



Faculty of Medicine
School of Medical Sciences

ANAT341

NEUROANATOMY

COURSE OUTLINE

SEMESTER 1, 2017

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It is your responsibility to make sure that you read and sign the **Student Risk Assessment Form** included in this outline before you attend your first prac in the dissecting room. Keep the signed form in your prac manual and bring it to classes with you. It is not necessary to give it to your tutor or Course Convenor).

Please read this outline in conjunction with the following pages on the [School of Medical Sciences website](#):

- [Advice for Students](#)
- [Learning Resources](#)

(or see "STUDENTS" tab at medicallsciences.med.unsw.edu.au)

COURSE STAFF

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COURSE INFORMATION

ANAT3411 Neuroanatomy is a 6UoC course.

It consists of 6 hours per week of face-to-face teaching (2 lectures and 2 x 2 hour practical classes).

Neuroanatomy is the study of the structure of the nervous system. ANAT3411 involves study of the nervous system structure at both the microscopic and gross levels as well as its development. It also introduces you to some basic research techniques used to explore brain structure. The ANAT3411 course focuses primarily on the human nervous system, although reference is made to findings in other mammals where relevant.

We try to put student learning in context, with reference to the latest developments in research and discussion of relevant clinical cases and scenarios. Students will also have the opportunity to extend their understanding of a chosen area and to develop skills in self-directed learning and critical evaluation by doing a short research project.

Course Aim

The aim of this course is to provide students with a basic understanding of the structural organisation of the human central nervous system in sufficient depth to form the basis for further clinical or research studies of the nervous system.

Student Learning Outcomes:

By the end of the course students will:

- I. have gained an overview of the topography and structural organisation of the brain and spinal cord.
- II. have a basic understanding of the functional anatomy of sensory and motor processing and higher cerebral functions such as language and emotions and to be able to apply this knowledge to the clinical situation.
- III. understand the principles of the blood supply and venous drainage of the nervous system and to be able to deduce the effects of rupture or occlusion of the major vessels.

See also UNSW Graduate Outcomes and attributes for Science students at <http://medicalsciences.med.unsw.edu.au/students/undergraduate/advice-students#graduate>

How the course relates to other courses

ANAT3411 is offered as component of the Anatomy major in the BSc and BMedSc, or as a year 3 elective in other BSc and BMedSc programs and in the BExPhys program. It is also a key component of the Neuroscience major in the BSc and BSc (Adv) programs. It builds on the basic knowledge of the nervous system, previously obtained in either ANAT1521, ANAT2111 or ANAT2511 and provides the background (prerequisite) for NEUR3211 Research Topics in Neuroscience (offered in Session 2). It also provides a useful (though not compulsory) basis for NEUR3221 Neurophysiology also (offered in Session 2).

Changes since 2016

- Review quizzes/adaptive tutorials are being prepared and will be made available each week through Moodle for formative assessment.
- Use of electronic media to assess knowledge in practical spot tests
- Addition of a second lecture on Cerebral cortex function. New media for practical class in motor disorders and cortical function.

Teaching Rationale and Strategies

The course involves 6 hours per week of instruction - 2 lectures and 2 x 2 hour practical classes. Each practical class is preceded by a lecture, which usually introduces you to the topic for the practical class. Lecture slides and notes are uploaded to Moodle prior to each lecture.

For most lectures given by Drs Carrive and Potas, diagram outlines will also be uploaded and you are encouraged to bring these to the lecture with you, either in hard copy or on a tablet. You will have the opportunity to develop and label these during the lectures. In practical/tutorial classes, students working in small groups under the guidance of their tutors will identify key structures in prosected specimens, models and on sections and MRI images of the brain using computer software (BrainStorm).

Students will also participate in tutorial discussion on relevant functional and clinical aspects. BrainStorm is available for you to use on-line so you can prepare and consolidate your learning outside of formal classes.

We encourage you to question, observe and share knowledge and experiences with your peers and your teachers. We endeavour to make the material interesting to stimulate in you an enthusiasm for the really fascinating subject matter that is covered in this course. This is of course dependent on your interaction and engagement with the course.

Practical classes are compulsory but you are also strongly encouraged to attend the lectures rather than just viewing them online. If you are unable to attend the lectures for some reason you **MUST** ensure that you view or listen to the lecture **PRIOR** to attending the practical classes.

Timetable

Lectures

| | | |
|-----------|-----------|---------|
| Tuesday | 5-6 p.m. | LG03 WW |
| Wednesday | 12-1 p.m. | LG03 WW |

Tutorial/Practicals

| | | |
|----------------------|-----------|------------------------|
| Wednesday & Thursday | 9-11 a.m. | Dissecting Rm (101) WW |
|----------------------|-----------|------------------------|

A number of practical classes (involving computers) will also use WW Rm G08.

See <http://medicalsciences.med.unsw.edu.au/students/undergraduate/advice-students#Practicals> for Dissecting Room Rules.

Attendance

Students are expected to attend **at least 80% of all scheduled learning activities.**

Attendance at practical classes will be recorded and students who do not attend at least 80% of practical classes may be prevented from undertaking examinations in this course. Please note that absences due to illness or misadventure will be factored into the 20% of allowable absences.

ANAT3411 Neuroanatomy – Class Schedule 2017

| Week | Date | Time | Venue | Activity |
|-------|---------------|---------|------------|--|
| 1 | Tues Feb 28 | 5-6 pm | LG03 WW | Lect: CNS Histology |
| | Wed Mar 1 | 9-11 am | Diss Rm | Prac: Neurohistology, Research Methods |
| | Wed Mar 1 | 12-1 pm | LG03 WW | Lect: Development of the Nervous System |
| | Thurs Mar 2 | 9-11 am | Diss Rm | Prac: Development of the Nervous System |
| 2 | Tues Mar 7 | 5-6 pm | LG03 WW | Lect: General Organisation of the Brain |
| | Wed Mar 8 | 9-11 am | Diss Rm | Prac: Gross Anatomy of the Brain |
| | Wed Mar 8 | 12-1 pm | LG03 WW | Lect: Spinal Cord 1 |
| | Thurs Mar 9 | 9-11 am | Diss Rm | Prac: Spinal Cord 1 – Gross, nuclei |
| 3 | Tues Mar 14 | 5-6 pm | LG03 WW | Lect: Spinal Cord 2 |
| | Wed Mar 15 | 9-11 am | Diss Rm | Prac: Spinal Cord 2 – tracts, lesions |
| | Wed Mar 15 | 12-1 pm | LG03 WW | Lect: Brainstem 1: Medulla |
| | Thurs Mar 16 | 9-11 am | Diss Rm | Prac: Brainstem 1: Medulla |
| 4 | Tues Mar 21 | 5-6 pm | LG03 WW | Lect: Brainstem 2: Pons & Midbrain |
| | Wed Mar 22 | 9-11 am | Diss Rm | Prac: Brainstem 2: Pons & Midbrain |
| | Wed Mar 22 | 12-1 pm | LG03 WW | Lect: Cranial Nerves 1 |
| | Thurs Mar 23 | 9-11 am | Diss Rm | Prac: Cranial Nerves 9 – 12 |
| 5 | Tues Mar 28 | 5-6 pm | LG03 WW | Lect: Cranial Nerves 2 |
| | Wed Mar 29 | 9-11 am | Diss Rm | Prac: Cranial Nerves 3 – 7 |
| | Wed Mar 29 | 12-1 pm | LG03 WW | Lect: Reticular Formation |
| | Thurs Mar 30 | 9-11 am | Diss Rm | Prac: Autonomic Nervous System |
| 6 | Tues April 4 | 5-6 pm | LG03 WW | Lect: Review of Long Tracts |
| | Wed April 5 | 9-11 am | Diss Rm | Prac: Revision |
| | Wed April 5 | 12-1 pm | LG03 WW | Lect: Group projects |
| | Thurs April 6 | 9-11 am | Diss Rm | Prac: Spot Test |
| 7 | Tues Apr 11 | 5-6 pm | LG03 WW | Lect: Auditory System |
| | Wed Apr 12 | 9-11 am | Diss Rm | Prac: Auditory & Vestibular Systems |
| | Wed Apr 12 | 12-1 pm | LG03 WW | Lect: Visual System |
| | Thur Apr 13 | 9-11 am | Diss Rm | Prac: Visual System |
| Break | Apr18-Apr 23 | | | No classes |
| 8 | Tues Apr 25 | 5-6 pm | LG03 WW | ANZAC-Public holiday |
| | Wed Apr 26 | 9-11 am | Diss Rm | ----- No prac |
| | Wed Apr 26 | 12-1 pm | LG03 WW | Lect: Thalamus |
| | Thurs Apr 27 | 9-11 am | Diss Rm | Prac: Thalamus |
| 9 | Tues May 2 | 5-6 pm | LG03 WW | Lect: Telencephalon |
| | Wed May 3 | 9-11 am | Diss Rm | Prac: Horizontal Slices of Forebrain |
| | Wed May 3 | 12-1 pm | LG03 WW | Lect: Cerebral Cortex: Somatosensory & Motor |
| | Thurs May 4 | 9-11 am | Diss Rm | Prac: Coronal Slices of Forebrain |
| 10 | Tues May 9 | 5-6 pm | LG03 WW | Lect: Cerebellum |
| | Wed May 10 | 9-11 am | Diss Rm | Prac: Cerebellum |
| | Wed May 10 | 12-1 pm | LG03 WW | Lect: Basal Ganglia |
| | Thur May 11 | 9-11 am | Diss Rm | Prac: Basal Ganglia/Cerebellar Disorders |
| 11 | Tues May 16 | 5-6 pm | LG03 WW | Lect: Limbic System |
| | Wed May 17 | 9-11 am | Diss Rm | Prac: Limbic System |
| | Wed May 17 | 12-1 pm | LG03 WW | Lect: Hypothalamus |
| | Thur May 18 | 9-11 am | Diss Rm | ----- No prac |
| 12 | Tues May 23 | 4 pm | BSB office | Group Projects due |
| | Tues May 23 | 5-6 pm | LG03 WW | Lect: Cerebral cortex- Higher Functions |
| | Wed May 24 | 9-11 am | Diss Rm | Prac: Cerebral cortex |
| | Wed May 24 | 12-1 pm | LG03 WW | Lect: Blood Supply of the Brain |
| | Thur May 25 | 9-11 am | Diss Rm | Prac: Blood Supply of the Brain |
| 13 | Tues May 30 | 5-6 pm | LG03 WW | Lect: Venous Drainage, Meninges, CSF |
| | Wed May 31 | 9-11 am | Diss Rm | Prac: Venous Drainage, Meninges & CSF |
| | Wed May 31 | 12-1 pm | LG03 WW | Lect: Chemical Systems in the Brain |
| | Thur June 1 | 9-11 am | Diss Rm | Prac: Clinical Cases |

Resources

See also [Learning Resources](#).

Online

- BrainStorm Interactive Neuroanatomy
 - URL and log in details on p. 32 (Spinal Cord 1 prac) of this manual.

Text Book

- T.W. Vanderah, and D.J. Gould. **Nolte's The Human Brain: An Introduction to its Functional Anatomy**, 7th ed. C.V. Mosby, 2015. This is a comprehensive text.

OR

- Crossman, A.R. and Neary, D. **Neuroanatomy An Illustrated Colour Text**, 5th ed. Churchill Livingstone, 2014. This text is adequate but covers just the essentials.

Library References

- M.F. Bear, B.W. Connors and M.A. Paradiso. **Neuroscience – Exploring the Brain**, 4th ed., Lippincott Williams and Wilkins, 2015. (3rd Ed 2007 OK if 4th not available)
- Waxman, S, G., **Clinical Neuroanatomy**, 26th ed. McGraw Hill, 2010.
- J.A. Kiernan: Barr's The Human Nervous System. **An anatomical Viewpoint**, 9th Edition. J. B. Lippincott, 2008.
- D. E. Haines: Neuroanatomy. **An Atlas of Structures, Sections and Systems**: 7th Edition. Urban and Schwarzenberg, 2007.
- E.R. Kandel, J.H. Schwartz, T.M. Jessell, S.A. Seigelbaum, and A.J. Hudspeth. **Principles of Neural Science**, 5th ed. Elsevier, 2013
- C. Watson, M. Kirkcaldie, and G. Paxinos, **The Brain**. Elsevier, 2010

Revision Facilities

BrainStorm is available on all student computers in the Wallace Wurth Building, including those in G06/07, G08 and G16/17.

Models and dissections of anatomical structures are available in the Anatomy Museum (Rm G09).

Assessment

| | |
|--------------------------------|------|
| Spot Test 1 | 20% |
| Spot Test 2 | 20% |
| Group Project (due week 12) | 15 % |
| Final exam (2hr written paper) | 45% |

Spot Test and theory examinations will be based on the specific objectives, learning activities and recommended reading listed for each class.

Spot Tests

These are practical examinations that assess your ability to identify structures in brain dissections and cross-sections (including MR images) and to answer relevant short theory questions. In each Spot Test you will rotate around 15 stations. You will be expected to be able to identify structures **shown in bold type** in the class notes and to answer simple theory questions about these structures.

Spot Test 1 will be held in Week 6 and will examine material up to and including the Autonomic Nervous System.

Spot Test 2 will be held during the exam period and will examine material from the Auditory System onwards.

Theory Examination

This will include both multiple choice and written questions and will test understanding of the structural organization of the brain, spinal cord and cranial nerves and its relationship to function, according to the Specific Objectives defined earlier.

Failure to complete an assessment

Failure to sit a test without lodgement of an application for Special Consideration with Student Central will lead to automatic failure of the test. A student may be required to sit a supplementary exam or written assignment in place of a missed test.

See <http://medicallsciences.med.unsw.edu.au/students/undergraduate/advice-students#Special Consideration>

Supplementary Exams

It is intended that the supplementary exam (if required) for ANAT3411 in Semester 1, 2015 will be held in **mid-July 2017** or during the first week of Semester 2 depending on the availability of the course convenors. Please note that applications for Special Consideration for supplementary exams are not usually accepted except in TRULY exceptional circumstances.”

Formative Assessment

(i) **Adaptive tutorials or Moodle quizzes** are currently being prepared and will be made available each week through Moodle for formative assessment.

(ii) **Review questions** have been included at the end of most practical classes and you are encouraged to work through these after each prac to get some feedback on how you are going. Answers will not be provided for these questions. You should be able to work them out yourself if you have attended the prac classes. If you can't answer them refer to your lecture notes or text book.

Neuroanatomy Group Project

The Neuroanatomy assignment is a compulsory component of the course. It will provide an opportunity for you to develop your research and critical thinking skills by undertaking a literature review of current research on a topic of your interest.

The purpose of this assignment is to help you to develop skills in the (UNSW) graduate capabilities listed below (see p. 6 for details):

- Research, inquiry and analytical thinking abilities.
- Communication.
- Information literacy.
- Teamwork, collaboration and management skills.

In week 4, students will be allocated to groups of approximately 4 students. Groups will be able to choose from one of 4 topics. Each topic will include several defined tasks but the final product needs to be a collaboration between groups members. Each group will be expected to submit a written report of no longer than 2,500 words in length.

This project is a **compulsory** requirement of the course and is worth 15% of your final mark for this course. Of this 12% will come from the written report and all students in each group will receive the same mark. The other 3% will be determined by members of the group, each of whom will provide a collective score for each team member. Information on the group project, topics and guidance on peer assessment will be provided in a lecture in Week 6.

Your assignment should be **no longer than 2500 words in length** and you are encouraged to use diagrams where appropriate. References should be cited in the body of the assignment.

Due Date:

This report should be handed in to **Rm G27 in the BioSciences Bldg by 4.00 p.m. on Tuesday May 23 (beginning of Week 12)**. Marks will be deducted for reports that are handed in after this time, unless [Special Consideration](#) is granted.

Project Topics for 2017:

These will be distributed after the commencement of the course.

Criteria for Assessment of the Group Project

Scientific Content:

- Identifies the major concepts related to the assignment topic
- Demonstrates an understanding of the assignment topic
- Uses peer-reviewed research articles to support stated facts and arguments.

Effective Communication:

- Clarity (clear, simple, grammatical language, terms explained)
- Logical structure, use of headings and paragraphs
- Appropriate language length, style and format for the intended audience
- Appropriate use of media (illustrations, graphs etc.)

Self-Directed Learning and Critical Evaluation:

- Sources (range, citation standards, quality, relevance)
- Critical thinking (evidence of awareness of bias in sources, others viewpoints, own views, logical argument)

Peer Assessment

- Attendance at group meetings
- Participation in planning of the report
- Contribution to group discussion
- Quality of contribution to the report
- Execution of allocated tasks effectively and on time

Guidelines for referencing in the Neuroanatomy Group Project

Any ideas which are not your own should be cited in the text as per the **APA Style** guidelines as follows:

- References by a single author should be cited as Author (date of publication), e.g. Carrive (1996) or if there are two publications listed for the same author in the same year add a or b after the date e.g. Carrive (1996a), Carrive (1996b).
- If the reference has two authors it should be cited as Author A and Author B (date) e.g. Carrive and Potas (1998).
- If there are more than two authors it should be cited as Author A et al (date) e.g. Carrive et al (1999).

Details of APA referencing guidelines can be found at:

<http://web.med.unsw.edu.au/infoskills/apa/apa.html>

Student Risk Assessment

| | | |
|--|--|---|
| <p>Medicine Teaching Laboratory</p> <p>Student Risk Assessment</p> |  <p>UNSW THE UNIVERSITY OF NEW SOUTH WALES</p> | <p>Gross Anatomy Practical Classes for Medical and Science Students DOC:PHSL-SRA-S&H-01rev1.1</p> |
|--|--|---|

| Hazards | Risks | Controls |
|---|--|--|
| <p>Physical</p> <p>Cold temperature (16°C)</p> <p>Sharp bone/plastic</p> | <p>Cold</p> <p>Penetrating wound of foot</p> | <ul style="list-style-type: none"> • Wear laboratory coat over appropriate warm clothing • Wear enclosed shoes with full coverage of the dorsum of the foot • Have appropriate immunisation • Do not eat, drink or smoke in the Dissecting Room • Do not place anything (e.g. pens, pencils) into your mouth • Use disposable gloves when handling wet specimens and do not cross-contaminate models or bones with wet specimens • Always wash hands with liquid soap and dry thoroughly with disposable paper towel before leaving • Low concentrations of chemicals used • Chemicals used in well ventilated area • Safety Data Sheets for chemicals available in the laboratory |
| <p>Biological</p> <p>Fungi, bacteria (tetanus), hepatitis B and C</p> | <p>Infection</p> | |
| <p>Chemical</p> <p>Formaldehyde</p> <p>Methanol</p> <p>2-phenoxyethanol</p> | <p>Corrosive/Flammable</p> <p>Irritant/toxic</p> <p>Irritant</p> | |

| Personal Protective Equipment required | | | |
|---|--|---|--|
|  <p>Closed in Footwear</p> |  <p>Lab. Coat</p> |  <p>Gloves</p> | |

| Emergency Procedures |
|---|
| <p>In the event of an alarm sounding, stop the practical class and wait for confirmation to evacuate from demonstrators. Then wash your hands and pack up your bags.</p> <p>Follow the instructions of the demonstrators regarding exits and assembly points.</p> |
| Clean up and waste disposal |
| <ul style="list-style-type: none"> • Cover wet specimens with the towels provided. Make sure that towels do not hang over the edge of the table, because this allows fluid to drip onto the floor. Fluids on the floor are a major safety hazard and should be reported to staff immediately. • Replace stools under the tables in your cubicle. • Remove your gloves and dispose in the bio-waste bins provided. • Wash your hands and instruments thoroughly with the soap provided and dry your hands with the paper towel. • Remove your laboratory coat when you leave the dissecting room. |
| Ethics Approval |
| <p>This type of practical has been previously considered and approved by the UNSW Human Research Ethics Advisory Panel (HREC09372).</p> |
| Declaration |
| <p>I have read and understand the safety requirements for this practical class and I will observe these requirements.</p> <p>Signature:.....Date:.....</p> <p>Student number:</p> |

ANAT-SRA-Med&SciStudent relates to RA-MED-06. Date for review: 1/2/2018

ANAT3411 NEUROANATOMY

PRACTICAL CLASS MANUAL

2017

| | |
|--|----|
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| Practical Class 3 - Gross Anatomy of the Brain | 20 |
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| Practical Class 5 - Spinal Cord: tracts, lesions | 28 |
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| Practical Class 7 - Brainstem 2: Pons & Midbrain | 35 |
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PRACTICAL CLASS 1

STRUCTURE OF NEURONS, NEUROGLIA AND SYNAPSES, AND EXPERIMENTAL METHODS IN NEUROANATOMY.

Suggested reading:

Nolte, 6th ed., pp.1 – 36; or 7th ed., pp. 1 – 38.

Specific Objectives

1. To recognise in light microscopic material the parts of neurons (somas, dendrites, axons and synaptic specialisations).
2. To recognise in electron micrographs the parts of the neurons and to know the ultrastructural characteristics of those parts. To know the differences between the ultrastructural appearance of axons and dendrites and the structure of the myelin sheath in the peripheral and central nervous system.
3. To recognise in electron micrographs the synapses and describe their morphological features and types.
4. To understand the basic techniques used by neuroscientists to study the structure and interconnections of neurons.

Computer Instructions:

Images for this practical class are on the SOMS student computers.

Select Class programs – Anatomy - NeuroHistology Class

These images in this file are to be used in conjunction with the Learning Activities in the ANAT3411 Class notes.

To access the images click START. This will take you to the first image (001). On the left you will see numbered thumbnail images. Just click on the image you wish to view (a scroll bar on the right of this field allows to access all of the thumbnail images).

When you are viewing an image, you can ZOOM IN by using the MAGNIFYING GLASS icon. ZOOM OUT by holding down the OPTION key and clicking.

The “VIEW” menu allows you to choose “FULL SCREEN” option. You can stay in this mode and move through consecutive images by using the up or down arrows. Use “ESC” to exit back to the normal viewing mode and to access thumbnail images for navigation.

