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The place of anatomy in medical education: AMEE Guide no 41*

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Abstract

This Guide, a combined work by three authors from different countries, provides perspectives into the history of teaching gross anatomy, briefly, from the earliest of times, through to a detailed examination of curricula in both traditional didactic approaches and Problem-Based Learning (PBL) curricula. The delivery of a module within a curriculum in tertiary education is interplay between the content (knowledge and skills) of a subject, the teaching staff involved, the students and their approaches to learning, and the philosophy underpinning the delivery of the learning material. The work is divided into sections that deal with approaches to learning anatomy from the perspective of students, to delivery of the content of the curriculum by lecturers, including the assessment of knowledge, and itemises the topics that could be considered important for an appropriate anatomy module in an integrated course, delivered in a way that emphasises clinical application. The work concludes by looking to the future, and considering what measures may need to be addressed to ensure the continued development of anatomy as a clinically relevant subject in any medical curriculum.

Part 1: Anatomy: past, present and future

The field of anatomy

Within the curricula for health care professionals, anatomy is the study of the structure of the human body. The subject known as *gross* or *topographic* anatomy includes the study of normal structures (that can be seen with the naked eye) and their arrangement into systems and regions. It is the focus of this AMEE Guide. Anatomy is complemented by histology (*microscopic* anatomy), embryology (*developmental* anatomy) as well as evolution (incorporating *comparative* anatomy). Anatomy also interfaces with physiology (through the correlation of structure with function) and pathology (by the recognition of abnormal structure), together with many clinical disciplines, particularly surgery, radiology and emergency medicine (by applying knowledge of normal and abnormal structure).

In 'traditional' medical courses, anatomy is studied in parallel with physiology, forming a basis for the subsequent study of pathology and the clinical disciplines. Prior to the introduction of 'Problem-Based Learning' (PBL) medical courses, establishing a full understanding of all normal anatomical structures was regarded as a necessary preliminary course before commencing with the later areas of study. Current PBL curricula present a more integrated approach, in that normal structure and function of the human body are studied concurrently with the pathologies and clinical applications.

Practice points

- The history of anatomy as a discipline has firmly established its place in medical education.
- As the teaching of anatomy has matured, the value of the 'deep approach' to learning has been shown to be superior to the 'surface approach,' although the latter has its place in a limited context, where the acquisition of knowledge does not require an understanding of principles or interpretations of applications.
- It is imperative to establish objectives for an anatomy course and then refine the curriculum to meet those objectives; there is also a need to evaluate the achieved objectives and to decide whether they match the intended ones – i.e. looking for good alignment – which is part of the constant review process required.
- The teaching interaction needs to be designed to match the teaching approach of the teacher with the learning approach of the learners, by accommodating their many and varied styles.
- Most recently, an emphasis on clinically oriented anatomy and the value of introducing professionalism into the anatomy curriculum have been shown to be important.

Designing accurate methods to assess what has been learned, with appropriate feedback from the learners, is the logical end point of the teaching/learning experience.

*Sections 2, 4 and 5 are abridged. The full text of the Guide is available in the AMEE publication, available from the AMEE Office (www.amee.org).

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Historical background

Although this is not an historical treatise, a brief historical overview of the teaching of anatomy, and its part in medical education, is in order. Historians have written extensively about the extent of knowledge in ancient civilisations around the world about the structure of the human body, particularly when it came to the elaborate rituals of embalming the deceased in preparation for the journey into the afterlife. Many of the ancient philosophers and medical practitioners imparted their knowledge of the structure and function of the human body to eager classes of students in small group teaching sessions. In Mediaeval times, anatomy was unsophisticated. Primitive squatting figures containing almost unrecognisable organs were the standard works used by practitioners of medicine. Moving out of the mediaeval period into the Renaissance, Leonardo da Vinci's anatomical studies enabled him to establish a clearer idea of the functioning of the human body. They also provided an understanding of the structures lying beneath its surface markings (in particular the musculature) which had frequently been represented inaccurately by artists (Keele 1964). Extracts of da Vinci's notes give insight into some of the ways he went about acquiring this understanding. Incidentally, they provide excellent illustrations of what we would now term a 'deep approach', i.e. actively searching for meaning:

> 'If you wish to know thoroughly the parts of man after he has been dissected you must either turn him, or your eye, so that you examine him from below, above and from the sides... Before you form the muscles make in their place threads which should demonstrate the positions of these muscles. The ends of these (threads) should terminate at the centre of the attachments of the muscles to the bones.'
>
> 'It was necessary to proceed by stages with as many bodies as would render my knowledge complete and this I repeated twice in order to discover the differences... My works are the issue of simple and plain experience which is the true mistress.'
>
> (Keele 1964)

The outcomes can be seen in his anatomical drawings. Leonardo da Vinci was able to reduce bones and joints to levers acting on fulcra and muscles to lines of force acting on these levers – illustrating his own physical conceptions applied to the human body. Interestingly, descriptive anatomy itself did not come to the fore until Vesalius published his *De Humani Corporis Fabrica* in 1543, 24 years after da Vinci's death. This was the work for which contemporary anatomists were ready, and it opened the flood gates of future anatomical progress (Keele 1964). The vast quantities of anatomic information have created a quandary as to what should be taught to medical students, and what to omit. How this dilemma is being handled, and how best to handle it as we move forward, will be discussed in detail below.

The value of dissection in teaching anatomy became apparent during this period and it remains important today. This work of art (Figure 1) from 1690, graphically depicts the importance of dissection in the teaching process. A quote from **Dream Anatomy** by Michael Sappol: 'A dissected arm emerges from a book, iconographically signifying that true anatomic knowledge comes from dissection of the human body and from the production of books based on such dissection' (Sappol 2006).

As for medical training, doctors were originally taught by the apprenticeship method. There was little in the way of formal anatomy training. Then small medical schools developed and anatomy was taught while rapidly dissecting unembalmed specimens. There was little or nothing in the way of formal didactic anatomy teaching. In the United States, the Flexner Report brought on rapid changes. The numerous unregulated, often for-profit, medical schools disappeared and accredited medical schools were a part of larger academic institutions. Anatomy became a standard part of the basic science curriculum that typically occupied the first 2 years of a 4-year programme. Up until recently, anatomy occupied a significant portion of the first year and included formal lectures and laboratory dissection of the entire body. Due largely to the explosion of information related to molecular biology, the basic science curriculum has become more crowded and the time for anatomy has become compressed to accommodate these new disciplines. In particular, time for laboratory dissection has been shortened, in some cases severely. Currently it is recognised that the anatomy laboratory experience not only teaches students human morphology and relevant terminology, but also it represents an environment where students can learn essential aspects of professionalism,

