A Core Syllabus for the Teaching of Neuroanatomy to Medical Students

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There is increasingly a call for clinical relevance in the teaching of biomedical sciences within all health care courses. However, this presupposes that there is a clear understanding of what can be considered core material within the curricula. To date, the anatomical sciences have been relatively poorly served by the development of core syllabuses, particularly for specialized core syllabuses such as neuroanatomy. One of the aims of the International Federation of Associations of Anatomists (IFAA) and of the European Federation for Experimental Morphology (EFEM) is to formulate, on an international scale, core syllabuses for all branches of the anatomical sciences using Delphi Panels consisting of anatomists, scientists, and clinicians to initially evaluate syllabus content. In this article, the findings of a Delphi Panel for neuroanatomy are provided. These findings will subsequently be published on the IFAA website to enable anatomical (and other cognate learned) societies and individual anatomists, clinicians, and students to freely comment upon, and elaborate and amend, the syllabuses. The aim is to set internationally recognized standards and thus to provide guidelines concerning neuroanatomical knowledge when engaged in course development. Clin. Anat. 28:706–716, 2015. © 2015 Wiley Periodicals, Inc.

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INTRODUCTION

Worldwide, major changes in medical courses are taking place, often because of the introduction of new subjects into programmes as knowledge develops and/or because of the move toward skills-based teaching in preparation for clinical practice. Whatever the reasons, as a result of these changes many medical courses have significantly decreased the time allocated to the biomedical sciences. For example, within the USA contact hours for gross anatomy has fallen from an average of 170 hr in 2002 to ~150 hr in 2012. However, the teaching of neuroanatomy in the USA appears not to have been so dramatically affected, contact hours only decreasing from 95 to 83 hr from 2002 to 2012. Comparing 2009 with 2012, contact hours increased with lecture hours remaining essentially the same with an increase in laboratory hours (Drake et al., 2014). This relatively favorable

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situation might reflect the large numbers of academics in anatomically-related departments whose research is neuroanatomical and/or to the many advances made in our understanding of the brain and other elements of the nervous system.

A second feature of curriculum change for medical courses has been a call for increased clinical relevance (e.g., Pabst, 2009; Moxham et al., 2011). This presupposes that there is a clear understanding of what can be considered core material within the medical syllabus. This presents a dilemma since we need to teach the basic sciences underpinning common conditions but also the rarer things that are severely debilitating or fatal. Indeed, the tension between learning “just in time” versus “just in case” is hard to resolve (Morley, 2003). In this article, we outline an approach to developing core syllabuses for neuroanatomy that takes an international approach and that, being ultimately web-based, is dynamic (i.e., keeping the content under constant review to ensure that it is fit for purpose) and democratic in that it enables regular updating from the whole community of stakeholders (including anatomists, neuroscientists, clinicians, students, and those politico-educational forces that often drive curricular change).

There have been several commendable attempts to define a core syllabus in gross anatomy in Europe and the USA, most recently by the Anatomical Society in the UK and Ireland (McHanwell et al., 2007). More specialized core syllabuses are rarer. The only core syllabus for neuroanatomy that has been published is for dental students (American Association of Dental Schools, 1992) and an article by Klueber (2003) that relates head and neck anatomy with neuroanatomy.

In association with the Trans-European Pedagogic Anatomical Research Group (TEPARG) of the EFEM, the IFAA is engaged in developing a series of core syllabuses for the anatomical sciences by means of Delphi Panels. Already published is a article concerned with the principles underpinning the development of the IFAA/EFEM core syllabuses (Moxham et al., 2014) and also a core syllabus for the gross anatomy of the head and neck in a medical course (Tubbs et al., 2014; Tubbs and Paulk, 2015). Here, we outline the core syllabus for neuroanatomy in a medical course using similar methodologies.

**METHODS**

For detailed information regarding the approach being adopted by the IFAA/EFEM in formulating core syllabuses, and for a thorough discussion of the guiding principles, the reader is referred to the article by Moxham et al. (2014). Briefly, and only for descriptive convenience, the process is divided into three stages (Fig. 1).

During Stage 1, a Delphi Panel was constructed that consisted of 19 persons from different countries with a coordinator. This Delphi Panel was instructed to provide a detailed list of topics within their remit (i.e., not to take a broad brush approach). The Delphi Panel for neuroanatomy consisted of 7 members from the UK; 4 from Spain; 2 from France; 1 from Switzerland; 1 from Portugal; 1 from Italy; 1 from Greece; 1 from Romania; 1 from the USA). The age ranged from 31 to 70+ years. Seventy-eight percent of the panelists were engaged in neuroanatomical research. Seventy-two percent are clinically qualified. One was a writer of a neuroanatomy textbook. All of the panelists were teachers of medical students and many were involved in pedagogic research. The coordinator of the panel was the President of the IFAA and he provided a draft list of topics for the panel to consider. This list was obtained by analysis of three contemporary neuroanatomy textbooks for medical students that contained significant detail to ensure a fulsome list of topics. The list was amended following comments from some members of the panel.