Learning Activities

1. Listen to a short explanation of the major techniques used in neuroanatomical research.
2. Using the computers in Rms 106 - 108, examine images 01, 02, and 03, which are photographs of preparations stained with Cresyl Violet to demonstrate nerve cell bodies (somas). What are in fact being stained are nucleic acids so that structures with a high content of RNA (ribosomes, nucleoli) and DNA (nuclei and nucleoli) are dark. Large clumps of ribosomes found in the cytoplasm of the nerve cells are called **Nissl substance**, and this type of stain often referred to as a Nissl stain (most commonly the dye use for this purpose is Cresyl Violet). This simple

technique gives a general view of the cell populations in the CNS but reveals little more than the size and density of the neuronal somas. In these preparations you can observe that the method helps to distinguish neuronal somas from **glial cells** (because in the glial cells only the nucleus stains) (images 01 and 02). It helps also in the identification of general patterns of cell topography as seen in image 03, a Nissl stained cross-section through the medulla which shows the characteristic shape of the inferior olivary nucleus.

3. Examine cells stained with the Golgi technique (images 04 and 05). This classical technique reveals the most about the morphology of neurons - staining somas, often axons, and especially because it reveals the structure of the **dendritic tree** of the cell. The critical factor for the stain is that, for as yet unexplained reasons, it only stains approximately 1% of cells, and therefore does not present a complicated tangle of dendrites and axons, but reveals isolated single-cell morphology. Observe the very different patterns of dendritic branching shown in images 04 (a retinal ganglion cell), 05 (a Purkinje cell from the cerebellum) and 06 (pyramidal cells in the cerebral cortex). In each image try to distinguish the **dendrites**, which are usually thick and highly branched, from the **axon**, very thin and usually not branching extensively near the soma. Apart from the Golgi impregnation technique itself there are some other techniques that provide a similar picture of neuronal morphology. Usually these stains are based on filling the neurons artificially with dyes or other stainable materials (such as **horseradish peroxidase**) resulting in a so-called Golgi-like preparation. Examine images 07 and 08, which show cells, which have been filled by intracellular injection of HRP (07) or lucifer yellow (08).
4. The location of major fibre tracts can be visualised using stains for myelin, which bind to the phospholipids of the myelin sheath. Such a stain (Weigert technique) is shown in image 09, a section through the medulla. Note the absence of staining of the cell bodies. Compare this with image 03, which is a Nissl stain of a similar level.
5. Review the electron microscopic features of nervous tissue on images 010 – 013. Identify the parts of the neuron including dendrites, axons, and somata. In the soma, the **nucleus** (and **nucleolus**) and the **cytoplasm** with the cytoplasmic organelles such as the **endoplasmic reticulum**, **Golgi apparatus**, **mitochondria** and **lysosomes** are to be identified (010, 011). Axons are unique, sharply defined processes, most obvious by the absence of rough endoplasmic reticulum in their cytoplasm. Observe the **axon hillock** and the **initial segment** of the axon (012). All parts of nerve cells have **neurofilaments** and **microtubules**, which form the cytoskeleton. They are most conspicuous in dendrites and axons where they are very important given the small diameter and long length of these processes. Examine image 013 (dendrites) and identify neurofilaments, which are 5-10nm in diameter, and microtubules, which are considerably larger, 20-25nm diameter, and are involved in intracellular transport.
5. Study the structure, origin and function of the **myelin** on images 014 – 015. Compare myelin sheaths in central and peripheral nervous systems. One glial (Schwann cell) cell wraps one axon in the peripheral nervous system (014), while one glial (oligodendrocyte) cell wraps many axons in the CNS (015).
6. Study the structure of synapses as seen in electron micrographs of central nervous tissue (016 – 019). Examine images 016 - 019 and try to distinguish **pre-** and **post-synaptic** elements of **chemical synapses** to identify the **presynaptic terminals**, **synaptic clefts**, **synaptic vesicles**, **synaptic densities**. When studying a synapse, it is important to identify the structures that form them and classify them

accordingly. The most common type is the **axo-dendritic synapse** (016, 013) many of which are onto specialised post-synaptic structures called **spines** (these are, as a rule, on dendrites; 017). Axo-somatic synapses are also common and are shown in 018. Image 019 illustrates the less common **electrical synapses** which are structurally identical with **gap junctions**.

8. Examine images obtained from neuroanatomical experiments. One group of techniques involves looking at connections between different parts of the brain and many of these take advantage of axonal transport. When a substance, such as HRP is transported retrogradely (towards the cell body) it accumulates in the cell body and labels the soma and dendrites, as shown in image 020. When the substance is transported anterogradely (away from the cell body) it accumulates in the axon terminals, as seen in image 021. Techniques that involve axonal transport can only be used in living tissue, whereas another technique, called Di I involves the lipophilic diffusion of the dye along the cell membrane. Given sufficient time, the dye can cross synaptic junctions so that an entire pathway can be displayed, as shown in images 022 and 023.
9. In recent years, a number of techniques have been developed which enable the identification of individual populations of cells based on their content of particular neurotransmitters. This is usually done by using antibodies that are specifically directed against a particular neurotransmitter (e.g. Glutamate, serotonin). A population of serotonergic neurons labelled using an antibody conjugated to HRP is shown in image 024. Immunocytochemistry is also used to look at structural features of neurons using antibodies directed towards structural proteins, as seen in figure 025.
10. Autoradiography is another way of visualising substances in cells. In this case the substance of interest is labelled with a radioactive tag and the tissue is exposed to photographic emulsion so the radioactivity appears as black grains, as shown in 026.
11. If time permits attempt the Adaptive Quiz on 'The Histology of the Nervous System', which can be accessed from the ANAT3411 Moodle page.

Review Questions: (to be done in your own time for revision)

1. How would you distinguish an axon from a dendrite in an electron micrograph?
2. List three features of a chemical synapse.
3. What is/are the function(s) of (i) neurotubules and (ii) neurofilaments?
4. What is the difference between the myelin sheaths of neurons in the PNS & the CNS?

Materials: School computers.

PRACTICAL CLASS 2

DEVELOPMENT OF THE CENTRAL NERVOUS SYSTEM

Suggested reading:

Nolte, 6th ed. pp. 37 – 52; or 7th ed., pp. 39 - 54

Specific Objectives

1. To understand the origins of the central nervous system from the neural tube and the process of neurogenesis.
2. To know the significance of the cerebral vesicles in the formation of the brain and the relationship of the different cerebral vesicles to each other.
3. To review the origins and subdivisions of the forebrain and hindbrain and describe how the cerebral hemispheres, the brain stem and cerebellum are formed.
4. To identify the structures forming the developing nervous system in the mammalian (pig) embryo and early human foetus.
5. To know the principle events in the formation of the cerebral cortex.

Learning activities

For much of this class you will be working through material on the computer that will enable you to review the major events in development of the nervous system. If you come across material that you do not understand or have any questions consult your tutor.

1. Open the **UNSW Embryology** program, NeuroClass page. This can be found at the following URL:
https://embryology.med.unsw.edu.au/embryology/index.php/ANAT3411_Neuroanatomy
(Note: you can also navigate to this page from anywhere within UNSW Embryology by selecting 'Science - ANAT 3411' in left hand menu).
On this page begin by clicking on the link to **Brain Awareness Week** and work through this module. It was originally designed for Year 12 students, but it provides a good overview of brain development, particularly if you have not already studied embryology.
2. Next, review the sequence of brain development using "**Embryo Images**" software by working through the **Nervous System Development** module. A link to the Embryo Images can be found on SOMS computers in the **Class Programs - Anatomy** menu or at the following URL:
http://www.med.unc.edu/embryo_images/unit-nervous/nerv_htms/nervtoc.htm
(Note: Details of cerebellum and pituitary gland development, covered in his module are not required for this course.)
2. Once you have completed that module, return to the **UNSW Embryology** program, NeuroClass page. This can be found at the following URL:
https://embryology.med.unsw.edu.au/embryology/index.php/ANAT3411_Neuroanatomy

Images that you will be required to view in this class appear in the approximate order in which you will study them.

When viewing the cross-sections, take note of the plane of the section, shown to the left of the image

3. Look at a section through the developing spinal cord (Stage 22 Spinal Cord) and note that the columnar ectoderm, which forms the wall of the neural tube, has assumed a three-layered appearance. On this section identify the innermost **ventricular layer**, the **intermediate layer** and outermost **marginal layer**. The ventricular layer (zone) is made of **neuroepithelial cells** that, by their successive divisions, produce new generations of cells. Cells that stop dividing (**neuroblasts**) migrate to the intermediate zone and will undergo further maturation there. On the virtual slide of this section, zoom in and you will be able to see mitotic profiles in the ventricular layer. On this slide you can also see the notochord sitting in the centre of the developing vertebra.

What is the function of the notochord?

4. On this section also identify the **basal** and **alar plates** of the developing spinal cord and the **sulcus limitans**, a groove that separates these two plates. Note that there is also a **roof plate** and **floor plate** of the tube connecting the two sides together; these regions are thin and are made of a ventricular layer only.

What structures form from the basal plates?

What structures form from the alar plates?

Notice the **dorsal root (spinal) ganglion** ventrolateral to the spinal cord. What is its embryonic origin and what is its function in the adult?

Origin:

Function:

4. On longitudinal sections of the Stage 13 pig embryo (G6L & G7L) identify the three primary cerebral vesicles: **forebrain**, **midbrain** and **hindbrain**. The forebrain (prosencephalon) will develop into the telencephalon (cerebral hemispheres) and the diencephalon. The hindbrain (rhombencephalon) will develop into the myelencephalon (future medulla oblongata) and more rostrally the metencephalon (future pons and cerebellum). In G7L note the location of the cephalic flexure (between forebrain and midbrain) and cervical flexure (between spinal cord and hindbrain). In frame (Stage 22) A3L identify the otic vesicles (labelled otocyst), derivatives of ectoderm which give rise to the inner ear. Identify the **optic vesicles** (B4L) from which the two retinas develop. Notice that they are connected to the **diencephalon**, the mid-part of the forebrain (B5L), by the **optic stalk**, and thus are part of the central nervous system.
5. The two main parts of the forebrain are the telencephalon and diencephalon. In the human embryo section A1L (coronal plane) identify the large telencephalic vesicles. Inside these, the **lateral ventricles** and the **choroid plexus** (which produces CSF) can be seen. Note also the location of the diencephalon and 3rd ventricle in this section. In a slightly more ventral coronal section (A3L) the cavities of the two telencephalic vesicles (the lateral ventricles) can be seen communicating with the ventricle of the diencephalon (**third ventricle**) through the **interventricular foramina**.
6. The cells of the telencephalon that are destined to form the grey matter of the cerebral cortex migrate a significant distance from the ventricular zone to collect

as a layer between the intermediate zone and the marginal zone: this is the **cortical plate**, which can be seen in section A1L (dark band in the outer part of the telencephalon). The **cortical plate** will develop into the adult cerebral cortex.

Examine the developing cortex in more detail in a high-powered section (Embryo Stage 22 Developing Cortex) and identify the following layers: **ventricular zone**, **subventricular zone**, **intermediate zone**, **cortical plate** and **marginal layer**.

7. Identify the parts of the diencephalon. In A4L, the large mass on either side of the 3rd ventricle is the **thalamus**. Ventral to this (A6L) one can identify the **hypothalamus** and the original anterior (rostral) end of the neural tube, the **lamina terminalis** (A6L). Recall that the optic nerves (which derive from the optic stalks) originate from the diencephalon (seen in B1L). Further caudally the **hypophysis** (pituitary gland) is seen, the neural part of which is a derivative of the diencephalon (B2L-B3L).
8. Return to frame A4L and identify the **mesencephalon** (= midbrain). Its dorsal part, the **mesencephalic vesicle**, a large, thin-walled structure overlaps the initial part of the metencephalon. In the adult this vesicle will reduce in size to form the cerebral aqueduct.
9. Identify the **metencephalon** (A6L, B1L-B5L, C1L-C3L). Its derivatives are the **pons** and **cerebellum**. The ventricular lumen of this part of brain stem is common with that of the myelencephalon and is called the **fourth ventricle**. The roof of the metencephalic part of the 4th ventricle is formed by the developing cerebellum (B2L-B3L) beyond which the ventricle forms two large **lateral recesses**. Further caudally, the expansion of the 4th ventricle causes the roof to thin until it is only a membrane bearing choroid plexus. The alar plates in this area are pushed laterally and they will lie lateral to the basal plates. Nevertheless the **sulcus limitans** (not labelled in sections) still marks the boundary between these two plates (B5L-C2L). As in the spinal cord, the basal plate gives rise to motor structures (nuclei) in the brainstem and the alar plates give rise to sensory structures (nuclei). Hence in the adult brainstem alar plate derivatives (sensory) lie lateral to basal plate derivatives (motor). This will be covered in more detail when we study the cranial nerve nuclei later in the course.
10. The **myelencephalon** (B6L-B7L and C1L-C3L) will form the **medulla oblongata**, the embryonic appearance of which is least different from the fully developed structure. Using the key below the image, follow the myelencephalon down (caudally) through these sections and you will see how the 4th ventricle gradually gets smaller. In the most caudal section of the myelencephalon (C3L) the 4th ventricle has closed down to form the central canal which will continue down the centre of the spinal cord.
11. Consider common conditions arising from abnormal development of the nervous system:
What is **spina bifida** and how may this affect development of the spinal cord and meninges?

What is the most common cause of spina bifida?

What is **anencephaly** and why does it occur?

Examine the embryology pots in the Anatomy museum and observe examples of spina bifida and anencephaly.

12. If you have time, complete the Adaptive quiz, 'The Development of the Nervous System'. This can be accessed from the ANAT3411 Moodle page. If you are not able to complete this during the prac, make sure you do it in your own time.

Other useful links:

http://php.med.unsw.edu.au/embryology/index.php?title=Neural_System_Development
http://php.med.unsw.edu.au/embryology/index.php?title=Neural_System_Development#Neural_Movies

Review questions (to be done in your own time):

1. List the secondary brain vesicles and the adult structures that derive from them.
2. In the developing brain where does neurogenesis take place?
3. At what stage of development (e.g. how many days or weeks after fertilisation) do each of the following events take place
 - (i) appearance of the neural plate
 - (ii) neural tube begins to fuse
 - (iii) rostral (head) end of the neural tube closes
 - (iv) caudal (tail) end of the neural tube closes
4. How might the likelihood of producing a baby with spina bifida be minimised?

Materials: Computers, models.

PRACTICAL CLASS 3

GROSS ANATOMY OF THE BRAIN

Suggested reading:

Nolte, 6th ed., pp. 53–64 & 99-102; 7th ed., pp. 56 – 68 & 103 – 106.

Specific Objectives

1. To identify the main gross features of the brain, including its major parts: the medulla oblongata, pons, midbrain, cerebellum, diencephalon and the four lobes of the cerebral hemisphere.
2. To identify the major components of the ventricular system (lateral, third and fourth ventricles, cerebral aqueduct, central canal and interventricular foramen)
3. To identify the major sulci and gyri (listed below in L.A.'s 4 - 6) and to locate the main functional areas of the cerebral cortex and know the sulci and gyri related to them.

Learning Activities

For this and the remaining practical classes you will be allocated to one of four prac groups and you must remain in this group for the duration of the course. You are not permitted to swap groups without permission from the course convenor.

For this class, divide into 3 groups of students. Each group is allotted one brain and one half-brain. Both specimens will be needed in this practical. At the end of the practical you should put the specimens back in their bucket - they should not be left out for too long, as they will dry out. Wet towels are provided to cover those specimens that are kept on trays. Students should ensure they **wear gloves at all times** when handling brain tissue.

1. With your subgroup, using specimens provided, identify the three major divisions of the brain: the **forebrain**, **midbrain** (mesencephalon) and **hindbrain**. The forebrain includes the **cerebral hemispheres** (telencephalon) and the **diencephalon**. The hindbrain includes the **pons**, **cerebellum** and **medulla oblongata**. The midbrain, pons and the medulla together constitute the **brainstem**.
2. Identify the components of the ventricular system of the brain: the cavity of the **fourth ventricle** is located between the pons and rostral part of the medulla (ventrally) and the cerebellum (dorsally). It is continuous caudally with the **central canal** of the spinal cord and rostrally with the **cerebral aqueduct** of the midbrain. The cerebral aqueduct opens rostrally into the **third ventricle**, the cavity of the diencephalon. It communicates on each side through the **interventricular foramen** with the **lateral ventricle** (located within the cerebral hemisphere).
3. Identify the 4 lobes of the cerebral hemispheres: **frontal**, **temporal**, **parietal** and **occipital**. Several major sulci separate the lobes from each other. Identify the **central sulcus**, between the frontal and parietal lobes, the deep **lateral sulcus** which separates the temporal lobe from the frontal and parietal lobes. On the medial surface is the **parieto-occipital sulcus**, between the parietal and occipital lobes. In dissected specimens, identify the **insula**, which is located in the depths of the lateral sulcus, where it is covered over by parts of the frontal, parietal and temporal lobes. Although formed by cortex, the insula does not belong to any of the 4 lobes just described – it is considered to be a separate lobe.

4. Examine the lateral surface of the forebrain and identify the **superior, middle and inferior frontal gyri**, which are separated from each other by the **superior and inferior frontal sulci**. The frontal gyri are separated posteriorly from the **precentral gyrus** by the **precentral sulcus**. In the parietal lobe identify the **postcentral gyrus and sulcus, the superior and inferior parietal lobules** and the **intraparietal sulcus**. In the temporal lobe identify the **superior, middle and inferior temporal gyri** and the **superior and inferior temporal sulci**.
5. Now examine the medial surface and identify the **cingulate gyrus and sulcus**. The cingulate gyrus surrounds a prominent white structure called the **corpus callosum**. Note that the medial end of the central sulcus frequently extends onto the medial surface, where it is surrounded by the **paracentral lobule**. Identify the **parieto-occipital and calcarine sulci** and the wedge-shaped region between them, the **cuneus** (Latin for 'wedge').
6. Now examine the ventral surface and identify the **olfactory sulcus** and the **olfactory tract** that runs along the sulcus. In the temporal lobe identify the **inferior temporal, occipitotemporal and parahippocampal gyri** and the **uncus**.
1. Drawing on knowledge obtained in previous anatomy courses, discuss the concept of functional localisation in the cerebral cortex. What is the function of the primary sensory and motor and language areas? On specimens, identify the areas listed below and the gyri and sulci related to them.
2. Complete the table below:

| Functional Area | Location |
|-----------------------|----------|
| Primary motor | |
| Primary somatosensory | |
| Primary visual | |
| Primary auditory | |
| Primary olfactory | |
| Motor speech | |
| Receptive speech | |

Review questions:

1. What gyrus:
 - (i) forms the medial border of the temporal lobe?
 - (ii) surrounds the corpus callosum?
2. What important functional area
 - (i) surrounds the calcarine sulcus?
 - (ii) occupies the precentral gyrus?

3. What is the largest component of the diencephalon?
4. A patient presents with slurred but coherent speech. Where in the cortex is the lesion likely to be?

Materials: whole and half brains, brain models, ventricle models.

PRACTICAL CLASS 4

SPINAL CORD 1 - Gross Anatomy, Major Nuclei, Reflexes

Suggested reading:

Nolte, 6th ed. pp 227 – 242; or 7th ed., pp. 233 – 248.

Specific Objectives

1. To study the general morphology and external features of the spinal cord including the meningeal coverings of the cord and the relationship between the spinal meninges and the vertebral column.
2. To identify the cervical and lumbar enlargements of the cord and understand their significance.
3. To understand the organisation of the grey and white matter of the spinal cord and to distinguish sections of cervical, thoracic, lumbar and sacral spinal cord and give reasons for each selection.
4. To describe the types of neurons found in the spinal cord and the principal neural connections and circuits in the grey matter.
5. To understand the pathways and functional significance of simple spinal reflexes.

Learning Activities

1. Examine a specimen of the spinal cord and compare its length with that of the vertebral column:
How far down the column does the spinal cord extend?

Why doesn't it reach the sacral levels if there are sacral spinal cord segments?

How then are sacral spinal cord segments defined?

2. Study the gross anatomy of the spinal cord by identifying its major surface features.
 - (i) Identify the following grooves on the spinal cord surface: **ventral (anterior) median fissure, dorsal (posterior) median sulci**, and, in the rostral half of the cord you may be able to discern the **dorsal intermediate sulcus**.
 - (ii) Identify the **ventral (anterior) and dorsal (posterior) spinal nerve rootlets**, which collect to form the **dorsal and ventral spinal roots** which then combine to form a **spinal nerve**. Identify the **dorsal root (spinal) ganglion**. The spinal nerve itself is very short and soon divides into dorsal and ventral rami. See if you can find these.

What does the dorsal root ganglion contain?

What is the function of the dorsal and ventral rami?

- (iii) At the caudal end of the cord find the **conus medullaris** and **cauda equina**.

At what level of the vertebral column does the spinal cord usually end?

Why are the nerve rootlets in the cauda equina so long?

3. Identify the covering of the spinal cord – the **pia mater**, closely covering the cord and nerve rootlets, and the arachnoid and dura maters, which together form the **dural sheath**. Note that the dural sheath extends beyond the dorsal root ganglion to fuse with the epineurium of the spinal nerve.

In situ, what separates the pia and arachnoid mater and what does it contain?

The spinal cord is suspended within the dural sheath by a series of **denticulate ligaments** that attach to the lateral sides of the cord between the dorsal and ventral roots. Note that the dural sheath is separated from the bone of the vertebral canal by the **epidural space**, which in the spinal region is occupied by fat and blood vessels. At its distal end the spinal cord is anchored to the coccyx by the **filum terminale**, an extension of the pia emerging from the tip of the conus medullaris.

4. Examine the changes in the diameter along the length of the cord and note that there are two regions that are distinctly wider than elsewhere - the **cervical** and **lumbar enlargements**.

Why are these regions so enlarged?

5. Examine prosections of the cervical region of the spinal cord in situ and identify as many of the features listed in Learning Activities 2 and 3 above.
5. At some stage during this practical you should examine bottle #156 in the anatomy museum. In this specimen a laminectomy has been performed to expose the cervical and lumbosacral regions of the spinal cord and their nerves in situ. Once again examine the features described in learning activity #2. In particular note the length of the spinal cord relative to the vertebral column, the position of the conus medullaris and the cervical and lumbosacral enlargements (i.e. vertebral level) and location of the dorsal root ganglia. Examine the meningeal coverings of the cord (dura, arachnoid, pia and denticulate ligaments are all visible).
6. Compare the levels at which the spinal cord and the dura mater usually end. What is the **lumbar cistern**?

Where is the safest place to take a sample of CSF and why?

