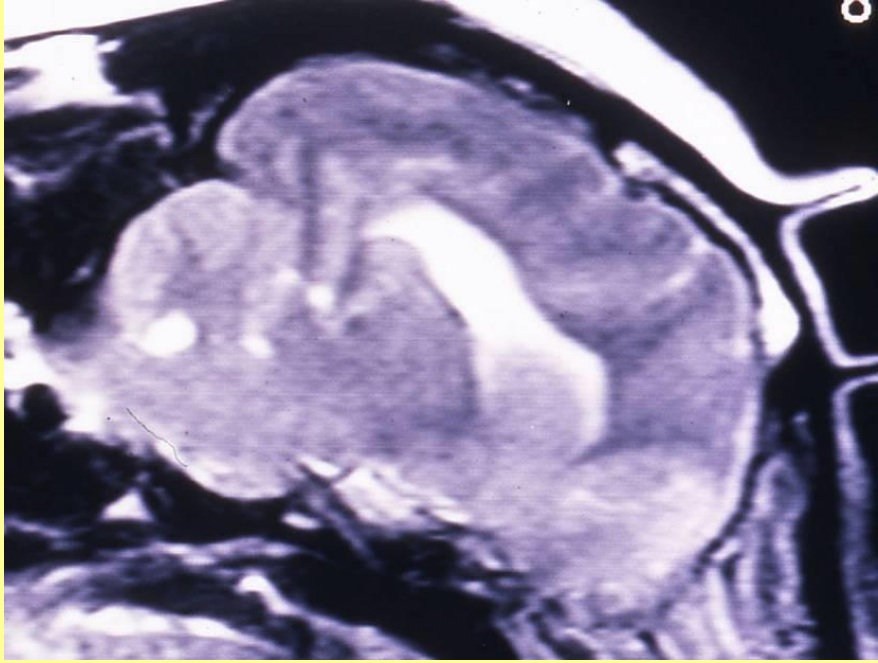
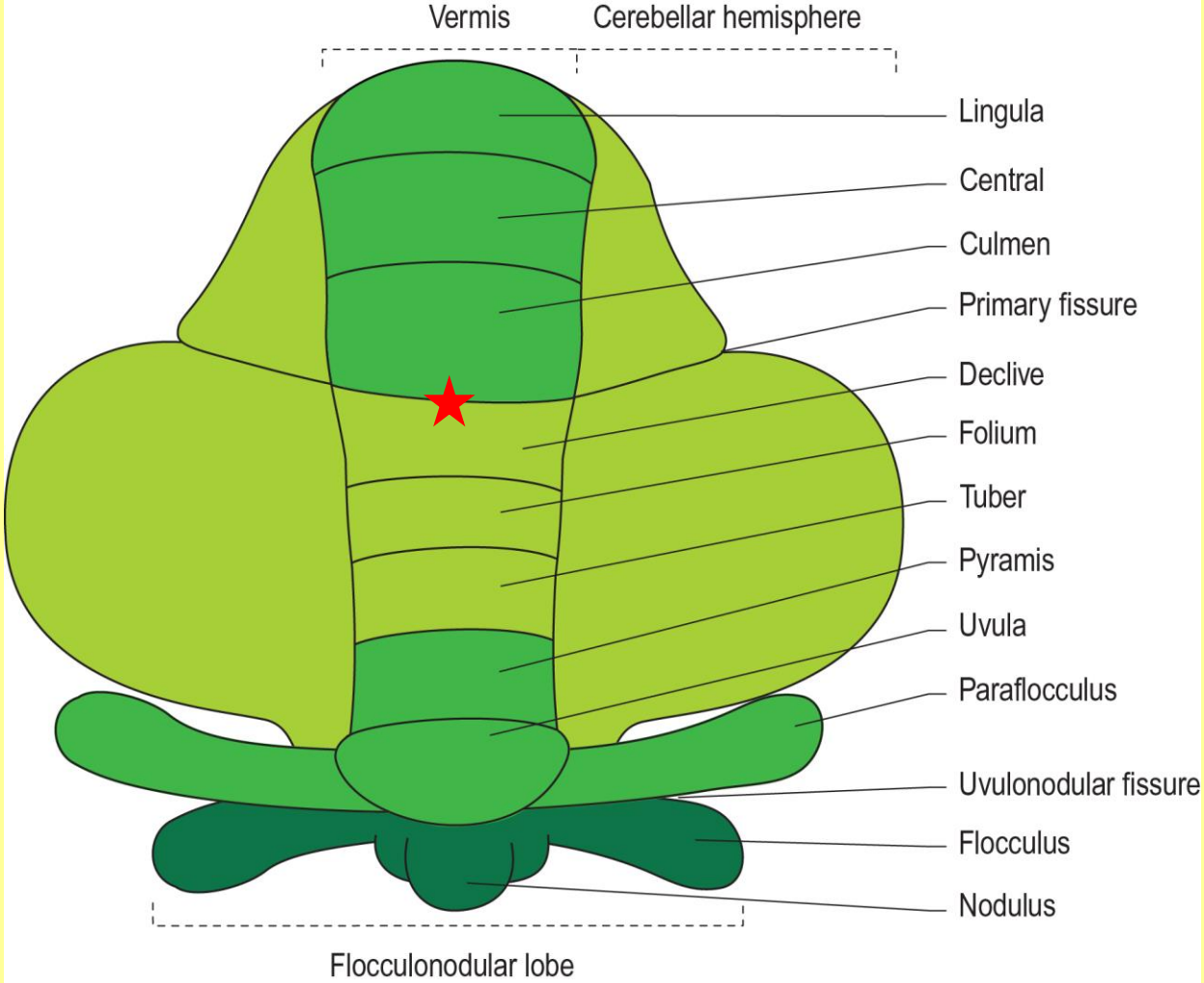


