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Contemporary Neuroscience Core Curriculum for Medical Schools

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Abstract

Medical students need to understand core neuroscience principles as a foundation for their required clinical experiences in neurology. In fact, they need a solid neuroscience foundation for their clinical experiences in all other medical disciplines also because the nervous system plays such a critical role in the function of every organ system. Because of the rapid pace of neuroscience discoveries, it is unrealistic to expect students to master the entire field. It is also unnecessary, as students can expect to have ready access to electronic reference sources no matter where they practice. In the preclerkship phase of medical school, the focus should be on providing students with the foundational knowledge to use those resources effectively and interpret them correctly. This article describes an organizational framework for teaching the essential neuroscience background needed by all physicians. This is particularly germane at a time when many medical schools are reassessing traditional practices and instituting curricular changes such as competency-based approaches, earlier clinical immersion, and increased emphasis on active learning. This article reviews factors that should be considered when developing the preclerkship neuroscience curriculum, including goals and objectives for the curriculum, the general topics to include, teaching and assessment methodology, who should direct the course, and the areas of expertise of faculty who might be enlisted as teachers or content experts. These guidelines were developed by a work group of experienced educators appointed by the Undergraduate Education Subcommittee (UES) of the American Academy of Neurology (AAN). They were then successively reviewed, edited, and approved by the entire UES, the AAN Education Committee, and the AAN Board of Directors.

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All medical schools are required to cover neuroscience in the curriculum.[1] In developing their neuroscience courses, medical school curriculum design teams and course directors must make a variety of decisions about course content, depth of coverage, educational methodology, teaching personnel, and assessment modalities. This article fills a gap by providing an organizational framework for approaching those decisions. Previous documents have outlined the neuroscience topics and learning objectives that should be addressed.[2,3] One of these documents presented general concepts and principles that apply to neuroscience education across the medical school curriculum, but many of the topics were expressed in broad terms.[3] The other provided a detailed list of topics to be included in the preclerkship curriculum, but did not offer guidance regarding which topics should be prioritized if it was impossible to cover the entire list.[2] This prospect has grown more likely in the intervening years because many medical schools have been reassessing traditional practices and making major structural and philosophical changes, such as a shorter preclerkship curriculum, earlier introduction of clinical learning experiences, and incorporation of competency-based approaches. These developments, together with the rapid expansion in biomedical knowledge and information processing technology, create a need for a systematic review of the core neuroscience curriculum. The guidelines presented here were developed by a curriculum work group of experienced medical educators appointed by the Undergraduate Education Subcommittee (UES) of the American Academy of Neurology (AAN). The process was iterative. In stage 1, one of the co-first authors (J.K.) produced a draft of the curriculum (Tables 1–5). In stage 2, the draft was revised by the other co-first author (D.J.G.) and the UES Chair (M.S.), who assembled the work group. In stage 3, the remaining members of the work group offered comments and suggested revisions that were incorporated into the curriculum, which was recirculated among the work group members for further changes until there was unanimous agreement. In stage 4, the curriculum was sent to all members of the UES, who were invited to comment and suggest revisions, which the co-first authors and M.S. used as a basis for refining the curriculum. Stage 5 recapitulated stage 3, with the refined curriculum circulated among the work group members until unanimity was achieved. In stage 6, the refined curriculum was sent back to the UES, which voted to approve it. This version of the curriculum was the input for stages 7–9, which were identical to stages 4–6 but at the level of the AAN Education Committee. The result was a final version of the curriculum that was submitted to the AAN Board of Directors, which approved it. After establishing the curriculum, one of the co-first authors (D.J.G.) drafted the remainder of the manuscript, providing context and justification for the curriculum. This manuscript was then processed in exactly the same way as the original curriculum, passing through the same 9 stages of review and revision by the work group, the UES, and the Education Committee, in turn.

