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Message from Editor-in-Chief

Peter G.M. de Jong, Ph.D.
Editor-in-Chief

Issue 20-3 of JIAMSE is a very special issue in several ways. First of all, every article in this issue focuses on the role of the basic sciences in modern medical education. This year marks the centennial anniversary of Abraham Flexner's seminal report on medical education in the United States and Canada. In 2006, IAMSE initiated the Flexner Revisited project to celebrate and recognize Flexner's contributions by examining his findings for the basic sciences in the context of medical education for the 21st century. This issue of JIAMSE provides the culmination of several studies from this project, brought together by Guest Editor Pat Finnerty.

Secondly, issue 20-3 is the last issue of the IAMSE journal that will be published under the name of JIAMSE. Starting January 2011, the peer reviewed journal of our association will be called Medical Science Educator. We hope that this new name is a better description of what our Journal is about: a place for medical science educators to publish their scholarly work helping to move medical science education forward. The content of the Journal will not change enormously, but the layout may look a little different. However, a new name will also be unrecognized by many, so we hope we can count on your help as active readers of our Journal to make the new name of our Journal known to your colleagues. Please encourage them to become a reader of the Journal, either through membership in IAMSE or by an individual Journal subscription.

With a new journal comes a new website. All information on Medical Science Educator can be found on the special journal website www.medicalscienceeducator.org. Information on the Editorial Board, instructions for authors and access to the published issues are presented on this site for your convenience. Medical Science Educator can also be followed on Facebook which is a great way to connect with others interested in our Journal and to follow the latest announcements.

I hope you will enjoy this special and last issue of JIAMSE and I look forward welcoming you back in Medical Science Educator next year!

Peter G.M. de Jong, Ph.D.
Editor-in-Chief

The Role and Value of the Basic Sciences in Medical Education: An Examination of Flexner's Legacy

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This year marks the centennial anniversary of Abraham Flexner's seminal report on medical education in the United States and Canada. It is remarkable that a report from an educator in Louisville, Kentucky could have such a dramatic and lasting impact on the field of medicine.

Another educator from Louisville has made a considerable contribution to medical education, Uldis Streips. While his reputation and impact will probably never reach that of Flexner, he has had a significant impact on his students and through them medicine. Further, he has been an active member of our association for many years, serving most recently as the editor of JIAMSE. Together with his team of Marshall Anderson as production editor and the rest of his editorial board, they have advanced the journal and promoted medical education. While Flexner identified a variety of issues and offered some argument for addressing these, Uldis, Marshall and the rest of the editorial team have been at the front lines making those things happen and sharing the 'stories' of others through the journal. We would like to take this opportunity to thank these dedicated individuals for their service to IAMSE by dedicating this special issue to them.

This issue of JIAMSE provides the culmination of a study conducted by IAMSE to examine one aspect of the issues raised by Flexner, that of the basic sciences. One of the greatest outcomes of Flexner's report and the changes that occurred in medical education in the early 20th century was the grounding of medical education in the sciences. While this was not a phenomenon solely due to Flexner's urging, as there were a number of initiatives already underway at the time, Flexner did bring the issue to wider attention.

The International Association of Medical Science Educators (IAMSE), having its origins in the focus of basic science in medical education, wanted to celebrate and recognize Flexner's contributions by examining his findings for the basic sciences in the context of medical education for the 21st century. In 2006, IAMSE initiated the Flexner Revisited project to examine the role and value of the basic sciences. We brought together a study group representing a wide array of medical educators; the composition of the study group is listed at the end of this manuscript. The specific goals of the study were: (1) Define and describe the sciences that constitute the foundation of medicine, (2) Identify the role and value of the sciences and scientific thinking in medical education, and (3) Identify the best practices of when, where and how the foundational sciences should be incorporated into medical education. To meet these goals, we defined five questions we would ask multiple groups of medical educators to address. The questions were:

1. What are the sciences that constitute the foundation for medical practice?
2. What is the value and role of the foundational sciences in medical education?
3. When and how should these foundational sciences be incorporated into the medical education curriculum?
4. What sciences could/should be pre-requisite components of the undergraduate medical curriculum (i.e. be part of the pre-medical requirements)?
5. What are examples of the best practices for incorporation of the foundational sciences in the medical education curriculum?

We posed these questions at a number of medical education gatherings including the IAMSE annual meetings, American Association of Colleges of Osteopathic Medicine, American Association of Medical Colleges and the Generalist in Medical Education. In addition, we asked for perspective papers from a number of individuals representing the various disciplines of medical education, including both the basic sciences as well as a clinical medical educator perspective. The papers in this special issue are their perspectives. The following is a summary of the findings of our study. An early report of this project was presented in the February issue of Academic Medicine.[1]

What are the sciences that constitute the foundation for medical practice of the future?

The traditional basic sciences (anatomy, physiology, biochemistry, microbiology/immunology, pathology and pharmacology) in addition to genetics, molecular biology, epidemiology and biostatistics and the behavioral sciences were considered the foundational sciences upon which a preparation for medical practice is based. The participants were unified in their sentiments that simply listing the science disciplines was not sufficient to capture the essence of the fundamental nature of these sciences to medical practice. The key is that the concepts must be relevant and applicable to medicine (human health and disease) to form the fundamental foundation for medical practice.

The breadth and depth of knowledge and understanding engendered considerable diversity of opinion. The collective consensus was that the goal should be to prepare medical students for entry into residency education.

What is the value and role of the foundational sciences in medical education?

The contribution of the basic sciences to the development of the medical practitioner goes beyond the factual information and serves to inform the critical thinking and decisional framework. The basic sciences were felt to be critical for clinical application and effective thinking skills. The application of the knowledge serves to provide a mechanism for the integrative approach to problem-solving. Those who have a deeper fund of basic science knowledge were better able to address uncommon and more complex clinical situations than those relying solely on a presentation and algorithm approach. [2]

Clinical medicine is based upon the recognition, classification and then treatment of abnormal physiology (pathophysiology). To appreciate the abnormal, the practitioner must first have a solid foundation in what is normal. The basic sciences define these parameters. The treatment is designed to modify these systems to return them towards the normal state.

Flexner championed the role of the basic science in medical education.[3] He posited that without a strong background and understanding of the scientific method and basic sciences, physicians would be no more than mere technicians, following a proscribed algorithm for diagnosis and management. The physicians who understood the underlying principles would be the ones to address the more complex issue and would be the leaders in developing new approaches.

When and how should these foundational sciences be incorporated into the medical education curriculum?

There was considerable interest in this question. Clearly, all respondents felt that the simple answer was early and often. In general, the consensus was that the science should be incorporated throughout the entire undergraduate medical curriculum and continued in the post-graduate experiences as well. The key elements were, however, that the sciences needed to be clinically relevant and that they should be presented in an incremental fashion. Rather than a ‘hard and fast’ approach, a more dispersed design was favored. This permitted the student the opportunity to distill the information, synthesize it with other knowledge and experiences and formulate new knowledge. The method of instruction impacts learning. With the sciences, as in learning itself, it is the process more than the content that is crucial. It was felt that an experiential instructional, thus learning, method would be superior to a simple didactic teaching style. Having the student actually experience the learning then the knowledge become ‘owned’ by the student rather than ‘borrowed’ from the instructor. Mimicry does not equal learning.

What sciences should be pre-requisite components of the undergraduate premedical curriculum?

To address the issue of pre-medical preparation opens the question of what we want as potential physicians. While a strong background in the sciences and a large core set of prerequisites would help to streamline the medical curricula, it would tend to narrow the diversity of the matriculate pool. A clear consensus of the respondents was that an undergraduate major in the science was not necessary for preparing a student to study medicine. Rather a well rounded education with a focus on the basic vocabulary and core concepts of science were essential. Pre-medical coursework promoting problem solving and thinking skills were considered of greatest importance.

The recently published HHMI/AAMC report, The Scientific Foundations for Future Physicians, well delineates the views of our respondents and sums nicely the issues of pre-medical foundations. [4]

What are examples of the best practices for incorporation of the foundational sciences in the medical education curriculum?

While Flexner used Johns Hopkins as his ideal model, identifying one or two exemplar programs was more problematic. Many quality programs were identified, and these are mentioned in the accompanying papers in this issue. Our respondent did identify characteristics of best practices that should be emulated. These included clinical context, incorporating clinical perspective in the ‘preclinical’ years and scientific perspective in the ‘clinical’ years and building upon principles of adult learning with the goal of knowledge application.

The papers in this special issue of JIAMSE address the topic of the basic sciences in medical education from the perspective of the various disciplines and provide a sense of what the basic sciences contribute to medical education. It is illuminating to compare the thoughts of Flexner from 1910 with those of our colleagues in 2010 and see the similarities.

In closing, we would like to acknowledge the effort of all those who comprised the IAMSE Flexner Revisited Study Group: Peter Anderson, Mark Andrews, Giulia Bonaminio, Robert Carroll, Sheila Chauvin, George Dunway, Aviad Haramati, Louis Pangaro, Gary Rosenfeld, Nehad El Sawi, Tom Schmidt, and Doug Wood.