Fig 7.3B Thomson and Hahn
Parasagittal section

- 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

Functional NA of the cerebellum



Functional regions

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

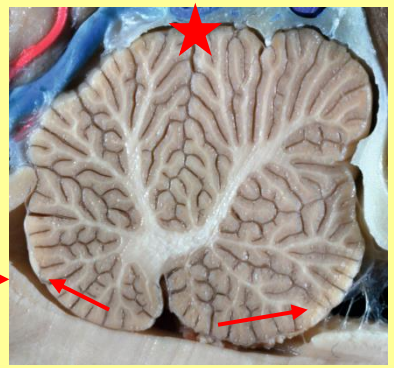


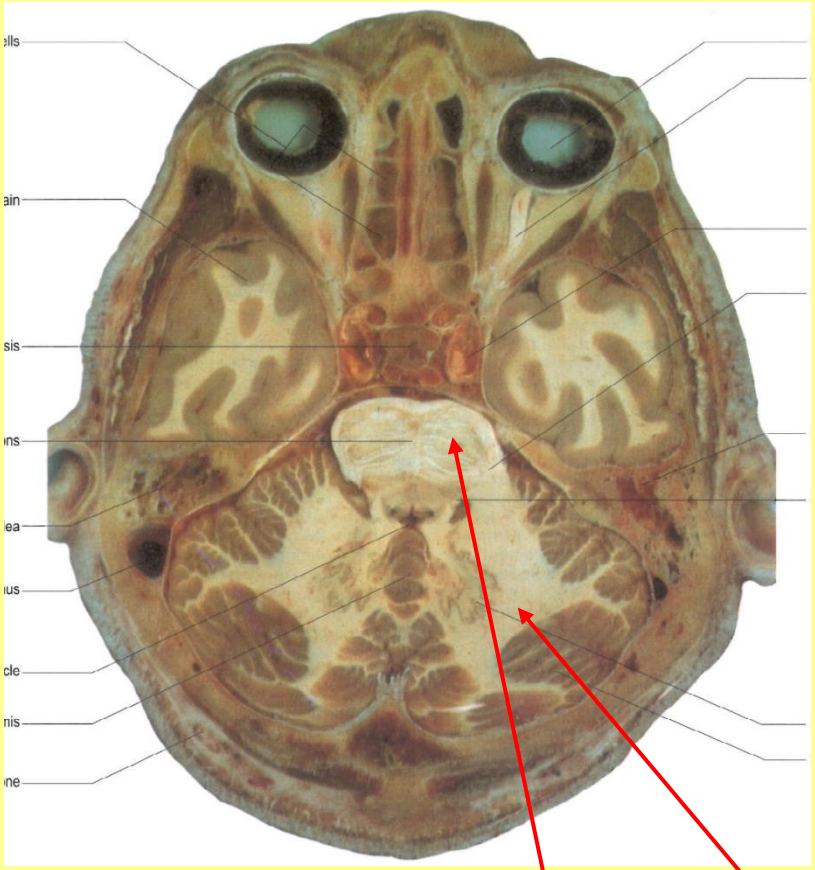
Fig 7.4a Thomson and Hahn
Cerebellum rolled out flat, star on primary fissure
Functional zones

Species difference

Species specific structure

- Medial vs lateral portions
- Snakes c/w mammals c/w primates

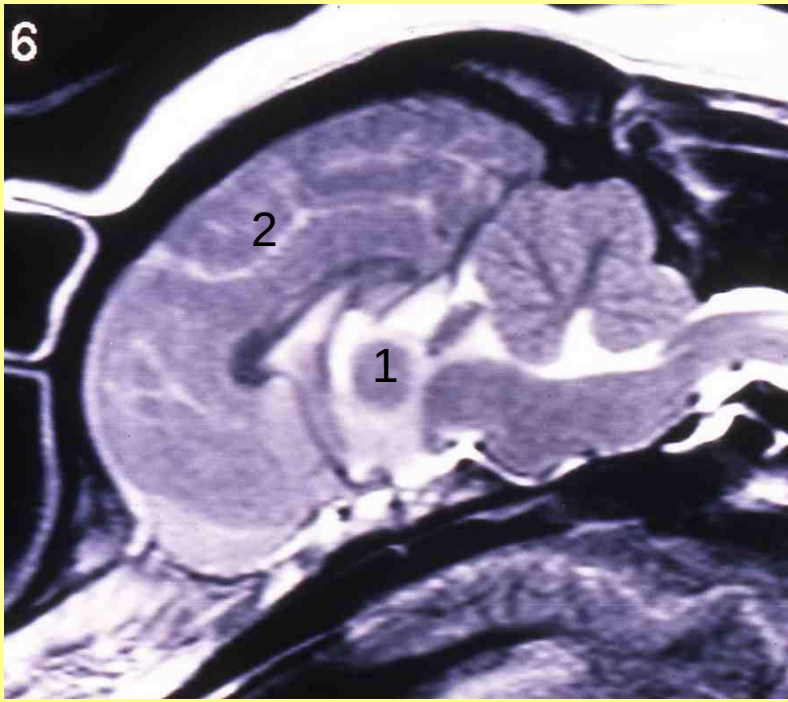
Fig 7.4 Thomson and Hahn
Trout brain, dorsal aspect



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

Forebrain Anatomy

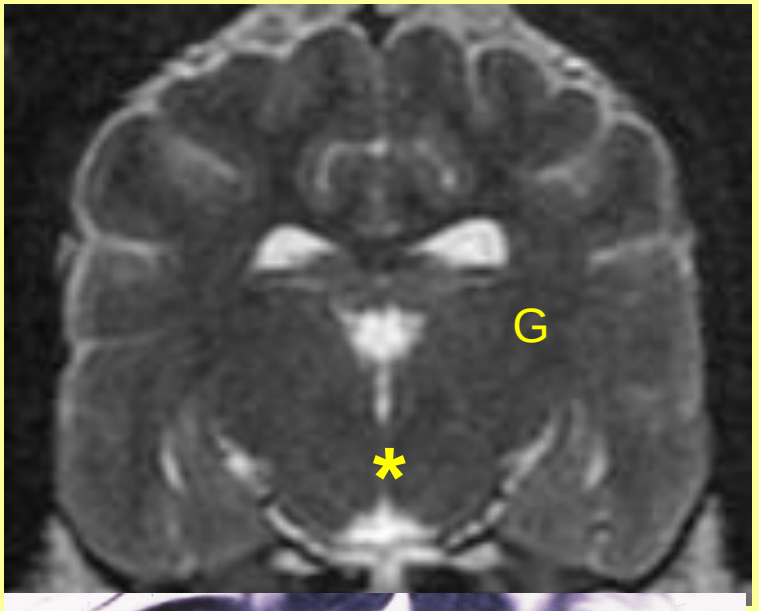
- Components
  - 1) Diencephalon
    - '…thalamic' structures
    - 1 = interthalamic adhesion
  - 2) Telencephalon
    - Cerebral hemispheres