Microscopic Anatomy

7. Examine cross-sections through the spinal cord by logging into "BrainStorm" on School computers:
URL: brainstormneuro.net
User name: student1
Pwd: brainstormstudent1

Open the program and select Cross-sections, Spinal Cord and then select the section through the thoracic region (double click on it). The sections photographed for these pages were stained for myelinated fibres, thus they demonstrate the extent of the white matter best. However, the density of myelinated fibres within the grey matter is not uniform and thus some nuclei within the grey matter are also recognizable, as clear, less stained regions. Observe the organisation of the **grey** and **white matter** (since this is a myelin, or axon stain the white matter stains darkly) and identify:

- (i) The grooves around the circumference of the cord: **ventral median fissure**, **dorsal intermediate** and **dorsal median sulci**.
- (ii) In the grey matter observe: **dorsal**, **ventral horns** and **intermediate zone**, **central canal**.
- (iii) In the white matter: **dorsal**, **lateral**, and **ventral funiculi** and **ventral white commissure**.

8. Now examine the sections through the cervical, thoracic, upper and lower lumbar levels and locate the **major nuclei** of the grey matter - the **substantia gelatinosa**, **nucleus proprius** (also known as the body of the dorsal horn), **nucleus dorsalis (Clarke's column)** found only between levels C8-L2/3 (best seen in the upper lumbar cross-section), **lateral horn (intermediolateral nucleus)**, found only between T1-L2/3, and the lateral and **medial motor nucleus**. Indicate their location on the diagrams provided.
9. Compare the appearance of sections from different levels of the spinal cord. Note the external characteristics of each level (shape, size, sulci etc.) and the relative amounts of grey and white matter. Complete the table below:

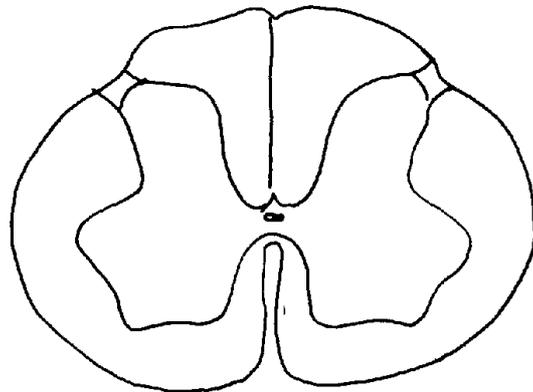
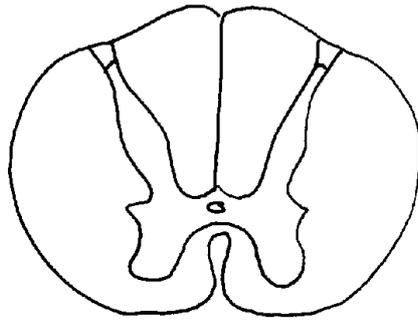
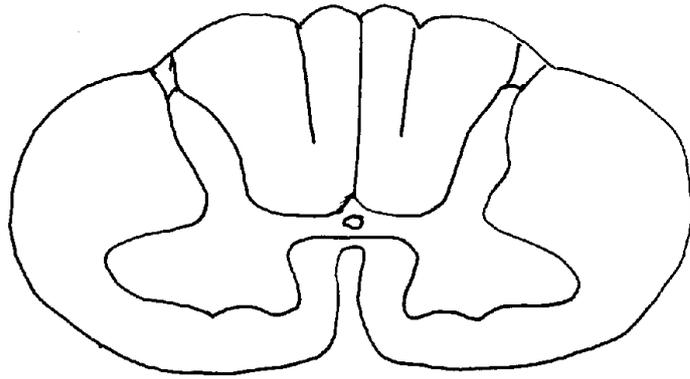
| Level | Distinguishing features | Functional significance |
|--------------|-------------------------|-------------------------|
| Cervical | | |
| Thoracic | | |
| Lower Lumbar | | |

10. Participate in tutorial discussion about simple spinal reflexes. What is the circuitry involved in the stretch and flexor (withdrawal) reflexes? What happens to the opposite limb during the withdrawal reflex and how does this occur? What is the "gamma reflex loop"? What is the clinical significance of these reflexes? What spinal segments are you testing when you test the knee and ankle jerks?

Review Questions:

1. How would you distinguish a cross-section from the lumbar region from one in the cervical region?
2. What nuclei would you find in cross-section through the thoracic region of the spinal cord? Which ones are not present in other regions?
3. How would you distinguish between the ventral and the dorsal sides of the spinal cord on a gross specimen?
4. Why is it important to take a lumbar puncture below the level of the L3 vertebra?
5. What does testing the stretch reflex tell the clinician?

Materials: Spinal cord dissections, models.



PRACTICAL CLASS 5

SPINAL CORD 2 – Major Long Tracts, Clinical Applications

Suggested reading:

Nolte, 6th ed. pp. 242 – 252, 259 – 263: or 7th ed., pp. 248 – 260 & 264 – 269.

Specific Objectives

1. To note the approximate positions within the white columns of the ascending sensory tracts (dorsal column system, spinothalamic, dorsal and ventral spinocerebellar) and of the major descending motor tracts (ventral and lateral corticospinal, lateral vestibulospinal, reticulospinal).
2. To understand the connections and functional significance of each of the above-named tracts.
3. To appreciate the functional deficiencies shown clinically to result from damage to the above-named tracts and regions of the spinal cord.

Learning Activities

1. Although the white matter is a large mass of ascending and descending axons there are distinct fibre tracts contained within it. Using “BrainStorm” examine a section through the cervical region of the spinal cord and establish the approximate position of the main fibre tracts within the spinal cord:
dorsal columns (gracile fasciculus) and (cuneate fasciculus), lateral and ventral corticospinal tracts, dorsal spinocerebellar tract, spinothalamic tract (sometimes referred to as the **anterolateral system**), and **vestibulospinal tract**.
Follow these tracts through consecutive sections of the cord and note changes in their size and/or location at different levels. As you do this mark the location of each tract in diagrams of spinal cord cross-sections (on previous page).
2. With your subgroup, as you identify the location of each tract, complete its details in the table provided. (Much of this information can be obtained by viewing diagrams and text screens for individual tracts in BrainStorm).
3. With your tutor view slides showing spinal cord pathology. Each of these slides was stained with a myelin sheath stain so that the degenerated tracts show up as pale areas in the white matter. One slide shows degeneration of an ascending sensory pathway.
Which tract is involved?

Try to deduce the resulting functional deficit:

4. The second pathological slide shows degeneration of the major descending motor pathway. Which tract is affected?

This would cause an **upper motor neuron lesion**. With the assistance of your tutor deduce the effects of such a lesion. (An upper motor neuron carries information down from motor areas of the brain to the spinal cord).

How would this differ from a **lower motor neuron lesion**? (A lower motor neuron directly innervates muscles).

Complete the table below:

| | Effects | Possible Causes |
|-------------|----------------|------------------------|
| UMN Lesion | | |
| LMN Lesions | | |

In some other diseases, as in a condition called '**motor neuron disease (or ALS)**' both upper and lower motor neurons may be affected simultaneously.

- Discuss the functional loss that would result from the hemisection of the spinal cord (**Brown-Sequard syndrome**). Deduce the symptoms that would result from a hemisection at C4 and compare it with the symptoms of a lesion at T6.

Review Questions:

- Where are the cell bodies of fibres in the cuneate fasciculus located?
- What is the function of the corticospinal tract?
- What is the function of the substantia gelatinosa?
- What would be the effect of lesion of the
 - spinothalamic tract on the right side?
 - gracile fasciculus on the right side?

| Tract | Cells of Origin | Crossed/uncrossed in spinal cord (relative to its origin) | Level of crossing (if relevant) | Site of termination | Function |
|------------------------|------------------------|--|--|----------------------------|-----------------|
| Gracile fasciculus | | | | | |
| Cuneate fasciculus | | | | | |
| Spinothalamic | | | | | |
| Dorsal spinocerebellar | | | | | |
| Lateral corticospinal | | | | | |
| Ventral corticospinal | | | | | |
| Vestibulospinal | | | | | |

PRACTICAL CLASS 6

BRAINSTEM 1: GROSS & INTERNAL ANATOMY OF THE MEDULLA

Suggested Reading:

Nolte, 6th ed. pp. 266 – 275 & 378-383; or 7th ed., pp. 272 – 281 & 383 - 387

Specific Objectives:

1. To describe the main parts of the brainstem (medulla, pons and midbrain) and the external features of these parts.
2. To identify the structures and landmarks on the dorsal surface of the medulla and in the floor of the fourth ventricle and to understand their relationship to the internal structure of the medulla.
3. To describe the basic internal organisation of the medulla and to be able to identify the more prominent structures seen on cross-sections at medullary levels.
4. To identify the course of the following major tracts of the medulla: corticospinal, dorsal column/medial lemniscus, spinothalamic, dorsal spinocerebellar, medial longitudinal fasciculus and olivocerebellar tracts
5. To identify the levels of decussation of the following tract systems: corticospinal, medial lemniscus (sensory decussation), olivocerebellar.
6. To identify the area of the reticular formation (medullary part).

Learning Activities:

Gross Anatomy

1. On a half-brain specimen, note the difference between the orientation of the long axis of the brain stem and that of the forebrain. Identify external features of the brain stem using dissected brain stem specimens and models. Identify the main parts of the brainstem (**medulla, pons** and **midbrain**) and the attachments of the **cranial nerves**. On the dorsal surface of the brainstem follow the **cuneate fasciculus** and **gracile fasciculus** to their termination, the **cuneate** and **gracile tubercles** which are swellings caused by underlying nuclei of the same name. Rotate the brainstem until a prominent bulge is encountered on its ventral-lateral aspect, this is the **olive** (formed by the principal inferior olivary nucleus). Medial to the olive, the **pyramid** can be seen emerging from the pons. At the caudal end of the medulla, many of the fibres in each pyramid cross to the opposite side forming the **pyramidal decussation**. At this level, the ventral median fissure can usually be seen to bend to one side or may even be obliterated as the pyramidal fibres cross to the opposite side. Also on the ventral surface of the brainstem, locate the **base of the pons (basis pontis)** that contains the **basilar groove** and extends laterally as the **middle cerebellar peduncle**. On the ventral surface of the midbrain identify the **cerebral peduncles** and **interpeduncular fossa**, and, on the dorsal surface of the midbrain, the paired **superior** and **inferior colliculi**.
2. The large, diamond shaped, opening on the dorsal surface of the pons and rostral medulla is formed by the floor of the **fourth ventricle**. Its shape gives it its name, the **rhomboid fossa**. Find and identify the other boundaries and openings of this ventricle (cerebral aqueduct, central canal of spinal cord, **superior and inferior cerebellar peduncles**, **superior medullary velum**, and **choroid plexus** of the **inferior medullary velum**). Identify the **obex**, the most caudal point of the

rhomboid fossa that, although not a functionally distinct anatomical entity, is a useful landmark. Inspect the rhomboid fossa, note the grooves (**median fissure, sulcus limitans**) and elevations (**median eminence**), on its floor. The sulcus limitans separates motor nuclei of cranial nerves (median eminences) from sensory nuclei (the vestibular nuclei) that lie lateral to the sulcus limitans in the fourth ventricle, forming the **vestibular area**.

Microscopic Anatomy

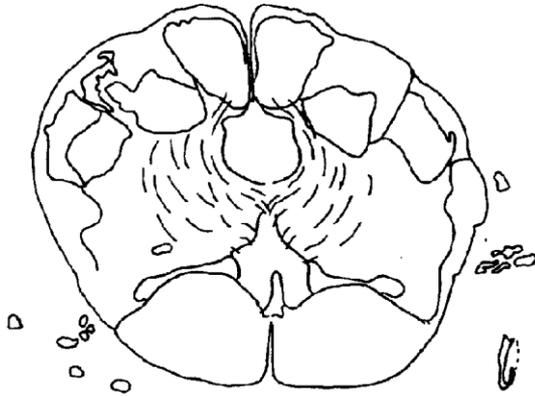
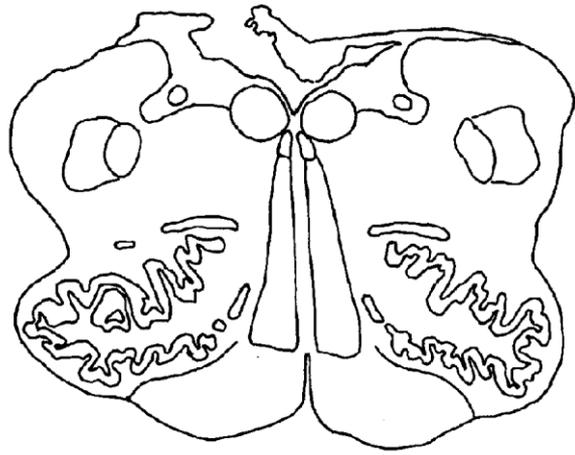
3. Using **BrainStorm**, study the microscopic anatomy of the medulla. It contains photographs of preparations stained for myelinated fibres so the tracts are darkly stained and the nuclei appear as less stained regions.
From the brainstem cross-sections menu, go to the **Medulla - pyramidal decussation**, which is at the caudal end of the medulla, and work through progressive sections of the brainstem as far as the pontomedullary junction level. As you examine these sections, fill in the location of each feature listed below in the outlines provided in this manual. Try to recognise the distinguishing features of each level. (Remember, at this stage you do NOT need to try and identify everything that is labelled on each BrainStorm section, just **focus on the structures listed in the learning activities** for this class). Sections through the most caudal part of the medulla are characterised by the massive **pyramidal decussation**, which is formed by corticospinal fibres crossing from the pyramids to enter the lateral funiculus of the spinal cord below. Grey matter of the **gracile nucleus** is just beginning to become visible in the gracile fasciculus. The cervical dorsal horn has been replaced by the caudal part of the **spinal trigeminal nucleus**, which is particularly prominent at this level.
4. In the next section (**Medulla – sensory decussation**) the distinguishing features are the presence of the dorsal column (**gracile and cuneate**) nuclei (which have almost replaced **the gracile and cuneate fasciculi**), and the **pyramids**, on the ventral surface. Lateral to the cuneate nucleus the **lateral (external) cuneate nucleus** is also visible and the **spinal trigeminal nucleus** is still prominent. The **central canal** is still visible, surrounded by the nuclei of cranial nerves (to be studied later). The lower end of the **inferior olivary nucleus** is just beginning to appear dorsal to the pyramid.
5. Sections through the rostral half of the medulla are characterised by the prominent **inferior olivary nucleus**, which lies dorsolateral to the **pyramids**. The dorsal column nuclei gradually disappear as one moves more rostrally, allowing the central canal to open up into the **fourth ventricle**. The **inferior cerebellar peduncle** (ICP) can be seen in the dorsolateral region of the medulla. At the rostral limit of the medulla, the ICP is covered externally by the grey matter of the **vestibular** and **cochlear nuclei**.
Note, other than the spinal trigeminal nucleus, structures associated with cranial nerves do not need to be identified at this stage. They will be studied in more detail later.
6. Identify the major tract systems of the medulla. Select each tract listed below in turn and follow it up or down through consecutive levels (using the up and down arrows) and note how it changes position at different levels. As you do this fill in its location at each level on the diagram outlines provided. You may wish to colour code each tract.
 - (i) The **corticospinal tract** makes up the pyramids on the ventral surface of the upper medulla and then crosses to the lateral side in the pyramidal decussation.

- (ii) The **spinothalamic tract** is located ventrolaterally in the caudal part of the medulla (in a similar position to the spinal cord) and is pushed more laterally and dorsally (by the inferior olivary nuclei) as it moves up through the medulla.
 - (iii) The **ventral** and **dorsal spinocerebellar tracts** run near the lateral surface.
 - (iv) The **gracile and cuneate fasciculi** continue from the dorsal columns of the spinal cord into the caudal medulla where they are gradually replaced by the gracile and cuneate nuclei respectively.
 - (v) The **medial lemniscus** arises in the closed medulla. It begins as the **internal arcuate fibres**, which arise from cells in the dorsal column nuclei. These fibres cross to the opposite side in the **sensory decussation** to form the **medial lemniscus**, which turns upward to ascend through the brainstem to reach the thalamus.
 - (vi) The **medial longitudinal fasciculus** (associated with the vestibular system) can be found on either side of the midline near the ventricular surface in the rostral levels of the medulla.
 - (vii) the **olivocerebellar tract** arises from the inferior olive and crosses the midline to enter the inferior cerebellar peduncle.
7. The major mass of cells and fibres of the brainstem core has been lumped together with the term, **reticular formation** (which consists of medullary, pontine and mesencephalic parts), although specific nuclei do lie within its mass. The reticular formation will be covered in more detail later in the course.

Review Questions:

1. What structures form the boundaries and roof of the fourth ventricle?
2. The decussation of which fibre system characterises the following levels of the medulla
 - (i) junction of spinal cord and medulla
 - (ii) rostral (open) medulla
3. What is the origin of the fibres of the medial lemniscus?

Materials: Whole and half-brain, brainstem specimens, BrainStorm.



PRACTICAL CLASS 7

BRAINSTEM 2 - PONS AND MIDBRAIN

Suggested reading:

Nolte, 6th ed. 275 – 283; 384-389; or 7th ed., pp. 283 – 290 & 388- - 393

Specific Objectives

1. To understand the internal organisation of the pons and the medulla and to be able to identify the characteristic features of cross-sections of the pons and medulla.
2. To describe the course of the following major tract systems through the pons and midbrain: corticospinal, corticopontine, spinothalamic, dorsal column/medial lemniscus, central tegmental tracts and the medial longitudinal fasciculus.
3. To identify the levels of decussation of the superior cerebellar peduncle and pontocerebellar tract, olivocerebellar tract, sensory decussation (medial lemniscus) and corticospinal tract.
4. To be able to recognize the characteristic features of cross-sections of the brain stem at the following levels: closed medulla, open medulla, ponto-medullary junction, mid-pons, isthmus, midbrain at inferior collicular and superior collicular levels.

Learning activities

1. Using BrainStorm, examine cross-sections of the pons. The pons is divided into the large **basis pontis** (base of the pons) and the relatively small **tegmentum**. In the caudal pons the IVth ventricle is at its widest and is virtually roofed by the cerebellum. More rostrally the **superior cerebellar peduncles** and between them the **superior medullary velum** delimit the ventricle. The base of the pons contains many small, scattered nuclei collectively known as the **pontine nuclei** - these massive islands of cells occupy the spaces between the fibre tracts of the basilar pons. Most of the nuclei in the pontine tegmentum belong to the reticular formation or cranial nerves and thus will be discussed in the next practical. However one pontine nucleus that should be identified now is the **locus coeruleus**, which is located in the lateral region of the periventricular grey matter, ventromedial to the superior cerebellar peduncle. It is the major noradrenergic nucleus in the brainstem. In fresh specimens locus coeruleus (L for blue spot) is dark blue in colour due to neuromelanin pigment found in its cells.
2. Identify the major long tracts in the pons. The **corticospinal tract** is in the basilar pons, intermingled with the pontine nuclei. The **medial lemniscus** is at the border of the basilar pons and the tegmentum, the **spinothalamic tract** travels through the lateral part of the reticular formation. Identify the massive **pontocerebellar tract**. These fibres are axons of the cells in the pontine nuclei; they cross the midline and travel in the **middle cerebellar peduncle** (MCP) towards the cerebellum. In the rostral pons identify again the **superior cerebellar peduncles**, which ascend from the cerebellum and enter the tegmentum of the isthmus.
3. At the isthmus the basilar pons is still present. The fibre systems in the isthmus are like those in the pons proper. Identify the now very flat **medial lemniscus** and the **spinothalamic tract**, which because it now appears as a lateral extension of the medial lemniscus is also known as the **spinal lemniscus**. Dorsal to the spinothalamic tract and just deep to the lateral surface is the **lateral lemniscus**,

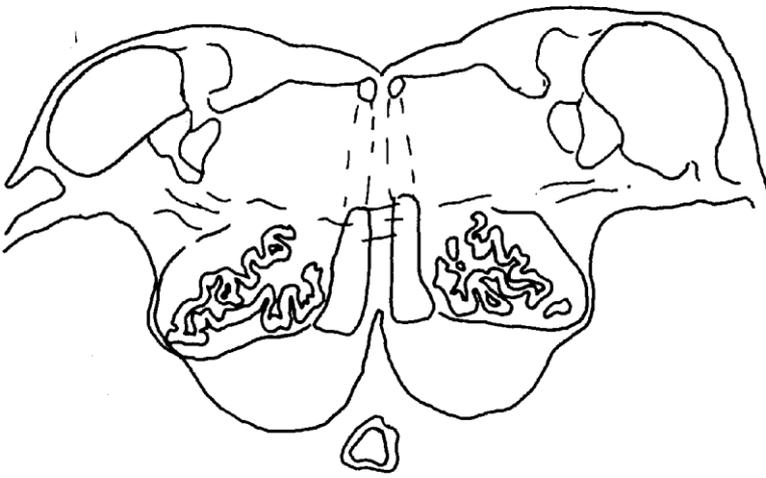
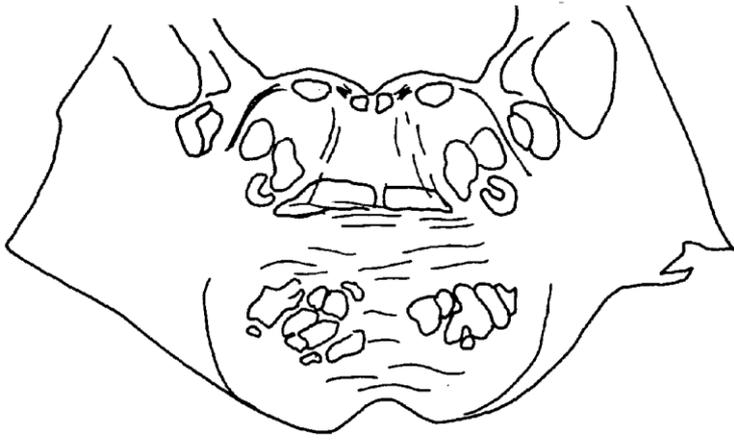
the principal auditory pathway, heading towards the inferior colliculus. In the tegmentum, identify the large masses of the **superior cerebellar peduncles**