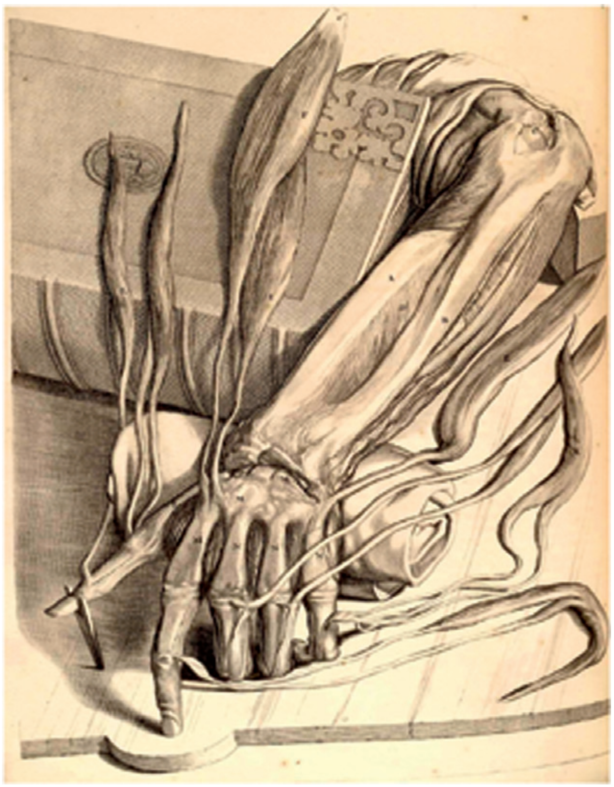

Figure 1. Ontleding des menschelyken lichaams Amsterdam, 1690. Copperplate engraving with etching. National Library of Medicine. Govar Bidloo (1649–1713) [anatomist], Gérard de Lairesse (1640–1711) [artist].

including teamwork, leadership, confidentiality and dealing with death.

Anatomy in tertiary curricula

What is the 'curriculum'? According to Bertram et al. (2000), the word has many interpretations, including something that is moving and changing, a range of subjects (content), the means through which the content is delivered and assessed, the aims and objectives of a programme, the strategies of teaching and learning, a reflection of the needs and interests of Society and more. There is, therefore, a strong social context within a curriculum (Bernstein 1975; Pawlina 2006).

Anatomy in traditional courses

Within traditional courses, anatomy programmes typically had a 'regional' organisation. All regions of the body were evenly distributed over the full complement of teaching weeks allocated to the subject. This arrangement inadvertently promoted the accumulation of details and isolated facts. For example, the learning tasks for the upper limb were sequenced in a linear fashion, working progressively down the limb (starting at the axilla and ending at the digits). Students were limited to tackling the limb in this order and it tended to be seen only as a sum of its many parts. The requirement to be sequential also caused some students to get progressively further behind as the programme continued. This problem was made worse because they met one of the difficult regions of the body (the axilla) very early and launched into the complexities of a large nerve network, the brachial plexus.

Not only was the organisation of the weekly study programme dictated by dissection, but the emphasis was subsequently on the anatomy of the dead. The most expedient order of dissection (that is usually from superficial to deep – for obvious technical reasons) is also not necessarily the most appropriate order in which to learn the subject. For example, the anterior abdominal wall and abdominal cavity traditionally are programmed before the posterior abdominal wall. Students were impeded (until the late in the programme), firstly from viewing the abdominal walls as an organised whole and secondly, from relating the abdominal viscera to the posterior wall (Eizenberg 1988).

An alternative to a regional programme is a 'systemic' one, in which each system of the body (skeletal, muscular, cardiovascular, respiratory, digestive, endocrine, urinary, reproductive and nervous systems) is studied separately. However, a purely systemic programme is equally sequential and linear. Whereas it aids the viewing of relationships within the same type of structure, it de-emphasises important relationships between neighbouring structures. Besides, it is boring to study every bone in the body before moving on to every muscle, and so on. In practice, the systemic aspects of anatomical structures (e.g. detailed descriptions of attachments and actions of muscles forming the walls of the region) tended to be crammed together with the regional aspects (their position), making it even more of an incoherent overload for the student.

Anatomy in current PBL courses

The introduction of PBL courses was seen as a way of dealing with certain issues affecting traditional courses, including the artificial division between preclinical and clinical domains, as well as the workload resulting from the knowledge explosion in all domains. PBL courses also aimed to achieve horizontal in addition to vertical integration. This lent itself to a system by system approach. In some institutions, anatomy of the living was preferred to dissection, which was regarded as a relic and disdainfully discarded by the more radical courses.

In many curricula, from being a major free-standing subject in a traditional course, anatomy became diminished and fragmented with even the order of its fragments dictated to by the PBL tutorial cases. The regions of the body that did not fit in tended to be ignored (despite warranted complaints from anatomists and surgeons). For example, the brain and spinal cord as the central nervous system were given appropriate emphasis in an integrated systems organisation, whereas the surrounding head, neck and back (with the cranial cavity and spinal canal) were much more difficult to classify. Similarly, the thoracic, abdominal and pelvic walls (with their respective cavities) suffered from not being direct components of the respiratory, digestive or urogenital systems. Under these circumstances, the human body soon found itself to be both 'decapitated' and 'discorporated.' Could there be a middle road?

Retaining anatomy and the related subjects of histology, embryology and physiology are essential and valued components of the training of every undergraduate student studying within a PBL curriculum. This requires the active participation by relevant staff members in curriculum design, implementation and evaluation, and student assessment activities. PBL curricula have the advantage of ensuring that students are immersed in a so-called spiral of learning, in which basic concepts are introduced at an early stage of their student careers, and are revisited at greater depth at regular intervals across the entire programme. The study of human structure and function should occur in the context of clinical application, based on the delivery of an integrated curriculum, as illustrated in Figure 2.

In order to fully appreciate why certain facts about structure and function need to be studied, and to ensure reasonable retention of the knowledge, the delivery of anatomy should ideally be integrated with the clinically relevant details. Hence the modern concept of delivering a course that is entitled 'clinical anatomy,' as opposed to the older titles used previously. Another important element of PBL curricula should be the assessment of the basic and diagnostic sciences by relevant staff members alongside clinicians during

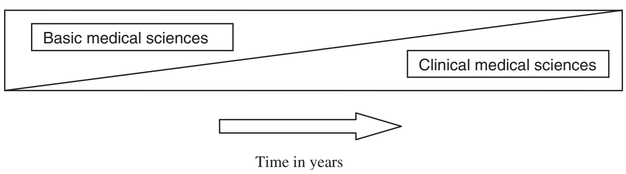

Figure 2. Integration through a medical programme.

examination cycles in the senior years of the programme. Increasing the 'visibility' of the basic and diagnostic scientists will underscore, for the students, the importance of revision of basic human structure and function in the clinical setting.