There are 2 fundamental reasons that medical students must learn neuroscience. First, all clinicians interact with patients who have neurologic disorders, which can result in substantial disability, as emphasized in the recently updated core curriculum guidelines for the required clinical experience.[4,5] Medical students need a foundational understanding of neuroscience to approach the evaluation and care of patients presenting with neurologic symptoms. Second, the nervous system plays a critical role in the function of other organ systems, and physicians must learn about it to have a holistic understanding of how the human body functions in health and in disease states.

Considerations When Developing the Neuroscience Course

Medical schools have traditionally relied on nonclinician basic scientists to teach foundational material and to determine the breadth and depth of coverage. In recent years, many medical schools have tried to ensure that the topics covered are clinically relevant by introducing measures such as increased clinician involvement in preclerkship courses. These measures can be helpful, but even if the curriculum were meticulously curated so that it included only major concepts with direct ties to clinical medicine, the scope of biomedical knowledge has expanded to such a degree that it would be impossible to cover all of this material in the preclerkship phase of medical school and unrealistic to expect students to remember it all. Fortunately, that degree of mastery is unnecessary. Advances in technology permit practicing physicians to access information almost instantaneously from any location. This has prompted the suggestion that medical education should shift from a just in case approach focused on teaching students everything they might ultimately need to know in their future clinical practice to a just in time model aimed at teaching students how to access and interpret reliable information efficiently.[6] Although this seems eminently reasonable, it remains necessary to identify a body of core concepts, principles, and facts. Even in a world with universal access to information, it is impractical for physicians to routinely perform online searches regarding basic principles and concepts of human anatomy and physiology. To offer some simplistic examples, it is hard to imagine how someone could function as a physician without having internalized the distinction between the pulmonary circulation and the systemic circulation or between the sympathetic and parasympathetic nervous systems, regardless of how quickly they could look up these terms. Even for simple factual material, such as the normal reference ranges that are routinely included in reports of laboratory results, it would be awkward for physicians to have to rely on those external sources each time serum sodium or hemoglobin values came up in a clinical discussion. Similarly, it would undermine patient confidence if their physician had to perform an online search each time a symptom, a previous procedure, or medication was mentioned.

Medical educators agree that some concepts and facts are foundational and must be internalized, whereas other material is less essential and can be learned in the moment, but there is no consensus on which topics belong in each category.[7-10] The challenge has been amplified in recent years, as medical schools have been introducing students into clinical settings earlier. This is motivated in part by the desire to adopt a just in time approach and in part by the rationale that it may be easier for students to learn and retain basic science concepts after they have clinical experience to provide context. Regardless of the motivation, the result is that less time is available for the preclerkship phase of medical school, which means that decisions about core material must be even more judicious. Table 1 lists factors that should be considered when making these decisions.

Curriculum Goals, Objectives, and Content

The factors listed in Table 1 vary from one medical school to another, so it would be impossible to adopt a completely uniform neuroscience core curriculum across all schools. The guiding principles, however, can be standardized. Table 2 lists the goals and objectives for the neuroscience core curriculum. Most of these objectives should be met in the preclerkship phase of the curriculum before students assume patient care responsibilities, but medical schools may take various approaches. Some schools may consolidate all of the objectives listed in Table 2 in a single course, whereas others might

Table 1 Considerations When Selecting Material to Include in the Preclerkship Curriculum