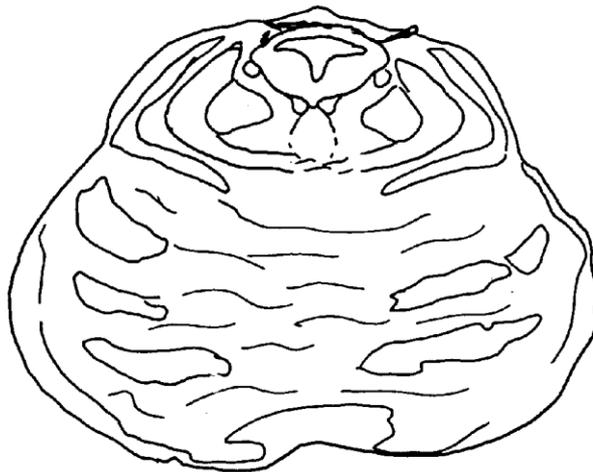
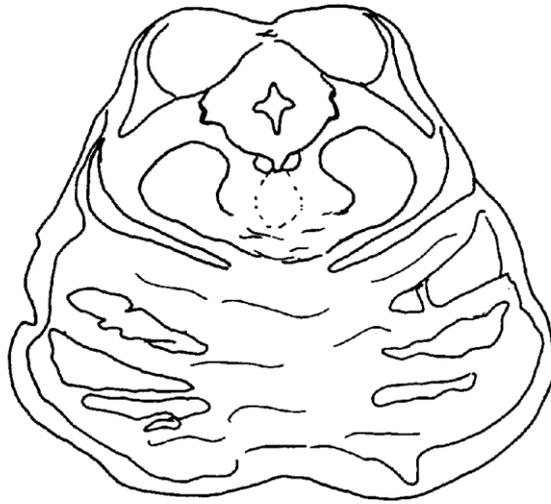
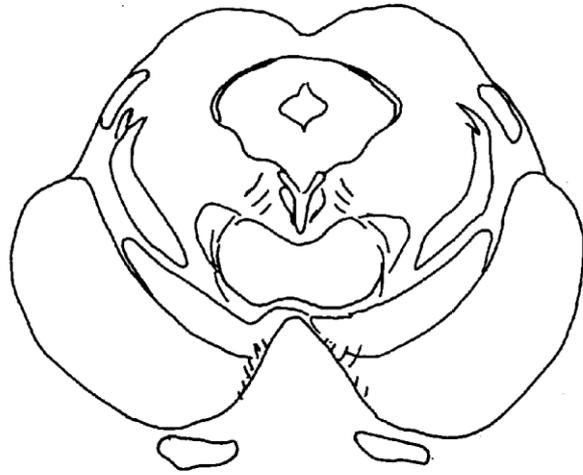
4. Examine the sections of the midbrain at the level of the superior and inferior colliculi. In sections at the level of the inferior colliculus, a part of the basilar pons is still present. Sections through the superior colliculus show more clearly the internal anatomy of the midbrain - identify the **inferior** and **superior colliculi**, which form the **tectum**. In the central part of the **tegmentum** surrounding the **cerebral aqueduct**, is the **periaqueductal grey matter**. Ventral to the periaqueductal grey identify the **red nuclei**. More laterally, the large **substantia nigra** is seen just dorsal to the crus cerebri. The rest of the tegmentum is occupied by the **midbrain reticular formation**.
5. Locate the fibre systems within the midbrain. First locate the tracts within the **crus cerebri** (base of the cerebral peduncle) and follow them down to the pons (these are all descending tracts). Most of the fibres belong to the **corticopontine tracts**, which arise from large areas of the cortex and terminate in the basilar pons. The **corticospinal tract** and most of the **corticobulbar tract** travel mainly in the middle third of the crus.
Follow the **medial** and **lateral lemnisci** and the **spinothalamic tract** up from the pons. In the midbrain they are located in the tegmentum, dorsolateral to substantia nigra. The lateral lemniscus can be seen to terminate in the inferior colliculus.
The **superior cerebellar peduncles** cross in the midline of the caudal midbrain, forming a major structure in the centre of the tegmentum. In the rostral midbrain the crossed fibres of the peduncles run next to the red nuclei.
Identify the **medial longitudinal fasciculi**.
6. Finally, you should now be able to tour through the brainstem sections at random and be able to recognize the characteristic features of the following brainstem levels: pyramidal decussation, closed medulla (sensory decussation), open medulla, ponto-medullary junction, caudal pons, mid-pons, isthmus, and the midbrain at inferior collicular and superior collicular levels. At each of these levels you should be able to locate the major nuclei and tracts covered in this and the previous practical.

Review Questions:

1. Construct a list of three distinguishing features of each level that would enable **you** to identify that particular level and fill these in the table provided. (It follows the brainstem X-section diagrams at the end of the notes for this class).
2. Name two tracts that occupy the cerebral peduncle
3. What structures form the base of the pons?
4. What major structure decussates at the level of the midbrain?

Materials: Dissected brainstems, brainstem models, BrainStorm.





| Level | Distinguishing features |
|---|--------------------------------|
| Medulla-pyramidal decussation | 1. 2. 3. |
| Caudal (closed) medulla (sensory decussation) | 1. 2. 3. |
| Rostral (open) medulla | 1. 2. 3. |
| Caudal pons | 1. 2. 3. |
| Mid-pons | 1. 2. 3. |
| Isthmus | 1. 2. 3. |
| Caudal Midbrain | 1. 2. 3. |
| Rostral midbrain | 1. 2. 3. |

PRACTICAL CLASS 8

CRANIAL NERVES IX - XII

Suggested reading:

Nolte, 6th ed., pp. 295 – 298, 304, 317 – 320, 378-383;
or 7th ed., pp. 301 – 305, 311, 323 – 326, 385 – 389.

Specific Objectives

1. To understand the functional groups of cranial nerve nuclei and the pattern of their organisation in the brainstem.
2. To recognise the cranial nerve nuclei of the medulla in brainstem cross-sections and understand their functional significance.
3. To review the origin of cranial nerves IX – XII from the brainstem and their exits from the skull.
4. To describe the formation of cranial nerves IX – XII and to understand the functional significance of each cranial nerve and the area that it innervates.
5. To consider the effects of lesions involving each of cranial nerves IX – XII.

Learning Activities

1. Functional components of the cranial nerves:
Spinal nerves contain up to two types of sensory (afferent) fibres - those supplying somatic structures, such as skin muscle and bone (known as **somatic sensory** fibres) and those supplying viscera (**visceral sensory**). Spinal nerves also contain up to two types of motor (efferent) fibres - those that supply skeletal muscle (known as **somatic motor** fibres) and those that supply smooth muscle and glands of viscera (**visceral motor**). You will recall that the motor fibres arise from columns of nuclei, that ascend throughout the ventral part of the spinal grey matter, and that the sensory neurons terminate in sensory nuclei that occupy the dorsal horn of the spinal grey matter

Cranial nerves can have any, or all of the above 4 functional components, as well as several other types, not present in the spinal nerves.

Branchial motor - supply skeletal muscle derived from the branchial (pharyngeal) arches of the embryo

Special visceral sensory - taste, smell

Special sensory - vision, balance, hearing

The nuclei for each of these functional components (like those in the spinal cord) form columns of cells (although these columns are sometimes broken) that maintain the same relative position throughout the brainstem.

Review the composition and structures supplied by the cranial nerves that emerge from the medulla. Complete the table on the next page:

| Cranial nerve | Components | Associated nucleus | Structures Supplied |
|------------------------|------------|--------------------|---------------------|
| XII Hypoglossal | | | |
| XI Accessory | | | |
| X Vagus | | | |
| IX Glossopharyngeal | | | |

2. On whole brains and models identify the glossopharyngeal (CN IX), vagus (CN X), accessory (CN IX) and hypoglossal (CNXII) nerves as they arise from the brainstem. On brainstem specimens identify the following gross features associated with cranial nerve nuclei: **hypoglossal trigone, vagal trigone, sulcus limitans, facial colliculus, vestibular area**. (The significance of the facial colliculus will be considered in the next class). It will help you with three-dimensional orientation if you refer back to the brainstem, and these landmarks, as you work your way through the cross-sections.
3. Using BrainStorm examine cross-sections of the medulla. Starting at the spinal cord - brainstem junction work your way up to the pontomedullary junction, identifying cranial nerve nuclei listed below. For each nucleus you should know:
- (i) its functional classification
 - (ii) which cranial nerve root or roots it contributes fibres to (if motor) or receives fibres from (if sensory)
 - (iii) if sensory, the location and type of receptors providing input and the sensory ganglion where their cell bodies are located.
 - (iv) if somatic motor, the target of its fibres
 - (v) if visceral motor, the target ganglion, and the eventual destination of the postganglionic fibres

All this information is available on relevant text and diagram screens in BrainStorm

In your own time complete the table at the end of notes for this prac (p.52).

To determine the levels of brainstem sections use the topography of the major crossing fibre systems as a guide.

At the level of the caudal medulla:

Identify the **accessory nucleus** replacing the lateral part of the ventral horn, and the **spinal nucleus of the trigeminal nerve**, which replaces the dorsal horn at this level. Identify also the **accessory nerve** arising from the lateral side of the medulla.

At the level of the closed medulla:

Identify the following: **hypoglossal nucleus and nerve, dorsal (motor) nucleus of vagus, nucleus ambiguus, nucleus of solitary tract, spinal nucleus and tract of the trigeminal nerve.**

At the level of the open (rostral) medulla:

These nuclei are still present, although there is a lateral shift in the position of the dorsal nucleus of the vagus and the solitary nucleus in relation to the hypoglossal. Lateral to the solitary nuclear complex identify the **vestibular nuclei** (as a group).

At the level of the pontomedullary junction:

The hypoglossal nucleus is no longer present. The **vestibular nuclei** can be seen in the floor of the ventricle, lateral to the sulcus limitans and the **cochlear nuclei** are visible covering the surface of the prominent inferior cerebellar peduncle. The fascicles of the **facial** and **vestibulocochlear nerves** can be seen.

4. Participate in tutorial discussion of the effects of a unilateral lesion of:
- (i) hypoglossal nerve,

 - (ii) accessory nerve

 - (iii) vagus nerve

(The glossopharyngeal nerve (CN IX) is rarely injured on its own and the vestibulocochlear nerve (CN VIII) will be covered in a later practical class).

5. Consider the following clinical problem:

A 68-year-old man was admitted to hospital with the sudden onset of severe dizziness (vertigo), hiccups and vomiting. He was also experiencing problems with his balance. On physical examination his soft palate was drawn up towards the left side when the patient was asked to say “ahh” and laryngoscopic examination showed there was a lack of mobility of the right vocal cord. Pain and temperature sensation was impaired in the trunk and extremities on the left side and on the right side of the face but touch and proprioceptive sensations were normal.

- (i) Deduce which cranial nerve nuclei may have been damaged to cause the signs and symptoms experienced by this man and from these findings, try to determine the approximate level of the lesion.

- (ii) How is it possible that pain and temperature sensations can be affected on the right side of the face and the left side of the body?

- (iii) Why is touch sensation unaffected in the trunk and limbs?

Review Questions:

- 1. What cranial nerve emerges from the brainstem between the olive and the pyramids?
- 2. What functional group does each of the following nuclei belong to?
 - (i) hypoglossal nucleus
 - (ii) solitary nucleus
 - (iii) dorsal motor nucleus of the vagus nerve
 - (iv) spinal nucleus of the trigeminal nerve
- 3. What do fibres arising from the nucleus ambiguus supply? Which cranial nerves carry these fibres to their targets?
- 4. What cranial nerve nucleus receives input from baro- and chemoreceptors?

Materials: Brainstem specimens and models, BrainStorm.

NB. Table of Cranial Nerve nuclei on next page

| Cranial n. Nucleus | Functional classification | Associated Cranial Nerve(s) | For Sensory nuclei: Location of afferent Cell Bodies | For Motor nuclei: Target of axons |
|--|----------------------------------|------------------------------------|---|--|
| Accessory nucleus | | | | |
| Spinal Nucleus of Trigeminal n. | | | | |
| Hypoglossal | | | | |
| Dorsal Motor nucleus of Vagus (DMNX) | | | | |
| Nucleus Ambiguus | | | | |
| Nucleus of Solitary tract (Solitary nucleus) | | | | |
| Vestibular nuclei | | | | |
| Cochlear nuclei | | | | |

PRACTICAL CLASS 9

CRANIAL NERVES III - VII

Suggested reading:

Nolte, 6th ed. pp. 305 - 316; 384-389; 469-472
or 7th ed., pp. 305 – 323; 388 - 393

Specific Objectives

1. To recognise the cranial nerve nuclei of the pons and midbrain in brainstem cross-sections and understand their functional significance.
2. To describe the composition of cranial nerves III – VII and their associated nuclei and to understand the functional significance of each cranial nerve and the area that it innervates.
3. To review the origin of cranial nerves III - VII from the brainstem and their exits from the skull. To describe the intracranial course of cranial nerves III – V and their relationship to the cavernous sinus.
4. To consider the effects of lesions of each of cranial nerves III – VII.
5. To describe the cortical inputs to the cranial nerve nuclei (corticobulbar tract).

Learning Activities

1. Revise cranial nerves III-VII. Make sure you know the functional components of each nerve and the nuclei associated with each nerve. Complete the table below:

| Cranial nerve | Components | Associated nucleus | Structures Supplied |
|-------------------|------------|--------------------|---------------------|
| III Oculomotor | | | |
| IV Trochlear | | | |
| VI Abducens | | | |
| V Trigeminal | | | |
| VII Facial | | | |

2. On whole brains and brainstem models, revise the location of the oculomotor (CN III), trochlear (CN IV), abducens (CN VI) and trigeminal (CN V) nerves as they leave the brainstem. Where are the cell bodies of sensory fibres in the facial and trigeminal nerves located?
3. On prosected specimens find each cranial nerve as it pierces the dura and compare this with the site of their foramina of exit from the skull. Observe the **extradural course of cranial nerves III - VI** and their relationship to the **internal carotid artery** in the **cavernous sinus**. Where is the **trigeminal ganglion** located?
4. Using BrainStorm identify the cranial nerve nuclei of the pons.
 - (i) In the caudal pons identify the **abducens nucleus** and the **internal genu of the facial nerve** around it. The **facial nucleus** is in the ventrolateral tegmentum. The **spinal nucleus of the trigeminal nerve** extends through the caudal part of the pons in the lateral part of the tegmentum. Note the **fibres of the facial nerve** passing between the facial nucleus and the spinal trigeminal nucleus.
 - (ii) In the mid-pons note the large, heavily myelinated **trigeminal nerve** as it passes through the **middle cerebellar peduncle**. At this level the spinal trigeminal nucleus has been replaced by the **principal sensory (pontine) nucleus of the trigeminal nerve**. The **motor nucleus of the trigeminal nerve** can be seen medial to it separated from it by the fascicles of the trigeminal nerve. In the corner of the tegmentum and the superior cerebellar peduncle the **superior vestibular nucleus** can be found.
 - (iii) At the level of the isthmus, the fibres of the **trochlear nerve** can be seen as they decussate before leaving the dorsal part of the brainstem.
5. Now examine sections through the midbrain:

The midbrain contains three important cranial nerve nuclei: the **trochlear** and **oculomotor nuclei** are in the ventral part of the periaqueductal grey matter and the **Edinger-Westphal** nucleus is near the midline adjacent to the oculomotor nuclei. Also adjacent to the periaqueductal grey is the **mesencephalic nucleus of the trigeminal nerve** in the form of a single layer of cells on its lateral and dorsal aspect. It is covered by the fibres of the **mesencephalic tract of the trigeminal nerve**. The fibres of the **oculomotor nerve** can be seen in the interpeduncular fossa at the level of the superior colliculus.
6. Participate in tutorial discussion of the effects of a unilateral lesion of the following cranial nerves:
 - (i) oculomotor nerve
 - (ii) trochlear nerve
 - (iii) abducens nerve
 - (iv) trigeminal nerve
 - (v) facial nerve

What cranial nerves are involved in the:

- (i) corneal reflex?

- (ii) pupillary light reflex?

- (iii) jaw-jerk reflex?

7. Also, discuss how fibres from the motor cortex are distributed to the cranial motor nuclei (**corticobulbar tract**), in particular the facial motor nucleus. How would you distinguish a lesion of the corticobulbar tract (upper motor neuron lesion) from a lesion of the facial nerve (lower motor neuron lesion)?

NB. BrainStorm contains detailed descriptions and diagrams showing the components, distribution and effects of lesions of each cranial nerve, including a simulated cranial nerve examination, in which you can introduce selected lesions and study their effects. This is called the 'Cranial Nerve Exam' and can be accessed directly from the Diagrams menu.

8. In your own time, complete the table of Cranial Nerve Nuclei on next page.

Review Questions:

- 1. What cranial nerve is closely related to the internal carotid artery deep in the cavernous sinus?
- 2. Where are the cell bodies of sensory fibres in the trigeminal nerve located?
- 3. What cranial nerve nuclei are located at the level of the superior colliculus?
- 4. List three brainstem somatic motor nuclei
- 5. List four effects of damage to the facial nerve in the internal acoustic meatus.
- 6. Damage to what cranial nerve(s) would result in:
 - (i) dilation of the pupil
 - (ii) medial deviation of the eye
 - (iii) paralysis of the muscles of mastication
 - (iv) loss of the corneal reflex
- 7. What is the function of the corticobulbar tract? What nuclei does it supply?

Materials: Brains, skulls, prosected specimens. brainstem models, BrainStorm.

| Cranial Nerve Nucleus | Functional Classification | Associated Cranial nerve(s) | For Sensory nuclei: Location of afferent Cell Bodies | For Motor nuclei: Target of axons |
|--|----------------------------------|------------------------------------|---|--|
| Abducens nucleus | | | | |
| Facial (motor) | | | | |
| Principal (main) sensory nucleus of trigeminal | | | | |
| Mesencephalic nucleus of trigeminal | | | | |
| Trochlear nucleus | | | | |
| Oculomotor nucleus | | | | |
| Edinger Westphal nucleus | | | | |

PRACTICAL CLASS 10

AUTONOMIC NERVOUS SYSTEM

Suggested reading:

Autonomic nervous system

Nolte, 6th ed. pp. 252 – 258; or 7th ed., pp. 260 - 264

Reticular Formation (Lecture)

Nolte, 6th ed. pp. 280-289; or 7th ed., pp. 286 – 295

Specific Objectives

1. To describe the organisation of the descending pathways involved in the control of the cranial and spinal autonomic nuclei.
2. To recognise the parts of the reticular formation involved in respiratory and cardiovascular control.
3. To describe the location and understand the function of preganglionic sympathetic and parasympathetic nuclei in the brainstem and spinal cord.
4. To understand the organisation of the autonomic outflow from the brainstem and spinal cord to peripheral target organs. To be able to describe and identify peripheral ganglia associated with the autonomic system and to understand the typical connections of the thoracic nerves with the sympathetic trunk.

Learning Activities

1. For revision, **during this practical class** complete the following table on the autonomic nervous system.

| | Sympathetic | Parasympathetic |
|--------------------------------|-------------|-----------------|
| level of emergence from CNS | | |
| length of preganglionic fibre | | |
| location of ganglia | | |
| length of postganglionic fibre | | |
| neurotransmitter at ganglion | | |
| neurotransmitter at target | | |
| distribution in body | | |

2. In order to understand the organization of the autonomic outflow from the central nervous system review on cross-sections in BrainStorm, the location of the cell bodies of **preganglionic sympathetic** neurons (spinal cord thoracic and upper lumbar levels) and find the nuclei containing the cell bodies of **preganglionic parasympathetic** neurons (brainstem). Identify the following autonomic nuclei:

In the spinal cord - the **lateral horn** (sympathetic, also known as the **intermediolateral nucleus** of T1-L3), and the **sacral autonomic nucleus** (parasympathetic, found at levels of S2-4).

In the medulla - the **dorsal motor nucleus of the vagus** nerve (parasympathetic).

In the midbrain - the **Edinger-Westphal nucleus** (parasympathetic).

Where do fibres arising from each of the above nuclei synapse (complete the table below)?

| Nucleus | Target |
|-------------------------------|--------|
| Lateral horn | |
| Edinger Westphal nucleus | |
| Dorsal motor nucleus of vagus | |
| Sacral autonomic nucleus | |

3. On specimens identify the **sympathetic trunk** (or chain) of ganglia. Spinal nerves connect to these ganglia by short "bridges", the **rami communicantes**. The ones carrying information from the spinal nerve to the ganglia (preganglionic) are known as the **white rami communicantes**, and the ones carrying information from the ganglia back to the spinal nerve (postganglionic) are known as the **grey rami communicantes**. The postganglionic fibres then travel to their peripheral target(s) with somatic motor fibres of the spinal nerve. Grey rami communicantes can be seen at all spinal cord levels whereas white rami communicantes can only be seen at levels T1 to L2/3. What accounts for the difference in "colour" between pre- and postganglionic fibres? Along the sympathetic trunk locate the swellings that are the **sympathetic ganglia**, they are found at each spinal level at thoracic and lumbar levels, but become sparser at cervical levels. Identify the three cervical ganglia: **inferior**, (commonly fused with the first thoracic ganglion to form the **cervicothoracic** or **stellate ganglion**), **middle cervical ganglion** (often absent) and the large **superior cervical ganglion** (sympathetic supply to the head).

4. Review the autonomic supply to the viscera:
 Sympathetic Supply:
 Identify the **thoracic (greater, lesser and least)** and **lumbar splanchnic nerves**. These contain preganglionic sympathetic fibres that synapse in ganglia that are scattered amongst plexuses located along the front of the abdominal aorta. Since these are anterior to the vertebral column they are called **prevertebral ganglia** and are named according to the arteries that they surround or accompany. The greater splanchnic nerve ends in the **coeliac ganglion**, the lesser and least splanchnic nerves end in the **aorticorenal ganglia**, and lumbar splanchnics end in the **superior mesenteric** and **inferior mesenteric ganglia**, which are located in plexuses of the same name. In general postganglionic sympathetic fibres from the prevertebral ganglia and plexuses travel along blood vessels to reach their targets. Sympathetic fibres from the inferior mesenteric ganglion continue inferiorly along the front of the aorta and into the pelvis where they supply the pelvic organs.