Certain Faculties have chosen to abandon dissection of the human body and students study anatomy using wet or plastinated cadaveric specimens and on models, in anatomy laboratories and in clinical skill laboratories. There have been several reasons as to why these Faculties have chosen this route – such as unfortunate experiences by members of the curriculum design teams during their undergraduate careers, reduced time for anatomy in the overall timetable, the question of whether learning anatomy on an embalmed geriatric cadaver is an appropriate resource for learning normal structure and function. Additionally, cost factors (both financial and staffing), the difficulty in obtaining sufficient numbers of cadavers for the whole class, are important factors influencing this trend. The arguments remain that cadaveric dissection is the most appropriate way to study the three-dimensional anatomy of the human body, as it is a process of discovery, develops manual skills required later in the career of a student and it is an excellent way to learn a team approach to learning. The cadaver may be considered to be the first patient to whom a junior Medical student is exposed, and serves as part of a vital induction process into the medical profession. The consequences of abandoning dissection are well documented in the literature when it comes to the negative impact on students' ability to successfully examine a patient in a clinical setting and later to perform surgery.

Disciplinary and professional perspectives

Learning anatomy involves focusing on the learning outcomes necessary if medical graduates are to make effective use of what they learned when confronted with real cases in professional practice (Bowden & Marton 1998). Knowledge is organised differently in the basic sciences compared to the clinical domains even for the same structures, such as ligaments.

From the disciplinary (anatomical) perspective, ligaments are considered in terms of their composition – collagen (dense connective tissue that resists stretching, thereby transmitting force) except for special ligaments of elastin (that allow stretch). They can also be considered in terms of their classification (accessory capsular, extracapsular and intracapsular), location, attachments, form, function, nerve supply (rich supply of proprioceptive and pain fibres), blood supply (relatively poor – hence their slow hearing), **relations** to other body structures and systems and their variations with age, sex and build.

From the professional (clinical) perspective, ligaments are considered in terms of ligament injuries and the pathological condition involved; the type of injury, varying from a sprain to a partial rupture to a complete rupture; the predisposing factors; the mechanism of injury; the effects of injury; the associated injury to related structures such as dislocation or bone fracture, including avulsion fractures; the signs and symptoms; the kinds of investigation warranted; diagnosis; treatment; complications such as lengthening of the ligament and weakness due to inadequate repair; prognosis and prevention through strengthening, training or strapping.

Both these ways of organising knowledge about ligaments are legitimate; they have a different focus and they are complementary. In the past, organising principles drawn from the professional perspective did not play a significant part in the design of the anatomy curriculum because the disciplinary perspective was the prevailing one. Currently, the disciplinary perspective could be becoming lost from PBL courses that have traded it for the prevailing professional perspective. Not enough clinical relevance creates a sense of feeling overwhelmed, and hence depression. Furthermore, an insufficient anatomical foundation creates anxiety because of a perception of being under-prepared for the clinical setting. Students who can handle the former scenario seem to be more suited to a traditional course, whereas those who can handle the latter scenario seem to be more suited to a PBL course.

Anatomy reinvented

There is a great divergence in medical schools in teaching medicine in general and anatomy in particular (Older 2004). Older reviewed the impact of these changes and calls for a common national core curriculum. He discusses the role of dissection and regards the student – cadaver – patient encounter as paramount in medical education. Anatomy has suffered as a result of its failure to evolve and adapt quickly enough (Turley 2007). Turley calls for anatomy to reinvent itself as a subject. But, how can anatomy reinvent itself before becoming yet further marginalised?

The pendulum is already starting to swing back, hopefully to the midpoint of its arc as the ideal medical course is likely to be a hybrid incorporating the best of traditional courses and PBL courses (Figure 3).

Both dissection (albeit targeted to focus on clinically important areas) and PBL tutorials (with learning tasks interpreting the anatomical basis of clinical phenomena) have vital roles. The former links well with regional anatomy, while the latter with systemic anatomy. In the ideal new anatomy programme, the disciplinary and professional perspectives are also genuinely integrated. Teaching and learning activities and the assessment of anatomy should have students continually moving from one perspective to the other in explaining clinical phenomena and their own observations. This can occur during anatomy practical classes, including dissection (e.g. where students are challenged to determine if their findings on a specimen or cadaver are normal) as well as during PBL tutorials (e.g. where students are challenged to determine if relevant radiographs to the case provided are normal).

However, the key to the reinvention of anatomy is the emergence of new entities such as 'general anatomy' and 'clinical anatomy,' that introduce terms together with the foundation of organ structure and the general arrangement of organs into body systems, before launching into the detailed study of a specific system. Also, the general arrangement of organs within regions and the basis for viewing them via imaging modalities would be presented. The understanding of anatomical principles is another basis for recognising clinical manifestations of disease processes. Thus

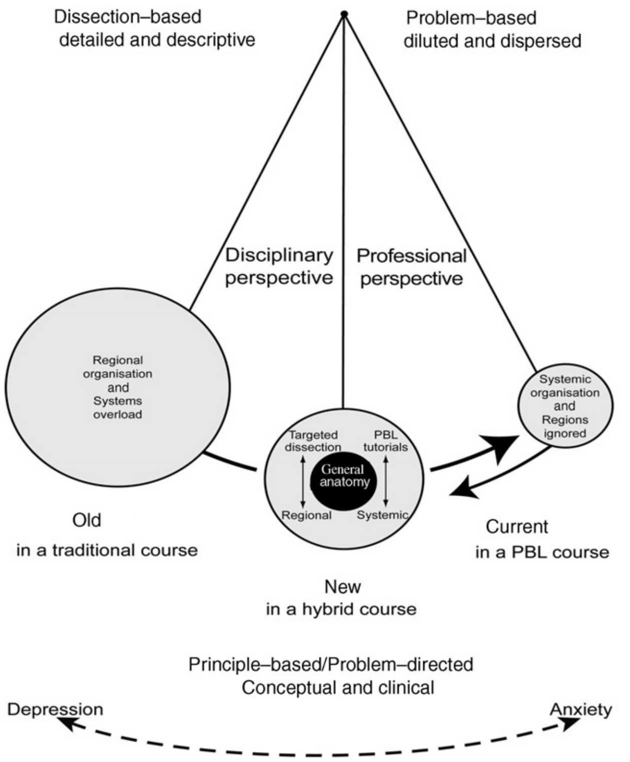

Figure 3. Types of anatomy programmes.

the ideal anatomy programme is 'principle based,' with the principles directed to their clinical applications, so that it is also 'problem directed.' Similarly, the ideal medical course will evolve into a '*principle based and problem directed*' course in contrast to either to the traditional discipline-based or current problem-based courses.

It is counterproductive to simply turn back the clock and for example, reinstate dissection in its former format, or for that matter reinstate a traditional medical course the same way it was previously. The qualitative improvement from the additional component of general/clinical anatomy as a solid centre for the pendulum will help it remain at rest mid arc. An otherwise hollow pendulum is easy to be pushed one way or the other, tending to overshoot and oscillate in response to dissatisfaction on trading one type of programme or course for another (without reinvention).

For courses such as anatomy within an ideal programme, the general precedes the specific. 'General anatomy' provides the foundation for 'specific anatomy' in the clinical setting, including both of its theoretical perspectives (systemic and regional) as well as the practical. General anatomy is also the glue that holds the components of specific anatomy together (Figure 4) (Eizenberg et al. 2008).