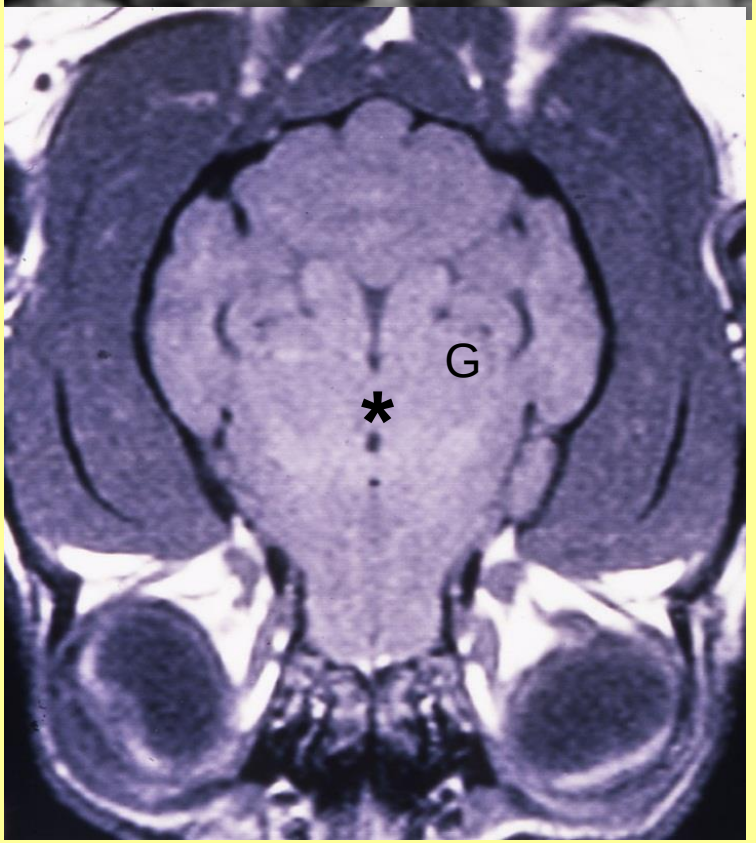


Dog brain, median section, MRI, T2

Diencephalon

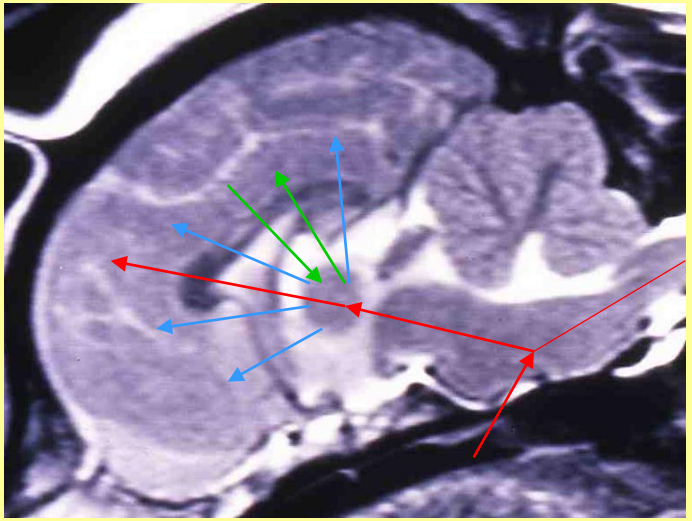
- Components
  - Thalamus
    - with interthalamic adhesion *
  - Hypothalamus
  - Epithalamus – pineal gland
  - Subthalamus
  - Metathalamus
    - Geniculate nuclei (G)
      - Lateral and medial
      - vision and audition pathways





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

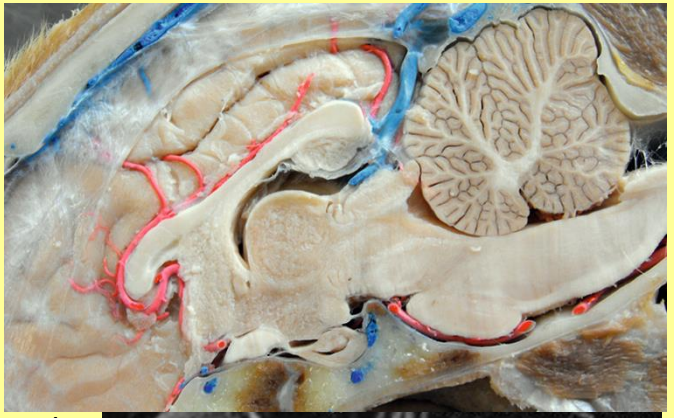


Clinical Signs of Thalamic Dysfunction

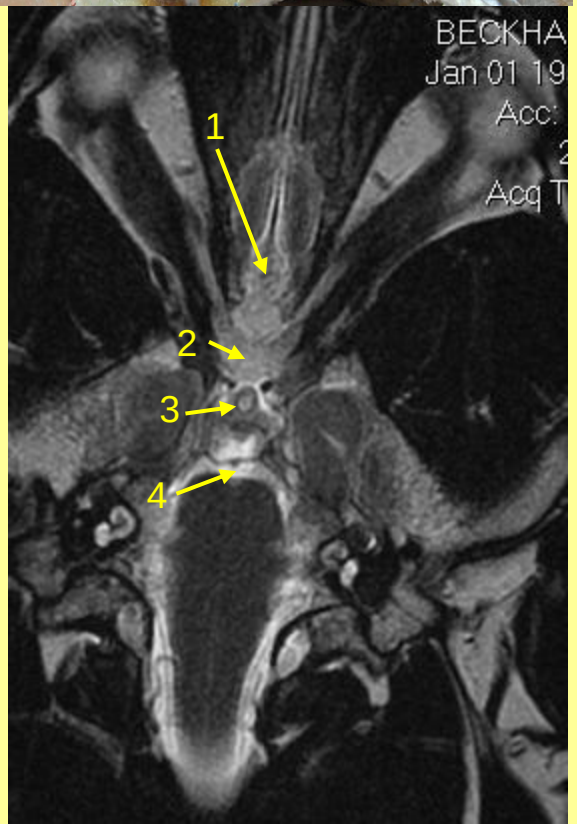
- Direct cortical projection
  - Sensory deficits
    - e.g. proprioceptive deficits, facial hypalgesia
- Local cortical connections
  - Seizures
- Thalamic reticular system
  - ARAS
  - Altered mentation