Consideration	Comments
Is this material essential?	The emphasis should be on facts and principles that are either critical to patient care or support an understanding of fundamental concepts.
Does this material align with course goals and objectives?	Course content should align with learning objectives that have been clearly and explicitly developed for the course and the institution's undergraduate medical education curriculum as a whole. If a topic for a session cannot be aligned with those objectives, the topic generally does not need to be covered (or the objectives need to be amended).
Is this material likely to become obsolete in the near future?	Course directors should distinguish content likely to remain stable over time (such as cranial nerve anatomy) from content that is likely to change before students begin to practice medicine (such as treatment modalities of autoimmune and genetic diseases). In addition to teaching foundational knowledge, it is imperative to teach life-long learning skills and practices.
Does this material lend itself to clinical correlation?	When possible, use clinical cases to illustrate basic neuroscience principles. This will help students learn and retain those principles. Furthermore, the same clinical cases used to highlight neuroscience principles can be useful for introducing or reinforcing additional core competencies beyond medical knowledge and patient care.
Would it be more appropriate to teach this material in the clinical phase of the curriculum?	At times, it may be easier for students to learn and retain basic science concepts after they have clinical experience to provide context. In developing the preclerkship curriculum, course directors should try to collaborate with directors of the neurology clinical experience and consider whether some content may be reserved to be presented or revisited at greater depth at a later stage in the medical school curriculum. It is also important to consider the best format for presenting that content, especially given that in later stages of the curriculum students often have more individualized schedules.
Are adequate local resources available for teaching this material?	Course directors should be aware of their local institutional resources and use them to maximum advantage when making choices about the course content. At the same time, they should avoid teaching at an inappropriate level of detail simply because local experts are available.
Are external resources available for teaching this material?	There are evolving national resources for educators for neurology specific content through organizations like the American Academy of Neurology (AAN) to assist in assuring that the neuroscience course meets with the expectations of other similar courses across the nation. The AAN also offers multiple opportunities for mentorship and leadership training for academic educators. There are also national organizations to assist in faculty development and enhancement of educational skills including the American Medical Association, the Accreditation Council for Graduate Medical Education, the Association of American Medical Colleges, the International Association of Medical Science Educators, Society for Neuroscience, the American Neurological Association, the National Science Foundation, and others.
Is this content likely to be tested on the USMLE step 1 examination?	Although course directors should develop their curriculum based on general principles and learning objectives, they should also be aware of the major content covered by the United States Medical Licensing Examination (USMLE) and explicitly communicate any content areas that students will need to study independently.
Would this material be most appropriate as a supplement for interested students, rather than a requirement for all?	Students who wish to supplement the school's basic neuroscience curriculum should be encouraged to do so and be provided with resources to facilitate such exploration. It is important to encourage exploratory learning, as this is often how students deepen their interest in clinical neurology and may eventually decide to pursue residency training in the field. The AAN has many resources for students interested in neurology, including a practical guide for those planning a career in the field.[11]

Table 2 Goals and Objectives for the Neuroscience Core Curriculum

Goals
To teach the foundational knowledge and basic clinical skills necessary to evaluate nervous system function and to provide care for patients with abnormal function
To teach the features of nervous system function that must be understood to evaluate other organ systems
Learning objectives
Students should be able to:
Describe the afferent and efferent pathways most relevant to clinical manifestations of neurologic disease, i.e., name the pathways, explain their function, state the level—if any—at which they cross from one side of the nervous system to the other, and identify their location on cross-sectional diagrams and neuroimaging studies at selected levels of the peripheral nervous system (PNS, including anterior horn cell, nerve root, plexus, peripheral nerve, cranial nerve, neuromuscular junction, and muscle) and central nervous system (CNS, including cerebral hemispheres, brainstem, cerebellum, and spinal cord)
Describe the anatomy, principal connections, and functions of major structures in the CNS and PNS
Explain the cellular and biochemical processes necessary for the normal function of the CNS and PNS
Explain the pathophysiology of major categories of disease that can disrupt nervous system function
Describe the interplay of biological and social factors in the genesis and maintenance of behavioral health and disease
Establish rapport with patients, obtain a comprehensive description of their neurologic symptoms and medical history, inquire about other pertinent symptoms, and summarize the information succinctly and accurately
Perform a systematic neurologic examination, with assessment of mental status, cranial nerves (including the ocular fundus), motor and sensory function, coordination, and gait, and distinguish normal from abnormal findings
Deduce the potential nervous system location (if any) where a focal lesion could result in the constellation of presenting neurologic signs and symptoms
Use the conclusions about neuroanatomic localization, together with other details of the history and examination, to draw inferences about possible diagnoses and develop a rational diagnostic and management approach

distribute them across several courses. For example, some schools teach normal structure and function in one course and abnormal function in a different course, whereas others combine them. At some schools, diseases traditionally categorized as neurologic are taught in the same course as those traditionally categorized as psychiatric; at other schools, they are taught in different courses. One common model is to teach communication and physical examination skills in a separate course, sometimes in conjunction with psychosocial, economic, and ethical topics. It would be futile to dictate the precise way in which any given medical school meets the objectives listed in Table 2 or in what order. Nonetheless, it is reasonable to offer guidance at a somewhat more granular level. Table 3 provides an outline of the subject matter that students should learn to achieve the core curriculum goals summarized in Table 2.