REFERENCES

1. Finnerty, Edward P., Chauvin, Sheila, Bonaminio, Giulia, Andrews, Mark, Carroll, Robert G. and Pangaro, Louis N. Flexner Revisited: The Role and Value of the Basic Sciences in Medical Education. *Academic Medicine* 2010, 85:349-355, 2010.
2. Woods, Nicole N., Neville, Alan J., Levinson, Anthony J., Howey, Elizabeth H.A., Oczkowski, Wieslaw J., Norman, Geoffrey R. The Value of Basic Science in Clinical Diagnosis. *Academic Medicine* 81: S124-127, 2006
3. Flexner A. Medical Education in the United States and Canada: A Report to the Carnegie Foundation for the Advancement of Teaching. Bulletin No. 4. Boston: Updyke; 1910. Available at: http://www.carnegiefoundation.org//sites/default/files/elibrary/Carnegie_Flexner_Report.pdf . Accessed October 29, 2009.
4. Association of American Medical Colleges–Howard Hughes Medical Institute. Scientific Foundations for Future Physicians. Available at: https://services.aamc.org/publications/index.cfm?fuseaction=Product.displayForm&prd_id=262&cfid=1&cftoken=F9879A96-CFB4-D414-35197D3ADBF868B2. Accessed October 29, 2009.

A Solid Building Requires a Good Foundation: The Basic Sciences in the Dutch Medical Curriculum, 1865-1965

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ABSTRACT

This article discusses the development of premedical and preclinical education in the Netherlands between 1865, when the 'unity of licensure' was achieved, and 1965, a year which marked the beginning of a series of innovations which resulted in a complete overhaul of the classical medical curriculum. It will be argued that Dutch premedical and preclinical education during the century between 1865 and 1965 was featured by a comprehensive treatment of the natural and preclinical sciences in order to provide students with a 'solid foundation' upon which their clinical knowledge and, eventually, their clinical competence should be built. However, the curriculum suffered from several major shortcomings: it was educationally insufficient, it lacked internal dynamics, it was extremely compartmentalized, and it became increasingly overloaded. As a consequence of both rigid legislation and an obsolete educational philosophy, these curricular shortcomings could not adequately be dealt with. Consequently, in the early 1960s, when the number of medical students exploded, the curriculum more or less imploded under its own weight. New legislation and the foundation of two new medical schools in the 1960s and 1970s, which could design their curriculum almost 'from scratch,' finally paved the way for implementing the major curricular innovations at the time already long overdue.

Development and organization of medical education in the Netherlands

Nineteenth-century academic medical education in the Netherlands closely resembled that in Germany, the Nordic countries, Austria-Hungary and Switzerland, where it had developed from the work of lecturing university professors in the Middle Ages.[1] In the second half of the 17th century and the first decades of the 18th century, Dutch medical schools ranked at the top of contemporary medical education; for example, Herman Boerhaave (1668-1738) was not only an excellent clinical teacher, but also developed the direct precursor of the 'discipline-based curriculum,' later adopted by many American medical schools as well, which dominated medical education until the 1970s.[2] Boerhaave's ideal curriculum consisted of a premedical phase (dedicated to mathematics and natural sciences), a preclinical phase (which featured animal and human dissection, post-mortem examinations, artificially produced diseases in animals, and knowledge of medicines) and finally a clinical phase, in which the student would be allowed at the bedside.[3] After Boerhaave's death, his system of clinical education gradually passed into disuse, and by the early 19th century, the French and English medical faculties had widely surpassed the Dutch. Like elsewhere, there was at the time in the Netherlands an extensive 'second class' of medical practitioners, predominantly trained by apprenticeship or at so-called 'Clinical Schools': rural and urban surgeons, rural and urban general practitioners, physicians who were only allowed to practice on board of ships or in the army, and midwives.[4] The academically educated physicians, on the other hand, did not consider themselves primarily as practitioners, but rather as learned and well-educated gentlemen, who tried to stay away as far as possible from the more unsavory aspects of medical practice, such as direct physical examination of a patient. Instead, their preferred actions were hearing the patient's story and, on this basis, prescribing complex and expensive recipes for wealthy clients (the proverbial 'gilded pills'). If cutting into the patient's body was inevitable, their role was to instruct the surgeons accordingly. In the decades before academic medicine was connected to the empirical sciences – a process that began around 1830 – the epitome of a learned doctor was a physician who was well versed into the highly speculative and complex theoretical systems (iatrophysics and iatrochemistry). Even excellent clinicians, such as Boerhaave, profoundly engaged in such speculation about the nature and causes of disease. In fact, as medicine lacked a solid scientific foundation, this was the only way to maintain its academic status.[5]

After 1840, the situation gradually improved. Inspired by the development of German scientific physiology and the French clinical school, some academic medical teachers in the Netherlands argued that first, medical science should become more empirically and scientifically based, and second, medical education should be improved and standardized: one type of medical school, one single general qualification ('unity of licensure'). To this end, in 1849 the *Nederlandsche Maatschappij tot Bevordering der Geneeskunst* (literally: Dutch Society for the Advancement of the *Art* of Medicine) was founded. Pressure upon the government resulted in 1865 in new legislation, the *Physicians' Act*, which effectively abolished the 'second class' of physicians and introduced the 'one portal system' of medical education. From then on, everybody who wanted to practice medicine had to pass two rather demanding exams, organized by state committees: a physics exam and a medical exam. The physics exam was encompassing; it included physics, chemistry; botany, 'natural history of animals and minerals,' knowledge of drugs 'as commodities' (i.e., 'materia medica') and also anatomy, comparative anatomy, and physiology.[6] The medical exam consisted of a theoretical part and a practical part. The theoretical part covered pathology and pathological anatomy, knowledge of herbal medicine, health theory, forensic medicine, general medicine, surgery, and obstetrics, and the preparation of medicaments. Finally, the practical part of the medical exam (called the 'practical physician's exam') both exclusively and comprehensively granted the right to practice medicine: passing the exam was necessary to practice medicine, and once passed, the graduate was allowed to practice medicine 'in its full extent.'[7] This was a major innovation, because until then, the right to practice as an academic physician was connected to the Ph.D. degrees in general medicine, surgery, and obstetrics, respectively.

In 1874, the state physics exam was split into two parts, a first physics exam covering the premedical sciences, and a second physics exam covering the preclinical sciences. Four years later, the theoretical part of the medical exam became the responsibility of the individual faculties; only the practical physician's exam remained under state control, nominally until 1921, though quite soon after 1878 even this became, in practice, a faculty exam. 'Nationwide' exams turned out to be too much of a burden for the individual medical faculties, who were required to organize this national exam every fourth year, but were unable to miss their clinical professors for a prolonged period.[6,8,9]

Though basically any student could apply for the state exams, no one was legally forced to attend university courses. Yet, it was hard to see how anybody could acquire the knowledge and skills required to pass these exams, except by attending the academic program.[10] The actual arrangement was peculiar: a system of exemptions of the state exams for students who had passed the academic exams was set up. More specifically, obtaining the academic candidate degree – comparable to a Bachelor's degree – granted exemption for the physics exam; similarly, obtaining the academic doctoral degree – comparable to a Master's degree – granted exemption for the theoretical medical exam. As the Ph.D. degree no longer granted the right to practice, it soon acquired a purely ornamental status. The non-academic practical physician's exam, for which no exemption could be obtained, emphasized that the state, rather than academia, was in control of licensure.[11] Still, the structure of the medical curriculum itself was not affected by this, as it was considered "the only sequence of disciplines in medical education any sensible human will ever recommend: First, the study of nature in its full extent, but not including humans or animals; next, the study of human and animal anatomy and physiology, and added to this general pathology, general medicine and pharmacology; and finally, the transition to the so-called practical disciplines, and study these in their full extent."[12] This view illustrates both the rising confidence that the empirical sciences are the ultimate foundation of medicine and the belief that medical education should be compartmentalized – a compartmentalization that both originated from and was maintained by the three staged academic exams (propaedeutic, candidate, and doctoral) and the practical state exam.

One might ask why this elaborate construction of state exams and exemptions was constructed: would it not have been more efficient to just make the academic route the exclusive way to become a doctor? The reasons are twofold. First, the Physicians' Act was a compromise designed to meet two conflicting concerns: on the one hand the fear that by abolishing the second class of physicians, health care in rural areas would plummet; on the other hand, pressure from a number of leading medical teachers to academize all medical education. Second, in 1865 the Act was announced as temporary legislation, awaiting the statutory regulation of higher education in general. This was actually achieved in 1876 by the Higher Education Act. Two years later, the Physician's Act was brought into line with the Higher Education Act and renamed the Revised Physicians' Act.[13] This Act brought the state exams – with the exception of, at least formally, the practical physician's exam – under faculty control.

As fear of shortage of physicians dominated the discussion which led to the conception of the Revised Act, a dual track system was set up: students who wanted to become doctors could chose between an academic and a non-academic track. It was an odd construction, for there was only a nominal difference between the two tracks: academic medical students had to pass the academic exams (propaedeutic, candidate, and doctoral) and the non-academic students the corresponding former state exams (now called first and second physics exam and theoretical-medical exam). But in practice these were exactly the same exams. Indeed, academic and non-academic students attended the same lectures and worked in the same laboratories. Secondary education determined for which track a student was eligible: only students who had attended the 'Gymnasium,' the secondary school in which the classical languages were taught, were admitted to the academic track. Students from the other type of secondary school ('hogere burgerschool', the equivalent of the German 'Realschule') were required to follow the non-academic track and pass the first and second physics exams and theoretical-medical exam. For students who merely wanted to practice medicine, there was no difference between the tracks; but students in the non-academic track could not apply for a Ph.D. In other words, students without a classical background – who more often came from middle- or even working-class families – could become practicing physicians, but were denied the ultimate hallmark of academic achievement. Most ironically, over the years it became increasingly clear that the non-classical secondary education prepared students much better for the study of the medical sciences than the classical gymnasium, where little mathematics, and hardly any science was taught.[14,15] In this respect, Abraham Flexner characterized the Dutch gymnasium as "the most conservative secondary school in Western Europe."[16] Dissatisfaction with this regulation was rampant and many scientifically ambitious non-academic medical graduates went abroad, mostly to Germany or Switzerland, to obtain a Ph.D.-degree. Meanwhile, their classically educated colleagues all too often did not care to pursue the Ph.D.-degree as it had little benefit in medical practice. This situation persisted until 1917, when the non-academic medical course was abolished and 'hogere burgerschool'- as well as Gymnasium-graduates had to follow the academic route.