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



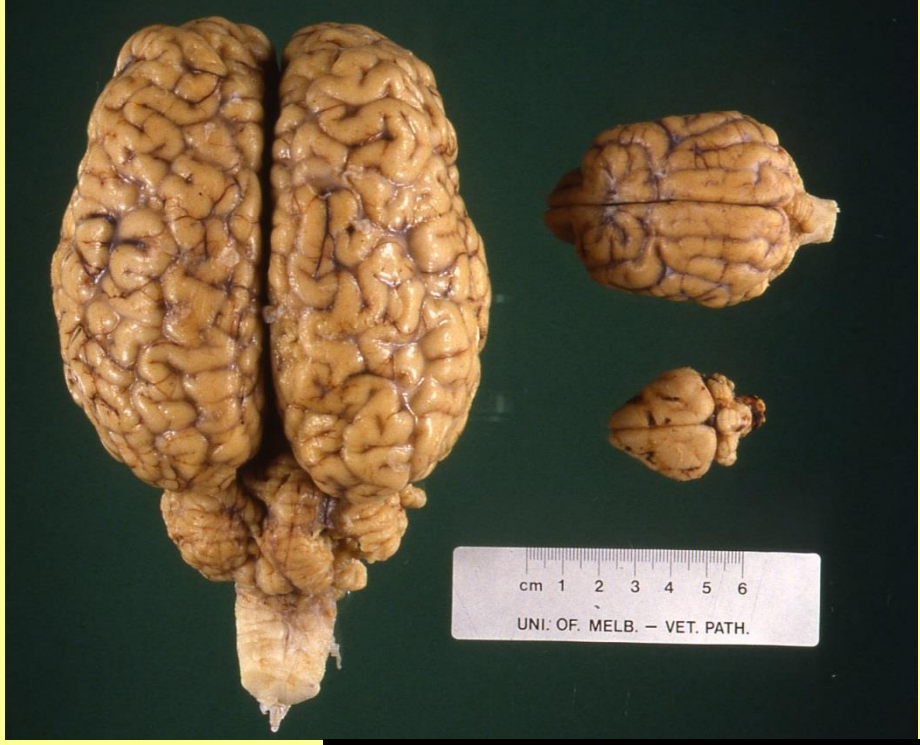
Dog brain, median section

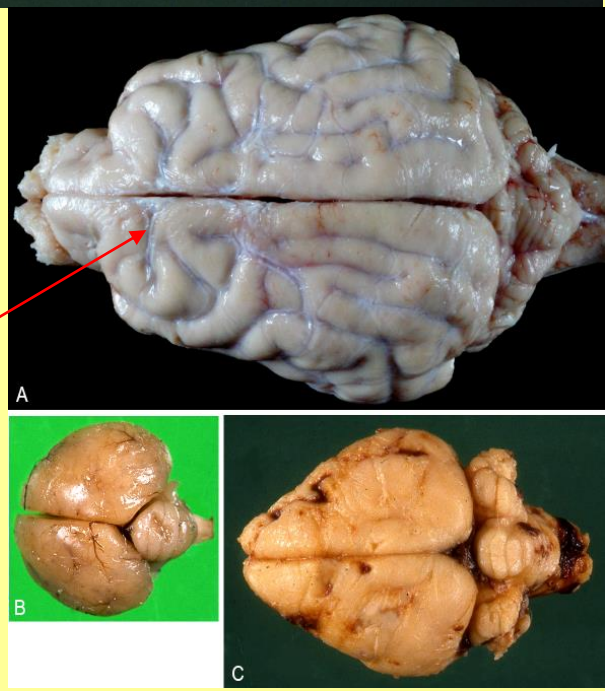


On the MRI, which structure is the hypophysis?