General/clinical anatomy

General anatomy should be the anatomy that all health science students receive as their initial learning experience. Whereas an introduction to the study of anatomy occurs already to some degree in the majority of programmes, it tends to be scant at worse and patchy at best. It has become clear that the way forward is to spend more effort and time on teaching fundamentals and how to find the details when required (at the expense of trying to directly cover all of them, particularly in one bolus). Students will be equipped with the necessary intellectual tools to then master subject matter met at any time in their training and career. It is this foundation of anatomical literacy and flexibility that enables anatomy to be successfully reinvented. A distinct domain is required to ensure all the theoretical as well as the practical components under the umbrella of general anatomy are addressed adequately (Figure 5) (Eizenberg et al. 2008).

General anatomy is *conceptual*, a concept being the idea or understanding of an object or an event. A principle is a recurring pattern of linked concepts (particularly of an object linked to an event). Principles provide general rules relating objects and events to each other. This enables deductive (*from Latin*: '*from*' + '*lead*') reasoning where the specifics are examples derived *from* a generalisation. In contrast, inductive (*from Latin*: '*to*' + '*lead*') reasoning allows patterns *to* emerge after gathering all the detailed information, then reflecting on them. Thus the specifics lead *to* a generalisation. Versatile learners require both forms of reasoning.

The application of anatomical principles is primarily to clinical contexts. The overarching goal is to help the learner competently (and confidently) meet new situations in future practice, armed with the capacity to reason from first principles (Tables 1 and 2).

Specific anatomy

The unit or building block of anatomy is an anatomical structure (from Latin: 'build') or organ (from Greek; 'tool'). Organs may be grouped according to a common function into systems (from Latin: 'organised wholes') or according to a common location into regions (from Latin: 'areas'). An organ is therefore simultaneously the structural (and functional) unit of a body system as well as an occupant of a region. Systemic anatomy is concerned with the organisational (intrinsic) properties of an organ – its structure and supply. Regional anatomy is concerned with the situational (extrinsic) properties of an organ – its position (spatial relationships to the body as a whole) and relations (those to its immediate neighbours). 'The information regarding particular individual organs is in the domain of what may be termed specific anatomy in contrast to general anatomy.'

Theoretical knowledge about specific organs, underpinned by general principles, enables an understanding of the body to be constructed from its units. This knowledge embraces components that manifest themselves in different ways depending on the type of organ involved (Figure 6).

It is not sufficient to know about anatomical structures in theory but it is also vital to experience how normal structures appear from the variety of ways they can be accessed in living patients. Sectional anatomy of the body at clinically important levels and in key planes forms the basis for interpreting computerised tomographic (CT), magnetic resonance (MR) and ultrasound (US) images. Surface anatomy (including projections of underlying organs), together with functional anatomy (movements, actions and reflexes), forms the basis

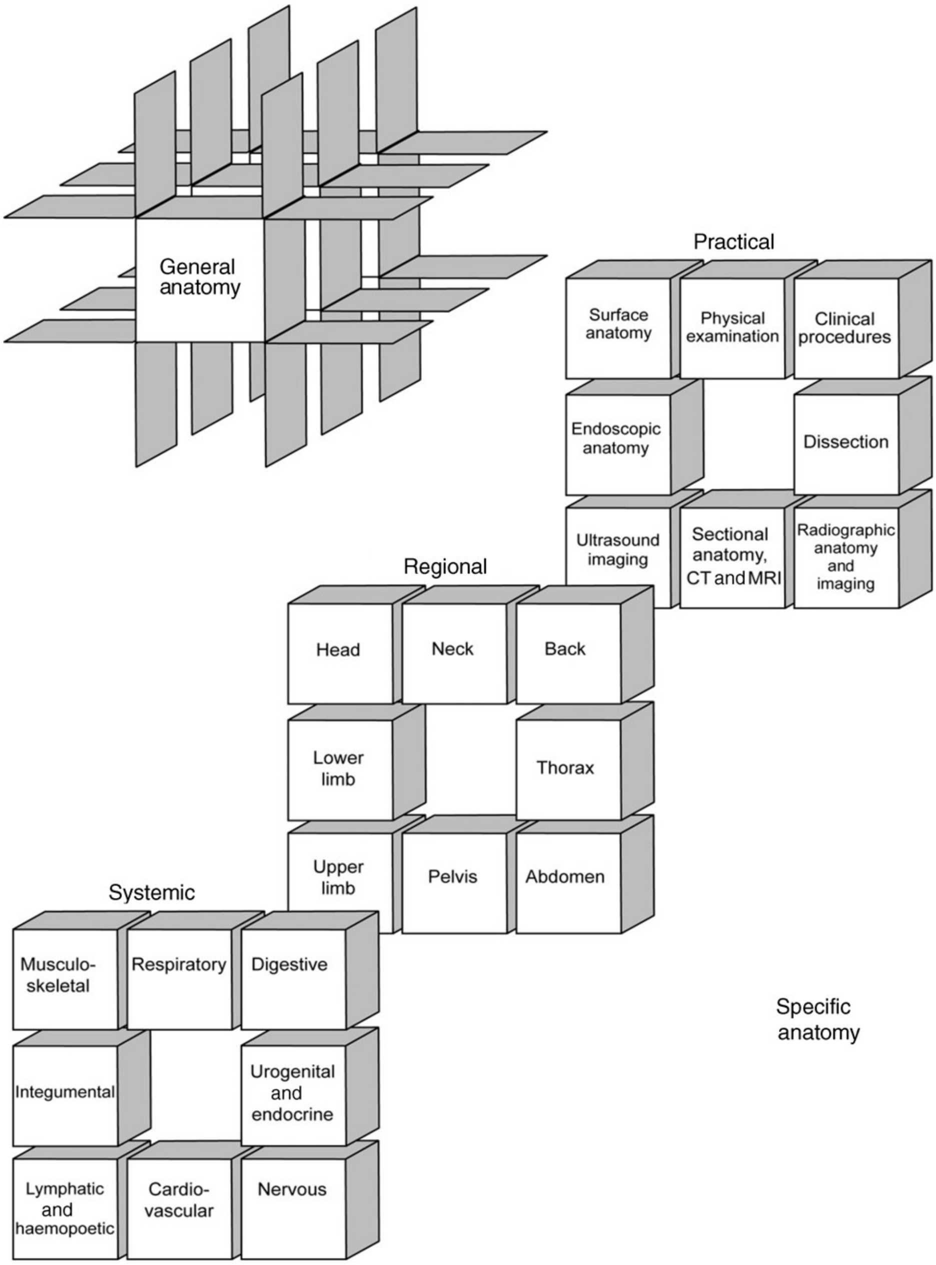

Figure 4. 'General anatomy' and 'specific anatomy'.