The order in which topics are listed in Table 3 is not meant to imply the order in which they should be taught. In fact, there is no single correct order. Regardless of whether the instruction begins at the molecular, cellular, pathway, or network level, students will lack context for some of the things they learn early. Table 3 provides several different ways to organize the subject matter, and many of the categories overlap, so the table includes intentional redundancies. What is important is that students gain some familiarity with all of these topics eventually and that they learn how the different organizational frameworks complement each other. A reference that offers an even more granular breakdown of the subject matter can be found in the 2008 Integrated Neural Science Core Curriculum available on the AAN website.[2] The 2014 competency-based longitudinal curriculum offers a more conceptual outline.[3] For any given topic, the level of detail will vary from one school to another and will be influenced by the factors listed in Table 1; among other considerations, disease prevalence, acuity, and severity may be prioritized differently at different institutions. The learning objectives and educational philosophy of the medical school as a whole will determine how much time is available for the neuroscience curriculum. At a minimum, the content summarized in Table 3 will require at least 8 weeks of dedicated time, whether it occurs in a single course or distributed across several courses. Faculty support for this endeavor should be commensurate with that commitment. Taking into consideration the work involved in direct teaching, course administration, and preparation of the instructional sessions and evaluation materials, a minimum of 25% full-time equivalent faculty support is recommended. Administrative support is also necessary. Whether the support for faculty and administrative staff derives from the department or the medical school, and how it is distributed among people teaching the course, will vary from one institution to another.

Teaching and Assessment Methodology

In addition to the degree of detail and the order in which topics are taught, neuroscience course directors must consider

Table 3 Subject Matter to be Covered in the Neuroscience Core Curriculum

1. Foundational neuroscience principles
a. Cell biology of the CNS and PNS (including neurons, glia, and myocytes)
b. General clinical-anatomic principles: divisions of the nervous system; orientation/structural nomenclature; principles of localization; and clinical differentiation of CNS and PNS lesions
c. Basic neuroanatomy (cerebrum, cerebellum, brainstem, spinal cord, nerve root/plexus/peripheral nerve, neuromuscular junction, and muscle)
d. Major afferent pathways, efferent pathways, and networks (pain/temperature/gross touch; vibration/position/fine touch; olfaction; vision; control of eye movement; audition; vestibular function; control of limb, trunk, and face movement; language; memory; reward; executive function; anger/aggression; and autonomic function)
e. Cellular neurophysiology (including resting potential, action potential, neurotransmitter release, and transmission/saltatory conduction)
f. Neurochemistry (major neurotransmitters and associated receptors)
g. Neuroendocrinology (adreno-, thyro-, and gonado- hypothalamic/pituitary axes; hypothalamic-neurohypophyseal system)
2. Skeletal and other structures associated with the nervous system (anatomy/physiology of cranium/spine; meninges; vascular supply; blood-brain barrier; ventricular system/choroid plexus; and venous drainage/lymphatic system)
3. Physical examination
a. Relevant aspects of general medical examination (e.g., general appearance, orthostatic vital signs, dermatologic findings, cardiac and carotid auscultation, peripheral pulses, evidence of trauma, and neck rigidity)
b. Neurologic examination (mental status; cranial nerves; motor system/reflexes; sensory system; coordination; and station/gait)
4. Neuroradiology
a. Basic physics of common neuroimaging techniques
b. Radiographic features of common disease processes (e.g., ischemia, demyelination, and tumor)
5. Special senses and brainstem
a. Cranial nerve functional neuroanatomy, I-XII (olfactory, visual, and oculomotor systems; sensory system of the head; head and neck motor outputs; auditory and vestibular systems; and speech/swallowing)
b. Pupillary response—normal function, examination, and related disorders
c. Visual, auditory, and vestibular processing—normal function, examination, and related disorders
d. Common cranial neuropathies—examination findings, diagnosis, and treatment
e. Arousal, consciousness, and sleep—normal function and alterations; examination of a comatose patient; and brain death examination
6. Somatic sensory system
a. Sensory receptors and differences among sensory neuronal types
b. Ascending sensory pathways (i.e., anterolateral system or spinothalamic tract and dorsal column/medial lemniscus system)
c. Descending pain modulatory pathways
d. Pain sensation (normal pain transmission/processing; pathologic changes to pain response; and treatment of pain/pain syndromes including headache and neuropathic pain)
7. Motor system
a. Functional anatomy of motor pathways (corticobulbar and corticospinal tract)
b. Neurophysiology of neuromuscular junction and muscle contraction
c. Neuromuscular disorders (pathologic basis/diagnosis/treatment)
d. Motor control systems functional anatomy (cerebellum, basal ganglia, and relevant networks; cortical motor control areas)
e. Movement disorders (pathologic basis/diagnosis/treatment)
8. Autonomic system, homeostasis control, and neuroendocrine system
a. Functional anatomy of the autonomic system (sympathetic/parasympathetic anatomy and physiology; syndromes associated with toxins/therapeutic overdoses acting on autonomic pathways; examination of the autonomic system; and diagnosis/treatment of disorders presenting with autonomic dysfunction)
b. Functional anatomy of homeostasis and central neuroendocrine system