Despite some changes in legislation, the structure of the Dutch medical curriculum was in 1965 still very much the same as in 1878.[17,18] The general outline was: [1] an essentially premedical (propaedeutic) year, which was spent in the Faculty of Mathematics and Sciences, in which physics, chemistry and biology were taught as separate sciences; [2] two candidate years in which the preclinical sciences were taught – by preclinical scientists – *as if* the student would become a scientific researcher in any one of these disciplines; [3] two doctoral years in which clinical theory was extensively taught, including pharmacology, pathology, and microbiology; and [4] two practical clinical years (clerkships) in which the student would become acquainted in practice with all clinical departments.[19] Teaching of both clinical theory and clinical practice aimed to be exhaustive, for students could start working as general practitioner immediately after graduation (i.e., without any further postgraduate training). In practice, the medical faculties had only very limited control over what happened to the student during the clerkship years, and, as they considered professional education outside the scope of their responsibility, they did not care very much either.[20]

While the structure of the medical curriculum did not show major changes, its content evolved with the development of the individual disciplines. Innovations often boiled down to adding new disciplines, in particular new medical specialties, to the program. The first formal effort at a more fundamental curriculum change occurred in 1936, when the Sociaal Hygiënische Commissie ('Social Hygienic Committee') published a preliminary report on medical education. In this report, the role of the premedical sciences (chemistry, physics, and biology) in particular was challenged.[21] The Committee proposed that the curriculum be restructured in order to enable students to focus on the human organism right from the beginning, with corresponding early introduction to the bedside. It was also recommended that some new disciplines, such as philosophy and psychology, should fill the space made available by reducing the premedical sciences. Probably as a consequence of the imminent World War II, none of the proposed improvements was implemented. Immediately after the war, a second, more ambitious, effort at reorganization was made, this time encompassing the whole of higher education. A large State Committee was established, divided into sections, of which Section K dealt with medical education. In its Report, which appeared in 1949, the members of Section K expressed the view that the primary aim of medical education should be to properly educate the general practitioner.[22] As this education was viewed as deficient, proposals were made to introduce a plethora of new disciplines, such as sociology, psychology, philosophy, the history of medicine, general health science, general microbiology, and general pharmacology. Being overly ambitious, the report can be seen as a recipe for failure. Yet, some tentative efforts to break the compartmentalization between the premedical, preclinical and clinical parts of the curriculum ensued. For example, at a small scale, preparatory clinical lectures were introduced in the last preclinical year, and parts of the premedical sciences were integrated into physical and chemical physiology. This can be construed as a 'rooftile'-curriculum, i.e., an organization in which advanced parts of earlier disciplines overlap, in time, with early parts of later disciplines. However, in spite of the weight of the Committee, its major proposals were not adopted: The 1921 Academic Statute – which formalized the 1878 structure of the curriculum – remained in effect, basically unchanged, until 1968.[23]

Thus, the first two decades after World War II witnessed few changes in the Dutch medical curriculum. In two senses, however, pressure on the curriculum increased: first, the medical sciences evolved at an increasing speed, without any system of filtering out the developments worthwhile including in the curriculum and those not; second, during the 1950s, and increasingly so in the 1960s, the number of students applying for medical education increased considerably. As medical faculties could not select their students and, until the second half of the 1960s, also not limit the number of students admitted, dissatisfaction with the state of affairs increased concomitantly. By 1965, enough momentum had accumulated to release a cascade of educational innovations within a relatively short time span (no more than a decade). We will give a concise overview of these developments.

Shortcomings of the Dutch medical curriculum

First, the medical curriculum was "educationally insufficient" in the sense that it was dominated by inferior instructional (didactic) formats: excessive reliance on and exaggerated faith in the utility of lectures and far too little practical work in the laboratories (in the preclinical phase) and in the hospitals (in the clinical phase).[19,24] For example, it was not unusual for students in Amsterdam to have lectures, six days a week, without interruption, from 8 o'clock till 12 o'clock, to be followed by special courses in the afternoon.[25] This amounted to approximately one lecture hour for each laboratory hour, whereas Pearce, Welch, and Howell already advocated a ratio of one lecture hour to six laboratory hours.[26] Van Rijnberk (1875-1953), an Amsterdam-based physiology professor who wrote many editorials about medical education between 1913 and 1946, presents a hierarchy of instructional formats, in descending order of importance: practical courses (laboratory experiments and dissections), demonstrations, theoretical lectures, and self-study from books.[27] This hierarchy is in line with Abraham Flexner's view: he also emphasizes "learning by doing" and prefers, for example, dissection to demonstration, and demonstration to anatomy lectures.[28] Flexner, in his 1925 comparison of European medical schools, characterized Dutch medical education as follows: "unrelieved demonstrative lecturing," "complaints are rife that students are passive," "all students hearing the same lectures… individuality does not disclose itself."[29]

Forty years later, the situation had hardly improved, theoretical lectures and self-study still being the predominant didactic formats.[30] The curriculum was also insufficient as it failed to achieve its formal aims: to prepare students for both scientific research and future medical practice (i.e. general practice). Students who wanted to be well-prepared for future practice were overly arrested in their progress, they were faced with the task to acquire in-depth knowledge of a large number of specialized scientific medical subjects, knowledge not necessary for everyday general practice.[31] On the other hand, pre-candidate education was insufficient for students who aimed at a scientific career, because it was stuffed with scientific facts, but did not foster students' scientific attitude.[32] In the late 1950s, basic science education of Dutch medical students was characterized as "extensive but shallow by necessity."[33] Partly, this was inevitable, due to the large number of disciplines included in the curriculum and the autonomy of individual teachers. On the other hand, it also was deliberately arranged this way: The 1949 Report of Section K of the State Commission re-emphasized the view that medical education should be extensive, rather than profound. Graduates should be able to enter general practice immediately.[22] Subject matter coverage should be exhaustive; students' achieving in-depth conceptual understanding was a major issue. Flexner considered Dutch medical education too broad to be a proper basis for a scientific researcher, and particularly criticized the absence of elective courses.[29] In the mid-1960s, the tradition to require "almost encyclopaedic factual knowledge" of students in every single discipline was criticized: it did not make sense because current knowledge would soon become obsolete and replaced by new factual knowledge.[34] Around the same time, the undue emphasis on the scientific aspects of medical education was called "sanctimonious," for while the faculty payed lip service to science, a majority of medical students was forced to fake interest in it.[35]

How can it be that Flexner's critical comments were still relevant forty years later? Apparently, the curriculum was highly resistant to change. For one thing, it lacked 'internal dynamics': there was no coherent philosophy of medical education to generate new ideas or innovations, and no advancing views. The aim to educate students to 'practice medicine on a scientific basis and in its full extent' did not change over the years, though it did become increasingly more fictitious. Whether or not a topic was included in the curriculum often depended upon a corresponding chair being part of the medical faculty. For example, though he considered pathological chemistry an important scientific discipline, Van Rijnberk doubted whether it could be included in the medical curriculum: it would be hard to find a teacher who was an expert in both biophysics and biochemistry.[36] If there were any dynamic forces on the curriculum, they came from outside; for example, in 1935, the Secretaries of State of the Departments of Education, Arts, & Sciences and Social Affairs explicitly asked the *Sociaal Hygiënische Commissie* to investigate whether the contribution of the premedical sciences could be decreased and the preclinical sciences could focus more on the human being – that is, increase their relevance for medical students. Though the government's primary aim was to achieve budget cuts by decreasing the length of the medical course, rather than to improve medical education, the investigation can be seen as an initiative for curricular change.[37]

This lack of internal dynamics was also reinforced by a third factor, the extreme compartmentalization of the curriculum. The gap between the self-contained premedical, preclinical, and theoretical clinical sciences and clinical practice was all but insurmountable. Premedical and preclinical teachers, in particular, had almost absolute power in determining the content of their courses; moreover, invariably, they were both teacher ánd examiner. Usually they were well aware of the latest developments in their own discipline, but they were hardly interested in the practical applications of their courses for clinical medicine.[38] This situation was maintained because the Faculty of Mathematics and Sciences, rather than the Faculty of Medicine, was in charge of the first year (propaedeutic) program. As late as 1965, a committee charged with preparing a proposal for curricular reform – the *Conventscommissie voor de Faculteit der Geneeskunde* at Utrecht University – complained that students were unable to integrate the premedical sciences into the preclinical subjects, and that the first year program was predominantly viewed as a hurdle to be taken. Students' aim was to pass the exams, rather than to acquire lasting knowledge.[17] In addition, the gap between the preclinical and clinical part of the curriculum was experienced by most students as absolute. As soon as the student entered the (theoretical) clinical phase, the scientific approach was abandoned in favor of a completely case-based approach. Students were often bewildered by this abrupt transition. Implicitly, the message was: forget what you have learned until now. You will hardly ever need it in your future career as a physician.[17] Yet, from an academic point of view, the separation between the preclinical and clinical sciences was "almost sacrosanct" and the curriculum was described as completely dis-integrated.[34,35] In this respect, little had changed in sixty years, for in 1901 it was already argued that students buried their knowledge of anatomy and physiology directly after their candidate (or second physics) exam, never to dig it up again.[39] Once in the clinic, they focused on the clinical tricks and the practical basis of diagnosis and therapy. The clinicians who supervised them had also withdrawn from anatomy and physiology, and even from the clinical laboratory: "My clinic is my laboratory," they would proudly say, "I don't need an additional one."[39] The extreme compartmentalization of Dutch medical education did not escape Flexner as well, for he observed its "total divorce of theoretical clinical instruction from practical experience of whatever kind."[29]