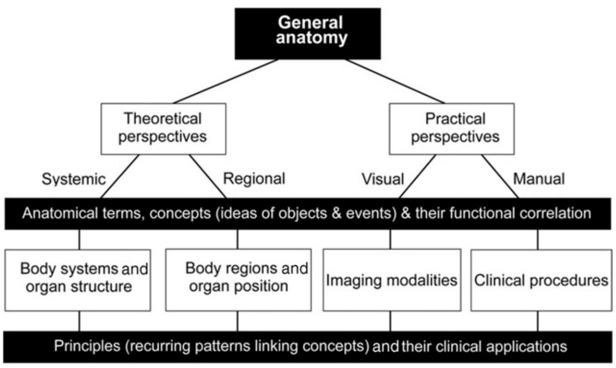

Figure 5. 'Components of general anatomy'.

Table 1. General objectives for 'General anatomy'.

By the end of the **General anatomy** teaching programme the student is able to:

1. 'Use correct **anatomical terminology**'
2. 'Understand the **concepts** and associated **principles** for each general type of organ, the **relationship of structure to function** and their ***clinical applications'***
3. 'Comprehend the arrangement of organs (with a common function) into *systems'*
4. 'Comprehend the subdivision of the body into *regions* (of organs in a common location)'
5. 'Appreciate **range of normality** (of the living body)'
6. 'Comprehend general principles of how a living body can be viewed by each type of **imaging** modality'
7. 'Comprehend the anatomical basis for general **clinical procedures'**
8. 'Develop skills for manipulating anatomical structures (with dissecting instruments)'

Table 2. Specific objectives for 'General anatomy'.

Learning objectives	Concepts (and associated principles) *Arrangement into systems* and *regions*	Relationship of organ structure to function *Clinical applications*
1. Terms	Terms of: position, relationship, comparison, movement	
2. Organs	Bone structure and bone marrow	Roles (mechanical and haemopoietic)
(a) Somatic structures:	Bony features	Growth of bones
	Cartilage	Blood supply of a long bone
	Parts of a developing long bone	*Fractures and epiphyseal injuries*
	Growth plate and epiphyseal line	
	Joint types (fibrous, cartilaginous and synovial)	Trade-off between mobility and stability
	Articular surfaces and articular cartilage	*Joint degeneration*
	Synovial cavity and synovial membrane	Roles of synovial membrane and fluid
	Fibrous capsule, ligaments and special structures	*Dislocations and ligament injuries*
	Muscle structure and attachments	Types of muscle contraction and actions.
	Tendons and aponeuroses	*Muscle* and *tendon injuries*
	Fascial septa, sheets and sheaths	Roles and regional adaptations of fascia
	Neurovascular hilum	Motor point, muscle units and muscle tone
	Myotomes	
	Skin structure, appendages and specialisations	Roles of skin
	Cutaneous nerve supply	Relaxed skin tension lines
	Dermatomes	Nerve overlap and internervous lines
	Axial borders and lines	*Referred pain and sites of referral*
	Neurosomes	Vascular supply territories
	Angiosomes	Watershed areas
	Lymphotomes	
	Viscera (hollow tubes and solid glands) structure	Motility of tubular viscera: *Visceral obstruction*
(b) Visceral structures:	Exocrine glands (and ducts)	Exocrine versus endocrine secretion
	Serous membrane and mesenteries	Mobility and fixation
	Muscular wall and sphincters	Role (and mechanisms) of sphincters
	Mucous membrane and junction zones	*Visceral strangulation*
	Nerve structure	
	Sensory and motor nerve fibres	*Nerve injuries*
(c) Supply structures:	Somatic and visceral nerve fibre types	Sensory and motor functions
	Spinal cord segments	Sympathetic and parasympathetic roles
	Spinal nerves, roots and rami	Reflexes and components of a reflex arc
	Plexuses and peripheral nerves	Segmental and peripheral nerve supply
	Nerve branches and distribution	*Reflex muscle spasm*
	Vessel structure	*Haemorrhage*: *Thrombosis and embolism*
	Arterial branches and anastomoses. 'End-arteries'	Arterial supply
	Venous tributaries and communications	*Arterial occlusion*
	Valves	Venous drainage, flow and *spread*. *Varicose veins*
	Lymph nodes and lymph drainage	Lymph drainage and flow
	Lymph duct termination in venous system	*Lymphatic spread*
	Lymphoid organs and tissue aggregates	Role in return of fluid to circulation.
		Role in defense
	Skeletal, *articular*, *muscular*, *integumental systems*	
3. Organ systems	*Respiratory*, *digestive*, *urogenital*, *endocrine systems*	
	Nervous (central *and* peripheral) *systems*	
	Arterial (pulmonary and systemic) *systems*	
	Venous (pulmonary, systemic and portal) *systems*	
	Lymphatic and haemopoietic system	
4. Body regions	*Head and neck*, *trunk, Upper and lower limbs*	Midline: Coronal morphological plane
	Paired and unpaired regions: Flexor and extensor regions	*Compartment syndrome*
	Compartments and layers	*Potential paths of direct spread*
	Mobile and fixed fascial planes	*Hernia*
	Body walls and parietal structures	*Prolapse*
	Serous sacs with body cavities	*Neurovascular endangerment*.
	Neurovascular bundles and pathways	
5. Range of normality	Normal variation	Constitutional *and* functional factors
	Anatomical variation	*Surgical and radiological implications*
	Pathological changes (congenital and acquired)	
6. Imaging	Plain radiographs and contrast studies	
	Sections: CT and MRI	
	Ultrasound	
	Endoscopy	
7. Clinical procedures	Creating an opening: ostomy	*Incisions*
	Surgical removal: ectomy	*Wound closure*
		Joint and body cavity taps
		Injections. Nerve blocks. Vascular access
8. Dissection skills	Manipulating anatomical structures	*Identify fascial planes*

Note: The use of italics in the table refers to the clinical applications of the topics in column 2.

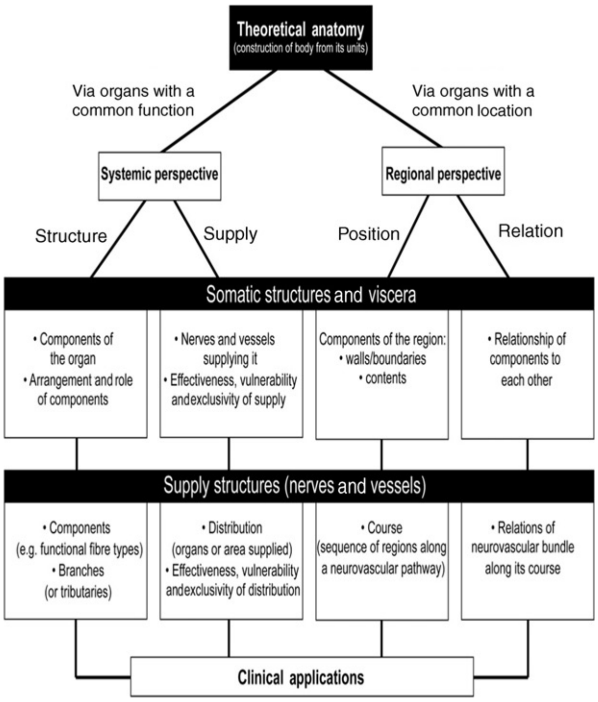

Figure 6. Theoretical perspectives of anatomy.