Parasympathetic Supply:
 On prosected specimens identify the **vagus nerve** and follow its course through the neck, thorax and abdomen. The vagus nerve fibres synapse on postganglionic fibres in or near their target organs (thoracic and abdominal viscera).
 The pelvic organs receive their parasympathetic supply from the **sacral autonomic nuclei** in spinal segments S2-S4. These (preganglionic) fibres form the **pelvic splanchnic nerves**, which can be

found branching from spinal nerves S2-S4, to supply the pelvic viscera and the hindgut. They synapse on postganglionic fibres in or near their target organs (hindgut and pelvic organs). Try to identify the pelvic splanchnic nerves in prosected specimens.

6. Participate in tutorial discussion of
 - (i) the descending pathways influencing autonomic function, including the role of the hypothalamus and the reticular formation.
 - (ii) What is Horner's syndrome and how might it be caused?

Review Questions:

1. What is the origin of preganglionic sympathetic fibres?
2. How do postganglionic sympathetic fibres reach their targets in the head?
3. What are the effects of loss of sympathetic supply to one side of the head?
4. What cranial nerves contain parasympathetic fibres?
3. What effect would a lesion of one vagus nerve have on visceral function?

Materials: Prosected specimens and models (cervical cord).

PRACTICAL CLASS 11

REVISION

PRACTICAL CLASS 12

SPOT TEST 1

SPOT TEST 1 **Thursday 6 April**

The midterm spot test in Neuroanatomy will take place during the scheduled practical class time and will include 15 x 2.5 minute questions using wet specimens and photographs. All the material covered up to and including the Autonomic Nervous System will be examined in this test. Don't forget, the pracs in week 1 will be included!

PRACTICAL CLASS 13

AUDITORY AND VESTIBULAR SYSTEMS

Suggested reading:

Nolte, 6th ed. pp. 342 – 377 or 7th ed., pp. 348 - 380

Specific Objectives

1. To recognise the spiral organ (of Corti), scalae, cochlear ganglion and vestibular end organs on a microscope section of the inner ear.
2. To understand the organisation of the auditory pathways. To identify the dorsal and ventral cochlear nuclei, trapezoid body, lateral lemniscus, inferior colliculus, brachium of the inferior colliculus and medial geniculate body in brain stem preparations.
3. To predict the effects of ipsilateral destruction of (i) superior temporal gyrus and (ii) cochlear nuclei.
4. To identify the vestibular complex in the brainstem and to understand the major connections of the complex with the motor nuclei of nerves III, IV and VI, cerebellum and spinal cord. To understand the neural circuitry producing the vestibulo-ocular reflex.
5. To define nystagmus and to explain the causes of nystagmus.

Learning Activities

1. Listen to a talk on the Vestibular System (in computer lab, Rm G08).
2. On a model of the ear review the structure of the middle ear to the extent that it helps you understand the transmission of sound waves from the eardrum through the stapes to the oval window. In the inner ear identify the **semicircular canals**, **sacculle**, **utricle**, **cochlea** and **vestibule**. Where is the **ampulla** of each semicircular canal located and what does it contain?

Study the relation of the inner ear to the middle ear cavity. A skull specimen is provided on which at least one temporal bone has been dissected to expose the **bony labyrinth**. Relate the semicircular canals to the rest of the skull and to each other.

Which semicircular canals on either side are parallel with each other?

Identify the **internal acoustic meatus**, which cranial nerve(s) pass through it?

2. Using BrainStorm, study the histological structure of the cochlea (accessed from the Histology menu; diagrams also available in Visual/Auditory menu). Identify the **scala vestibuli** and **tympani**, **cochlear duct**, **basilar**, **tectorial**, and **vestibular membranes** and the **spiral organ (Organ of Corti)**. Identify the **inner** and **outer hair cells** (within the Organ of Corti). In the **modiolus** identify the **spiral (cochlear) ganglion** containing the cell bodies of the fibres of the cochlear division of the **vestibulocochlear nerve**.
3. On brainstem specimens identify the **inferior colliculus**, the **inferior brachium**, and the **medial geniculate nucleus**. Auditory radiations run in the **sublenticular part of the internal capsule** to the primary auditory cortex in the temporal lobe. On dissections of the cortex, locate the primary auditory cortex (areas 41 and 42) on the two **transverse temporal gyri** (of Heschl) extending medially from the **superior temporal gyrus**. What features of sound are mapped onto the cortical surface, and what is the topography of the map? Find the **planum temporale** just behind the transverse temporal gyrus (can best be seen on the horizontal sections,). This area is typically much larger on the left than the right hemisphere, and is involved in receiving and understanding speech (**Wernicke's area**).
4. Examine cross-sections of the brainstem and trace the vestibulocochlear nerve more centrally.

At the pontomedullary junction identify: **dorsal** and **ventral cochlear nuclei** and **cochlear part of vestibulocochlear nerve**.

In the caudal pons identify the **superior olivary nuclei** and the **trapezoid body**, a bundle of transverse fibres running just underneath the medial lemniscus. Continue following the **lateral lemniscus** rostrally. The lateral lemniscus ends in the **inferior colliculus** which projects via the **brachium of the inferior colliculus** to the **medial geniculate nucleus** of the thalamus.

5. Identify the nuclei of the **vestibular complex (as a group)** - it is not necessary to identify each vestibular nucleus. Identify the **medial longitudinal fasciculus**, (connecting the vestibular nuclei with the motor nuclei controlling eye and head movements) and the **vestibulospinal tract** (connecting the vestibular nuclei with neurons in the spinal cord).
6. The vestibular system interacts with the visual system to keep an object on the area of retina with acute vision (fovea) even when the head moves, this is a reflex termed the **vestibulo-ocular reflex**, and it is based on connections between the vestibular nuclei and the oculomotor nuclei through the medial longitudinal fasciculus producing appropriate, **conjugate eye movements**. When the eyes reach the limit of their excursion they flick back to the opposite side and begin slow tracking again. These are the **fast** and **slow components** of **optokinetic nystagmus**. If you are turning to the left, in which direction is the fast component of the nystagmus? In which direction is the slow component? Have one of your colleagues spin around fast 15-20 times then stop abruptly and stare straight ahead, observe the fast and slow components of this **postrotatory nystagmus**, what is the direction of each component? What would you propose is the basis for this phenomenon?

Review Questions:

1. What is the function of the
 - (i) inner hair cells
 - (ii) outer hair cells
2. Why is the apex of the cochlea more sensitive to low frequency sounds?
3. Why does a lesion of auditory cortex on one side **not** have a significant effect on the patient's perception of hearing?
4. What organs in the ear detect angular movements of the head and where are they located?
5. Define the vestibuloocular reflex.

Materials: Brainstem specimens, horizontal slices, ear models, BrainStorm

PRACTICAL CLASS 14

THE RETINA AND VISUAL PATHWAYS

Suggested reading: Nolte, 6th ed. pp. 415 – 455; or 7th ed., pp. 419 – 458.

Specific Objectives

1. To describe the chief structural features of the retina, including the relative position of receptor, bipolar and ganglion cells and the significance of the macula lutea and optic disc.
2. To identify the optic nerve, optic chiasm, optic tract, lateral geniculate body, superior colliculus, medial longitudinal fasciculus and visual cortex on class specimens and slides.
3. To describe the pathway from receptor cells to the visual cortex and predict the results of damage to optic nerve, optic chiasm, optic tract and visual cortex.
4. To describe the roles of superior colliculus and pretectal area in visual reflexes.

Learning Activities

1. Using the models provided, identify the 3 layers of the eye (outer fibrous, middle vascular) and inner nervous layers. Review the major neural features of the eye including the retina, fovea, optic disc and optic nerve. Also, identify the main structures involved in light refraction (the cornea, lens and ciliary body).
2. Examine a histological specimen of the peripheral part of the retina in BrainStorm (Histology - Retina) and identify the **receptor outer segment layer, outer nuclear layer, outer plexiform layer, inner nuclear layer, inner plexiform layer, ganglion cell layer, and optic nerve fibre layer**. Note also the presence of the branches of the central retinal a. in the ganglion and nerve fibre layers. Now examine a histological section through the foveal region (Histology – Fovea). Find the **fovea**, and note the absence of **the ganglion cell and outer nuclear layers**. Observe the **perifoveal region** where ganglion cells are piled up around the edge of the fovea. Explain the significance of the different cell densities in the various layers.
3. Your tutor will demonstrate the proper use of the ophthalmoscope, but some key points to remember are: perform your examination in a dim or dark environment, have your "patient" fixate a spot in the distance (so his/her accommodation is at infinity). With an ophthalmoscope examine the back of the eye, it will be a reddish-orange colour. Find some blood vessels and focus the ophthalmoscope on them, follow the blood vessels until they lead you to the **optic disc**. (If they disappear you have followed them in the wrong direction, turn around and retrace your steps). Once you have found the optic disc, look slightly temporal to the disk for the greenish-yellow **macula lutea** (difficult to find without having had extensive experience). Compare your findings with the illustrations and models provided.

Using the ophthalmoscope or a small pen torch test the **pupillary light reflexes** on a colleague. Shine the light in one eye and observe the effects in each eye.

4. Have one of your colleagues stand approximately half a metre in front of a large chalkboard. Cover one eye, and have him or her stare (fixate) at a spot directly in front. From outside the visual field, move a target from each side, and from above and below him until it is just visible. Mark that location on the board. Draw an ellipse which connects the four points you have just plotted. Without the subject moving make a similar plot for the other eye using a different colour of chalk. Now you have plotted your colleague's **visual field**, identify the **binocular portion** and **monocular crescents, superior and inferior visual fields**. Which part of the retina do these regions fall on? On your plot where would you place the optic disc for each eye? Using the material provided demonstrate that the optic disc is indeed a blind spot.

5. Find the **optic chiasm** on the whole brain and note its relationships. On the brainstem specimens and horizontal and coronal slices trace the **optic tract** to the **lateral geniculate nucleus (LGN)**. If the coronal sections are made at an appropriate location you should be able to see the prominent mass of grey which is the lateral geniculate nucleus, notice its relationship to the lateral ventricle, hippocampus, tail of caudate, and medial geniculate nucleus. Many optic nerve fibres terminate in the LGN, others send collateral branches or bypass it entirely to enter the **brachium of the superior colliculus** which runs between the pulvinar and the medial geniculate nucleus. On the brainstem specimens find the superior brachium and its targets, the **pretectal area** and **superior colliculus**. Fibres from the lateral geniculate nucleus form the **optic radiations**, which travel in the retrolenticular portion of the internal capsule. They stand out well on both coronal and horizontal slices as a neat white stripe since they are heavily myelinated. Many of the above structures are also apparent on the BrainStorm brainstem and coronal forebrain cross-sections - make sure you have seen and recognised them.

5. On whole and half brains find **primary visual cortex (area 17)**. How is visual space mapped topographically onto the cortex?

Find the approximate regions of **areas 18 and 19**. What is the function of these areas?

7. Discuss the probable causes of each of the following lesions and deduce the visual field defect that results from each:
 - (i) section of the right optic nerve,

 - (ii) medial compression of the optic chiasm

 - (iii) lateral compression of the optic chiasm

 - (iv) section of right optic tract,

 - (v) stroke involving right occipital lobe.

8. Participate in a tutorial discussion about the pupillary light reflex and the process of accommodation. What is meant by the terms:
 - (i) direct pupillary reflex?

 - (ii) consensual pupillary reflex?

Consider the effects of the following lesions on the pupillary reflexes in the right (R) and left (L) eyes:

- (i) R optic nerve

- (ii) R oculomotor nerve

Review Questions:

1. What cell types synapse in the outer plexiform layer of the retina?
2. The pupillary light reflex is a test for which cranial nerves?
3. What layers of the lateral geniculate nucleus receive inputs from the contralateral eye?
4. What is the function of retinal inputs to the midbrain (superior colliculus and pretectal area)?
5. For each condition below state the site(s) where the lesion might have occurred:
 - (i) left homonymous hemianopia
 - (ii) bitemporal hemianopia
6. What part of the visual field is located at the anterior end of the inferior bank of the calcarine sulcus?

Materials: Ophthalmoscopes, torches, eye models, brain & brainstem specimens.

PRACTICAL CLASS 15

DIENCEPHALON

Suggested reading:

Thalamus - Nolte, 6th ed., pp. 390 – 407; or 7th ed., pp. 394 – 411.

Specific Objectives

1. To identify the gross features and position of the diencephalon.
2. To be able to recognise and describe the regions of the diencephalon (thalamus, subthalamus, hypothalamus and epithalamus).
3. To understand the organisation of the thalamic nuclei. To identify and describe the major thalamic nuclei (listed below in L.A. 9) and understand the main connections of each nucleus.
4. To identify the outline of the ventricular system associated with the diencephalon i.e. the body of the lateral ventricle and the third ventricle.
5. To identify the major regions of the hypothalamus.

Learning Activities

Gross Anatomy:

1. Study the dissected brain stem specimens. Identify the following structures: **third ventricle**, **epithalamus** (**pineal** (often removed) and **habenula**) and **thalamus**. Lateral to the thalamus is the mass of fibres called the **internal capsule**, which continues inferiorly into the **cerebral peduncles** of the midbrain.
2. Now examine the medial surface of the half brain specimen and identify the **hypothalamus**. Within the hypothalamus identify the **tuber cinereum** with the **infundibulum** emerging from it and the **mammillary body**. Identify the **hypothalamic sulcus**, **thalamus** and **epithalamus**, **corpus callosum**, **septum pellucidum** and **interventricular foramen**. If present, note the **lamina terminalis** above the **optic chiasm** and below the **anterior commissure**. What is the significance of the lamina terminalis?
3. Returning to the brain stem specimen, identify several distinct surface features of the thalamus. The **anterior nucleus** emerges as a small lump on the antero-superior pole of the thalamus, known as the **anterior tubercle**. It is opposed posteriorly by the **pulvinar**, a large mass overhanging the superior colliculus. On the inferior and ventrolateral aspect of the posterior thalamus identify the **medial** and **lateral geniculate nuclei** respectively. They are easily found by following their major afferent tracts: follow the tract from the inferior colliculus to the MGN, and the optic tract to the LGN (anterior and lateral to the MGN). Another surface feature of the thalamus is the **interthalamic adhesion (massa intermedia)** which may be present connecting the two thalami in the midline, this is simply an ependymal connection, there are no fibres within it which run between the thalami (i.e. it is not a commissure).

Microscopic Anatomy

4. The internal structure of the thalamus is best studied on cross-sections in BrainStorm. As you identify the structures described below indicate their location on the diagrams provided at the end of the notes for this class. When examining these cross-sections, you will be overwhelmed if you try to identify every labelled structure in each section. **Just focus on the structures listed below.** We will revisit these sections again when we study the forebrain and you will learn about the other structures then.

From the Cross-sections menu select the "Coronal Forebrain" submenu and begin your study with the most posterior section, (Midbrain-Pulvinar) and proceed anteriorly using the back-forward arrows in the upper right corner. The more caudal sections pass through the junction of the thalamus and midbrain. In the Midbrain-Pulvinar section identify the large **pulvinar** nucleus dorsally and the **medial geniculate nuclei** ventral to it and lateral to the midbrain structures. In the Coronal Thal. (LGN/MGN) section both medial and lateral geniculate nuclei can be seen ventral to the pulvinar and lateral to the midbrain. More rostrally the midbrain becomes continuous with the subthalamus and the pulvinar is replaced by the **lateral posterior** and **ventral posterior** nuclei.

5. Examine sections through the subthalamus/thalamus junction (Coronal VP-Subthal and Coronal VL-Subthal).

In the section Coronal Thal. (VP/Subthal) identify in the region of the **subthalamus**, the **red nucleus**, anterior most portion of the **substantia nigra**, **cerebral peduncles**. Dorsal to this region, is the thalamus itself. Identify the **external medullary lamina**. Between it and the internal capsule are the "islands" of cell bodies that constitute the **reticular nucleus**. Also identify the **internal medullary lamina**, as it splits around the large **centromedian nucleus**, a member of the **intralaminar group of nuclei**. Medial to the internal medullary lamina is the medial nuclear group, formed primarily by the **dorsomedial nucleus** (also known as the **mediodorsal nucleus**) which can be seen in this section seen here, but increases in size in more rostral sections). Lateral to it is the lateral nuclear group, which can be subdivided into a dorsal tier, (the largest component of which is the **pulvinar**); and a ventral tier which includes the **medial** and **lateral geniculate nuclei** (more caudally), and the **ventroposterior nucleus** (in this section). In the epithalamus, find the **habenula**. Dorsal to the thalamus observe the **lateral ventricle** laterally and the **fornix** medially.

Examine the section (Coronal thal (VL/subthal)). Note in the subthalamic region that the red nucleus has now disappeared and has been replaced by the **subthalamic nucleus**. The most rostral part of the **substantia nigra** is still present. In the thalamus, the **dorsomedial nucleus** has increased in size and the **centromedian** nucleus is still present. In the lateral part of the thalamus, the **lateral posterior nucleus** has replaced the pulvinar dorsally and the ventrally, the ventral posterior nucleus has been replaced by the **ventrolateral nucleus**. The **external medullary lamina** and the reticular nucleus are still visible. A component of the epithalamus, **stria medullaris thalami** can be seen on the medial surface of the thalamus passing caudally towards the habenula. Immediately ventral to this is the cavity of the **third ventricle**, separating the two thalami. In the rostral part of **interpeduncular fossa** the posterior parts of the **mammillary bodies** of the hypothalamus can be seen.

6. In sections through the mid-thalamus (e.g. Coronal VL-Mam. body and VL-Amygdala) observe the relationship of the diencephalon to the **corpus callosum**, **ventricles**, **internal capsule**. The lateral and medial groups of thalamic nuclei are more apparent separated by the **internal medullary lamina**. The major nucleus of the medial group is the **dorsomedial nucleus**. Note the presence of the **massa intermedia** (non-neural) joining the medial sides of the two thalami in this brain. At these levels the lateral group of thalamic nuclei is formed by the **lateral posterior nucleus** dorsally and the **ventral lateral nucleus** ventrally. Note the now more prominent **reticular nucleus** appearing on the lateral surface of the thalamus, embedded in the **internal capsule**, which covers the lateral surface of the thalamus. The **stria medullaris thalami** is still visible on the medial border of the thalamus. In the subthalamic region, the **subthalamic nucleus** can be seen. The many

fibres in this region go to the ventral tier of the thalamus and will be considered in further detail in a later practical. Ventromedial to the subthalamus the **mammillary bodies** of the **hypothalamus** can be seen giving rise to the **mammillothalamic** tract, which passes dorso-rostrally to end in the anterior nucleus.

7. Now examine a section through the **optic chiasm** (Coronal VA-Optic chiasm). The lateral part of the **anterior commissure** is also in view. The **dorsomedial nucleus** is still present but getting smaller. Dorsal to it the **anterior nucleus** can be seen. At this rostral level, the lateral mass is formed exclusively by the **ventral anterior nucleus** (the dorsal tier has disappeared). The reticular nucleus is still present on the lateral surface of the thalamus. Observe the **internal capsule** lateral to the thalamus. The **hypothalamus** can be seen dorsal to the optic chiasm, separated from the thalamus by the **hypothalamic sulcus**. Lateral to the optic chiasm and hypothalamus is the **anterior perforated substance** where many small blood vessels (branches from the Circle of Willis) enter the brain.
8. Section Coronal Thal (Ant)/ Anterior Comm, passes through the anterior pole of the thalamus. The dorsomedial nucleus has now disappeared and the thalamus is formed by the **anterior nucleus** medially and the **ventral anterior nucleus** (covered by the reticular nucleus) laterally. Note the **internal capsule**, which covers the lateral surface of the thalamus, and the **anterior commissure**, which crosses the midline ventral to the thalamus.
9. Discuss the functional significance of the thalamus as a subcortical station communicating with the cortex. On the table on the next page, indicate the major connections between areas of the cortex and the thalamic nuclei. In BrainStorm this information can be easily obtained for each nucleus on the relevant information page, which can be found by selecting/searching for the nucleus (by name) and clicking the Text (T) button.