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



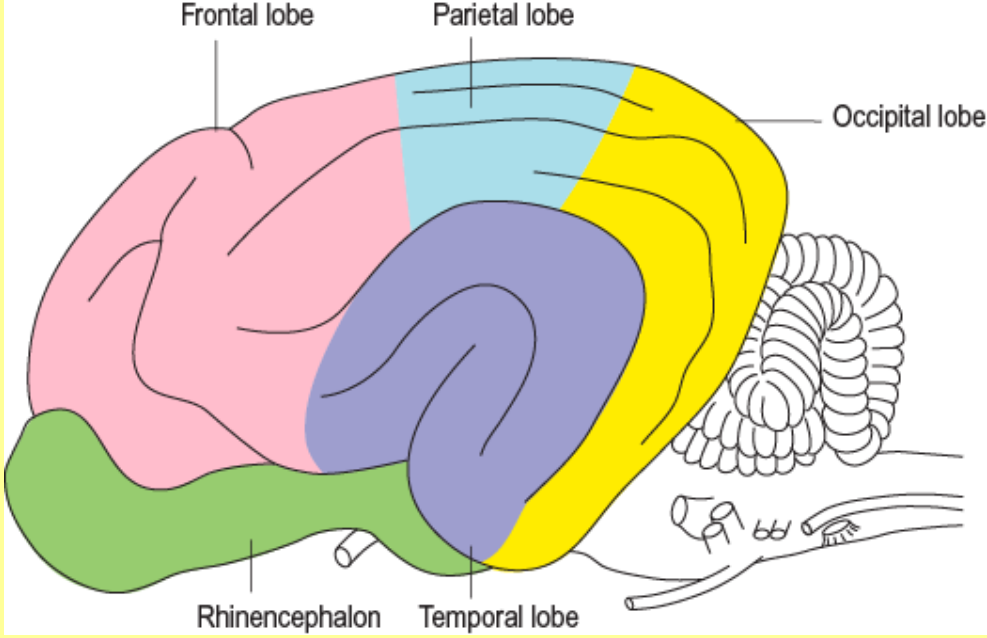


Cruciate sulcus

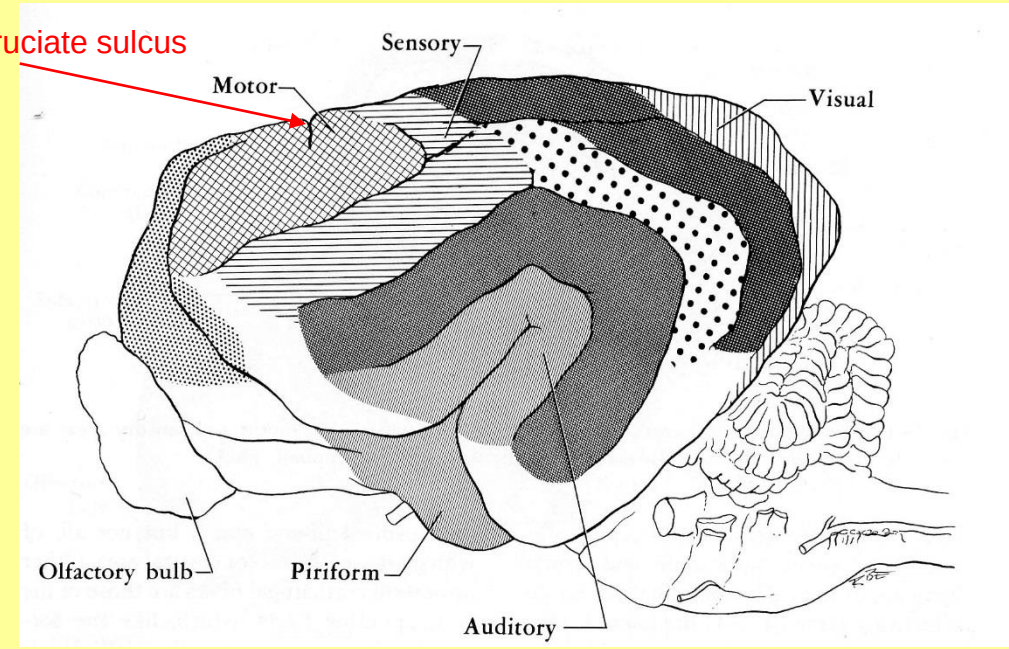
Equine, dog, rabbit, and bird (B) brains dorsal aspect; Thomson & Hahn 1-8