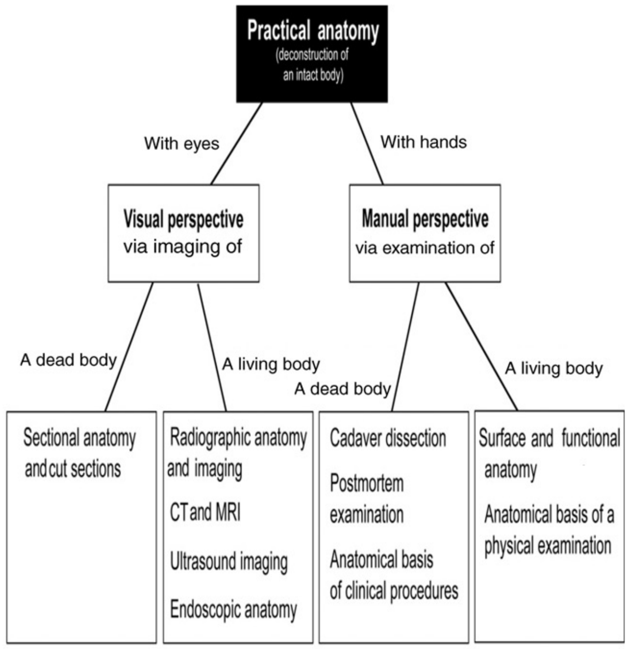

Figure 7. Practical perspectives of anatomy.

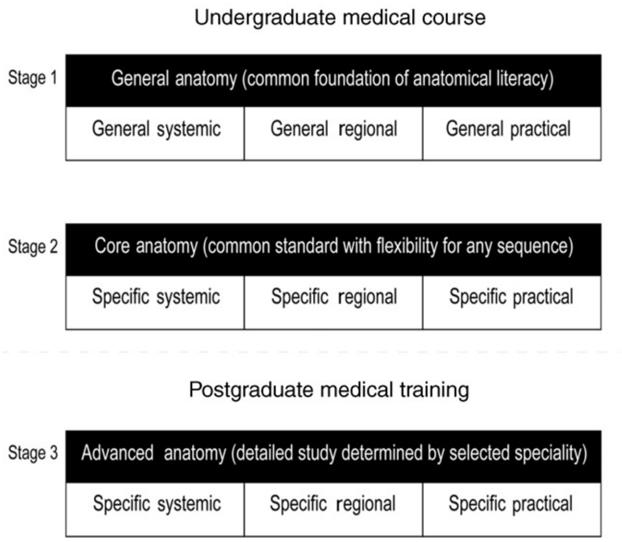

Figure 8. Stages of anatomy programmes.

for conducting the physical examination of a patient, as well as performing clinical, including emergency, procedures.

Practical knowledge about specific organs, also underpinned by general principles of the ways they can be seen and handled, enables an understanding of how an intact body can be deconstructed. This knowledge embraces components which manifest themselves in different ways, depending on the type of practical perspective involved (Figure 7). Reconstruction of the human body occurs with the clinical application of this knowledge of anatomy.

There are many advances on the horizon, particularly involving imaging techniques both diagnostic (e.g. ultrasound) and interventional (e.g. angioplasty), as well as endoscopic and microsurgical procedures. A thorough knowledge of anatomy is now more important than ever, in order that the diagnostician does not see too little or too much (Lucic et al. 2003).

However, what specific anatomy is appropriate for undergraduates in contrast to postgraduates? Essential factual information is trapped between the pincers of a principle and its application to a first port-of-call practitioner. The challenge for any undergraduate curriculum is to extract this from extraneous descriptive detail that may only be of use to a postgraduate specialist or anatomical researcher. The former can be termed 'core anatomy' and the latter 'advanced anatomy' (Figure 8).

Conclusion

Anatomy, if sufficiently proactive, can help shape the future of medical education, as well as being shaped by it. In reinventing itself via advancing, and not just retaining the best of the past and the present, anatomy has the capacity to lead by being an educational exemplar for other programmes to reinvent themselves. This might even be of help to certain undergraduate medical courses facing the threat of being externally dismantled, as well as help to provide a secure foundation for future postgraduate training.

Part 2: Student learning and the learning of anatomy

This section is published in full in the AMEE Guide, available from AMEE (www.amee.org). It explains how interventions in the curriculum, teaching and assessment designed to help students improve their learning can be enhanced by using a holistic strategy based on the research findings from the field of student learning.

Part 3: A curriculum for anatomy

Interventions in the content and structure of an anatomy programme

Departments in the so-called preclinical years of traditional medical courses provided learning environments often with heavy workloads and a lack of clear goals and standards. Anatomy was generally regarded as a main offender that tended to result in students adopting surface approaches to their learning. The main danger of a discipline-based course is dislocation from the faculty goals of subjects that can be taught in a vacuum (Eizenberg 1991).

Within the context of a particular programme, students face a multitude and variety of specific learning tasks with many opportunities to use deep or surface approaches – or even to neglect the tasks. The origin of students' approaches to a particular problem is their intentions. Since students may have different intentions in different learning situations, then the same student may use either approach on different occasions (Laurillard 1984). In reading tasks, many students fail to see the point in what they are reading simply because they are not looking for it (Marton and Saljo 1984). Student approaches to learning are associated not only with their conceptions of learning in general, but also specifically with their conceptions of what they are learning (Prosser and Trigwell 1999), in this case the learning of anatomy. Deep approaches involve the active searching for meaning, preferably with an underlying conscious intention to understand. The following curricular interventions are designed to encourage students to adopt deep approaches, particularly via influencing intentions regarding the anatomy programme, that would also be compatible with their aspirations regarding the medical course as a whole (Eizenberg 1986).

Construction of goals and objectives linked to aims of the course (for openness to students)

There is a three pronged rationale for using statement of aims and objectives (Ramsden 2003):

(1) education is about changes in students' thinking and knowledge;
(2) it is useful at the start of a course to inform students plainly, methodically and accurately as to what they need to learn and
(3) it is what students do, rather than what teachers do, that ultimately determines whether changes in their understanding actually take place.

Clear statement of objectives optimise the likelihood for students to have appropriate conceptions of what anatomy is about, what learning it entails and what having learnt it successfully means. In order to encourage students to have the intention of gaining an understanding of the subject, it is also particularly important to ensure vocational relevance and minimise unnecessary workload due to uncontrolled proliferation by:

(1) linking the goals of the subject or programme to aims of the medical course (Table 3),
(2) constructing general objectives to meet the goals (Table 4) and
(3) displaying these to students and teachers, both in the department and related departments, vertically and horizontally. It is also helpful to clearly state what the goals do not include.

Table 3. Goals of anatomy curriculum for the medical course.