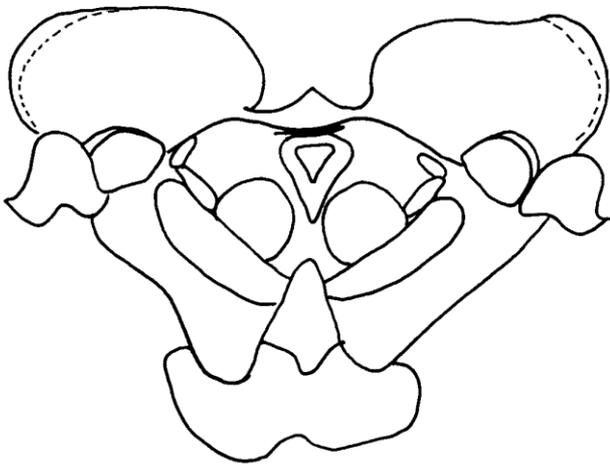
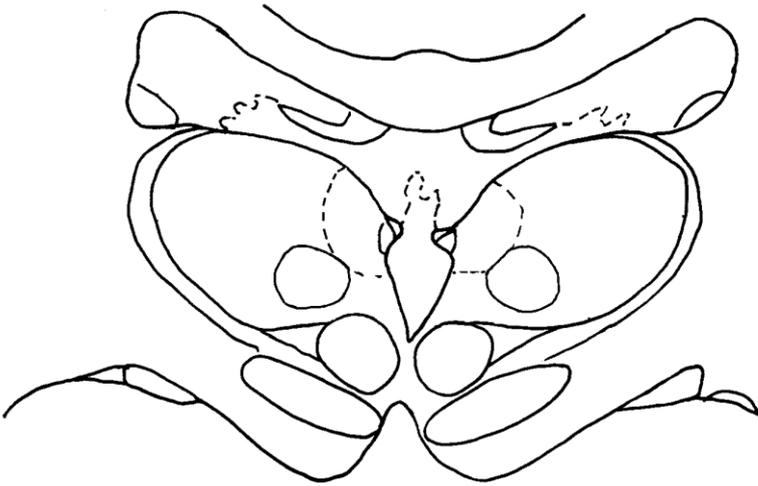
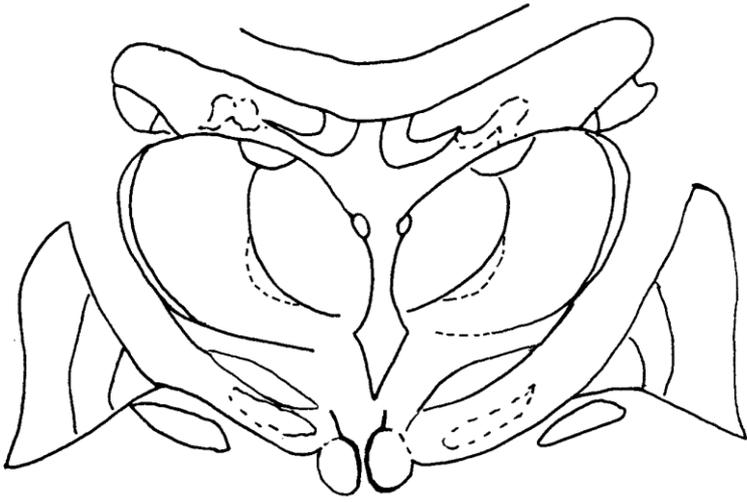
| THALAMIC NUCLEUS | TARGET CORTICAL AREA |
|-------------------------------|-----------------------------|
| Lateral Nuclear Group | |
| lateral geniculate nucleus | _____ |
| medial geniculate nucleus | _____ |
| ventral posterior nucleus | _____ |
| ventral lateral | _____ |
| ventral anterior | _____ |
| pulvinar | _____ |
| Anterior Nuclear Group | |
| anterior (anteroventral) | _____ |
| Medial Nuclear Group | |
| dorsomedial (mediodorsal) | _____ |

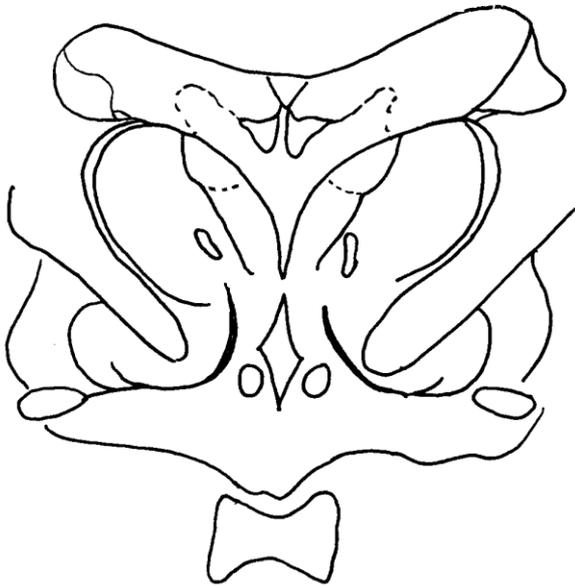
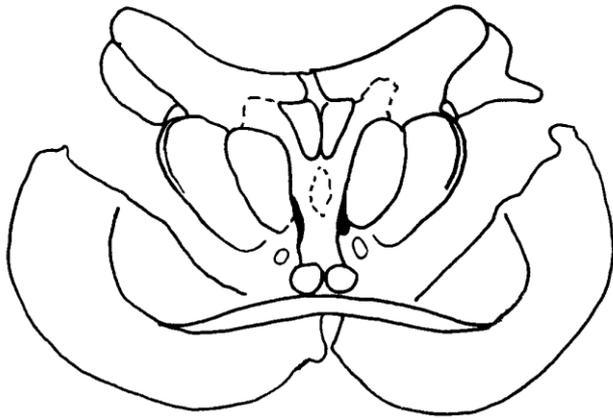
1. What thalamic nucleus
 - (i) receives input from the mammillary body?
 - (ii) projects to the precentral gyrus?
 - (iv) relays visual information to the cortex?
 - (v) receives input from the medial lemniscus & spinothalamic tracts?

2. What major structure covers the lateral surface of the thalamus?

3. What structures form the boundaries of the third ventricle?

Diagrams to complete during the practical class can be found on the next page.





PRACTICAL CLASS 16

TOPOGRAPHY OF FOREBRAIN 1: HORIZONTAL SLICES

Suggested reading:

Nolte, 6th ed. pp. 67 – 72; 99 – 103, 407 – 413.
or 7th ed., pp. 70 – 71; 103 – 106, 411 – 416.

Specific Objectives

1. To identify the components of the forebrain in horizontal sections.
2. To identify the caudate nucleus, globus pallidus, putamen and the relationship of these grey masses to the thalamus and cerebral cortex.
3. To identify the internal capsule and predict the results of damage to it from a knowledge of its chief fibre components.
4. To identify parts of the ventricular system and their relationship to the basal ganglia, thalamus and limbic structures.

Learning activities

An understanding of the anatomy of the forebrain, as seen in horizontal and coronal slices is becoming increasingly important because of the development of imaging technologies such as MRI and CT scanning, which produce images of the brain in cross-sections. In the next two practical classes you will examine sets of wet horizontal and coronal slices, myelin-stained cross-sections and MRI's in BrainStorm, as well as CT and MRI scans on radiographic film. In BrainStorm, myelin-stained horizontal sections can be accessed from the Cross-sections menu and MRI's from the Radiology menu. Corresponding MRI's and myelin stained images where possible, are linked, so as you work through this practical toggle backwards and forwards between these two representations so you can compare them

1. Observe a demonstration by your tutor of major features listed below on prosected specimens.
2. Using prosected specimens, examine the horizontal slices taken above the lateral ventricle. These show a large mass of white matter, the medullary centre of the hemisphere (also known as the centrum semiovale), surrounded by the cerebral cortex. The medullary centre contains fibres that run in different directions: many are commissural fibres from the corpus callosum, others run towards the cortex from the direction of the thalamus (forming the corona radiata). The commissural fibres of the corpus callosum form the roof of the lateral ventricle.
3. Examine slices through the lateral ventricle. In the highest slice identify the **caudate nucleus** (head and body) in its lateral wall and the **corpus callosum**.
4. As you move down through the ventricle, identify the **head** and **tail** of the **caudate nucleus**, the **lentiform (lenticular) nucleus**, the **thalamus** and their relationship to the internal capsule. Identify the two parts of the lentiform nucleus: the **globus pallidus** and the **putamen**. Lateral to the putamen are the **external capsule**, **claustrum** and **extreme capsule** just deep to the **insular**

cortex. In these sections the caudate nucleus appears twice (its head and its tail) as it circles around the lentiform nucleus. The caudate nucleus runs in the lateral wall of the lateral ventricle. Identify the **anterior horn, body, atrium (collateral trigone), posterior and inferior horns** of the **lateral ventricle**. Notice that most of the lateral ventricle surrounds the thalamus, while its inferior horn extends into the temporal lobe and the posterior horn into the occipital lobe. In lower slices the large **hippocampus**, covered by a sheet of white matter called the **alveus**, can be seen emerging from the inferior horn. Identify the **choroid plexus** protruding into the lateral ventricle - notice that the attachment of the plexus is along a line next to the fornix (see below).

5. Identify the **fornix**. This is a major tract of the brain that runs virtually free for most of its length. It originates in the temporal lobe and forms the medial wall of the lateral ventricle as it passes up behind and over the thalamus until it passes in front of the **interventricular foramen** to enter the grey matter of the **hypothalamus**. The fornices of the two hemispheres are attached to each other, above the third ventricle, and many fibres pass from one side to the other forming the **hippocampal commissure**. The dorsal surface of this commissure is attached to the undersurface of the splenium of the corpus callosum. The **column of the fornix** forms the anterior boundary of the interventricular foramen before it enters the hypothalamus to terminate in the **mammillary body**.
6. Now examine slices through the **internal capsule** and note the position and relations of its major parts: **anterior limb, genu** and **posterior limb**. Note the three parts of the posterior limb: **lenticulothalamic** (posterior limb proper), **retrolenticular** and **sublenticular parts**. Indicate the approximate location of the following fibre tracts in the internal capsule: **pyramidal tract (corticospinal + corticobulbar tracts), parts of the corticopontine system, anterior, middle, optic** and **auditory radiations**.

Discuss the clinical significance of the internal capsule. Deduce the effects of a lesion involving the posterior limb.

7. If available, examine a wet slice through the anterior commissure. Otherwise, examine the slice Horiz. – Ant Commissure in BrainStorm. The cut fibres of the **anterior commissure** appear on the medial surface of the hemisphere just anterior to the columns of the fornices. The slice below shows the more lateral parts of this fibre bundle, passing through the basal ganglia towards the temporal lobes, which the anterior commissure connects.
8. Study the white matter passing through the **corpus callosum**. Identify the major parts of the corpus callosum - **the genu, body and splenium**. The fibres that pass through the genu form the medial wall of the anterior horn, and connect the frontal poles to each other. The fibres looping through the genu from one frontal lobe to the other form the **forceps minor**. Similarly, there is posterior forceps connecting the occipital poles through the splenium of the corpus callosum: this is called the **forceps major**. Participate in tutorial discussion of the effects of cutting the corpus callosum (a procedure which is occasionally done to reduce the severity of epileptic seizures resulting in a “split-brain”).
9. Now examine the myelin stained and MRI sections in the horizontal and sagittal planes in BrainStorm. These can be accessed from the Cross-sections (forebrain) and Radiology menus. Work through each of these sets of images and identify where possible the **frontal, parietal, temporal** and **occipital lobes, insula, claustrum, amygdala, hippocampus, lateral ventricle, internal capsule, caudate nucleus (head and tail), putamen, globus pallidus, thalamus, fornix, corpus callosum (body, genu, splenium)**. In the more medial sagittal sections the **anterior commissure, hypothalamus, cerebellum** and components of the brainstem (**medulla, pons and midbrain**) are also visible. In the most medial sagittal forebrain section (Sagittal - mammillary body) also note the major grey matter structures of the brainstem including the **substantia nigra** and the **red, inferior olivary, cuneate** and **spinal trigeminal nuclei**.

Review Questions:

1. What tracts are located in each of the following parts of the internal capsule:
 - (i) posterior limb

 - (ii) anterior limb

 - (iii) sublenticular part

 - (iv) retrolenticular part

2. In a horizontal slice, what structures are separated by the
 - (i) anterior limb of the internal capsule?

 - (ii) posterior limb of the internal capsule

3. What structures surround the interventricular foramen?

4. List the structures that surround the body of the lateral ventricle:
superior (roof):

inferior (floor):

medial:

lateral:

Materials: Whole and half-brains, horizontal slices.

PRACTICAL CLASS 17

TOPOGRAPHY OF FOREBRAIN 2: CORONAL SLICES

Suggested reading (for practical):

Nolte, 6th ed., pp. 474 – 478, 638 - 657;
or 7th ed., pp. 476 – 478, 632 - 651

Suggested reading (for Lecture – Basal Ganglia)

Nolte, 6th ed., pp. 479 - 493
or 7th ed., pp 475 - 494

Specific Objectives

1. To gain a full understanding of the internal organisation of the cerebrum using coronal sections.
2. To identify the specific rostro-caudal order of the internal structures of the hemisphere and their relationship to the surface features of the cortex.

Learning activities

1. Observe a demonstration by your tutor of the structures listed below on these specimens. It is advisable to compare the coronal sections with the intact hemispheres in order to determine the exact position of each section, and also to correlate them with the horizontal slices to gain a fuller understanding of the three-dimensional organization of the hemisphere.

First, try to identify the features listed below in wet cross-sections and then on Coronal MRI sections in BrainStorm.

2. In the more anterior sections identify the **genu of the corpus callosum**, the **anterior horn of the lateral ventricle**, and the **olfactory tract**, (MRI Coronal - Ant. Horn, MRI – Coronal Ant limb). Identify the **head of the caudate nucleus** and note that it merges basally with the **putamen**. The region where these nuclei merge is called the **nucleus accumbens**. Dorsally, the head of the caudate nucleus and putamen move apart but they are still connected to each other by strands of grey matter passing through the **anterior limb of the internal capsule**. This gives the complex a striated appearance, hence the name **corpus striatum**. Medial to the nucleus accumbens, in a ventral continuation of the septum pellucidum, is the **septal area**, which is an important part of the limbic system. It is at about this level that the **anterior commissure** appears. Behind the genu and below the body of the corpus callosum the septum pellucidum separates the anterior horns of the lateral ventricles from each other, while more posteriorly the septum becomes gradually smaller and the ventricles move away from the midline. Notice that the medial wall and roof of the anterior horn contain those fibres of the genu of the corpus callosum which move towards the frontal pole (forceps minor).
3. Sections from the middle third of the hemisphere extend from the olfactory trigone to the splenium of the corpus callosum and are the most complex in their organisation. Examine these sections (sections MRI Coronal - Ant. Commissure to MRI Coronal – Pulvinar), and observe the internal organization of the **lentiform nucleus**, with the two segments of the **globus pallidus** medially and the darker **putamen** laterally. Note in the sections that the putamen extends beyond the globus pallidus in all directions. Medial to the lentiform nucleus identify the **internal capsule**. Follow this white band of fibres posteriorly into the **crus cerebri**.
4. Identify the major masses of the **diencephalon**. Although not labelled you may be able to distinguish the medial and lateral groups of the thalamic nuclei (which are separated by the internal medullary lamina). On the ventral surface of the thalamus identify the **optic tract** and follow it posteriorly to its termination in the **lateral geniculate nucleus**. Only the posterior part of this nucleus is attached to the main body of the thalamus: anteriorly it may seem separated from

the thalamus by the fibres of the internal capsule. The grey matter around the basal part of the third ventricle is the **hypothalamus**, delimited posterolaterally by the cerebral peduncles.

5. Ventral to the thalamus and lateral to the hypothalamus is the **subthalamic region** (MRI Coronal – Mid-thalamus). Identify the **subthalamic nucleus** which appears just dorsal to the fibres of the internal capsule. In the caudal sections through the thalamus you may identify parts of the midbrain such as the **substantia nigra** and **red nucleus**. In the posterior region of the thalamus identify the large mass emerging from the back of the thalamus, the **pulvinar**.
6. Focus your attention on the **temporal lobe** and identify the superior, middle and inferior temporal, occipitotemporal and parahippocampal gyri. In the section through the uncus (MRI Coronal - Ant. Commissure) identify the **amygdala** (a structure usually missed by the horizontal sections). Immediately behind the amygdala the **inferior horn of the lateral ventricle** starts. The inferior horn contains the **hippocampus** in its floor and the **tail of the caudate nucleus** in its roof. The inferior horn of the ventricle appears to open medially into the choroidal fissure - this is an artefact caused by mechanical damage to the **choroid plexus**, a pial-vascular structure that seals off the ventricle.
7. In the posterior set of sections (MRI Coronal - Splenium and MRI Coronal - Post. Horn) identify the **collateral trigone of the lateral ventricle**: this is the part connecting the body of the ventricle with the posterior and inferior horns. Lateral to the collateral trigone and posterior horn a distinct white band, the **optic radiation** can be observed.
8. Now go back to Learning Activity (LA) 2 and try to identify each of the structures described in LA's 2-7 on myelin-stained coronal sections of the brain (Coronal Forebrain series, accessed from Cross-section menu).
Note that the plane of these sections is not exactly the same as that of the MRI sections.

Note: In frame Coronal Thal. (VA)/Optic Chiasm the fibres of the **ansa lenticularis** can be seen looping around the internal capsule as they pass from the globus pallidus to the thalamus. Other fibres from the globus pallidus, the **lenticular fasciculus**, take a more direct route to through the internal capsule to the thalamus. Just before entering the thalamus, the ansa lenticularis and the lenticular fasciculus unite to form the **thalamic fasciculus**, which terminates in the motor nuclei of the thalamus.

9. If you have time, revisit the sagittal MRI's and myelin stained sections and try to identify as many of the structures listed in LA's 2-7 as you can.

Review Questions:

1. List the structures that surround the inferior horn of the lateral ventricle:
2. List the components of the corpus striatum
3. List, in correct order, the major structures that a needle would pass through if it were inserted into the lateral sulcus and reached the third ventricle.
4. Name two fibre bundles passing between the globus pallidus and the thalamus

Materials: Whole & half brains, coronal and horizontal slices, ventricle models.

PRACTICAL CLASS 18

CEREBELLUM

Suggested reading: Nolte, 6th ed. 494 – 521; or 7th ed., pp. 495 - 522

Specific Objectives

1. To identify the main external features of the cerebellum (listed below).
2. To understand the internal organisation of the cerebellum, including the functional morphology of the cerebellar cortex and deep cerebellar nuclei. To summarise the basic cell types and circuitry of the cerebellum.
3. To distinguish between archi-, paleo- and neocerebellum on the basis of topography, main connections and function.
4. To name the major fibre components of each cerebellar peduncle and to identify the afferent and efferent pathways connecting the cerebellum to other parts of the brain.

Learning Activities

1. With a whole brain specimen or model, orientate the cerebellum and ascertain which surfaces are related to the tentorium cerebelli, occipital bone, petrous bone and brain stem. Which part of the cranial cavity does the cerebellum occupy?
2. Using whole brain, and isolated whole cerebellum identify the **cerebellar hemispheres** and **vermis**, and the numerous **folia** on their surface. Note that the folia are all oriented transversely. Recognise the superior and inferior surfaces of the cerebellum and the **horizontal fissure** that separates them. Identify the three anatomical lobes of the cerebellum and sulci (fissures) that separate them:
 - (i) **flocculonodular lobe** - consisting of the **nodulus** and paired **flocculi**
 - (ii) **anterior lobe** - on the superior surface anterior to the **primary fissure**
 - (iii) **posterior lobe** - the remainder of the cerebellar hemispheresIdentify the **posterolateral fissure**, which separates the flocculonodular lobe from the posterior lobe (on inferior surface)

The cerebellum can also be divided on the basis of its connections into functional regions. Delimit the regions of the hemispheres and vermis which constitute the:

- (i) **vestibulocerebellum** - flocculus, nodulus,
 - (ii) **spinocerebellum** - anterior lobe, most of **vermis** and **paravermal zone**,
 - (iii) **neocerebellum** – (also known as pontocerebellum) - lateral parts of the hemispheres including the **tonsils**.
3. Use a specimen which has been cut sagittally into half brain or half cerebellum to study the structure of the vermis. Note the numerous lobular folia, and the strands of white matter extending into them, the appearance of the cerebellum from this perspective led the early neuroanatomists to call the structure **arbor vita** or "tree of life". Identify the two "ends" of the vermis: the **lingula** (anterior) and **nodulus** (posterior). The lingula rests on a thin sheet of white matter that helps to roof the fourth ventricle, the **superior medullary velum**, while the nodulus hangs down into the widest part of the ventricle. Although there are numerous grooves or sulci separating adjacent folia there are five deep fissures which divide the vermis into lobules, these are quite variable and you are not responsible for recognizing them all, however, you should be able to identify on these specimens: **uvula**, and **nodulus**, and **primary** and **posterolateral fissures**.
 4. Inspect the surface of the cerebellum related to the fourth ventricle and identify the three pairs of **cerebellar peduncles** (**superior**, **middle**, and **inferior**) on both the cerebellum specimen and the dissected brain stem. Note that the superior medullary velum stretches between the superior

peduncles and that the three peduncles enter the white matter of the cerebellum in the following medio-lateral order: superior peduncle, inferior peduncle, middle peduncle.

5. On sections of the brainstem in BrainStorm find each of the **cerebellar peduncles, nodulus and flocculus**, and identify the deep cerebellar nuclei (**fastigial, emboliform, globose and dentate**). There is good representation of these nuclei in the lowest of the X-sections: Horizontal Forebrain. The large dentate nucleus can also be seen well on paramedian sections of the gross cerebellar hemisphere (X-sections – Sagittal Forebrain). Review the connections of each of these nuclei with the cerebellar cortex, thalamus, red nucleus and vestibular nuclei.
6. Using BrainStorm, examine photomicrographs of the cerebellar cortex Histology – Cerebellar Cortex. In figure B a heterochromatic stain has been used to indicate axons (blue) and cell bodies (purple). Identify the white and grey matter, and recognize the cell layers: **granule cell layer, Purkinje cell layer,** and **molecular layer**. Purkinje cell bodies are readily apparent, forming a layer one cell thick. Now study the Golgi stained section in figure A and again recognise the cell layers. The Purkinje cell's dendritic tree is completely stained. Is this section taken parallel or perpendicular to the plane of the folia? Compare the size of the Purkinje cell body with those of the granule cells (only cell bodies stained). Granule cells are among the smallest and most numerous nerve cells in the nervous system.
7. Participate in tutorial discussion of the connections of the vestibulo-, spino- and neocerebellum with the vestibular system, spinal cord, thalamus and cerebral cortex. Name the major afferent and efferent tracts of each of the three functional parts of the cerebellum and decide which peduncle each of these tracts runs in.
8. Consider the following clinical problem:
A 37 year - old man visited his physician because he had noticed clumsiness of his right arm which had started 6 months previously and was getting worse. He also noticed he had a tremor in his right hand when he attempted to insert a key in a lock. When he walks he tends to keel over to the right and passive movements of the arms and legs revealed hypotonia and looseness on the right side. When asked to walk heel-toe in a straight line he swayed over to the right side. When asked to touch his nose with his right index finger the right hand displayed tremor and the finger tended to overshoot the target. Using your knowledge of neuroanatomy try to explain each sign and symptom. Is the lesion likely to be in the midline or to one side and if so, which side?

Review Questions:

1. What areas of the cerebellar cortex project to the
 - (i) fastigial nucleus?
 - (ii) dentate nucleus?
 - (iii) interposed nucleus?
2. List two effects of damage to the flocculonodular lobe
3. What is the main source of input to the neocerebellum? They enter the cerebellum via what peduncle?
4. What is the origin of the climbing fibres of the cerebellar cortex?

Materials: Cerebellum dissections, brain, half brains, models.

PRACTICAL CLASS 19

BASAL GANGLIA/CEREBELLAR DISORDERS

Suggested reading: as for Basal Ganglia Lecture
Nolte, 6th ed., pp. 479-493 and 520-521
or 7th ed., pp 475-494 and 518-521

Specific objectives

1. To gain a basic understanding of the circuitry of the basal ganglia and the major neurotransmitters involved.
2. To appreciate the significance of the direct and indirect loops of the basal ganglia
3. To explain how loss of the dopaminergic neurons of the nigrostriate pathway causes the symptoms of Parkinson's Disease (PD).
4. To recognise other common basal ganglia disorders (hemiballismus, chorea, athetosis) and know the structures involved.
5. To recognise the signs of a medial cerebellar lesion and a lateral cerebellar lesion.
6. To appreciate the differences between basal ganglia and cerebellar motor disorders.