Continued

Table 3 Subject Matter to be Covered in the Neuroscience Core Curriculum *(continued)*

9. Cognitive function
a. Mental status examination for assessment of cognitive disorders
b. Functional anatomy and domains of cognitive function (memory; language; executive function; visuospatial function; and association cortices)
c. Alzheimer disease and other dementias (pathologic basis/diagnosis/treatment)
d. Delirium (pathophysiology/assessment/diagnosis/treatment)
10. Behavioral function and behavioral disorders
a. Mental status examination for assessment of psychiatric disorders
b. Neurodevelopmental disorders
c. Substance-related and addictive disorders (acute intoxication; withdrawal; and identification and management of drug use/misuse/abuse/dependence/addiction)
d. Specific behavioral disorders (including psychotic, especially schizophrenia spectrum; bipolar; depressive; anxiety; obsessive-compulsive; trauma and stressor-related; dissociative; somatic system; personality; feeding and eating; and sexual dysfunctions and gender dysphoria)
e. Behavioral manifestations of systemic and primary neurologic disorders
11. Neurodevelopment and neurodevelopmental disorders
a. Embryology and neurodevelopment—normal function and related disorders
b. Neurogenetics
c. Metabolic disorders affecting development
12. General etiologic categories of neurologic disease (autoimmune/demyelinating; cerebrovascular; epilepsy; genetic—including mitochondrial; headache/pain; infectious; neoplastic; neurodegenerative; secondary to systemic illness; sleep disorders; and trauma)
13. Ethical and socioeconomic management considerations (brain death; decisional capacity/legal competence; driving; end-of-life care; and gun safety)

the presentation format. Even before COVID-19, many medical students opted to watch videos of lectures rather than attend the lectures in person.[12] Another trend that predates the pandemic, motivated by the observation that learners may listen passively to lectures without necessarily processing or internalizing the material, is the emphasis on a variety of nonlecture formats intended to foster more student participation and direct engagement with the subject matter. These formats are collectively referred to as active learning, and they are typically conducted in small groups, each with a facilitator. The goal is usually to explore topics in depth, even if it means covering fewer topics than a traditional lecture would include. Case-based learning, problem-based learning, team-based learning, student-directed learning, and flipped classrooms are all terms for active learning formats. Examples of these educational techniques and tips on how to use them effectively are available in several reviews.[13-15] As both educational philosophy and technology have evolved, the options for teaching sessions (whether traditional lectures and laboratories or active learning exercises) have expanded dramatically. They can be asynchronous or synchronous, in person or remote, or any combination.