Subsequently, each panel member evaluated every item/topic in the list according to whether it is considered to be “essential,” “important,” “acceptable,” or “not required” in a core syllabus. Table 1 provides an example of the form used by the neuroanatomy Delphi Panel (for the medulla oblongata). Although in the form provided a blank section was available for comments from the panel members, few significant comments were received. The topic list in the survey questionnaire comprised 529 neuroanatomical structures (19 developmental items, 83 topics related to the neuron, neuroglia, receptor and effector endings and dermatomes and myotomes, 86 items for the spinal cord, 57 items for the brainstem, 34 for cranial nerves and their nuclei, 14 for the midbrain, 48 for the diencephalon and the pituitary, 90 for cerebral hemispheres, reticular formation and the limbic system, 49 for the autonomic nervous system, 14 for the ventricles and CSF, 12 for the meninges, and 23 for vessels and the blood-brain barrier) and included 166 selected miscellaneous pathologies appropriate for neuroanatomical correlation taught to medical students.
Each item was now categorized so that the “essential,” “recommended,” “just acceptable,” and “not required” elements were brought together. To accomplish this, a general rule was followed that was discussed by Moxham et al. (2014) and agreed in advance. Where 60% of the panelists considered an item as being essential, this was categorized as being “core (essential).” Where between 30% and 59% of the panelists classified an item as being essential, the topic was designated as being “recommended.” Classification of “acceptable” or “not required” came when the panelists only recorded essential designations between 20% and 29% and <20%, respectively.

This is the stage at which the findings of the Delphi Panel are now presented to a more wide-ranging audience through this article (and eventually through the IFAA website). Stages 2 and 3 of the development of the core neuroanatomical syllabus do not involve the Delphi Panel but is based upon the comments and suggested amendments from anatomical societies, anatomists, and neuroscientists, and medical clinicians on a global basis. The results of these deliberations will be reviewed, and modified on a regular and continuous basis by the IFAA’s Federative International Programme for Anatomical Education (FIPAE). Details concerning the processes to be employed by FIPAE, and thereby how consensus is obtained, will be provided on the IFAA website when the core syllabuses are sent out for general consideration.

FINDINGS

The lists below summarize the findings of the neuroanatomy Delphi panel (Stage 1) preparatory to more general consultations (Stages 2 and 3) (Moxham et al., 2014):

### General aspects of the nervous system:

A medical student should have core anatomical knowledge of:

1. the early stages of neurulation in the embryo.
2. the development of the brain from neural tube closure to the formation of the brain vesicles.
3. the process of myelination in the CNS.
4. the structural classification of neuronal types.
5. the main neurotransmitters at synapses.
6. the actions of neurotransmitters.
7. the structure of both myelinated and unmyelinated nerve fibers.
8. the arrangement of a typical spinal nerve and nerve roots.
9. the differences between sensory ganglia and autonomic ganglia.
10. peripheral nerve plexuses.
11. the concept of the segmental innervation of skin (dermatomes).
12. the concept of segmental innervation of muscles.
13. the stretch (myotatic) reflex.
14. the structure and function of Golgi tendon organs—neurotendinous spindles.
15. the tendon (inverse myotatic) reflex.
16. the anatomy of the flexor reflex.
17. a “motor unit”
18. the basis for clinical examination of sensory modalities.
19. the basis for clinical assessment of muscle power, wasting, fasciculation, contracture, tone, and muscular coordination.
20. drug actions on neuromuscular junctions.
21. drug actions on nerve endings on secretory cells.
Topics recommended for teaching the development of the nervous system (but not core) include:

- Spinal cord development—the basal plate (motor neurons)
- Spinal cord development—the alar plate (1st afferent neurons/sensory pathway, sensory neurons of posterior gray column)
- Development of meninges, spinal cord, and vertebral column.
- Development of and fate of medulla oblongata (myelencephalon).
- Development and fate of pons (ventral metencephalon).
- Development and fate of cerebellum (dorsal metencephalon).
- Development and fate of midbrain (mesencephalon).
- Development and fate of the diencephalon.
- Development and fate of the telencephalon including cerebral hemispheres.
- Development of cerebral cortex.
- Formation of internal capsule and cerebral commissures.