Telencephalon

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

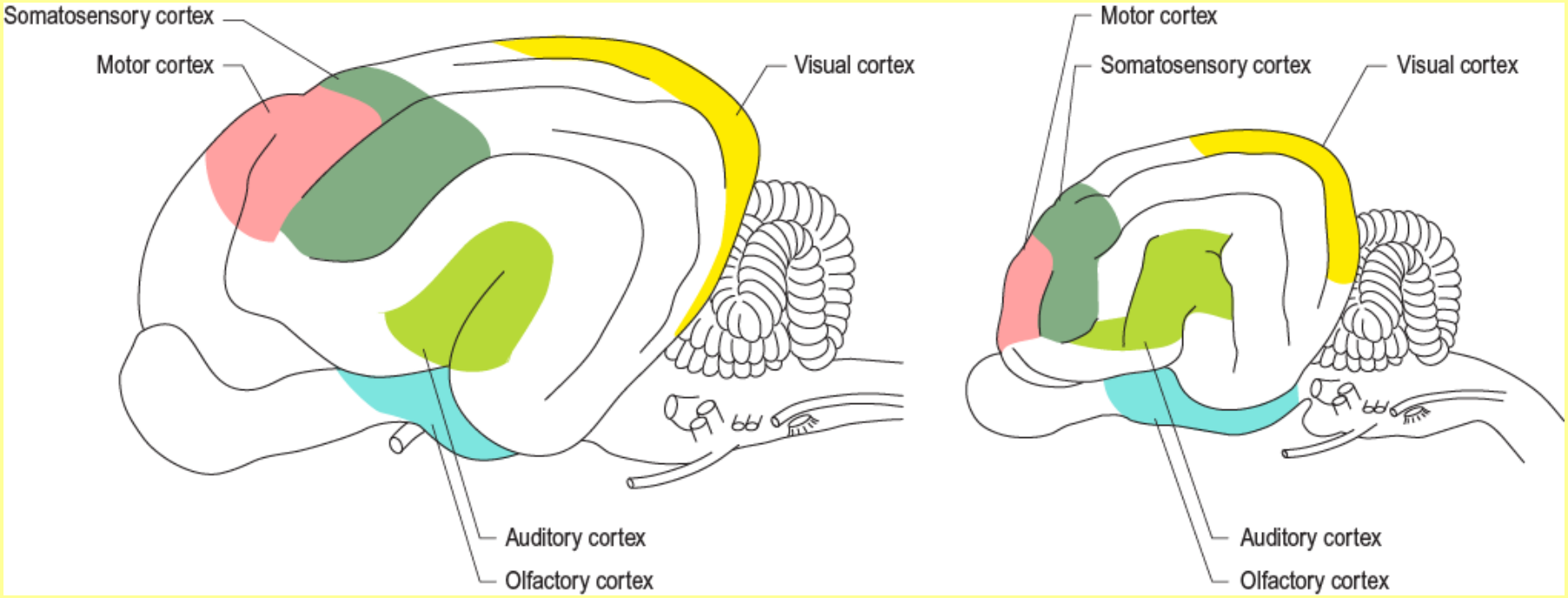


Thomson and Hahn, 1.10



Functional areas of the forebrain Jenkins 16-10

Functional areas of telencephalon

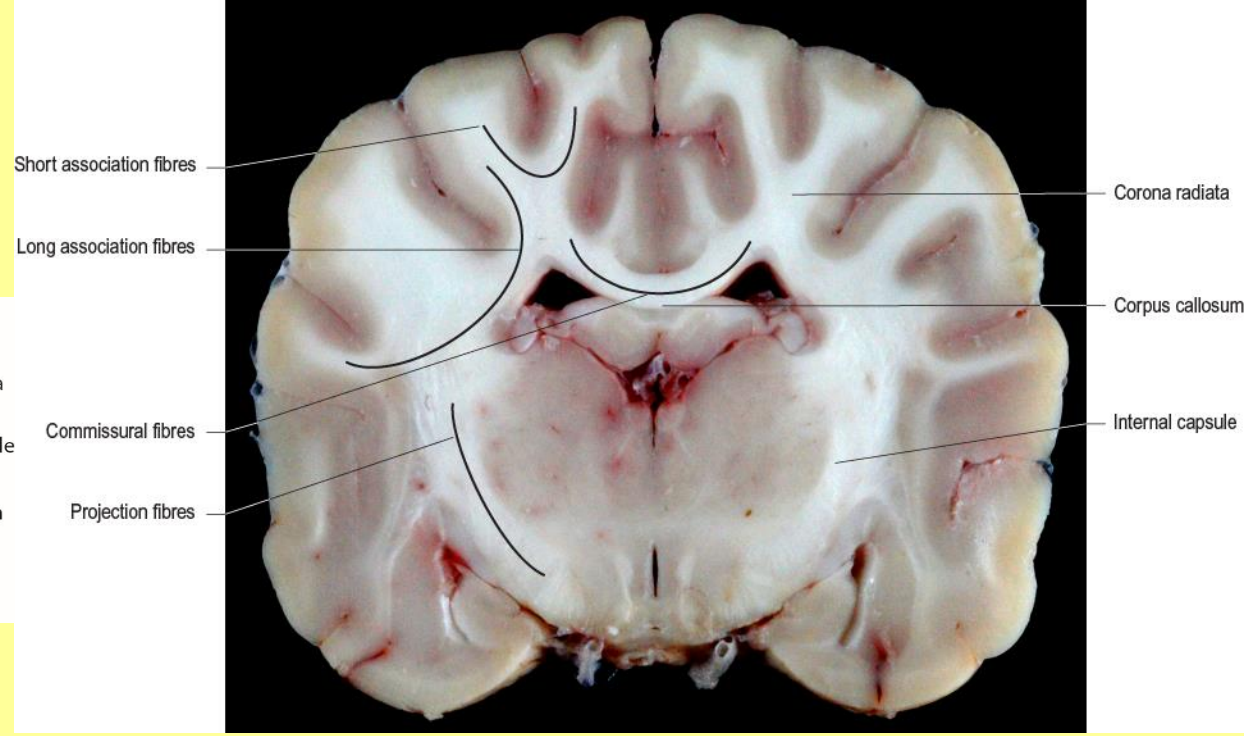


Thomson and Hahn, 1.11, dog and cat brains

Motor cortex – learned / skilled motor function
c/w brainstem motor nuclei – semi-automatic motor function