Learning Activities

1. View several short videos demonstrating different motor disorders resulting from basal ganglia or cerebellum damage
2. Review each video with your tutor. Identify: i) the motor deficit observed, ii) the main nuclei involved, iii) the major connections to relevant brain nuclei.
3. Discuss how the relevant pathway results in the observed motor deficit. Where relevant, discuss possible treatments and their limitations.
4. What disorder results from a lesion in the subthalamic region? What would you predict such a lesion would cause and can you explain your prediction in terms of the basal ganglia circuitry?
5. What is meant by the terms chorea and athetosis? What parts of the basal ganglia are thought to be involved?
6. How can the underlying circuitry explain the difference between intention and resting tremor?

Review Questions:

1. List three common symptoms of Parkinson's disease.
2. State the two major sources of input to the striatum and for each, state the neurotransmitter involved.
3. Explain, on the basis of its circuitry, how interruption of the indirect loop would result in a hyperkinetic disorder?
4. Why does a medial cerebellar lesion cause abnormal nystagmus?
5. What is dysdiadochokinesia

Materials: Motor disorder videos

PRACTICAL CLASS 20

OLFACTORY AND LIMBIC SYSTEMS

Suggested reading:

Olfactory System - Nolte, 6th ed. pp. 330 – 339 or 7th ed., pp 336 - 345

Hypothalamus (lecture only) - Nolte, 6th ed., pp. 580 – 594: or 7th ed., pp. 579 - 593

Limbic System - Nolte, 6th ed. pp. 595 – 605; or 7th ed., pp. 594 - 604

Specific Objectives

1. To identify the subcortical and cortical parts of the limbic system in dissected human specimens, models and diagrams, and note the relation between the structures of the limbic system and the lateral ventricles. To identify the major fibre tracts which connect these structures to each other, to the thalamus, hypothalamus and brainstem.
2. To understand the organisation of the hippocampal region and to discuss the afferent and efferent connections of the hippocampal formation.
3. To identify the component parts of the olfactory pathway.

Learning Activities

1. On whole and half brain specimens examine the components of the olfactory system. Identify the **olfactory bulbs and tract**. A groove down the olfactory tract divides it into **medial** and **lateral olfactory striae**, which separate distally to form the **olfactory trigone**. Targets of the olfactory striae include the **anterior perforated substance**, the **uncus**, and the anterior portion of **parahippocampal gyrus (entorhinal cortex)** and the **amygdala**.
2. Examine human brain slices and dissected specimens and identify the **amygdala, hippocampal formation**, (including **subiculum, hippocampal gyrus, dentate gyrus**), **fimbria, alveus and fornix, hippocampal commissure, septal area cingulate gyrus**. Follow the **stria terminalis** (which runs in the groove between tail of caudate and thalamus) from the **amygdala** to the septal area. A major outflow of forebrain limbic system to brain stem runs in the **stria medullaris thalami** to the **habenula**, then from habenula to the brainstem. Identify the parts of the thalamus that belong to the limbic system (**anterior nucleus** and **mediodorsal nucleus**). Note carefully the position of these structures in relation to the third ventricle and lateral ventricles. On coronal slices you may be able to see the **mammillothalamic tract** connecting **mammillary bodies** to anterior nucleus, this forms an integral component of the **Papez circuit**. Draw a simple wiring diagram which completes this circuit.
3. Using BrainStorm examine coronal sections through the forebrain and identify the following components of the limbic and olfactory systems: **interpeduncular nucleus** (found in the midbrain), **habenula, mammillary bodies, stria medullaris thalami, mammillothalamic tract, mediodorsal nucleus, stria terminalis, amygdala, anterior perforated substance, olfactory tract, anterior commissure** and **septal area**. (If necessary, use the “index” function, select the name of the structure of interest and click “X” - this will take you to the best Cross-section for that structure). The ventrally located region of confluence of caudate and putamen below the anterior limb of the internal capsule is known as the **nucleus accumbens**. It is adjacent to the **septal area**, and is a component of the limbic loop of the basal ganglia.
4. Using BrainStorm, examine a cross-section through the hippocampus (the most posterior coronal forebrain section shows it best) and identify **hippocampal and dentate gyri, subiculum, fimbria, fornix** and **hippocampal commissure**. Now examine the BrainStorm diagram of the hippocampal formation and note the layers of the hippocampal and dentate gyri and their major afferent and efferent connections.

5. Review the connections of the amygdala and the hippocampal formation, particularly their relationship to the hypothalamus. Consider the effects of bilateral lesions involving
 - (i) amygdala
 - (ii) hippocampal formation
 - (iii) removal of the temporal lobes (Kluver-Bucy syndrome).

Review Questions:

1. What structures make up the hippocampal formation?
2. Describe the deficit that results from a lesion of the hippocampal formation
3. What is the functional relationship between the amygdala and the hypothalamus?
4. What is 'conditioned fear'?
5. State the major connections of the fornix.

Materials: Whole and half-brains, slices, prosections, BrainStorm.

PRACTICAL CLASS 21

CEREBRAL CORTEX

Suggested reading: Nolte, 6th ed., 541 – 571; or 7th ed., pp. 541 - 570

Specific Objectives

1. To review the major external features of the cerebral hemisphere and identify the lobes between them.
2. To identify significant sulci and gyri and understand the functional roles of the areas identified.
3. To understand the histological organisation of the neocortex, including regional variations.

Learning Activities

1. Using brains and half brains, review the major external features of the cerebral hemispheres and identify the lobes and boundaries between them. Find the following structures, most of which you have seen before: **interhemispheric (or longitudinal) fissure, lateral sulcus, central sulcus, pre- and postcentral sulcus, parieto-occipital sulcus, calcarine sulcus, superior, middle and inferior frontal gyri, precentral and postcentral gyri, superior, middle and inferior temporal gyri, insula**. Some new structures you should find are listed below:
On the lateral surface of the parietal lobe identify the **inferior and superior parietal lobules**, separated by the **intraparietal sulcus**. Within the inferior parietal lobule try to delimit **supramarginal gyrus** (usually wraps around the end of the lateral sulcus) and **angular gyrus** (usually wraps around the end of the superior temporal gyrus).
Identify the three parts of the inferior frontal gyrus - the **pars opercularis, pars triangularis** and the **pars orbitalis**. The pars opercularis and triangularis together constitute the so-called **motor speech area (or Broca's area)**.
In dissections where the inferior frontal gyrus has been removed, identify the insula. In the temporal lobe, identify the transverse temporal gyri and behind them the planum temporale.
The second major speech area, the receptive speech (Wernicke's) area, occupies the planum temporale, posterior part of the superior temporal gyrus and the supramarginal gyrus.
2. On the inferior surface of the brain find the **orbital gyri, gyrus rectus, olfactory bulbs** and **olfactory tract, occipitotemporal and parahippocampal gyri**, (separated by the **collateral sulcus**) and the **uncus**.
3. On the medial surface of a half brain, find the **cingulate gyrus, paracentral lobule**, the three cerebral commissures (**corpus callosum, anterior commissure** and **hippocampal commissure**), and the **posterior commissure**. Note the space between the back end of the corpus callosum (splenium) and the colliculi of the midbrain. This is the **transverse cerebral fissure** where arteries and veins gain access to the interior of the cerebrum. Identify the parts of the corpus callosum: **rostrum, genu, body** and **splenium**. The grey matter under the rostrum of the corpus callosum is the **paraterminal gyrus**, it is continuous with a thin layer of grey matter on either side of the **septum pellucidum**, the septal nuclei. Taken together, paraterminal gyrus and septal nuclei are often called the **septal area**.

4. Review the histology of the cerebral cortex. How does neocortex differ from archi- and paleocortex? What characterises each of the following types of neocortex?
- (i) homotypical
 - (ii) heterotypical granular
 - (iii) heterotypical agranular

Where is each type found?

5. Participate in tutorial discussion of the localisation of function within the cerebral cortex. Locate each of the following functional regions and discuss the effects of isolated lesions to each region
- (i) Primary somatosensory area
 - (ii) Primary motor area
 - (iii) Prefrontal area (prefrontal lobotomy)
 - (iv) Broca's motor speech area (dominant hemisphere)
 - (v) Receptive Speech area (dominant hemisphere)
 - (vi) Primary Visual Cortex
 - (vii) Primary Auditory area

What is the function of the association areas of the cortex?

What is meant by the terms apraxia and agnosia and how might each of these conditions occur?

What is "cortical neglect" and how is it caused?

Review Questions:

1. Where in the cortex is somatic sensation from the face represented?
2. What is the precise location of the motor speech area?
3. Where is the paracentral lobule located and what is its function?
4. Describe the effect of a lesion involving the receptive speech area.
5. What fibre bundle interconnects the receptive and motor speech areas?
6. What cortical layer is most prominent in the primary motor area?

Materials: Whole and half-brains and models.

PRACTICAL CLASS 22

BLOOD SUPPLY TO THE BRAIN

Suggested reading:

Nolte, 6th ed. pp.119 – 140, 258, 289 - 293, 406 - 407, 413, 486 – 487.

or 7th ed., pp. 126 – 153, 264 – 266, 295 – 299, 410 – 411, 413 – 414, 487 – 488.

Specific Objectives

1. To identify the vertebral, basilar and anterior, middle and posterior cerebral arteries, the anterior and posterior communicating arteries and the arterial circle (of Willis).
2. To understand the distribution of blood vessels to the brain and to identify the cortical and perforating branches and the regions at which they enter the brain. To discuss the significance of these vessels and predict the result of blockage or rupture of one or more of these branches.
3. To identify named branches of the vertebral and basilar arteries and their supply areas.

Learning Activities

1. On the whole brain specimens identify the **internal carotid artery**, and its branches: **anterior cerebral artery**, **middle cerebral artery**, and if present **anterior choroidal artery**. Find the **anterior** and **posterior communicating arteries** and the **posterior cerebral artery**, observe how they form a large system for collateral circulation, the **cerebral arterial circle** or **Circle of Willis**. Usually the anterior and posterior communicating arteries are small and carry little blood, however a blockage in, for example, the proximal portion of the posterior cerebral artery could be compensated for by blood flow through the internal carotid-posterior communicating artery-distal posterior cerebral artery. Examine your specimen and look for signs that this might have occurred in this patient.
2. Identify the individual groups of central arteries and note their exact position. From your (now advanced) knowledge of the topography of the brain, try to deduce the structures and regions supplied by each group. Below is a checklist that you should consult in detail when you have compiled your own list. If you find discrepancies try to work out what made you make the mistake. Use the brain slice specimens to work out the topography of the supply areas of the arteries. If in doubt your tutor could help.

Anteromedial group: septal area, anterior regions of hypothalamus.

Anterolateral group (also called striate or lenticulostriate arteries): head of caudate nucleus, claustrum, external capsule, putamen, lateral globus pallidus, most of the internal capsule (except the ventral part of the posterior limb), lateral hypothalamus. This group includes the **medial striate artery** (recurrent artery of Heubner), which arises from the ant. cerebral a., but moves sharply backwards on it to supply more lateral regions. Try to identify this small, but important vessel.

Posterolateral group (also called thalamogeniculate arteries): midbrain, posterior aspect of thalamus.

Posteromedial group: midbrain (medial parts), anterior and medial thalamus, subthalamic region, middle and posterior hypothalamus.

On the head specimens find another branch of the internal carotid artery, the **ophthalmic artery**.

3. Find the **vertebral arteries** and trace the branches that emerge from them as you ascend up the brainstem: **anterior spinal** (if present), **posterior inferior cerebellar**, **basilar**, **anterior inferior cerebellar**, **superior cerebellar**, and **posterior cerebral**. Gently lift the basilar artery and observe the numerous deep penetrating branches, the **pontine arteries**. **Penetrating branches of the**

posterior cerebral artery enter the brain stem through the **posterior perforated substance** in the floor of the interpeduncular fossa to supply upper midbrain and posterior thalamus.

4. Study the set of cerebral arterial angiograms ensuring that you view both internal carotid and vertebral injections from both A-P and lateral views. Find the arteries listed in L.A. 1 above, note that the posterior inferior cerebellar is a branch of the vertebral artery and this can usually be used to distinguish it from the anterior inferior cerebellar, a branch of the basilar artery. On the lateral view of the internal carotid injection distinguish branches of the anterior cerebral artery, the **pericallosal** and **callosomarginal arteries**.
5. Using diagrams from the lecture, review the cortical regions supplied by the anterior, middle, and posterior cerebral arteries, and the general pattern of blood supply to the brainstem
6. Predict the effect of blockage or rupture of the
 - (i) middle cerebral artery,
 - (ii) anterior cerebral artery,
 - (iii) posterior cerebral artery,
 - (iv) anterior choroidal artery,
 - (v) one vertebral artery,
 - (vi) posterior inferior cerebellar artery and
 - (vii) anterior spinal artery.

Review Questions:

1. A patient presents with numbness and paralysis of the right leg and foot. What artery has probably been occluded?
2. List three likely effects of occlusion of the left middle cerebral artery.
3. What important cortical areas are supplied by the posterior cerebral artery?
4. What is the blood supply to the
 - (i) posterior limb of the internal capsule?
 - (ii) medial region of the medulla?
 - (iii) dorsolateral region of the medulla?
 - (iv) midbrain?

Materials: Whole and half brains, prosected specimens, skulls

PRACTICAL CLASS 23

VENOUS DRAINAGE, MENINGES & CEREBROSPINAL FLUID

Suggested reading:

Nolte 6th ed. pp. 80 - 110, 141-147; or 7th ed., pp. 84 -111; 144 - 151

Specific Objectives

1. To identify the venous drainage of the brain and to describe the system of venous sinuses.
2. To understand the orientation and relations of the horns and body of the lateral ventricles, IIIrd ventricle, cerebral aqueduct, IVth ventricle and central canal of caudal medulla and spinal cord.
3. To describe the meninges of the brain and spinal cord and understand their relationship to cranial and spinal vasculature and bones.
4. To identify and describe the sites of formation of the cerebrospinal fluid, the mechanism of its circulation and drainage into the venous system. To predict the effect of long term result of blockage of the flow of cerebrospinal fluid inside the brain.

Learning Activities

1. The venous sinuses can perhaps best be identified initially by examining the grooves they leave on the inside of the skull. On both the skull and on dissected head specimens identify the **superior sagittal, inferior sagittal, transverse, sigmoid, straight, superior petrosal and inferior petrosal sinuses** and the **confluence of sinuses**. Identify the **great cerebral vein** (of Galen), draining into the straight sinus. How does the great cerebral vein form? Identify the **thalamostriate vein** on brainstem specimens.
2. Review the layers of the meninges covering the brain and spinal cord: **pia mater arachnoid mater** and **dura mater**. Identify the large septa of dura forming the **falx cerebri, tentorium cerebelli,** and **diaphragma sellae**. Discuss the relationship between the meninges and the cranial vasculature, including the location and common causes of **subdural** and **extradural haematomas**.
3. See if any **choroid plexus** is left on your half brain, you would expect to find them in any of the ventricles. From which arteries are each of the choroid plexuses formed? The choroid plexuses are important sites of formation of cerebrospinal fluid although CSF formation can continue in situations where the choroid plexus is absent (due to developmental abnormality or surgery). Approximately 30% of CSF is of extra-choroidal origin. Trace the flow of CSF formed in the lateral ventricle through the interventricular foramen to the third ventricle, down the cerebral aqueduct to the fourth ventricle and down the central canal of the spinal cord. CSF leaves this system through 3 foramina in the pia, the 2 **lateral apertures (Foramina of Luschka)** and the unpaired **median aperture (Foramen of Magendie)**. Try to locate these openings in brain specimens. Choroid plexus can often be seen emerging through the lateral apertures on the ventral surface of the brain, near the cerebellopontine angle.

After leaving the ventricular system through these apertures CSF is now located in the subarachnoid space, large areas where CSF collects are called cisterns, you should be familiar with the location of the **cerebellomedullary (cisterna magna), superior** and **pontine cisterns**.

Finally, CSF flows across a pressure gradient into the venous blood, primarily along the superior sagittal sinus. The sites of this reabsorption are the **arachnoid granulations** which look like grains of sand embedded in the dura, look for them on the head dissections, and some may also be present on surface of the arachnoid along the midline on the whole brain specimens.

4. What is the function of CSF? How does it differ in composition from blood plasma?

Discuss the effects of blockage of:

- (i) the interventricular foramen and
- (ii) the cerebral aqueduct.

What is the difference between the communicating and non-communicating forms of hydrocephaly?

5. Divide the class up into 4 groups of students. Allocate clinical cases (described with next practical class) as follows:

Group 1: Cases 1, 5

Group 2: Cases 2, 6

Group 3: Cases 3, 7

Group 4: Cases 4, 8

In your own time and before the next class each group should work through answers to the questions for each case and be prepared to present these to the rest of the group in the next practical class (10 – 15 minutes per case). In each case try to establish a possible single lesion that could cause the disturbances described. Different types of lesions (i.e. haemorrhages, tumours, degenerative processes) may cause similar sets of symptoms but the onset of the disease may be remarkably different. In the cases described there will be some hint regarding the onset and history of the disease, but from the neuroanatomical point of view the final set of symptoms are important in localizing the lesion.

Review Questions:

- 1. How is the great cerebral vein formed? What does it drain into?
- 2. The internal jugular vein is the continuation of which venous sinus?
- 3. What sinuses carry blood away from the cavernous sinus?
- 4. What specialisations enable CSF to be absorbed into the venous system and where are they located?
- 5. What type of hydrocephalus would result from a blockage of the cerebral aqueduct?

Materials: Skulls, head prosections, brains, half brains, ventricle models

PRACTICAL CLASS 24

CLINICAL SIGNS AND STUDY OF CLINICAL CASES

Suggested reading:

You may find the following pages in **Crossman and Neary 5th ed.** helpful (see Textbooks on p. 8 for full reference):

Spinal cord - pp. 88 - 90; brainstem – pp.101, 108; cerebral hemisphere – pp. 138

Problem solving – pp 171 - 178

Case histories

CASE 1

A boy, five years old, complained of pain in the back and legs and had a fever of 39.5°C. The following morning he was unable to get out of bed because of weakness in the muscles and he could not move his right lower limb. Examination showed no disturbance in the movements of the head and neck, or left lower limb, but there was complete paralysis of the right thigh, leg and foot. Muscular tone was greatly reduced and the tendon reflexes (knee and ankle jerks) were abolished in the right lower extremity. After a few days the feverish condition subsided and the boy felt normal except for the persisting paralysis. After three weeks, he was able to flex and adduct the right thigh and extend the leg, but no other movement returned in that extremity. At the end of the month the muscles of the foot and leg and of the back of the thigh were relaxed, flaccid and demonstrated marked atrophy. Aside from the pain suffered at the time of the onset there were no sensory disturbances.

- (i) Which common infectious disease does the onset of this case (fever, aches & pains in joints) resemble?

- (ii) It is obvious that the somatic motor system is affected. What are the symptoms of an upper motor neuron lesion?

- (iii) What are the symptoms of the lower motoneuron lesion? Is the lesion characteristic of upper or lower motoneurons?

- (iv) How is it possible that the sensory system was not affected?

- (v) Once you have established the possible cause of the resulting paralysis try to establish the location and level of the lesion considering groups of muscles that were involved. Which were the levels that were involved at the onset of the disease but in which the inflammation subsided without causing a complete destruction of the motoneurons? (Diagrams appendix 1 will be of assistance)

- (vi) What disease do you think this patient was suffering from?

CASE 2

A welder, aged forty-eight, presented himself for treatment of a burn on his right hand caused by having picked up a hot iron. He did not feel either heat or pain at the time, nor had the burn since caused him any pain. Examination showed a loss of pain and temperature sensation over the thorax and both upper extremities. There was no detectable disturbance of tactile sensation, no ataxia or loss of sense of posture or of passive movement. The knee jerk was normal and there was no disturbance of motor functions except that there was weakness and atrophy of the small muscles of both hands.

- (i) Was the onset of the disease in this case sudden or gradual? What kind of lesions would be typical of a gradual onset of symptoms?

- (ii) The weakness and atrophy of muscles in the hands suggests involvement of which segments of the spinal cord? (Diagrams in appendix 1 will be of assistance)
- (iii) What structures in these segments must have been destroyed?
- (iv) How would you account for the loss of pain and temperature sensation in the thorax and upper extremities? What structures must have been affected?
- (v) Why were proprioceptive and tactile sensations not disturbed?

CASE 3

A man, aged thirty-four, noticed a tingling sensation in his feet and later suffered from shooting pains in his legs. After several months he experienced difficulty in walking in the dark, and when walking in the light, it was necessary to watch the ground to keep from falling. Although his lower limbs were as strong as ever, he would stagger and sway from side to side as he walked. Examination disclosed no weakness or atrophy of the muscles, but when relaxed they did not exhibit the normal tone. The knee jerk was abolished. There was a complete loss of sense of posture and passive movement and of the vibratory sense in the lower limbs. When the skin of the limb was touched with the two points of a compass he would not recognize the duality of the contact or accurately locate the area stimulated. Except for this loss of tactile localization and discrimination there was not much disturbance of exteroceptive sensation.

- (i) What is the evidence in this case of damage to the nerve fibres in the dorsal columns?
- (ii) How would you account for the incoordination of the movements of the legs in walking?
- (iii) How would you account for the loss of sense of posture and passive movement?
- (iv) Was the knee jerk abolished because of a lower motor neuron lesion?
- (v) What could be the possible cause of pain sensation at the onset of the disease?

CASE 4

A bartender, aged forty-six, received a stab wound in the back. He was treated in hospital for spinal shock but even after weeks of treatment signs of permanent damage remained. There was a wasting of the small muscles of the right hand. In the right lower limbs there was a spastic paralysis, with an increase of the knee jerk together with a loss of sense of posture and passive movement. On the left side there was no paralysis or muscular wasting and the reflexes were normal. There was a loss of sensation to pain, heat and cold over the entire left of the body as high as the level of the third rib, but no disturbance of proprioception was found. All cutaneous sensation was abolished over a strip along the ulnar side of the right upper limb, but except for this area tactile sensation was normal over the entire body.

- (i) What does the atrophy of the small muscles of the right hand indicate? What kind of neurons were damaged?