One reason behind this compartmentalization was the extreme reluctance of those responsible for medical education to admit students who had even the slightest gaps in their preclinical or theoretical clinical knowledge in the wards.[40] Obviously, the structure of the academic course, with its division in phases – propaedeutic, candidate, and doctoral – supported the compartmentalization. Moreover, within the phases, disciplines were also self-contained as a consequence of the belief of many professors that every individual science should be taught and examined as if there were no other disciplines and no other exams at all, and as if these sciences were devoid of any practical applications.[41,42] Even within disciplines, teaching was compartmentalized: For example, it was not uncommon for laboratory work in anatomy to be completely disconnected from the corresponding explanatory lectures. In some cases, laboratory experiments preceded the theoretical basis by six months.[43] This problem of fragmentation was highly persistent: in the 1960s, it could occur that renal physiology was taught by the physiologist a year or so before the anatomy of the kidney was dealt with by the anatomist. After the candidate exam, the pathologist would teach the pathology of the kidney, to be followed, again after a gap of several months, by the clinical aspects of renal diseases, to be taught by the internist. The 'logical' sequence from normal to abnormal and from structure to function would not necessarily be observed as well, for in some cases the internist might precede the pathologist by several months. Finally, the surgeon demonstrated kidney surgery. "How can a medical student be expected to construct a clear picture, based on *conceptual understanding* (italics ours) of the normal function and pathology of the kidney, having learned about these organs in such a fragmented and haphazard way?"[44]

A fourth shortcoming was curriculum overload. Complaints concerning curricular overload can be traced back to 1883, when it was noticed that duration of the student years and the difficulty of the study for medical students had increased, largely as a consequence of three requirements, which were, taken together, incompatible: [1] that physicians should be able to practice medicine "in its full extent," [2] that every physician would be able to work independently on scientific problems, and [3] that the level of both study and exams would be high.[45] However, in the late nineteenth and early twentieth century, overload was compensated for, so to speak, by a particular form of curricular inefficiency: medical students had too much unscheduled time, particularly in the second and third year of medical school, which were assigned for the better part to anatomy and physiology, which was probably too much.[40] Basically, only seven months each year were effectively used for teaching and studying.[46] Teachers could still afford to be unselective in terms of what they wanted the students to learn, which students perceived as "throwing books at us."[43] During the long holidays, students were expected to study these books, but they were probably not very motivated to do so. Thus, curricular overload may have been limited to certain parts of the academic year, in particular the months immediately prior to the examinations. As the exams were until the 1960s exclusively individual, long holidays were necessary for teachers to perform the "endless series of (oral) exams."[47] Lack of scheduled time had an additional drawback: it decreased students' commitment, which was aggravated by the fact that students who flunked were permitted to repeat exams over and again, basically interminably.[48]

Initially, teachers could alleviate problems of overload to some extent by removing obsolete topics and decreasing the (sometimes excessive) amount of time dedicated to other subjects. Descriptive anatomy, for example, contained a lot of "dead wood."[43] Bachmeyer, an outsider to Dutch medical education, proposed in the early 1950s that one year at least could be cut from the program by introducing practical clinical work earlier and eliminating many of the lectures, a recommendation that was reiterated twenty years later.[18,19] Quite consistently over the years, though, the balance between addition of new and removal of obsolete subjects in the curriculum was tilted towards the addition side, as new knowledge accumulated at a faster rate than old knowledge could be done away with.[35,49] Rigid adherence to the criterion of completeness and the requirement that the curriculum should deliver fully prepared general practitioners prevented any attempt at curricular differentiation.[50] Thus, by 1960, the actual duration of the average student's medical study surpassed the nominal duration of seven years by approximately one year and a half.[51] That students were well aware of the problems is illustrated by the fact that, in the early 1960s, medical students at Utrecht University opposed against abolishing lectures and practicals on Saturdays: they were afraid that adopting Saturdays as holidays would increase the duration of the already lengthy medical course.[52]

What probably strikes most if one views Dutch medical education in an international context is the excessive length of the pre-clerkship course, including the theoretical-clinical phase. Whereas in the early twentieth century most students saw their first patient at the beginning of their fifth year, around the mid-1960s, this had increased by one year, and even after five years preparation, when they entered the ward they were given hardly any responsibility at all. To emphasize the contrast, an international review observed that in nearly every country, the medical student comes into contact with the patient in the beginning of the third year, and that there is "much talk of making this contact begin earlier."[53]

Finally, despite all intentions, the medical curriculum poorly prepared students for medical practice. In the nineteenth century, too few patients were available; due to the low quality of medical care at the academic hospitals, only people who could not afford to go elsewhere were treated there. Other hospitals were not involved in medical education. In the twentieth century, the quality of care in academic hospitals improved, the primary problem now being too many clerks present at understaffed wards. Thus, there was insufficient room for practical clinical skills training, even during clerkships, and young graduates generally lacked the skills necessary to work independently as a general practitioner. A survey in the 1930s showed that they felt themselves inadequately prepared for medical practice.[54] Graduates were expected to learn practical skills while practicing medicine. A practical (post-graduate) clinical year, often proposed but never implemented, was viewed by some as a solution to the long-standing problem of insufficient practical training. We know of no proposals to introduce practical skills training in the undergraduate course before 1965. Whatever pressure was exerted on the curriculum, the need to introduce practical clinical courses before the clerkships did not arise.

The inability to attack the problems of educational insufficiency, compartmentalization, lack of internal dynamics, curricular overload, and length caused the Dutch medical curriculum in the early 1960s to compare unfavorably to medical education in several other countries. Particularly striking was the low output rate: only 69% of students who started the study graduated, which was low in comparison to the medical course in other European countries, were it often approached 90%.[51,55] Starting in the early 1960s, the number of students that enrolled exploded, from approximately 750 each year in the 1950s to over 1400 in 1965. As any applicant who had successfully completed the H.B.S. or the gymnasium (provided he or she attended the science department of these schools) was legally entitled to enter the medical faculty without the need to pass admission exams, this number was expected to further increase. In addition, increasing awareness of educational developments in other parts of the world also contributed to the perceived inadequacy of the Dutch medical curriculum.[18] The results of three world conferences on medical education in 1953, 1959, and 1966, the flow of literature on curricular and educational reform elsewhere, and teacher's personal contacts with new medical schools or programs, contributed to increased feelings of discontent and desire for change. In the early 1960s, there was a surplus of physicians in the Netherlands; consequently, a number of doctors who saw no professional future for themselves in the Netherlands went (temporarily) for employment to the U.S., where they were faced with curricula that were much further developed and integrated than the traditional Dutch medical course. Probably, their enthusiastic reports also contributed to the desire for curricular innovations.[30,56] Finally, the prevailing reform 'spirit' in society at large in the 1960s may have instigated junior faculty (e.g., at Utrecht University in 1965) and even students (at Amsterdam University, also in 1965) to initiate projects for curricular reform.

Premedical education from 1865-1965

Until 1876, only one preparatory school granted direct access to the university: the gymnasium, in which approximately half of the instruction time was devoted to the classical languages. This was not a serious problem for, at the time, the purpose of any academic education was to prepare students for their position as member of the 'learned class,' rather than for a scientific profession. Thus, the lack of training in mathematics and sciences of graduates of the gymnasium was not viewed as a serious drawback: This deficit could easily be made up in the propaedeutic year, the first year at university. In fact, the primary function of the premedical or propaedeutic year was to compensate for the deficient gymnasium course. For example, the 1867 State Commission responsible for the state exams declared:

> "There is no need for a physician to be a mathematician, physicist, chemist, botanist or zoologist in the extended sense of the word; to achieve his full education, however, he should devote himself for some time to mathematics, physics, chemistry, zoology, and botany. In due course, he can forget the details of what he learned in these courses, even

> though he will continue to receive the benefits of his studies for his further development, because these disciplines have taught him to observe accurately, and to arrive at the appropriate decisions on basis of these observations. What he has learned will be infinitely more valuable for him than having his memory stuffed with facts and words: he has learned to see, think, compare, judge!"[57]

Until the Higher Education Act came into force in 1876, the propaedeutic program consisted of mathematics, physics, chemistry, botany, and zoology, with mandatory testimonia – i.e., exams not represented on the diploma – for comparative anatomy and knowledge of minerals. By this Act, mathematics was transfered from the propaedeutic year to the last two years of the gymnasium. This school was split into a liberal arts and a scientific department, the latter adopting some science – though at the time mostly of the 'natural history' type – in the curriculum. In addition, the mandatory testimonia in the propaedeutic year for natural history of minerals and comparative anatomy were abolished. Natural history of minerals was integrated with chemistry and probably limited to a little knowledge of soil conditions, which was considered relevant for the prevention of epidemics. Comparative anatomy in the strict sense was moved to the candidate (preclinical) phase. Consequently, the propaedeutic program at the beginning of the last quarter of the nineteenth century consisted of physics, chemistry, zoology, and botany.