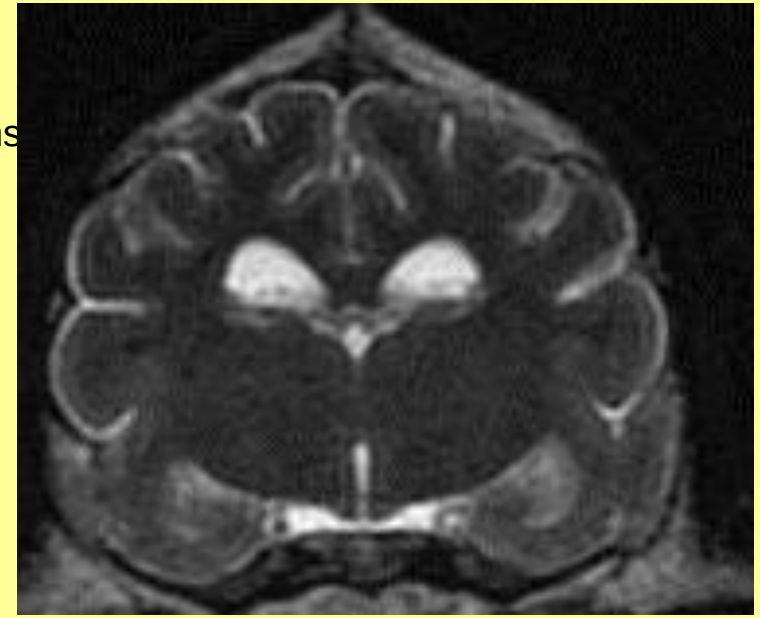
Telencephalon: white matter

Dog brain, Thomson and Hahn 1.13



Dog brain, Thomson and Hahn 1.12

- 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



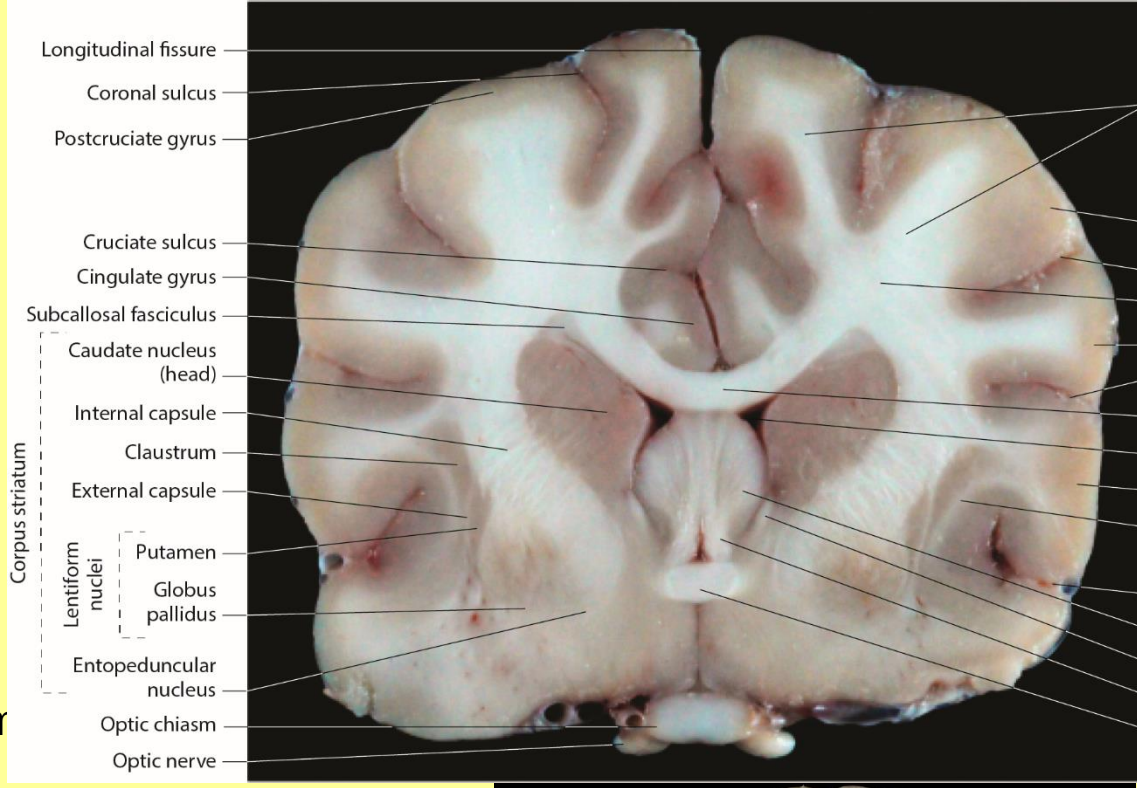
Telencephalon – GM

- Superficial GM
  - Cerebral cortex
- Deep GM

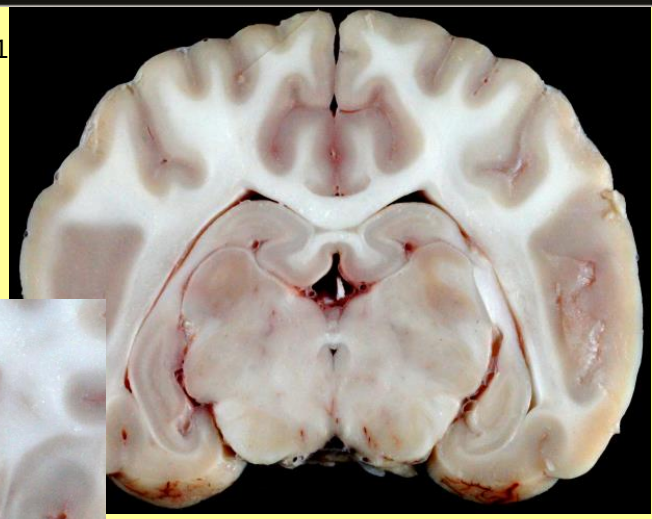
  1) Basal nuclei
  - GM + WM = corpus striatum
  - Primary connections with cerebral cortex

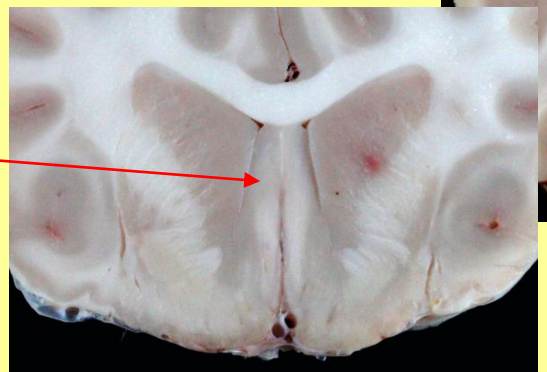
  2) Hippocampus
  - Part of the limbic system
  - Behaviour, learning, memory

  3) Septal nuclei
  - Behaviour (sexual and aggressive)