- (ii) What segments of the cord must have been involved in the lesion and to what extent?
- (iii) What kind of neuron lesion could cause the spastic paralysis of the right leg? How could this be the result of the lesion that caused the atrophy of the small muscles of the right hand?
- (iv) Considering the disturbances of the motor system alone, would you establish a unilateral or bilateral lesion of the cord?
- (v) Can all the symptoms be explained on the basis of a unilateral lesion? If so, how would you account for the loss of proprioceptive sensation on one side of the body and of pain and temperature sensation on the opposite side?
- (vi) How can you explain the complete loss of sensation along the ulnar side of the right upper limb?
- (vii) Why was tactile sensation normal all over the body except for the small area referred to in (vi)?

CASE 5

A man, sixty-seven years old, suffered a stroke and was unconscious for several hours. After recovering consciousness he could not speak and his right limbs were paralysed. After a few days his speech returned though he had considerable difficulty in using his tongue. An examination made six weeks after the seizure showed a spastic paralysis of the right upper and lower limbs with increased muscle tone and exaggerated tendon reflexes. When protruded, the tongue turned to the left and the musculature of its left side showed atrophy. Pain and temperature sensation were normal over the entire body, but there was a loss of sense of posture and passive movement (proprioception) and an impairment of tactile sensation over all of the right side of the body except the head.

- (i) What does the involvement of both limbs on one side suggest as to the site of the lesion?

- (ii) Which side of the tongue is paralysed if it deviates to the right when protruded?
- (iii) Why is there atrophy in the muscles of the tongue. What nerve is affected? How does this help to locate the lesion?
- (iv) What brainstem tract must have been included in the lesion to give rise to the sensory symptoms? On which side was the lesion located?
- (v) Based on the sensory and motor symptoms locate the lesion. Which artery is probably involved?

CASE 6

A man, aged fifty, suddenly became giddy and fell upon the floor, but did not lose consciousness. It was noted that he kept both eyes turned toward the left. Eight weeks later, the strength and tone of the muscles and the deep reflexes were normal and equal on the two sides, but there was a paralysis of the left vocal cord and of the left side of the soft palate. The finer movements of the left limbs were not perfectly coordinated. When walking or when standing with his eyes closed he would tend to fall to the left. There was a complete loss of pain and temperature sensation over the left side of the face and the right side of the body below the head. Tactile sensation was normal over the entire body.

- (i) Which specific system could be involved if dizziness and conjugate deviation of the eyes occur? What does this tell you about the localization of the lesion?

- (ii) Which major tract is affected if there is a complete loss of pain and temperature sensation over half of the face?

- (iii) What does the paralysis of the left vocal cord indicate as to the location of the lesion?

- (iv) Why is the pain and temperature sensation lost on the right side of the body while a similar deficiency occurred on the opposite (left) side of the face?

- (v) Which artery supplies the area in which the lesion is likely to have occurred?

CASE 7

A woman, fifty-eight years old, suffered a stroke, following which she was paralysed on the right side. Weeks later, neurological examination revealed that she was unable to open her left eye fully because of drooping of the upper eyelid (called ptosis). Moreover, the left eyeball was turned outward and slightly downward. The left pupil was dilated and did not react to light, although the consensual light reflex in the other eye was present. When protruded, the tongue turned somewhat to the right, showing a weakness of the musculature of that side, but there was no atrophy. Also on the right side, there was a paralysis of the muscles of the lower part of the face, that is, of those below the eye. The paralysis of the right extremities was accompanied by increased muscle tone and exaggerated reflexes.

- (i) Why was the left eyeball turned outward and slightly downward?
- (ii) Why was there a drooping of the eyelid (ptosis)? Which are the possible causes of this sign?
- (iii) Which part of the pupillary light reflex arc is likely to be affected if the absence of the reflex is accompanied by the presence of the consensual reflex in the other eye?
- (iv) What nerve must have been damaged to cause the above effects?
- (v) What type of motor neuron lesion caused the facial paralysis? How can one distinguish between a peripheral (lower motoneuron) and central (upper motoneuron) paralysis of the facial muscles? Would the usual criteria (increased muscle tone, exaggerated reflexes, presence or absence of atrophy) be of any use in this case?
- (vi) Where would you locate a rather restricted lesion causing a paralysis of the eye-muscles on the left and spastic hemiplegia on the right side? How do you account for the lingual and facial paralysis?

CASE 8

A woman, sixty-five years old, while engaged in a heated argument with a neighbour, suddenly fainted. She remained unconscious for 36 hours. When consciousness returned, she was unable to move the left upper or lower limb. An examination, made six weeks after the seizure, showed a spastic paralysis of the left upper and lower limbs with increased muscle tone and exaggerated tendon reflexes. When protruded, the tongue turned to the left, but there was no atrophy. There was a left facial paralysis involving the muscles below the eye. Sensation was impaired over the entire left side of the body, including the face, but all forms of sensation were not affected to the same degree. The sense of posture and passive movement was lost. Tactile sensation was more defective than thermal, while pain was detected on both sides. Tests showed that she was blind to all objects in the left half of the field of vision (homonymous hemianopsia).

(i) Which tract must have been affected to cause the limb paralysis?

Which tract must have been damaged to cause the lingual and facial paralysis?

On which side?

(ii) Why did the muscles above the eye escape paralysis?

(iii) Was the lesion of the visual pathway placed in front of or behind the optic chiasm, and why? Was the lesion located on the left or right side?

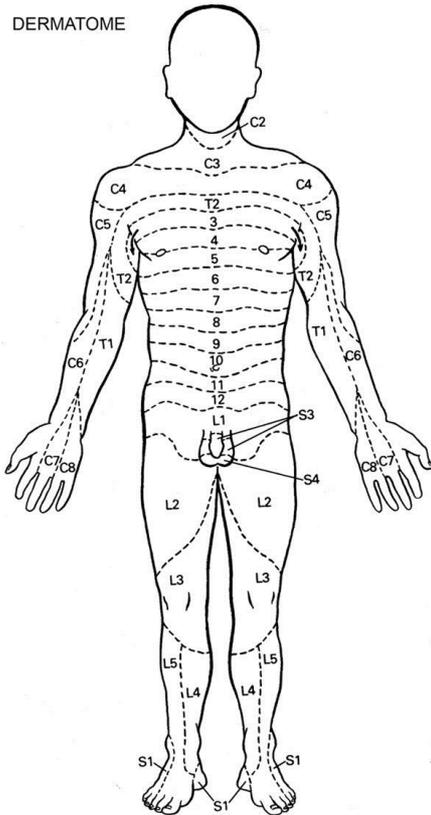
(iv) Why are some sensory modalities more affected than others?

(v) Based on the motor and sensory deficits, locate the site of the lesion. What artery is most likely to have been involved?

APPENDIX 1

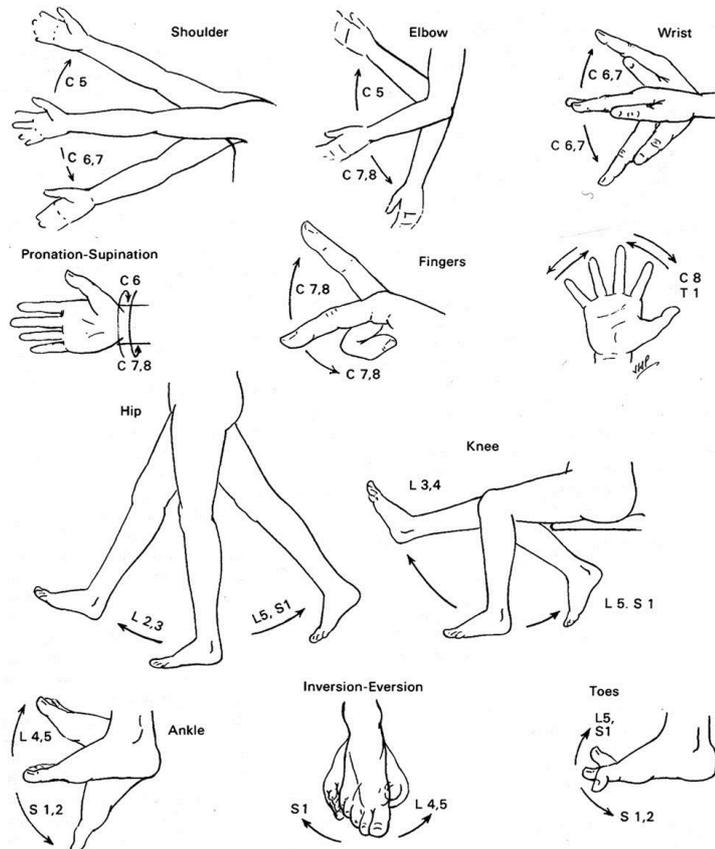
SPINAL NERVE DISTRIBUTION

DERMATOME



MYOTOME:

from Hollinshead's Textbook of Anatomy
C. Rosse & P.G. Rosse
Lippincott-Raven, 1997



Segmental innervation of the muscle groups producing movement in the limbs: Only segments principally responsible for the innervation of a movement are shown. These are the segments of greatest clinical usefulness. For a more complete account refer to Table 13-1. (Based on Last R.J. Anatomy. London: Churchill, 1972.)

APPENDIX 2

GLOSSARY OF NEUROANATOMICAL TERMS

- afferent** L. afferens; conveying toward a centre (centripetal).
- amygdaloid** Gr. amygdale = almond, and eidos = resemblance. The name given to an almond-shaped nucleus.
- anterior** L. compar. of ante = before; at or toward the front, toward the head in front or forward.
- arachnoid** Gr. arachne = spider, and eidos = resemblance: resembling a cobweb. Specifically, the arachnoid membrane, the middle membrane covering the brain and spinal cord.
- astrocyte** Gr. astron = a star, and kytos = a vessel or cell. A type of glial cell of a shape to suggest stars.
- autonomic** Gr. autos = self, and nomos = law. Hence that part of the nervous system controlling the autonomic functions of the body (e.g. heart, respiratory system, digestive system).
- axon** Gr. axon = axis. Adopted for the name of the axis cylinder, the principal output process of neurons.
- brachia** plural of L. brachium = an arm or arm-like process. Cerebellar B.: the arms of the cerebellum
- brain** AS braegen = brain; perhaps related to Gr. brechmos = forehead.
- callosum** neuter of L. callosus = hard. Applied to the corpus callosum.
- caudal** L. cauda = tail; toward the tail; behind or toward the rear.
- caudate** L. cauda = tail; having a tail or tail-like part.
- cephalic** Gr. kephale = the head; in, on, near or toward the head; as in anterior
- cerebellum** L. diminutive of cerebrum = small brain.
- cerebrum** L. cerebrum = brain.
- chiasma** Gr. chiasmus = placing crosswise; crossing the median plane and connecting unlike parts. X-shaped crossing as in character chi.
- cinerea** feminine of L. cinereus = ashy (grey coloured).
- cingulum** L. cingulum = a girdle (or belt).
- cisterna** L. cisterna = a reservoir or cistern.
- colliculus** L. mound, diminutive of collis = hill.
- commissure** L. commissura; from con(com) = together, and mittere = to put. Hence a joining or a seam. In neuroanatomy, the term is used for connections between the two sides of the brain or spinal cord, connecting corresponding parts.
- convolution** L. con = together, and volvere = to roll: a gyrus
- cornu** L. = horn. Applied especially to horn-shaped structures in the central nervous system; for example, cornu Ammonis or Ammon's horn (the hippocampus), named after a horned Egyptian god. The same root is also used to indicate anything made of a horny substance, such as the cornea of the eye or the str. corneum of the epidermis.
- corpus** L. corpus = body, plural corpora; main part of any organ
- cuneus** L. cuneus = a wedge
- cuneiformis** L. = wedge-shaped
- decussation** L. decussare = to intersect; from decussis = ten, represented by the symbol X, hence any crossing. Compare the analogous word chiasm, of Greek derivation. Hippocrates wrote "if the wound (of the head) be situated on the left side, the convulsions will seize the right side of the body," but the observation that the nerve paths cross had to wait until the sixteenth century.
- dendrite** Gr. dendrites = pertaining to a tree; from dendron = tree, as in rhododendron. The term dendrite is used to refer to the processes (other than the axon) from a nerve cell.
- diencephalon** Gr. dia (dia = through, and encephalon (q.v.). Hence the "between" brain.
- diploë** feminine of Gr. diplous = double or folded.
- distal** farthest from the centre or the point of attachment or origin; opposite to proximal.
- dorsal** L. dorsum = the back, of, on, or near the back (top of hemispheres, but the back of the brainstem).
- dura** L. durus = hard. Dura is feminine to agree with mater (mother), for the original term is dura mater, or the strong mother of the brain (the outer strong covering of the brain and spinal cord). This use of 'mater' in the sense of protector goes back to the Semitic or Arabic fondness for fanciful metaphors. 'Dura mater' is said to be Stephen of Antioch's translation of the term employed by Hali Abbas, the Arabian.

efferent L. efferent = to carry out; carrying away from the central part (centrifugal).

emissary L. emissarium = a drain; from ex(e) = from, and mittein - to send. Applied as an anatomical term by Santorini in the eighteenth century, for the small veins that leave the cranial cavity by penetrating the skull.

encephalon Gr. enkephalon = brain; from en = in, and kephale = head.

ento (endo). Gr. entos = within; a combining form meaning within or inner.

ependyma Gr. epi = upon, and endyma = a garment. Hence an outer garment, but in anatomy applied to the lining of the cerebral ventricles and spinal canal.

falx L. falx = a sickle. The falx of the brain (falx cerebri) is crescent-shaped.

fasciculus L. diminutive of fascis = small bundle or packet.

filum L. = a thread; descending through the French fil and its diminutive, filet = a fine thread, but in English the word means a ribbon or band.

fimbria L. fimbriae = fringe, any finger-like structure.

foramen L. a hole; a small opening, perforation or passage.

fornix L. = arch, vault.

funiculus L. diminutive of funis = a cord. Used chiefly, but not exclusively, neuroanatomy, particularly to describe the regions of the white matter of the spinal cord.

ganglion Gr. ganglion = swelling. The term originally meant only a subcutaneous swelling, from which comes our use of the term for cystic swellings on tendons. However, Galen limited its application to a swelling on a nerve and it is from this usage that the word ganglion nowadays is most often applied to a group or knot of nerve cells.

geniculate L. geniculare = to bend the knee; from geniculum, diminutive of genu = knee.

glia. Gr. glia = glue. A contraction used as a synonym for neuroglia.

gyrus Gr. gyros = a circle. Our modern words gyrate and gyroscope come from this root.

hippocampus. Gr. hippos = horse, and kampos = sea monster. The curved gyrus which bears this name was so called because its shape suggests that of the well-known sea-horse. The gyrus was well described by Varolius (1543-1575).

hypophysis Gr. hypo = under, and physis = growth. Hence growing under the brain. This is another name for the pituitary gland.

indusium L. = a woman's undergarment, from induo, to put on. Indusium griseum = a thin layer of grey matter on the surface of the corpus callosum, supracallosal gyrus.

insula L. = island.

lamina L. thin piece; thin plate or layer.

lateral L. latus = a side; of, at, from or toward the side; anything located to the side.

lemniscus Gr. lemniskos = a band or fillet.

lobulus L. diminutive of lobus = lobe.

medial L. medius = middle; of or in the middle; the median plane or axis of a body or part.

medulla L. medulla = marrow. Used especially in the nervous system, as is also the term medullated, which indicates that a nerve fibre is sheathed with myelin. The adjective describing such fibres is medullary. Medulla is also used to name the non-cortical part of some organs, such as the kidney and adrenal.

medulla oblongata L. long marrow, the proper name for the lowest part of the brainstem.

meninges Gr. meninx = membrane; plural, meninges. The term meninges is reserved for the membranes covering the brain and spinal cord.

mesencephalon Gr. meso = middle, and encephalon (q.v.)

myelin Gr. myelos = marrow (compare medulla, above), and the ending in -in.

neurilemma Gr. neuron = nerve, and lemma = a husk. Schwann, in 1838, discovered this sheath of the axis-cylinder of nerves, which in the peripheral nervous system is formed by the cells named after him.

neuroblast Gr. neuron = nerve, and blastos = germ.

neuroglia Gr. neuron = nerve, and glia = glue.

neuron Gr. neuron = nerve. Hippocrates applied the term neuron to tendons, fascial bands, and indeed to all whitish structures. Aristotle limited the word to nerves. It is now used in a still more limited sense, to describe the excitable cells (the nerve cells, together with their processes) in nervous tissue.

nucleus L. a nut, kernel; a group of neuron cell bodies in the brain.

oblongata Feminine form of L. oblongus = rather long or oblong (see medulla oblongata)

oligodendroglia. Gr. oligos = scanty, dendron = tree, and glia = glue. A glial cell types characterized by small round cell body with slender, inconspicuous, branching processes.

operculum L. operculum = a lid. In neuroanatomy the term describes the nervous tissue covering the insula (parts of the frontal, parietal and temporal lobes)

para- Gr. a prefix meaning: by the side of, beside, alongside of, by, past, beyond.

pallidus L. pallidus = pale.

parasympathetic Gr. para = beside, and sympathetic. A term coined as a name for part of the autonomic nervous system.

paravertebral Gr. para = beside, and L. vertebra = a joint in the spine; from vertere = to turn. The paravertebral ganglia lie alongside the vertebral column

peduncle L. pedis = foot; a stalk-like bundle of nerve fibres connecting various parts of the brain; stem or supporting part.

pellucidum L. per = through, and lucere = to shine. Used of the septum pellucidum, through which light can shine.

peri- Gr. a prefix meaning: around, about, surrounding, enclosing.

pia L. pius = kindly or tender. Pia is the feminine of pius, which is used in this gender to agree with mater = mother. This term, pia mater, like dura mater, is a translation of a fanciful metaphorical phrase of Semitic origin. In the early Arabic anatomical texts such terms as mother and apple were frequent. Here pia mater means the tender protector of the brain and spinal cord, it is the innermost, highly vascular meninx covering the brain and spinal cord.

pineal L. pinea = a pine cone. Presumably so named from the shape of this body.

pituitary L. pituita = mucous secretion. In the time of Galen the mucus from the nose and mouth was thought to come from the brain, hence this structure was so named. It has been suggested that the word spit comes from the same origin. It was a long time before Schneider (1614-1680) demonstrated that nasal mucus (pituita) came from glands in the nose, and did not filter through the cribriform plate of the ethmoid from the brain.

plexus L. plexus = something woven, a braid, a network

pons L. pons = a bridge. The same root is familiar to us in pontoon.

posterior L. compar. of posterus = following; at or toward the rear, behind; toward the tail.

posterolateral adjective from L. posterus = behind, and latus = side. This is but one of a number of terms compounded with postero-meaning behind.

precentral L. prae (pre) = in front of, and centrum = centre.

pulvinar L. pulvinar = a pillow. Not a very good name for this part of the thalamus.

putamen L. putamen = shell (covering or a paring).

quadrigemina L. quadri-, combining form or quattuor = four, and geminus = twin. In neuroanatomy the 'quadrigeminal bodies' is an alternative term for the superior and inferior colliculi combined.

radicle L. radicula, diminutive of radix = root.

rhombencephalon Gr. rhombos = a rhomb or lozenge, and encephalon (q.v.).

rostral L. rostralis; of, in, or on a rostrum, toward the head; in front or forward.

rubrospinal L. ruber = red, and spina = the spine. The name given to the tract from the red nucleus down the cord. Spina originally meant nothing more than a thorn.

sella turcica L. sella = saddle, and turcica = Turkish. A descriptive name for the saddle-shaped prominence on the sphenoid bone. A pituitary gland sits in this saddle.

septum L. saepes = a hedge; a part that separates two cavities or two masses of tissue; also a partition.

solar plexus L. sol = sun, and plexus = something woven. In this instance the nerves are supposed to radiate like the rays of the sun.

splenium Gr. splenion = bandage. Applied to any structure whose shape suggests a bandage. Most commonly used to describe the posterior part of the corpus callosum. Unfortunately, splenion also means a fern, and perhaps the resemblance is to a fern leaf or frond.

spongioblast Gr. spongia = sponge, and blastos = germ.

spongiocyte Gr. spongia = sponge, and kytos = vessel or cell.

stellate L. stella = star. Hence shaped like a star.

stria L. any of a number of parallel lines, stripes, bands or furrow; a strand of longitudinal fibres in brain.

striatum L. striatus = furrowed; and neuter form, striatum, is applied to the corpus striatum. The combining form striato- is used in several combinations as, for example in striatospinal.

subcortical L. sub = under, and cortex = bark or outer covering. Applied to anything beneath the cortex or the brain.

substantia L. substantia = material.

subtemporal L. sub = beneath and temporal.

subtentorial L. sub = under, and tentorium.

sulcus L. sulci (pl.) from sulcatus = a furrow; a groove or furrow; the shallow grooves separating the gyri of the brain.

suprasellar L. supra = above, and sella = saddle. Applied to anything lying immediately above the sella of the sphenoid bone. See sella turcica.

sympathetic Gr. syn = with, and pathos = suffering. The n of syn is changed to m before a labial consonant.

tapetum L. tapetum = tapestry or carpet. So named from a supposed resemblance.

tectospinal L. tectum = roof, and spina = a thorn or the spine. Applied to pathways passing from the tectum to the spinal cord.

tectum L. tectum = a roof. Applied to the roof of the midbrain.

tegmentum L. tegmentum = a cover. The upper covering of the cerebral peduncle.

telencephalon Gr. telos = end, and encephalon (q.v.)

tentorium L. tentorium = a tent. The name of the fold of dura dividing the cerebellum from the cerebrum.

thalamencephalon Gr. thalamos = an inner chamber, and encephalon.

thalamus Gr. thalamos = bed, bedroom, inner chamber.

torcular L. torcular = a wine press or storage vat: from torquere = to twist. Our word torque comes from this root. Torcular is often combined with the name of Herophilus (335-280 B.C.), a physician of Alexandria; torcular Herophili = confluens sinuum.

trochlear L. = relating to the trochlea, a pulley; specifically to that of the superior oblique muscle; name of the cranial nerve innervating this muscle.

tuber L. tuber = a knot or swelling. For example, tuber cinereum.

uncinate L. uncinatus = hook-shaped.

uncus L. uncus = a hook. Applied to several hook-shaped structures in the brain.

velum L. velum = veil or covering.

ventral L. ventralis; of, near, or toward the belly (below in brain).

Taken from: Pepper, O.H.P. 'Medical Etymology', Philadelphia: W.B. Saunders, Co., 1949, 45-49.
 Also Stedman's Medical Dictionary, 21st Ed. and Webster's New World Dictionary, 2nd College Edition, 1972

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