The integration of the 1876 Higher Education Act and the 1878 Revised Physicians' Act formalized access to the medical faculty for graduates from the H.B.S., the non-classical preparatory school. These students were directly admitted to the non-academic 'parallel track.' As they were much better prepared, it took them on the average only one year to pass the propaedeutic exam, whereas most students from the Gymnasium spent two years in the premedical phase. Over the years, the propaedeutic phase increasingly became a replication of the sciences taught in secondary school. For example, it included all of elementary physics (among which, for instance, the theory of continuity of gasses and liquids), all of chemistry (organic as well as inorganic), all of comparative anatomy (including, for example, the development of tertianaschizont), and botany (including, for example, a broad knowledge of cambium and phloem and of plasmolysis).[58] Not surprisingly, the propaedeutic program was repeatedly challenged; botany, in particular, was probably never taken too seriously. Anecdotes about students' cheating abound; for example, at botanic identification exams, it was not uncommon for students to help each other by surreptitiously substituting the prepared difficult and exotic plants for well-known, easier to identify specimens. Even bribery – paying the assistant in charge to prepare particular plants for the exam – occurred. It is hard to believe the professors were entirely unaware of this, but in all likelihood, they did not want to flunk students on as obsolete a subject as botany. That is, substantial knowledge of botany was considered superfluous as early as 1870, even for the (few) physicians who still did run a dispensary; for them, a little knowledge of commodities sufficed.[59] Still, it would take another century before botany, together with the other premedical sciences, was removed from the curriculum by the revision of the Academic Statute (in 1968).

Physics and chemistry, as premedical sciences, were mostly viewed as auxiliary sciences for the study of physiology.[59] From the late nineteenth century onwards, proposals were made to remove at least parts of them from the first-year program.[43,60] The most radical proposal was to transfer the entire premedical education to the secondary schools, and dedicate the first semester of the first year in medical school completely to anatomy, with an emphasis on this discipline's scientific-biological aspects.[61] In the event, all these proposals suffered the same fate: they were ignored. At least in part, this was due to the prevailing spirit of academic conservatism and also to vested interests: the propaedeutic year of the medical curriculum was an important source of income for the Faculty of Mathematics and Sciences. In addition, proponents of the premedical sciences also made themselves heard. Physics, for example, was defended on basis of several arguments: first, it was necessary to understand physical processes occurring in the body; second, it served to make students familiar with the experimental method and enabled them to apply this method, when necessary, to diagnosis or therapy; and third, it contributed to students' physical thinking.[62] However, it was also argued that elementary physics should be properly taught in secondary school, and that the medical curriculum should not include a comprehensive course in physics, but capita selecta, for example, in acoustics, radiation (X-rays, in particular), and energy. It should be noted that this was an ideal, not the current practice in the propaedeutic year: in fact, physics, as well as the other premedical sciences, was taught in a self-contained way, largely devoid of medical application, and in the form of a synopsis. This is where academic conservatism comes in: Van Rijnberk, for example, vehemently rejected the notion that practical utility (for medicine as a profession) should be a criterion for inclusion of any subject in the curriculum. If, for example, zoology is taught, then this should be "true" zoology, as it is performed and taught by the zoologist, not "medical" zoology.[43] In this respect, Van Rijnberk defended the classic academic ideal of pure scholarship, devoid of any vocational interests, an ideal also strongly supported, in America, by Flexner. Obviously, the fact that the Faculty of Mathematics and Sciences controlled the content of the propaedeutic year effectively prevented that medical physics and medical chemistry, as opposed to pure physics and pure chemistry, was taught. In fact, during the propaedeutic year, medical students attended lectures in chemistry together with physics students and lectures in comparative anatomy and botany together with biology students.[63,64] This organization, which remained formally in effect until 1968, was viewed unfavorably by many, the main complaint being that teachers at the Faculty of

Mathematics and Sciences lacked 'medical feeling' and that science teachers preferred their own discipline's students to those in medicine. There were also rumors that this faculty was inclined to employ their 'second-rate' teachers for medical students, teachers who acted as 'drill masters.'[65]

Yet, over the years, the character of the propaedeutic year gradually shifted from making up for deficient secondary education to elaborating upon it. Its primary aim increasingly became to instil in students a scientific attitude or the ability to "think scientifically." As such, this aim was explicitly mentioned in the 1921 Academic Statute.[66] Whether it was actually accomplished was quite another matter, however: the Committee-Pekelharing expressed serious doubts in this respect. Though this Committee considered some preliminary education in physics, chemistry, botany, and zoology indispensable, it was not satisfied with the way it was currently taught at medical school, which at the time largely boiled down to reinforcement of knowledge already acquired at secondary school.[32] A decade later, the new Academic Statute argued for some reduction of the premedical sciences – it was observed that the curriculum of the gymnasium had recently improved in this respect – but the emphasis should remain on complete elementary physics and complete chemistry (organic as well as inorganic).[66]

Of course, a scientific education worth the name also includes practical laboratory work; hence, the importance of such work for medical students was repeatedly emphasized, and complaints were often voiced. Van Rijnberk, for example, noted that, in contrast with their English peers, Dutch medical students were offered little opportunity for practical (laboratory) work in the premedical sciences.[65] Over the years, this probably improved somewhat; for example, in the 1950s, at Utrecht University, practical work in medical physics in the first year was scheduled on 16 afternoons.[67] Most notably, the author here talks about medical, not elementary, physics. Yet, across the board, the quality of the premedical practicals was relatively poor, as they were very much of the 'cook-book type.'[68] The laboratory practicals in the premedical sciences were also used as an argument in favor of keeping the propaedeutic year the responsibility of the Faculty Mathematics and Sciences, or, as an alternative proposal, to accommodate the first year of the medical course in a yet to be founded *interfaculty* – a joint administrative institute of the Faculty of Sciences and the Faculty of Medicine that would be responsible for propaedeutic medical education. This plan was never realized, though.[69]

Thus, propaedeutic year in the first half of the twentieth century witnessed a shift from elementary sciences via a regurgitation of secondary school science to a program featured more by capita selecta with a medical angle from physics, chemistry, and biology. For example, the first-year course in medical physics at the University of Utrecht in the mid-1950s dealt with subjects such as viscosity, surface tension, photography, double refraction, and nuclear physics, with examples of application of these subjects in physiology, diagnosis, or therapy.[67] Despite such innovations 'from within,' the position of the premedical sciences remained contentious: should they be included in the medical curriculum at all? In 1936, the *Sociaal Hygiënische Commissie* considered an early orientation of medical students toward their future life in medicine absolutely essential, and recommended, as a start, to divorce first year courses for medical and science students, and to organize separate lectures and practicals for medical students.[21] In all likelihood, this would be easier to achieve than a full transfer of the entire first year to the Faculty of Medicine, though this would be the ultimate aim. In fact, though the 1921 Academic Statute affirmed the predominance of the premedical sciences in the first year, it offered limited opportunity to introduce preclinical science in this year's program; in addition, students were formally allowed to attend lectures and practicals of the second year before they had passed the propaedeutic exam – which was, explicitly for this purpose, renamed the 'first candidate exam,' while the former candate exam became the 'second candidate exam.' Consequently, some Dutch universities, such as Leiden University, in the 1950s provided introductory courses in gross anatomy and physiology in the first year.[82] Apparently, students appreciated this early introduction of anatomy and physiology, because it fulfilled their 'natural' need to become familiar with the preclinical disciplines in an early stage and enabled them to see the relations between the premedical and preclinical sciences.[19] However, real integration of premedical and preclinical disciplines was precluded, first because the Academic Statute still required that physics, chemistry and biology be taught, as individual disciplines with the explicit aim of developing medical students' scientific thinking; and second, because two different faculties remained responsible for the first and second year program. By the mid-1960s, however, there was a widespread belief, shared by both students and most teachers, that the premedical year in its current form had become an obstacle to curricular improvement. For example, in 1965, the *Conventscommissie* expressed the belief that physics, chemistry, and non-human biology had lost their function in medical school long since.[17] Around the same time, students at the University of Amsterdam also wanted the premedical sciences to be removed from the curriculum and to start the first year with physiology and physical chemistry.[55] Though international comparisons were not as common then as they are today, authors then did not fail to notice that in this respect, Dutch medical education definitely lagged behind that in other European countries, such as Sweden and England.[51]

The *Conventscommissie* proposed that those parts of the premedical sciences that had no direct bearings on the human organism should be integrated with other subjects in order to make them meaningful to beginning medical students. Subjects specifically mentioned in this respect were medical physics, analytical and organic chemistry, physical chemistry, and botany; zoology, provided that it would be presented as an independent introduction to human biology, could escape this fate and remain an individual discipline. The *Conventscommissie* also emphasized that, at any time, students should be able to perceive the relationship between what they were being currently taught and their ultimate aim, that is, becoming a physician.[17] Finally, in 1968, the premedical year was formally abolished when Revised Academic Statute came into effect. However, vestiges of non-human biology could be found in the propaedeutic program – the new Statute dropped the term 'first candidate exam' and restored the traditional expression 'propaedeutic exam' – until well into the 1980s.[70]