Individual learning preferences vary, and no single format is optimal for all students or topics. Some students prefer live lectures, where they can ask questions immediately if they need further clarification of what the lecturer just said.[16] Others favor lecture videos that they can pause, rewind, slow down, or speed up as they see fit. Some learners value working through problems with their peers in small group sessions, but some prefer working through problems independently, at their own pace, and in their own style. Only a few studies have provided rigorous evidence of the beneficial effects of problem-based learning.[17-19] Ideally, the neuroscience course should offer students multiple modalities in which to learn the material, with students selecting the approaches they find most effective. Practical considerations—especially scheduling constraints and faculty availability—often make it impossible to achieve this ideal. Course directors must do their best with available resources.

When considering teaching format, it is important to recognize that most learning occurs outside the setting of formal teaching sessions. Students will only truly absorb and consolidate material—whether conceptual or factual—by studying it and engaging with it independently. It is difficult to learn something just from hearing about it in a single lecture. It is less commonly appreciated that the same is true of active learning sessions—long-term learning only occurs if students reflect on the material before and after the session. Moreover, because active learning often trades breadth for depth, important topics may be ignored completely in the formal teaching session, with the presumption that students will study those topics on their own. Thus, regardless of the teaching format, the main goals are to motivate students to study independently and to help them learn to do so effectively. Faculty should be encouraged to emphasize broad principles, rather than mere facts, and to use techniques that maximize student involvement. For example, traditional lectures, whether delivered live or via prerecorded video, can be made more interactive by pausing frequently to pose questions to the audience.

The COVID-19 pandemic has highlighted many of the issues regarding teaching format. Even the most traditional medical schools were compelled to adjust rapidly to remote learning techniques. At schools where students could previously decide whether to attend lectures in person or watch them via video, quarantines and social distancing eliminated the option of in-person lectures, at least for some students. Small group sessions were converted to a remote format, resulting in a very different dynamic. It may be very easy for participants to be distracted and difficult for facilitators to detect when participants are attentive, especially if the video is not turned on. Virtual small group sessions bypass the time and expense of transportation and parking, making student and faculty schedules much more flexible, but they require students to invest in technology (including devices with a camera), find a conducive setting, and have reliable internet access. These considerations disproportionately affect students with limited finances. In any event, the pandemic has increased awareness of the availability of resources for remote group sessions, increasing the range of options available to course directors when deciding how to deliver course content. Many of the adaptations necessitated by the COVID-19 pandemic will probably endure beyond its conclusion.

Of course, the pandemic disrupted not only education but also the delivery of clinical care. One result has been that after years of slow adoption, remote outpatient visits and consultations are now routine and widely accepted. It is now clear that many interactions that were previously conducted in person can occur remotely.[20] Medical students must learn how to interact with patients virtually. At the same time, they must learn the limitations of virtual interactions. Some valuable aspects of face-to-face interaction are lost in remote visits. For example, for patients whose clinical presentation requires an assessment of heart sounds, muscle tone, or deep tendon reflexes, there is no substitute for a hands-on physical examination. More generally, even when the information gleaned from the physical examination does not alter decision making, the examination ritual itself may be therapeutic.[21,22] At a more basic level, some of the most fundamental lessons medical students must learn about eye contact and body language are difficult to teach in a virtual format. Course directors will need to consider these issues when making decisions about the format of some teaching sessions.

Some of the same factors that influence course content also apply to decisions about methods of student assessment. Rather than test rote memorization, methods that assess conceptual understanding and clinical application are recommended. Current assessment methodologies are listed in Table 4. Each has advantages and disadvantages.[23] Course directors should select from among these options the ones that best align with their course philosophy, structure, and resources. As noted in Table 1, course directors must also remain informed about the topics and level of detail for which students will be held accountable on high-stakes external examinations, such as the United States Medical Licensing Examination (USMLE) step 1 and step 2. For example, the recent decision to discontinue the step 2 Clinical Skills examination may prompt course directors to introduce more rigorous assessment of physical exam skills.