Clinically related topics recommended are spina bifida, meningocele, meningomyelocele, myelocle, syringomyelocele, hydrocephalus, and anencephaly.

For topics related to the neuron, the following items are recommended for teaching (but not core):

- Neurocytology
- Molecular structure of ion channels
- Molecular anatomy of axonal transport through nerve cell processes
- Synapse ultrastructure
- Distribution and fate of neurotransmitters
- Blocking agents at synapses
- Neurotransmitter manipulation for neuronal diseases
- Reactions of neurons to injury
- Axonal reaction or axonal degeneration
- Recovery following injury
- Regeneration of axons
- Transneuronal degeneration
- Effects on end organs of nerve degeneration
- Neuronal ageing

Neuronal plasma membrane structure and neuronal tumours were not considered at this stage to be core or recommended for teaching.

While knowledge of the glia is not core, it is recommended that the student should have a basic knowledge of the structure and functions of glial cells. In particular, astrocyte structure and function (astrocyte subtypes), oligodendrocyte structure and function, reactions of neuroglia to injury, and multiple sclerosis are recommended teaching topics. Ependyma structure and function, microglia structure, and function, the extracellular space in the CNS, and neuroglial tumors are not at this stage considered to be core or recommended topics.

For general topics concerning peripheral nerves, the formation of myelin, conduction in peripheral nerves, local anesthetics and nerve conduction, trauma to peripheral nerves, herpes zoster, and polyneuropathy were recommended but not considered to be core. Not required to be taught are: endoneurial spaces. Blood vessels and lymphatics of peripheral nerves, neuromyositis, nerve transplantation, and peripheral nerve tumors.

For receptor endings and effector endings, the following topics were considered at this stage not to be core but to be recommended for teaching:

- The anatomical classification of types of receptor endings
- Physiological classification of types of receptor endings
- Nonencapsulated receptors
- Free nerve endings
- Nonencapsulated receptors
- Merkel's discs
- Nonencapsulated receptors
- Hair follicle receptors
- Encapsulated receptors
- Meissner's corpuscles
- Encapsulated receptors
- Pacinian corpuscles
- Encapsulated receptors
- Ruffini's corpuscles
- Cutaneous receptor functions
- Transduction of sensory stimuli into nerve impulses
- Joint receptors
- Neuromuscular spindles—structure and function
- Neuromuscular junctions in skeletal muscle
- Neuromuscular junctions in smooth muscle
- Neuromuscular junctions in cardiac muscle
- Phantom limb
- Neuromuscular blocking agents
- Anticholinesterases
- Bacterial toxins
- Myasthenia gravis

Not core or recommended for teaching were denervation supersensitivity of skeletal muscle and hypokalemic periodic paralysis and hyperkalemic paralysis.

Remaining general topics recommended for teaching (but not core) include:

- Involuntary movement of muscles—Tic
- Involuntary movement of muscles—Choreiform movements
- Involuntary movement of muscles—Athetosis
- Involuntary movement of muscles—Tremor
- Involuntary movement of muscles—Myoclonus
- Involuntary movement of muscles—Tonic spasm

**Blood vessels of the brain:**

A medical student should have core anatomical knowledge of:
1. the internal carotid artery (anterior circulation) 
2. the vertebral artery (posterior circulation) 
3. the basilar artery 
4. arteries to specific brain areas 
5. the external cerebral veins 
6. the internal cerebral veins 
7. the dural venous sinuses 
8. the cerebral circulation 

The following topics were considered at this stage to be recommended for teaching, but not core:

Cerebral ischemia 
Diseases that produce alteration in blood pressure 
interruption of cerebral circulation 
Postural hypotension 
Cerebral aneurysms 
Congenital aneurysms 

Not required for teaching include:

Veins of specific brain areas 
Physical and psychological shock 
Change in blood viscosity 
Carotid sinus syndrome 

Meninges:

A medical student should have core anatomical knowledge of:

1. the general arrangement of the meninges of the brain 
2. the dural venous sinuses 
3. the functional significance of the meninges 
4. intracranial haemorrhage and the meninges: extradural, subdural, subarachnoid and intracranial haemorrhages in infants 

Recommended topics for teaching, but not core, are movements of the brain in relationship to the meninges in head injuries and migraine headaches 

Not required for teaching included the following items/topics:

Dural nerve supply 
Dural arterial supply 
Meningeal headaches 
Headaches caused by cerebral tumours 
Alcoholic headache 
Headaches due to diseases of the teeth, paranasal sinuses and eyes 