Preclinical education

From 1865 until 1921, the preclinical years (the second and third year) were almost entirely devoted to morphology (anatomy, histology, and cytology) and physiology (physical as well as chemical), or, to put it another way, to the sciences that deal with the normally structured and normally functioning organism. Physiology was generally considered the basis of medical science.[59,71] After 1921, parts of general pathology were moved to the preclinical program; at mid-century, pathology in the Dutch medical curriculum started in the second year and extended into the fifth year.[72] Some relatively minor changes occurred in the 1950s and early 1960s; for example, pharmacognosy was removed from the curriculum, and histology was assigned a more independent position.[73] In these years, instruction during the second and third year covered the subjects of gross and microscopic anatomy, physiology, biochemistry, and general pathology.[19] At Utrecht University and Nijmegen University, pharmacology (both lectures and practicals) was also included in the candidate program, but at the other faculties, it was still limited to the theoretical-clinical years (the doctoral program). At that time, disciplines such as health science, psychology, and social medicine had already worked their way into the preclinical curriculum.[74]

A salient feature of the preclinical curriculum, and a relic from the traditional university, was that the preclinical years were basically not graded: Second and third year programs were given every other year, and students just flowed in after they had passed their propaedeutic or first physics exam. Academic freedom enabled students to basically attend the courses in whatever order they wanted, though the universities provided the students with general recommendations regarding the optimal sequence. Probably, most students followed these recommendations, for Flexner observed that the Dutch student was "characterized by his teachers as usually docile and industrious, [and] follows a beaten path with great conscientiousness."[93] It is not clear how long this situation persisted; as the candidate exam was taken at the end of the third year, it may formally never have been abolished at all, though in practice the preclinical years in the 1950s were to a large extent graded. In the 1920s, Van Rijnberk was not happy with the situation, for he believed that anatomy and histology should be dealt with extensively before teaching of physiology and pathology could start. At the time Flexner visited the Netherlands, in practice, academic freedom to attend courses in any order was probably already limited, if only because practicals and courses more and more built on each other.

The basic aim of the preclinical years was that students should built a firm, stable, and extended knowledge base, which could last a lifetime. In 1909, the Committee-Pekelharing listed what preclinical education should achieve in students: A thorough knowledge of human anatomy, of circulation in mammals (before birth and during life), of respiration, muscles, and nerves, of the senses (eye and ear), of digestion and metabolism. In addition, students must be able to operate the microscope in order to know the intricate structure of organs and tissues, to be able to recognize tumors and to understand microscopic changes in diseased organs, and to investigate blood, sputum, and urine. Moreover, they must have some skills in chemical analysis and some knowledge of the substances the human body consists of.[76]

Though the structure of the preclinical years remained largely unchanged, the content of specific disciplines evolved. For example, in pathology, between 1900 and 1940, the emphasis gradually shifted from pure (morphological) pathology to pathological physiology. In general, anatomy had a large share in the preclinical program, with dissection being considered the most informative, but due to capacity constraints not the most practiced, educational format. In the 1960s, compared to other countries, anatomy was still excessively taught in the Netherlands, though the differences between medical faculties were considerable: the number of hours devoted to gross anatomy in the second and third year ranged from 225 (125 lecture hours and 100 practical hours at Utrecht University) to 572 hours (305 lecture hours and 267 practical hours at Leiden University).[74]

In addition to building a firm and stable knowledge base, the preclinical sciences – like the premedical sciences – also played an important role in fostering a scientific attitude in students.[25] Probably, Flexner did approve the solid scientific foundation in the biomedical disciplines (in this respect, the Dutch curriculum was modeled after the German system), though he would have rejected the teaching of encyclopaedic scientific knowledge predominantly by means of lectures, as was the practice in the Netherlands at the time. Rather, students should be trained in the scientific method of the basic sciences, which was also the appropriate tool for medical practice, Flexner argued.[1] Nonetheless, the scientific standard of preclinical education was a source of concern over the years. On the one hand, basic science education was too broad for students who 'only' wanted to become practicing physicians, on the other hand, it was not sufficiently scientific for students who pursued a research career.[77] Therefore, the introduction of a dual track system was repeatedly advocated.[39,78-80] In such a system, students would be able to choose between a more vocationally oriented, shorter premedical and preclinical track, and a scientifically oriented track. Initially, the predominant belief was that future practitioners who did not want to engage in scientific research needed less scientific education than the standard medical course provided (i.e., the practitioner's course could be shortened), but from the 1950s onward the prevailing view was that the then standard curriculum was too much of a professional school, and that students who opted for a scientific career required more – or at least better – instruction in the basic sciences than the program provided for. Thus, it was argued that the scientific standard should be raised, and in the early 1960s, some Dutch medical schools experimented with a mandatory elective in the basic sciences. An important secondary aim of this elective was to spot those students with particular interest in basic science research, who could possibly be recruited as future research personnel.[24,33,48,81,82] A similar, but more ambitious project was the five-months scientific practical which was inserted between the preclinical and clinical phases in the newly founded Rotterdam Medical School in the mid-1960s.[52,83] Though it was reported that students were enthusiastic about the six-week scientific elective at Leiden University, the Nijmegen scientific elective was not met with unequivocal enthusiasm, one important reason being that the number of holidays was substantially reduced. Students in Rotterdam, many of which "just wanted to become physicians," in general considered this scientific practical a waste of time and effort and a hurdle to be passed before they could embark on their clinical studies.[48,82,84]

In short, preclinical education suffered from the same shortcomings as premedical education some decades earlier: from a scientifically solid and up-to-date course in the late nineteenth and early twentieth century it evolved into a more encyclopaedic 'stuffed-with-facts' course in the 1950s and 1960s. Increasingly, the drawback that the courses were compartmentalized, self-contained, organized by autonomous departments isolated from the clinic, and taught in suboptimal instructional formats was felt. Though it was not appreciated by many students, the fact that the basic sciences were taught as if the students would be future anatomists, physiologists, pathologists, etc. was understandable, because the medical course was until the 1970s the only route to become a basic science researcher. But while students who wanted to become practitioners emphasized that they just needed to know the basics of anatomy and physiology, in order to become properly equipped for clinical work, their professors rhetorically asked: "...is it possible to become a physician without knowing the full structure of the human body?," and: "are not all parts of this body of equal importance?," the answers, of course, being "no" and "yes," respectively.[58] In addition, to defend comprehensive teaching of the basic sciences, an obvious argument was used: "What is irrelevant for practice today, may become routine tomorrow."[41] As an historical coincidence, on exactly the same day (i.c., March 26, 1921) when Van Rijnberk's recommendation that physiology should be taught, not on basis of its relationship with clinical medicine, but as if all medical students would be future professors in physiology, was published, W. D. Halliburton in the *Lancet* expressed sympathy for students complaining of curricular overload and argued that, for physiology in particular, "in the details of its many ramifications one must make a judicious selection, and the choice must naturally first fall on those parts of the subject in which the practical outcome is already realised rather than on those the application of which is still to seek."[85,86] Over the years, Van Rijnberk stuck to his belief, though in 1938 he sounded less convinced when he considered the inclusion of essentially useless subject matter "a necessary feature of medical education."[87] He strongly opposed reducing the amount of anatomy and other preclinical sciences in the curriculum. "Good practice is based on thorough theoretical understanding," was his adage. Anatomy and physiology, as taught in medical school, will be "the student's foundation which will last a lifetime."[88] "Students know too much of anatomy? That will give the clinicians a good laugh!" Van Rijnberk ironically exclaimed, quoting Petersen.[89]

Though opinions diverged considerably with respect to the content and extent of the basic sciences, there seems to be agreement that they were poorly taught. The opportunities for hands-on work, in particular, were very limited. This was a long-standing problem, already noted in the late-nineteenth century.[61] Van Rijnberk explicitly added an extra argument in favor of practical laboratory work: it not only provided students with knowledge and fostered their scientific insight, but it also supported the development of fine hand and finger dexterity, as well as eye-hand coordination.[42] This "learning by doing" was also one of Flexner's preferred methods of instruction, and, though he was laudatory of teachers as well as preclinical laboratories, he expressed concern about insufficient facilities and resources for teaching in the laboratories.[1]

A third problem was students' lack of opportunity to choose capita selecta in the preclinical sciences, an illustration of Flexner's observation that "...individuality does not disclose itself" in Dutch medical education.[29] Students as well as teachers were familiar with this problem, which in the 1960s re-emerged as the question of 'electives,' or 'curricular differentiation.' Overload, fear of students' missing even the slightest knowledge considered necessary to become a good physician, and shortage of teachers probably all contributed to this problem. The situation improved somewhat after 1973, when general practice became an official medical specialty, and the need to prepare all students equally for general practice became somewhat less strongly felt.[90]

Unlike the premedical sciences, the role of the preclinical sciences in the medical curriculum was generally taken for granted. Criticism was limited to the aim of these sciences and, most notably, to the way they were taught. As early as

1874, the belief that in-depth scientific knowledge was necessary to avoid physicians' reverting to routine behavior and empiricism was challenged.[91] Insofar as scientific knowledge was necessary, societal pressure and competition between practitioners would ensure that physicians would stay informed about scientific progress in the medical domain. Not knowledge for its own sake, but the ability to apply this knowledge in line with scientific methods would be the hallmark of a good physician, who would be, first and foremost, a medical practitioner. Scientific medicine and the practice of medicine, though mutually supportive, have different goals. There is no need for the future physician to be chemist, physiologist, pathologist or anatomist.[91] In any case, students would bury their knowledge of anatomy and physiology directly after their candidate's exam, never to disinter it again. Once in the clinic, they focused on the clinical tricks and the practical basis of diagnosis and therapy. The clinicians who supervised them had also withdrawn from anatomy and physiology, and even from the clinical laboratory: "My clinic is my laboratory," they would proudly say, "I don't need an additional one." Or: "We educate general practitioners, not scientists."[39]

Though the preclinical sciences were seen as requisite for physicians, there were early doubts about the importance of descriptive anatomy, in particular.[92] Presumably, it contained much "dead weight," because students were expected to learn whole textbooks by heart, or at least teachers were not very selective in assigning subject matter.[43] Besides, there was an overemphasis on factual knowledge and little attention for correlation, neither between the sciences themselves nor between the sciences and medical practice. Again, what strikes most is how long it took for innovation to occur: in the mid-1960s, medical students still had to learn the complete descriptive anatomy, the physiology of all organ systems, and the biochemistry of all metabolic processes.[34] Yet, the same author who considered much of this knowledge superfluous, did not recommend a reduction of the basic sciences in general, for, as he argued, "a solid foundation is a primary prerequisite to construct a building," in which resonate Van Rijnberk's words of the 1920s. That is, a shift of emphasis was indicated, rather than a reduction.[34] But at the time, this belief had grown increasingly obsolete, and a substantial reduction and reorganization of the preclinical curriculum was long overdue.