Teaching Personnel

The subject matter listed in Table 3 spans a broad range of academic disciplines, and few—if any—individuals possess expertise in all of them. Course directors will need to enlist the support of many colleagues in developing and teaching the course; Table 5 offers a list of content experts who may be helpful. At the same time, course directors will need to guard against the tendency for experts to let their excitement about their discipline (and especially their own research) distort the balance of topics in the curriculum. The material should be covered in sufficient depth to ensure that students have a foundational understanding of the topic without overwhelming students with details that are unrealistic or impractical for

Table 4 Methods of Assessment

1. Small group presentations/participation
a. Rubric-based assessment of student performance, including narrative evaluation
2. Knowledge-based examinations (institutional or nationally standardized)
a. Multiple-choice questions
b. Short answer
c. Essay
3. Laboratory skills
a. Gross neuroanatomy laboratory practical (i) Gross specimens (ii) Virtual dissections (iii) Neuroradiology images
b. Histopathology laboratory practical (i) Microscope slides (ii) Virtual microscopy images
4. Portfolio-based assessment
a. Log of elective educational sessions attended
b. Independent topic reviews (including literature search strategy)
c. Log of shadowing experiences and other clinical interactions
d. Reflections on clinical experiences, competencies attained to date, and personal strengths and weaknesses
5. Clinical skills
a. Objective structured clinical examination (OSCE) assessment of neurologic examination, clinical reasoning, and communication skills

Table 5 Faculty With Potentially Relevant Expertise

1. Basic science content experts—including, but not limited to, those with mastery of the following areas:
a. Neuroanatomy
b. Neurochemistry
c. Neurogenetics
d. Neuropathology
e. Neuropharmacology
f. Neurophysiology
2. Clinical science content experts—including, but not limited to, those with mastery of the following areas:
a. Neurology (adult and pediatric)
b. Psychiatry
c. Neurosurgery
d. Neuroradiology
e. Neuropathology
f. Palliative care
g. Rehabilitation medicine
3. Additional clinical science experts
a. Cardiology
b. Geriatrics
c. Hematology
d. Immunology
e. Infectious disease
f. Ophthalmology
g. Orthopedics
h. Otolaryngology
i. Pain medicine
j. Psychology
k. Rheumatology
4. Core competency experts
a. Communication
b. Health care systems
c. Informatics
d. Interprofessional clinical practice in neurology (teaming)
e. Narrative medicine
f. Precision medicine and personalized medicine (personomics)
g. Professionalism
h. Quality improvement

practicing physicians. One viable strategy is to have a clinician experienced with treating nervous system disorders codirect the course with a basic neuroscientist. They can do most of the teaching themselves, incorporating input from colleagues who are content experts in particular fields. Alternatively, content experts can participate in the teaching, as long as they agree to teach at the level of detail established by the course directors and they have a firm grasp of what material the students have already learned and what material they will be learning subsequently. Given the trend toward including additional core competencies into the curriculum at all levels, the course leadership should be familiar with the elements of each of the core competencies, staying abreast of them and obtaining consultation as necessary.

Discussion

Because of recent developments in medical education, the rapid pace of biomedical discovery, increasing options for virtual interaction, and advances in information processing technology, it is important to reconsider what medical students should learn about neuroscience and how they should learn it. The curriculum presented here reflects the growing trend in medical education to shorten the preclerkship phase of training. The goal is to provide students with a conceptual framework that will allow them to find the answers to questions they encounter in their clinical training and beyond. The focus is on foundational concepts and organizing principles that are well established and unlikely to be revised substantially by the time students enter the clinical environment. The proposed curriculum does not specify the level of detail at which to cover the topics, nor does it stipulate which facts students should commit to memory. Those judgments must be made locally, and opinions are bound to differ, but the general rule should be that topics should only be included (and tested) when there is a compelling educational reason to do so. The guidelines presented here are intended as a resource for faculty and course directors making those decisions.

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Continued

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