Ventricular system and the formation and fate of the cerebrospinal fluid:

A medical student should have core anatomical knowledge of:

1. the lateral ventricles 
2. the third ventricle 
3. the cerebral aqueduct (aqueduct of sylvius) 
4. the fourth ventricle 
5. the central canal of the spinal cord and the medulla oblongata 
6. the subarachnoid space 
7. cerebrospinal fluid and its functions 
8. formation of cerebrospinal fluid 
9. circulation of cerebrospinal fluid 
10. absorption of cerebrospinal fluid 
11. the extensions of the subarachnoid space 
12. raised cerebrospinal fluid pressure, the optic nerve and papilledema 
13. hydrocephalus 
14. cerebrospinal fluid of the spinal cord 
15. examination of cerebrospinal fluid 

Blood-brain barrier:

A medical student should have core anatomical knowledge of:

1. the structure of the blood-brain barrier. 
2. the functional significance of the blood-brain and blood cerebrospinal fluid barriers. 
3. drugs and the blood-brain barrier. 
4. Topics considered to be recommended for teaching include the blood-cerebrospinal fluid barrier, the cerebrospinal fluid-brain interface, and brain trauma and the blood-brain barrier. 

Spinal Cord:

A medical student should have a good knowledge of the anatomy of the spinal cord, including:

1. the arrangement of the meninges of the spinal cord—dura, arachnoid, and pia mater. 
2. the functional localization of neurons in the ventral horn. 
3. the functional localization of neurons in the dorsal horn. 
4. the intermediolateral horn, the gray commissure and the central canal. 
5. the basic structure of white matter in the spinal cord. 
6. functional knowledge of the ascending tracts in the posterior white column—fasciculi gracilis and cuneatus. 
7. functional knowledge of the ascending tracts in the lateral white column—posterolateral (lissauer’s) tract. 
8. functional knowledge of the ascending tracts in the lateral white column—anterior spinocerebellar tract. 
9. functional knowledge of the ascending tracts in the lateral white column—lateral spinocerebellar tract. 
10. functional knowledge of the ascending tracts in the lateral white column—posterolateral (lissauer’s) tract. 

11. functional knowledge of the ascending tracts in the anterior white column—antior spinthalamic tract.
12. functional knowledge of the lateral spinotential tract (anterolateral system)—pain and temperature pathways (including injury to the later spinotential tract).
13. functional knowledge of pain control in the CNS—the analgesia system.
14. functional knowledge of the anterior spinotential tract (anterolateral system)—light touch and pressure pathways (including injury to the anterior spinotential tract).
15. functional knowledge of the posterior white column: fasciculi gracilis and cuneatus—discriminative touch, vibratory sense, and conscious muscle joint sense (including injury to the fasciculus gracilis and fasciculus cuneatus).
16. functional knowledge of the posterior spinocerebellar tract—muscle joint sense pathways to cerebellum.
17. the functions of the anterior spinocerebellar tract.
18. the concepts relating to conscious sensory information and unconscious sensory information.
19. differentiation between somatic and visceral pain with an understanding of the treatment of chronic pain.
20. functional knowledge of the descending tracts in the posterior white column.
21. functional knowledge of the descending tracts in the lateral white column—lateral corticospinal tract.
22. functional knowledge of the descending tracts in the lateral white column—rubrospinal tract.
23. functional knowledge of the descending tracts in the anterior white column—antior corticospinal tract.
24. functional knowledge of the descending tracts in the anterior white column—vestibulospinal tract.
25. the reflex arc and the influence of higher centers on spinal reflexes, upper motor neuron lesions, and lesions of the corticospinal tracts ("pyramidal" tracts) and of descending motor pathways other than the corticospinal tracts (the "extrapyramidal" tracts).
26. lower motor neuron lesions.
27. the relationship of muscular signs and symptoms to lesions of the nervous system.
28. the effects of complete transection of the spinal cord.
29. the science underpinning Parkinson’s disease.

The following items/topics relating to the spinal cord were, at this stage, considered to be recommended for teaching but not core:

- Ascending tracts in the lateral white column—spinotectal.
- Ascending tracts in the lateral white column—spinoreticular tract.
- Ascending tracts in the lateral white column—spino-olivary tract.