Premedical and preclinical education after 1965

After a long period of relatively little change the decade between 1965 and 1975 eventually witnessed an accelerated development. In fact, the popular stereotype of the "sixties" as an era of major changes may, with respect to Dutch medical education, not be all that far from the truth. In the decade between 1965 and 1975, four major events occurred that had far-reaching ramifications for the medical curriculum: first, the foundation of a seventh medical faculty (at Rotterdam) in 1965, the first medical school in the Netherlands with a designed, rather than historically developed, curriculum; second, the major revision of the Academic Statute in 1968; third, the establishment of general practice as an individual medical specialty in 1973 – which relieved the medical faculties from the obligation to prepare graduates directly for family practice – and finally, the foundation of the eighth medical school (at Maastricht) in 1974, the first medical school with a problem-based learning curriculum in The Netherlands, and one of the first in the world. For preclinical medical education, the revision of the Academic Statute in 1968 was probably the most important of the four innovations, for it legally permitted medical faculties to break the barriers between the preclinical sciences: whereas until then anatomy, biochemistry, physiology, pathology etc. had to be taught as individual disciplines, the new Statute phrased it quite differently: students in the preclinical years should study the "macroscopical, microscopical, submicroscopical, and molecular structure and development of organisms, especially of man," and the "functions of living organisms, including chemical and physical aspects."[93] This new conception of preclinical education – in which the premedical and preclinical years were effectively integrated – can easily be seen as a necessary precondition for a curriculum to embody problem-based learning. Today, in the wake of the Maastricht curriculum, all eight Dutch medical schools have either integrated and innovated their entire curriculum, or at least adopted major elements from such programs. Today, unlike in 1965, Dutch medical education no longer compares unfavorably to that in other countries in Europe or North America. In addition, to facilitate developments towards further innovation, many schools have relatively large departments of educational development and research. Consequently, proportionally more contributions from the Netherlands appear in international medical education journals than would be expected on basis of the size of the medical community.[94]

REFERENCES

1. Flexner, A. *Medical education. A comparative study*. New York: The MacMillan Company; 1925.
2. Papa, F.J., and Harasym, P.H. Medical curriculum reform in North America, 1765 to the present: A cognitive science perspective. *Acad Med*. 1999;74:154-164.
3. Lindeboom, G.A. Medical education in the Netherlands, 1575-1750. In: O'Malley, C.D. (Ed*.). The history of medical education. UCLA Forum in medical sciences, No. 12*. (pages 201-216). Berkeley, CA: University of California Press; 1970.
4. Beukers, H. Medical education in the Netherlands in the nineteenth century. In: Ogawa, T. (Ed.). *History of medical education. Proceedings of the 6th International Symposium on the Comparative History of Medicine. Susono-shi, Shizuoka, Japan, September 17-24, 1981*. (pages 192-195). Tokio, Japan: Saikon Publishing Company, Ltd. 1983.
5. Van Geuns, J. Het tegenwoordige standpunt der geneeskundige wetenschap, in betrekking tot het onderwijs. *Archief voor Geneeskunde*. 1842;2:381-389.
6. Editorial. *Nederlandsch Tijdschrift voor Geneeskunde*, 1865;1(Eerste Afdeeling):214.
7. Wachelder, J.C.M. *Universiteit tussen vorming en opleiding. De moderniseringvan de Nederlandse universiteiten in de negentiende eeuw*. (page 137). Hilversum, The Netherlands: Uitgeverij Verloren; 1992.
8. Groen, M. *Het wetenschappelijk onderwijs in Nederland van 1815 tot 1980. Een onderwijskundig overzicht. Vol. 1: Wetgeving. Civiel effect. Godgeleerdheid. Rechtsgeleerdheid. Indologie. Geneeskunde* (pages 307-374). Eindhoven, Netherlands: Technische Universiteit Eindhoven; 1987.
9. Van Lieburg, M.J. De natuurkundige staatsexamens voor medische studenten en de constructie van een natuurwetenschappelijke basis voor de artsenopleiding tussen 1865 en 1880. *Gewina*, 1995;18:139-180.
10. Groen, M. *Het wetenschappelijk onderwijs in Nederland van 1815 tot 1980. Een onderwijskundig overzicht. Vol. 1: Wetgeving. Civiel effect. Godgeleerdheid. Rechtsgeleerdheid. Indologie. Geneeskunde* (page 325). Eindhoven, Netherlands: Technische Universiteit Eindhoven; 1987.
11. Beukers, H. Medical education in the Netherlands in the nineteenth century. In: Ogawa, T. (Ed.). *History of medical education. Proceedings of the 6th International Symposium on the Comparative History of Medicine. Susono-shi, Shizuoka, Japan, September 17-24, 1981*. (page 203). Tokio, Japan: Saikon Publishing Company, Ltd.; 1983.
12. Simon Thomas, A.E. Waar zullen de artsen kunnen gevormd worden? *Nederlandsch Tijdschrift voor Geneeskunde*, 1865;1(Eerste Afdeeling):468.
13. Wachelder, J.C.M. *Universiteit tussen vorming en opleiding. De moderniseringvan de Nederlandse universiteiten in de negentiende eeuw*. (page 138). Hilversum, The Netherlands: Uitgeverij Verloren; 1992.
14. Burger, H. Onderwijsbelangen. III. *Nederlandsch Tijdschrift voor Geneeskunde*, 1910;54(Eerste Helft,3):142.
15. Burger, H. Onderwijsbelangen. IV. De Onderwijsregeling in Duitschland. *Nederlandsch Tijdschrift voor Geneeskunde*, 1910;54(Eerste Helft,4):204
16. Flexner, A. *Medical education. A comparative study* (page 69). New York: The MacMillan Company; 1925.
17. Conventscommissie voor de Faculteit der Geneeskunde. *Nota over de artsopleiding*. Utrecht, The Netherlands: Stafconvent Rijksuniversiteit Utrecht; 1965.
18. Thung, P.J. *Medical education in the Netherlands: Recent history and developmental trends*. Leiden, The Netherlands: Universitair Medisch Centrum; 1970.
19. Bachmeyer, A.C. Medical schools in Western Europe. The Netherlands*. J Med Educ*, 1952;27(4, Part Two): 64-75.
20. Van Rijnberk, G.A. Hervorming van de opleiding van den geneesheer. (Reactie op een brief van een doktersvrouw). *Nederlandsch Tijdschrift voor Geneeskunde*, 1918;62(Tweede Helft,22):1731-1732.
21. Tuntler, J.H. Praeadvies over de opleiding van den arts, uitgebracht aan het hoofdbestuur der Nederlandsche Maatschappij tot Bevordering der Geneeskunst, door de Sociaal Hygiënische Commissie in Maart 1936. *Nederlandsch Tijdschrift voor Geneeskunde*. 1937;81(42):5019-5082.
22. De Waart, A. et al. Rapport van Sectie K. In Reinink, H. J. et al. (Ed.), *Rapport van de Staatscommissie tot reorganisatie van het hoger onderwijs* (pages 243-244). Den Haag: The Netherlands: Staatsdrukkerij en – Uitgeverijbedrijf; 1949.
23. Groen, M. *Het wetenschappelijk onderwijs in Nederland van 1815 tot 1980. Een onderwijskundig overzicht. Vol. 1: Wetgeving. Civiel effect. Godgeleerdheid. Rechtsgeleerdheid. Indologie. Geneeskunde* (page 358). Eindhoven, Netherlands: Technische Universiteit Eindhoven; 1987.
24. Julius, H. W.. *Reorganisatie of hervorming van het hoger onderwijs in de geneeskunde*. Utrecht,