By the end of the medical course the student effectively uses anatomical knowledge, skills and attitudes:

1. to identify and interpret the **normal structure** of the human body; throughout life span (appreciating the *range* of normality of the *living* human body) **correlating structure with function**.
2. as a part of:
   (i) recognising the **structural alterations** in disease processes and their **clinical manifestations**.
   (ii) eliciting and interpreting **physical signs**.
   (iii) performing clinical (diagnostic and treatment, including emergency) **procedures** required of a 'first-port-of-call' doctor.
3. as a part of:
   (i) applying scientific knowledge in the analysis of problems.
   (ii) continuing independent learning.
4. In communicating information relating to the structure of the human body to medical and non-medical personnel.

Notes: The goals *do not* include:
(a) the knowledge of a large quantity of the information contained in a *detailed* study of anatomy.
(b) the anatomical knowledge and skills required for the successful practice of specialties.

A comprehensive set of specific objectives and curriculum content (syllabus) can be then drafted (Table 5). Ideally a national or global core curriculum may ensure a minimum standard or at least provide a guide to assist anatomists in medical schools in constructing their own local adaptations.

Matching curriculum, teaching and assessment (clarifying goals and standards)

In addition to linking the goals of the subject to the faculty aims and constructing a set of general objectives consistent with the subject goals, it is most important to match the syllabus, teaching methods and assessment in turn to those objectives (Figure 9). This needs to be clearly tabulated for all teachers (and examiners), as well as students, so that everyone is equally involved in the process (Table 6).

By seeing how each objective is addressed by a particular learning activity and related to the assessment, students are in an informed position to formulate their intentions and determine if they have the capabilities and desire to put in the required effort to achieve them. Ideally, students will perceive the goals and objectives of the curriculum, i.e. the intentions of the subject (and hopefully the intentions of all the teachers and examiners) to be appropriate and, most importantly, matched well with their own intentions. A common example of mismatch of intentions and perceived goals is anxiety regarding perceived assessment demands. The matching can also be extended horizontally to other subjects with integration or at least coordination of the programme regarding sequence

Table 4. General objectives for anatomy.

(A) Knowledge (B) Skills (C) Attitudes

By the end of the medical course the student should:

(A) Comprehend

(1) The **terminology** of anatomy.
(2) The **concepts and associated principles** for each *general type* of organ:
  (a) *somatic structures* (skin, fascia, skeletal muscles, bones & joints)
  (b) *visceral structures* (glandular organs & mucosal lined tubes of smooth muscle)
  (c) *supply structures* (vessels & nerves) both somatic and visceral
(3) The organisation of anatomical structures, which contribute to a common function, into (organ) **systems** and the subdivision of the human body into **regions.**
(4) The essential information from a *systemic perspective* (structure and supply) for *specific* **anatomical structures** forming the components of systems.
(5) The essential information from a *regional perspective* (position and relations) for *specific* **anatomical structures** forming the components of regions.
(6) The **applications** relating directly to clinically important areas of anatomy.
(7) The **surface markings** of clinically important structures, on normal *living* bodies and the **correlation of structure with function** (for important movements, actions & reflexes).
(8) The anatomical basis of **physical examination** (systemic & regional) of the *normal* living body
(9) The appearance of normal structures in **radiological images** (plain radiographs, contrast studies, CT, MRI and ultrasound) of living bodies.
(10) The appearance of **the human body in section** at important levels & planes and of **cut-sections** of normal viscera.
(11) The appearance of normal features (in hollow organs, body cavities and joint cavities) viewed via **endoscopy** on living bodies
(12) The anatomical structures observed, palpated or pierced in **clinical** (diagnostic and treatment, including emergency) **procedures**

(B) Develop

(1) **Observational and organisational skills** to identify and interpret:
  (a) exposed anatomical structures and regions.
  (b) surface markings on normal living bodies.
  (c) the anatomical structures involved in movements, actions and reflexes.
  (d) the naked-eye appearance of cut sections of normal viscera.
  (e) sections of the body at important levels and planes.
  (f) normal structures in radiological images.
(2) **Versatility to think both systemically and regionally** (when acquiring & interpreting findings particularly from a physical examination or imaging investigation)
(3) The capacity to **reason from first principles** in facing clinical problems with an anatomical basis.
(4) **Communication skills** (written and oral) to describe and explain the normal structure of the body.
(5) **Skills for physical examination** of the normal living body.
(6) **Skills in the manipulation of anatomical structures** (with dissecting instruments).

(C) Appreciate

(1) The **range of normality** of the living human body (***normal variation***) due to age, sex and body build and the effects of posture, phase of respiration and pregnancy.
(2) The common occurrence of **anomalies** (***anatomical variation***) which differ from 'text-book descriptions' of the typical case.
(3) The importance of one's own observations (as seen in the historical development of anatomy as a science).
(4) The need for continuing independent and collaborative learning of knowledge relating to structure, to keep pace with future advances.

of major topics and, most importantly, the timing of assessments.

Defining essential information (to control and rationalise workload)

Anatomy is widely known to include a massive amount of information. In order to rationalise the potentially daunting workload, students require perspective into what is important for clinical competency, preferably in advance of trying to learn about a particular topic. Even if a topic is designated as being 'essential,' students are often unclear as to what that means, in other words, what they should be able to do, let alone the criteria in deciding whether or not the particular topic is in fact essential. A check list of topics (coupled with appropriate emphasis) can give perspective to the relative importance of anatomical structures prior to reading about them.

In addition to decrease the workload, a check-list can direct students away from unreflective quantitative accumulation of facts and towards utilising those that are associated with qualitative understanding of principles and applications. As distinct from 'spoon feeding,' it provides a 'spoon with which to feed.' It also encourages questioning (between student and teacher and even among teachers) as to why a topic is considered important (i.e. a key principle or application involved). Such questioning can produce in-depth and two-way discussions – with the focus directed to meaning.

Determining what is 'core' content for anatomy

This process will result in the development of an official Faculty 'core' document for a specific medical programme that is made available to all staff and students. The starting point of the process should be to itemise in as explicit a fashion as possible the graduate profile of an institution, in other words to itemise the intention of the curriculum. Once the end point is determined, faculty will be able to work backwards, from the senior years to the junior years of the programme, and set out what core information is required for the clinical settings and the basic and diagnostic sciences settings, following the concept of the spiral of learning. At regular intervals, the

Table 5. Matching within an anatomy programme.

Objectives (& content domain)	Teaching methods*	Printed learning materials	Interactive learning materials: '*Anatomedia*'	Assessment: Written format**	Assessment: Practical format**
General Anatomy (Concepts and Principles)	Lectures and Practical Classes	'*General Anatomy*: *Principles and Applications*'	'*General Anatomy*' module	Underpins examinations for all semesters	
Systemic (and functional) Anatomy Regional (and surface) Anatomy Clinical procedures and Dissection Imaging and Sectional Anatomy		'*Practical Anatomy*: *Guide and Dissector*'	Other modules: '*Systems*' '*Regions*' '*Dissection*' '*Imaging*'	MCQs and Structured short answer questions***	Specimens of organs and bones Specimens of regions/Surface markings Clinical procedures X-rays and CT sections

Notes: *Anatomy also permeates PBL (and associated self-directed learning) and Clinical Skills tutorials.
**Anatomy also permeates the PBL examinations and clinical skills examinations.
***Only those facts linking key principles to clinical applications are required for examination purposes.