The gating theory.
Functions of the cuneocerebellar tract.
Functions of the spinotectal tracts.
Functions of the spinoreticular tract.
Functions of the spino-olivary tract.
Visceral sensory tracts.
Descending tracts in the lateral white column—lateral reticulospinal tract.
Descending tracts in the lateral white column—descending autonomic fibers.
Descending tracts in the lateral white column—lateral olivospinal tract.
Descending tracts in the anterior white column—tectospinal tract.
Descending tracts in the anterior white column—reticulospinal fibers.
Renshaw cells and lower motor neuron inhibition.
Hypertonia (spasticity, rigidity).
Tremors
Spasms
Athetosis
Chorea
Dystonia
Myoclonus
Hemisection of the spinal cord (Brown-Sequard Syndrome).
Syringomyelia
Arterial blood supply of spinal cord.
Veins of spinal cord.
Ischaemia of the spinal cord.
Lesions of anterior and posterior nerve roots.
Acute spinal cord injuries.
Compression of spinal cord.

The following topics were found to be neither core nor recommended for teaching:

- Intersegmental tracts in the posterior white column—posterior intersegmental tract.
- Intersegmental tracts in the lateral white column—lateral intersegmental tract.
- Intersegmental tracts in the anterior white column—anterolateral intersegmental tract.
- Hemiballismus
- Relief of pain by rhizotomy or cordotomy.
- Tabes dorsalis
- Syringomyelia
- Pernicious anaemia and multiple sclerosis
- Myelography

**The brainstem:**

A medical student should have core anatomical knowledge of:

1. the location of the medulla oblongata and its relationship to other components of the brainstem, both anatomically and functionally
2. the major anatomical features of the medulla oblongata
3. the arterial blood supply of the medulla oblongata, particularly to appreciate the effects of vascular disorders.
4. the clinical effects of raised pressure in the posterior cranial fossa as affecting the medulla oblongata.
5. the gross anatomical appearance of the pons and relate the pons to the other components of the brainstem.
6. the gross appearance of the cerebellum and its relationship to other regions of the brainstem.
7. the functional architecture of the cerebellar cortex (molecular, purkinje, and granule cell layers).
8. the deep cerebellar (intracerebellar) nuclei—dentate, emboliform, globose, and fastigial nuclei).
9. the white matter of the cerebellum—intrinsic, afferent, and efferent fibers of cerebellar hemispheres.
10. the corticopontocerebellar pathway.
11. the gross anatomy of the 4th ventricle (roof and floor, lateral boundaries).
12. While the internal structure of the medulla oblongata and the pons as seen in transverse section is not core, it may be recommended to enable students to know the main tracts and nuclei within the brainstem and to appreciate differences of internal structure between caudal and cranial parts of the pons.

The brainstem topics regarded at this stage as recommended for teaching (but not core) include:

Raised pressure in posterior cranial fossa.
Vascular disorders affecting the medulla oblongata.
Anatomy and fiber composition of cerebellar peduncles.
Cerebro-olivocerebellar pathway.
Cerebroreticulocerebellar pathway.
Anterior spinocerebellar tract.
Cuneocerebellar tract.
Cerebellar afferent fibers from the vestibular nerve.
Globose-emboliform-rubral pathway.
Dentothalamic pathway.
Fastigial vestibular pathway.
Fastigial reticular pathway.
Functions of vestibulocerebellum (archicerebellum).
Functions of spinocerebellum (paleocerebellum).
Functions of cerebrocerebellum (neocerebellum).
Tela choroida
Cerebellar disease—hypotonia.
Cerebellar disease—postural and gait changes.
Cerebellar disease—voluntary movement ataxia.
Cerebellar disease—dysdiadochokinesis
Cerebellar disease—reflexes disturbances.
Cerebellar disease—ocular movement disturbances.
Cerebellar disease—disorders of speech.
Cerebellar disease—vermis syndrome
Cerebellar hemisphere syndrome.
Hydrocephalus associated with 4th ventricle.

Brainstem topics not regarded as core or recommended for teaching include:

Lateral medullary syndrome of Wallenberg.
Arnold-Chiari phenomenon.
Medial medullary syndrome.

Medial pontine syndrome (Mullard-Gubler syndrome).
Lateral pontine syndrome (Foville’s syndrome).
Pontine tumors
Pontine hemorrhage
Infarctions of the pons
White matter of cerebellum—arbour vitae of vermis
4th ventricle tumours

Cranial nerve nuclei and their central connections:

A medical student should have core anatomical knowledge of:

1. the motor nuclei of the cranial nerves (somatic motor, branchiomotor, and general visceral nuclei).
2. the general sensory nuclei of the cranial nerves.
3. the central connections of the olfactory nerve.
4. the optic nerve—central connections—optic chiasma, optic tract, and lateral geniculate body, geniculo-calcarine tract.
5. neurons of the visual pathway and binocular vision.
6. direct and consensual light reflexes.
7. the accommodation reflex.
8. the corneal reflex.
9. lesions of the visual pathway.
10. trigeminal cranial nerve nuclei—central connections.
11. trigeminal neuralgia.
12. the abducens cranial nerve nucleus.
13. lesions of the oculomotor, trochlear, and abducens nerves.
14. facial cranial nerve nuclei central connections.
15. facial nerve lesions and bell’s palsy.
16. the vestibular nuclear complex.
17. the cochlear nerve.
18. glossopharyngeal cranial nerve nuclei central connections.
19. the carotid sinus reflex.
20. vagus cranial nerve nuclei central connections.
21. accessory cranial nerve central connections.
22. salivation and swallowing reflexes.
23. hypoglossal cranial nerve nucleus central connections.
24. clinical tests for examining cranial nerves.
25. brainstem death.

Topics related to the cranial nerves considered at this stage to be recommended for teaching, although not core, include:

Visual body reflexes.
Pupillary skin reflex.
Examination of the fundi.
Oculomotor cranial nerve nuclei—central connections.
Trochlear cranial nerve nucleus—central connections.
Reflexes of the trigeminal nerve, including jaw jerk reflex.
Reflexes of the facial nerve, including blink, stapedial, and lacrimal reflexes.
Descending auditory pathways.
**Midbrain:**

A medical student should have core anatomical knowledge of:

1. the location and external features of the midbrain.
2. the aqueduct.
3. the crus cerebri.
4. the substantia nigra.
5. the red nucleus.
6. the superior and inferior colliculi.
7. cranial nerve nuclei III and IV.

Topics that are recommended for teaching at this stage, but are not core, include:

- Relationships of the midbrain.
- Transverse sections of the midbrain.
- Medial longitudinal fasciculus.
- Midbrain lesions.

The pretectal nucleus was considered to be a midbrain topic not regarded as core or recommended for teaching.

**Diencephalon and pituitary gland**

A medical student should have core anatomical knowledge of:

1. the general arrangement of the diencephalon.
2. the 3rd ventricle.
3. the location and relationships of the thalamus.
4. the general functions of the thalamus and efferent and afferent connections.
5. the location and relationships of the hypothalamus.
6. the general functions of the hypothalamus.
7. afferent and efferent connections of the hypothalamus.
8. the optic chiasma.
9. the location and relationships of the pituitary gland.
10. division of the pituitary into adenohypophysis and neurohypophysis.
11. the control of the pituitary and the general principles of neuroendocrinology.

Topics that at this stage were recommended for teaching, but not core, include:

- The ventral posterior nucleus of the thalamus.
- The medial and lateral geniculate nuclei.
- The suprachiasmatic, supraoptic, and paraventricular nuclei of the hypothalamus.
- The mamillary bodies.
- The blood vessels of the pituitary gland.
- The epithalamus.
- The anterior and posterior commissures.
- The location and functions of the pineal gland.

**Cerebral hemispheres:**

A medical student should have core anatomical knowledge of:

1. the structural components of the cerebral hemispheres.
2. the main sulci and gyri of the cerebral cortex.
3. the lobes of the cerebral hemisphere.
4. internal structures—lateral ventricles, tela choroidea.
5. the components of basal ganglia (basal nuclei).
6. the regional anatomy of the basal ganglia.
7. the regional anatomy of the internal capsule.
8. the connections of the corpus striatum—afferent fibers.
9. the circuits between the basal ganglia and the cortex.
10. the common syndromes of the basal nuclei—parkinson’s disease.
11. cerebral white matter—commissures.
12. cerebral white matter—association fibers.
13. cerebral white matter—projection fibers.

Concerning the cerebral hemispheres, recommended for teaching topics (but not core) include:

- Regional anatomy of the amygdaloid nucleus.
- Connections of the corpus striatum—corticostriate fibers.
- Connections of the corpus striatum—thalamostriate fibers.
- Connections of the corpus striatum—nigrostriate fibers.
- Connections of the corpus striatum—brainstem striated fibers.
- Connections of the corpus striatum—efferent fibers.
- Connections of the corpus striatum—striatopallidal fibers.
Connections of the globus pallidus.

Connections of the input nuclei of the basal ganglia (caudate nucleus, putamen, and nucleus accumbens).

Connections of the output nuclei of the basal ganglia (globus pallidus internal segment, ventral pallidum, substantia nigra pars reticulata).

Connections of the intrinsic nuclei of the basal ganglia (globus pallidus external segment, subthalamus nucleus, substantia nigra pars compacta, and ventral tegmentum).

Common syndromes of the basal nuclei—chorea.