Thomson and Hahn, A13, A16, A1

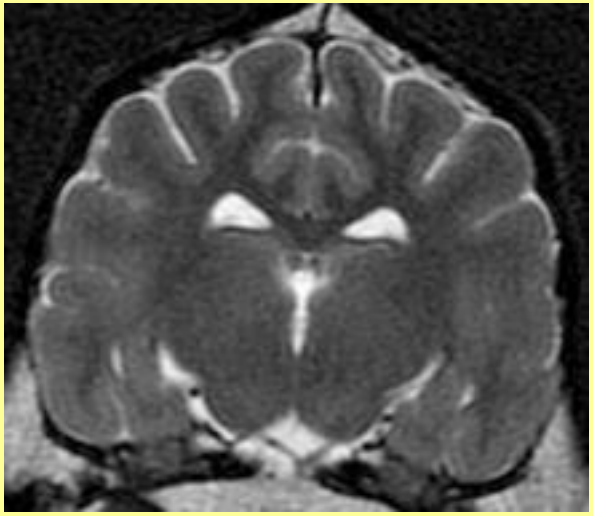


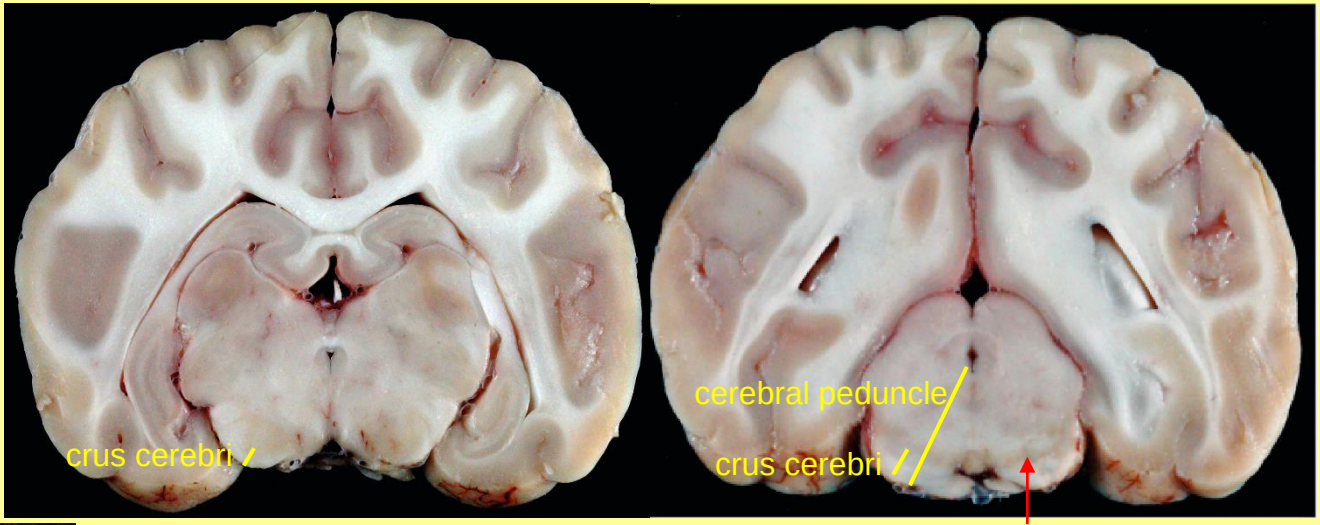


Telencephalon – Basal Nuclei

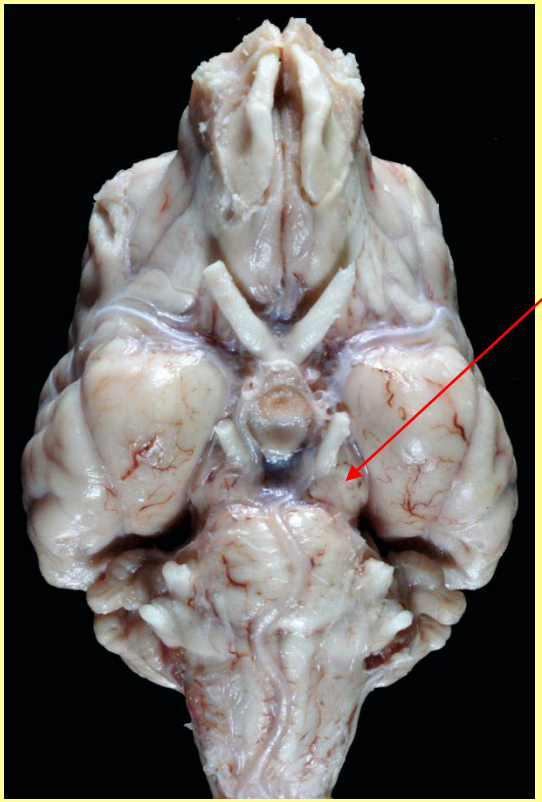
- Function
  - Storage of motor patterns / rituals
  - Modify learned motor activity
    - Planning
    - Regulation
    - Execution
  - Neostriatum
    - Caudate and putamen nuclei
    - Inhibitory influence
    - Lesions→hyperactivity and hypertonus
      - obstinate progression = head pressing
  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

www.pawfun.com/





Thomson and Hahn, modified figs A3,17,18



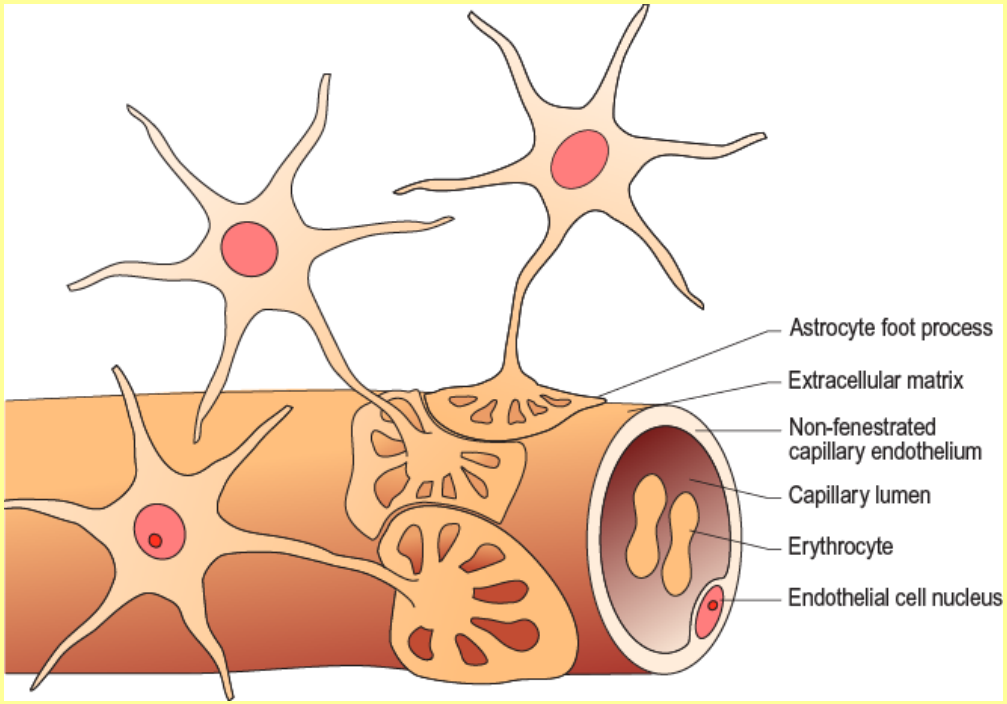
Cerebral peduncles c/w crus cerebri

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

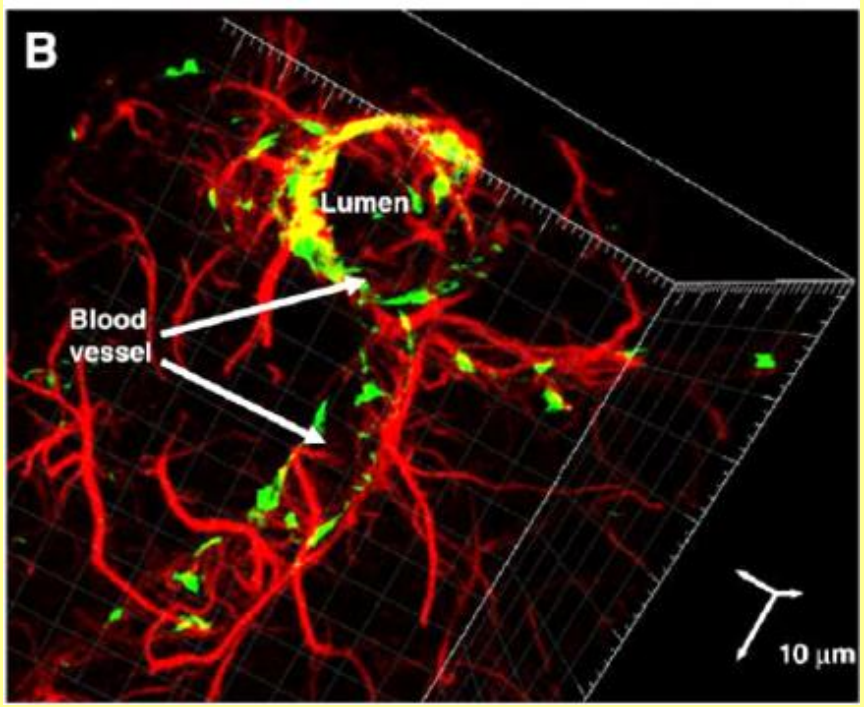
Crus cerebri
- efferents from cortex
  - Corticopontine, corticonuclear, corticospinal tracts

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



Thomson and Hahn, fig 3-19



Immunostaining – astrocytes, endothelial cells

Weiss N et al: The blood-brain barrier in brain homeostasis and neurological diseases. Biochim Biophys Acta 1788:842-857 (2008)

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

Diseases often lead to leaky vasculature

Blood-CSF barrier

- Fenestrated endothelium
- Basement membrane
- Ependymal cells with tight junctions


607