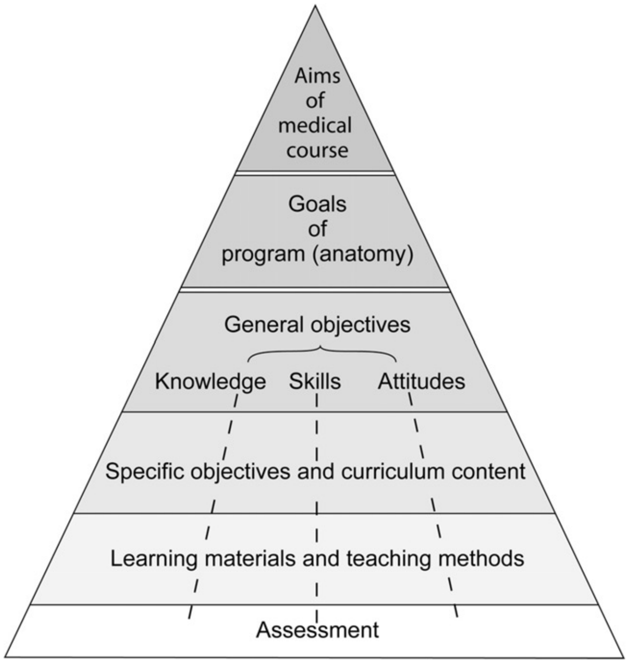

Figure 9. Matching of a programme to its course (Eizenberg 1986).

Table 6. An anatomy syllabus.

General objectives	*Specific objectives (and subject matter)*
1. Terminology	Check-list for each *general type* of anatomical structure
2. Concepts and Principles	(See Tables 1 and 2:
3. Organisation into Systems & Regions	Specific objectives in General Anatomy)
4. Anatomical Structures (Systemic perspective)	Chart of *specific* anatomical structures (organised into systems) and *indication of their relative importance*
5. Anatomical Structures (Regional perspective)	Chart of *specific* anatomical structures (organised into regions) and *indication of their relative importance*
6. Clinical Applications	Applied anatomy syllabus
7. Surface (& Functional) Anatomy	
8. Physical Examination	Surface & functional anatomy (& physical examination) syllabus
9. Radiological Anatomy	Imaging syllabus
10. Sectional Anatomy & Cut sections of viscera	Events at key levels. List of specific viscera
11. Endoscopic Anatomy	List of specific endoscopies
12. Clinical Procedures	List of specific clinical procedures

core document needs to be work-shopped by staff involved in the junior and the senior years, so that ideas can be shared and debated. This is an important way to ensure that only 'core' is delivered within a curriculum. It also brings about a healthy dialogue between what has traditionally been called the staff in the 'preclinical' and in the 'clinical' years. One of the spin-offs of such collaboration is a marked degree of 'buy-in' when it comes to curricular change. Another is a greater commitment to delivering a programme where there is more integration of subjects, both horizontally and vertically.

The process of preparing such a 'core' document may be described as follows. During the course of several ongoing workshops held at a faculty over time, all departmental and divisional submissions of 'core' learning material, specific to the disciplines of these departments and divisions, for the full number of years of the medical programme should be rigorously interrogated. The objective is to refine all submissions, bearing in mind the knowledge and skills requirements of the 'generalist' graduate, for example, having to function, upon graduation, semi-autonomously as a pre-registration intern and community service officer. What should emerge out of this process are definitive 'core' learning outcomes for the programme that will:

- inform all departments/divisions about what needs to be taught during the years of the programme,
- inform the students (and the appropriate Accreditation Panel) what is expected of students to know for the purposes of assessment and
- be used as the basis of assessment of students (so that core learning is appropriately featured and weighted in future student assessments).

The language of medicine

There has been a growing call for a basic course in Year 1 that covers the basic terminology used in medicine – explaining the origins of terms (mostly from Greek and Latin), how medical terms are constructed for use in describing the 'normal' structure and function of the human body, and the 'abnormal' structure and function encountered in the pathologies. There is increasing evidence that students who have mastered the basics of medical terminology perform better in their various courses than students who have no knowledge in this area and who resort to rote learning of terminology (Smith et al. 2007).

Incorporating applications in the syllabus (increasing vocational relevance)

In order to form a bridge between anatomy and the clinical subjects, and to increase the vocational and personal relevance of the subject, the medical student would be well advised to comprehend the applications relating directly to clinically important areas of anatomy. Furthermore, staff should have, as a goal, the full integration of the material delivered in macroscopic anatomy, clinical anatomy, histology, embryology and physiology.

Rather than simply tacking on applications to an already large syllabus, applications should be incorporated within the teaching programme. Some may be already incorporated within PBL tutorials, while the remainder can be included in practical classes or ideally via independent learning utilising suitable interactive multimedia, such as 'Anatomedia' (Eizenberg et al. 2002–2006, 2008) where students can work through the clinical questions at their own pace and receive immediate feedback from pop-up windows with the associated explanation. At the time of viewing specimens of the relevant regions and systems, the structures that are of subsequent clinical importance can be indicated.

Specific objectives for applications are best in the form of questions. This ensures student engagement, with the strategy to avoid the provision of 'unwanted answers to unasked questions' (Popper 1972).

Conclusion

Learning intentions are most influenced by a well-designed curriculum, particularly if it is compatible with student aspirations (vocational relevance, academic interest, personal development and social interaction) regarding the course as a whole. The rate limiting step to appropriate learning approaches (and outcomes) is intent. For students to engage in learning tasks, clear tasks must be constructed and they must be interested to engage in them.

Part 4: Learning materials and teaching anatomy

This section is published in full in the AMEE Guide, available from AMEE (www.amee.org). It explains how learning materials and teaching are intimately related. The latter can be transformed with appropriate use of the former. Interactive multimedia will not replace teachers, but can release teachers from being drained (and subsequent burn-out) by covering much of the theory that would otherwise create a huge lecturing load. This would minimize the time that can be devoted to lectures explaining principles as well as to practical classes (ideally dissection incorporating clinical procedures) involving active discovery of their implications and applications. Teaching can be transformed into being *interpretive*, rather than merely *descriptive*. This trade-off is a more productive use of expertise that is likely to be much more satisfying for teachers and students alike.

Part 5: Anatomy assessment, programme evaluation and teachers

This section is published in full in the AMEE Guide, available from AMEE (www.amee.org). It looks at how students' achievement of the learning outcomes relating to anatomy can be assessed, and the detrimental effects of inappropriate assessment. It examines how it is possible to evaluate the extent to which effective teaching is going on in an anatomy programme and how the results can be used to help improve its quality. It is argued that the future of anatomy is much rosier than the present, provided clinical anatomists fill the vacuum left by the gross anatomists of the past. For anatomy to reinvent itself as a subject, anatomists need to reinvent themselves . . . as *clinical* anatomists.

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