Common syndromes of the basal nuclei—athetosis.

Common syndromes of the basal nuclei—hemiballismus.

Septum pellucidum.

Topics that are not required for teaching include:

Regional anatomy of the claustrum.
Nerve cells of the cerebral cortex—Betz cells.
Variations in cortical structure.
Nerve cells of the cerebral cortex—stellate cells.
Nerve cells of the cerebral cortex—fusiform cells.
Nerve cells of the cerebral cortex—horizontal cells (of Cajal).
Nerve fibers of the cerebral cortex—cells of Martinotti.
Nerve fibers of the cerebral cortex—radial fibers.
Nerve fibers of the cerebral cortex—tangential fibers.
Nerve fibers of the cerebral cortex—bands of Baillarger.
Nerve fibers of the cerebral cortex—striate cortex.
Nerve cells of the cerebral cortex—pyramidal cells.
Layers of the cerebral cortex.
Circuitry of the cerebral cortex.

Cortical areas and lobes:

A medical student should have core anatomical knowledge of:

1. frontal lobe localization and functions.
2. parietal lobe localization and functions.
3. occipital lobe localization and functions.
4. temporal lobe localization and functions.
5. the vestibular area.
6. association cortex localization and functions.
7. cortical localization of language.
8. cerebral dominance.
9. consciousness
10. sleep
11. lesions of the motor cortex.
12. muscle spasticity following lesions of the motor cortex.
13. lesions of the frontal speech areas (incl broca’s area).
14. lesions of the temporal speech areas (incl wernicke’s area).
15. combined lesions of the motor and sensory speech areas.
16. lesions of the prefrontal cortex.
17. lesions of the sensory cortex.
18. lesions of the primary visual area.

19. lesions of the primary auditory area.
20. epilepsy
21. the arterial blood supply to cerebral hemispheres.
22. anterior cerebral artery syndrome.
23. middle cerebral arterial syndrome.
24. posterior cerebral arterial syndrome.

Topics that are considered to be recommended for teaching, but not core, include:

Taste areas.
Insula localization and functions.
Lesions of the frontal eye field.
Lesions of the dominant angular gyrus.
Lesions of the somesthetic association area.
Lesions of the secondary visual area.
Lesions of the secondary auditory area.

Cerebral cortical potentials is a topic not recommended for teaching.

Reticular Formation and Limbic System:

A medical student should have core anatomical knowledge of:

1. the general arrangement and functions of the reticular formation.
2. the limbic system.
3. the hippocampal formation.
4. the connecting pathways of the limbic system.
5. the functions of the limbic system.

Topics that were considered to be recommended for teaching, but not core, are:

Afferent projections of reticular formation.
Efferent projections of reticular formation.
Functions of the reticular formation.
Disorders of the reticular formation and loss of consciousness.
Amygdaloid nucleus.
Structure of the hippocampus and dentate gyrus.
Afferent connections of the hippocampus.
Efferent connections of the hippocampus.
Disorders of the limbic system.
Temporal lobe dysfunction.

Destruction of the amygdaloid complex is a topic not required to be taught.

The autonomic nervous system:

A medical student should have core anatomical knowledge of:

1. the general organization of the autonomic nervous system.
2. sympathetic efferent nerve fibers (sympathetic outflow).
3. sympathetic afferent nerve fibers.
4. sympathetic trunks and ganglia.
5. parasympathetic efferent nerve fibers (craniosacral outflow).
6. parasympathetic afferent nerve fibers.
7. the major autonomic plexuses.
8. parasympathetic autonomic ganglia.
9. preganglionic transmitters.
10. postganglionic transmitters.
11. higher control of the autonomic nervous system.
12. the functions of the autonomic nervous system.
13. the autonomic innervation of the eye, upper eyelid, and iris.
14. the autonomic innervation of the salivary glands.
15. the autonomic innervation of the lacrimal gland.
16. the autonomic innervation of the heart.
17. the autonomic innervation of the stomach and the intestine as far as the splenic flexure.
18. the autonomic innervation of the descending colon, pelvic colon, and the rectum.
19. the autonomic innervation of the medulla of the suprarenal gland.
20. the autonomic innervation of the involuntary internal sphincter of the anal canal.
21. the autonomic innervation of the urinary bladder.
22. the autonomic control of erection of the penis and the clitoris.
23. the autonomic control of ejaculation.
24. the autonomic control of accommodation reflexes.
25. the autonomic control of the cardiovascular reflexes.
26. referred pain and the autonomic nervous system.

Recommended topics for teaching (but not core) include:

- Ganglion blocking agents.
- Postganglionic nerve endings.
- Blocking of cholinergic receptors.
- Blocking of adrenergic receptors.
- Autonomic innervation of kidney.
- Autonomic innervation of uterus.
- Autonomic innervation of arteries of the upper limb.
- Autonomic innervation of arteries of the lower limb.
- Horner’s syndrome.
- Argyll Robertson pupil.
- Urinary bladder following spinal cord injuries.
- Defecation following spinal cord injuries.
- Erection and ejaculation following spinal cord injuries.
- Intermittent claudication.
- Hypertension.
- Causalgia.

Not recommended for teaching was degeneration and regeneration of autonomic nerves, Frey’s syndrome, Hirschsprung’s disease (Megacolon), and sympathectomy as a method of treating arterial disease (Raynaud’s disease).

**Imaging:**

A medical student should have core anatomical knowledge of:

1. CT and MR SCANNING of the brain, and vertebral column/spinal cord.
2. the radiographic appearances of the intracranial cavity and the vertebral column.
3. cerebral angiography.

**DISCUSSION**

The findings of the Delphi Panel for Neuroanatomy is here presented unadorned and unamended, as required by the IFAA for the first stage of the process of devising a core syllabus. Some readers might be surprised at the exclusion of certain topics from the lists of core material (e.g., headaches, Horner’s syndrome). However, the findings of the panel are just the initial stage in the formulation of the core syllabus for the teaching of neuroanatomy to medical students. Indeed, even at this phase of the process, the authors would welcome comments that will be passed to FIPAE for their consideration as the syllabus goes to the second phase of evaluation (see Moxham et al., 2014). Indeed, using Delphi processes just as a survey methodology can lack rigor if this is the only stage employed in attempting to obtain consensus. However, it is often in the lack of consensus following a Delphi analysis that the interesting questions arise as the reasons are explored for that failure to agree on a question or series of questions.

In the present survey, consensus across the panel was not always evident, particularly when viewed across the entire survey and not just for individual topics. For example, 22% of the panel were totally committed to a detailed syllabus that could be termed “maximalist,” whereas a further 22% were “minimalist,” doubting the need for undergraduate medical programmes to have much neuroanatomy content and preferring the material to be taught in a postgraduate setting. The issue of the appropriate timing of teaching of some of these topics is not one that is addressed here but will need to be raised at some point in the future. The increasing incidence of neurodegenerative disorders such as Alzheimer’s disease or Parkinson’s disease means that qualified doctors are going to encounter these patients more frequently than in the past before they have undertaken any specialist training. If the needs of these patients are to be appropriately managed then thought will need to be given to when medical students or doctors in training should receive appropriate education in the relevant neuroanatomy. To provide another example, 33% of the panel (mainly from Southern Europe) did not see the need to
include clinical examples in the core syllabus. Despite such differences, these are important findings that FIPAE will find useful as the core syllabus progresses further.

The approach chosen by the IFAA and EFEM/TEPARG is one of exploring the detail of the syllabus, all the existing core syllabuses in the anatomical sciences that have been published generally taking a broad brush approach. The broad brush approach has both advantages and disadvantages. The primary advantage is that the syllabus is flexible enough to accommodate local idiosyncrasies/expertise; the potential disadvantage is that it may be too flexible to be useful and could still lead to unacceptable levels of variation between medical courses. This is a well-recognized challenge experienced by all curriculum planners, even where learning outcomes are employed. The difficulty of defining learning outcomes has been explored extensively by Hussey and Smith (2002, 2008). Once the IFAA/EFEM syllabus is formulated it would be useful to triangulate between the various core syllabuses to see where similarities and differences exist. At this early stage, we envisage that more similarities than differences will emerge.

Finally, the question must be asked—What is the purpose of a core syllabus and how does it restrict curriculum development? While recognizing the difficulties of obtaining universal agreement on the details, a core syllabus should provide the minimum level of knowledge expected of a recently-qualified medical graduate in order to carry out many clinical procedures safely and effectively (thus to ensure that students are not overloaded with facts). The aim is to set standards not impose them. Thus, the core syllabus does not dictate WHEN or HOW the syllabus is delivered. Furthermore, the core syllabus must not be regarded as “set in tablets of stone” but will evolve over time. The core syllabus embodies the philosophy that knowledge is not required “just in case” nor “just in time” (Morley, 2003) but “what is needed, when it is needed.” It certainly does not mean that ONLY core material should be taught and examined because the strength of a university system lies in the fact that there are different “schools of thought.” However, it cannot be right that core material that signifies international norms is not covered in a medical school’s curriculum.

REFERENCES