The Netherlands: Boekhandel H. De Vroede; 1951.
25. Van Rijnberk, G.A. Een en ander over hooger onderwijs in de geneeskunde. VI. De taak van den hoogleeraar. *Nederlandsch Tijdschrift voor Geneeskunde*. 1916;60(Tweede Helft,16):1365-1368.
26. Van Rijnberk, G.A. Hervorming van de opleiding van den geneesheer. 3. Pearce's denkbeelden. Nederlandsch Tijdschrift voor Geneeskunde. 1918;62(Tweede Helft,21):1655-1659.
27. Van Rijnberk, G.A. De geneeskundige opleiding in Europa, bezien door een Americaan. 9. Slotbeschouwingen. *Nederlandsch Tijdschrift voor Geneeskunde*. 1925;69(Tweede Helft,19):2068-2069.
28. Van Rijnberk, G.A. De geneeskundige opleiding in Europa, bezien door een Americaan. 5. De laboratorium-wetenschappen. *Nederlandsch Tijdschrift voor Geneeskunde*. 1925;69(Tweede Helft, 15):1644-1647.
29. Flexner, A. *Medical education: A comparative study.* (p. 261) New York: The MacMillan Company; 1925.
30. Greep, J.M. Medische opleiding in de Verenigde Staten. *Nederlands Tijdschrift voor Geneeskunde*, 1967;111(16):736-744.
31. Winkler, C. Bijlage IV bij het Rapport van de Commissie Korteweg. *Nederlandsch Tijdschrift voor Geneeskunde.* 1901;37(Eerste Deel,10):516-520.
32. Pekelharing, C.A. et al. Rapport der blijvende commissie voor het praktische en het aanvullende geneeskundig onderwijs, benoemd door het hoofdbestuur der Nederlandsche Maatschappij tot Bevordering der Geneeskunst, ingevolge het besluit der Algemeene Vergadering van Dinsdag 10 Juli 1906. *Nederlandsch Tijdschrift voor Geneeskunde*, 1909;53(Eerste Helft,6):357-384.
33. Noach, E.L. De opleiding van onderzoekers in de geneeskundige basisvakken. *Nederlands Tijdschrift voor Geneeskunde*. 1958;102(I,1):36.
34. Kuijjer, P.J. De betekenis van de niet-klinische vakken voor de geneeskundige opleiding. *Nederlands Tijdschrift voor Geneeskunde*. 1965;109(I,23):1090-1091.
35. Boerema, I. Vereenvoudiging van de medische studie. *Universiteit en Hogeschool*. 1965;12:194-201.
36. Van Rijnberk, G. A. Een en ander over hooger onderwijs in de geneeskunde. V. Voortzetting van het praeclinische onderwijs in de clinische jaren: Clinische physiologie. *Nederlandsch Tijdschrift voor Geneeskunde*. 1916;60(Tweede Helft,11):903-905.
37. Goudsmit, J. *Anderhalve eeuw dokteren aan de arts. Geschiedenis van de medische opleiding in Nederland.* (page 82). Amsterdam, The Netherlands: SUA; 1978.
38. Goudsmit, J. *Anderhalve eeuw dokteren aan de arts. Geschiedenis van de medische opleiding in Nederland.* (page 72). Amsterdam, The Netherlands: SUA; 1978.
39. Winkler, C. Het hooger onderwijs in de geneeskunde in Nederland. *De Gids: Nieuwe Vaderlandsche Letteroefeningen*. 1901;10:8-11.
40. Salm, A.J. Over de opleiding der artsen. *Nederlandsch Tijdschrift voor Geneeskunde.* 1906;50(Eerste Helft):108-112.
41. Van Rijnberk, G.A. Een en ander over hooger onderwijs in de geneeskunde. II. De verhouding der praeclinische, "theoretische" en "laboratorium"-wetenschappen, tot de eigenlijke geneeskunde. *Nederlandsch Tijdschrift voor Geneeskunde*. 1916;60(Tweede Helft,8):595-598.
42. Van Rijnberk, G.A. Een en ander over hooger onderwijs in de geneeskunde. IV. Nadere beschouwingen over de beteekenis en inrichting van het praeclinische onderwijs: Het wetenschappelijk peil van de colleges en het nut der practica. *Nederlandsch Tijdschrift voor Geneeskunde*. 1916;60(Tweede Helft,10):805-808.
43. Mulder, J. and Van Rijnberk, G.A. Onderwijsvraagstukken. 9. Nog iets over de opleiding van de artsen in Nederland. *Nederlandsch Tijdschrift voor Geneeskunde*. 1924;68(Eerste Helft,9):894-898.
44. Boerema, I. Vereenvoudiging van de medische studie. *Universiteit en Hogeschool*. 1965;12:197.
45. Koster, W. Stemmen uit den vreemde. *Nederlandsch Tijdschrift voor Geneeskunde*. 1883;19(Eerste Afdeeling,12):187-89.
46. Eijkman, K.H. and Van Rijnberk, G.A. Onderwijsvraagstukken. Iets over de studie in de geneeskunde. *Nederlandsch Tijdschrift voor Geneeskunde*. 1932;76(Tweede Helft,17):1910-1914.
47. De Langen, C.D. Enkele vragen inzake het geneeskundig onderwijs. V. Het geneeskundig onderwijs aan onze universiteiten. *Nederlandsch Tijdschrift voor Geneeskunde.* 1942;86(IV,43):2618.
48. Mertens, A.Th.L.M. Veranderingen in het curriculum van de medische faculteit te Nijmegen. *Nederlands Tijdschrift voor Geneeskunde*. 1966;110(39):1706-1708.
49. Galjaard, H. De basisvakken en de geneeskunde. *Nederlands Tijdschrift voor Geneeskunde*. 1977; 121(43):1723-1726.
50. Prakken, J.R. De medische opleiding. *Nederlands Tijdschrift voor Geneeskunde*. 1966;110(1):2
51. Veeneklaas, G.M.H. et al., Het medisch onderwijs in Scandinavië en Groot-Brittannië. *Nederlands Tijdschrift voor Geneeskunde.* 1965;109(28):1281-1284.
52. Binneveld J.M.W. and Vleesenbeek, H.H. *Medische Faculteit Rotterdam. Analyse van een*

experiment. (page 15). Leiden, The Netherlands: H. E. Stenfert Kroese B.V.; 1976.

53. Burnet, E. Medical education and the reform of medical studies. *Quarterly Bulletin of the Health Organisation of the League of Nations*. 1933;2(11): 684.
54. Pekelharing, C.A., and Hartman, J.C M. De praktische oefening van den jongen arts. *Nederlandsch Tijdschrift voor Geneeskunde*. 1910;54(Eerste Helft):1844-1848.
55. Wackers, F. J. Th. Het "Werkplan Kernopleiding" van de Medische Faculteit der Amsterdamse Studenten. *Nederlands Tijdschrift voor Geneeskunde*, 1966;110(1):34-37.
56. Eskes, T.K.A.B. Medische opleiding in de Verenigde Staten. XI. De opleiding van arts en vrouwenarts aan de Western Reserve University te Cleveland, Ohio, U.S.A. *Nederlands Tijdschrift voor Geneeskunde*. 1967;111(23):1047-1051.
57. Van Lieburg, M.J. De natuurkundige staatsexamens voor medische studenten en de constructie van een natuurwetenschappelijke basis voor de artsenopleiding tussen 1865 en 1880. *Gewina*, 1995;18:139-180 (quote on page 174).
58. Mulder, J., and Van Rijnberk, G.A. Onderwijsvraagstukken. 3. Vakschool of universiteit? *Nederlandsch Tijdschrift voor Geneeskunde*. 1923;67(Tweede Helft):2664.
59. Sanders, H. De voorbereidende studiën van de geneeskundige en de natuurkundige examens. *Nederlandsch Tijdschrift voor Geneeskunde*. 1870;6(Eerste Afdeeling):94.
60. Ter Kuile, Th.E. *De universitaire medische studie*. (p. 14). Amsterdam, The Netherlands: Scheltema & Holkema's Boekhandel; 1906.
61. Straub, M. *De vorming van den geneeskundige. Rede, bij de aanvaarding van het buitengewoon Hoogleeraarsambt aan de Gemeentelijke Universiteit van Amsterdam, op Maandag 18 Maart 1895*. (p. 12) Haarlem, The Netherlands: De Erven F. Bohn; 1895.
62. Burger, H.C. Het onderwijs in de natuurkunde aan de studenten in de geneeskunde. Openbare les gehouden te Utrecht op 11 October 1922. *Physica: Nederlandsch Tijdschrift voor Natuurkunde*. 1923;3:1-10.
63. Querido, A. *Doorgaand verkeer. Autobiografische fragmenten*. (page 14) Lochem: Uitgeversmaatschappij De Tijdstroom; 1980.
64. Goudsmit, J. *Anderhalve eeuw dokteren aan de arts. Geschiedenis van de medische opleiding in Nederland.* (page 68). Amsterdam, The Netherlands: SUA; 1978.
65. Van Rijnberk, G.A. Nieuwe banen voor de geneeskundige opleiding. 2. De jongste denkbeelden in Engeland. *Nederlandsch Tijdschrift voor Geneeskunde*. 1919;63(Eerste Helft,9):652.
66. Smidt, H.J. *Het Academisch Statuut. Koninklijk besluit van 15 Juni 1921, Staatsblad No. 88. Met aantekeningen. Tweede, herziene uitgave*. Alphen aan de Rijn, The Netherlands: N. Samson N.V.; 1932.
67. Burger, H.C. How much physics? In: Clegg, H. (Ed.), Proceedings of the First World Conference on Medical Education, London, 1953. Held under the auspices of the World Medical Association. (page 133-139). London, UK: Oxford University Press; 1954.
68. Querido, A. *De binnenkant van de geneeskunde. Een autobiografie, opgetekend in samenwerking met Jacky Bax en Ruud Overdijk*. (page 24). Amsterdam, The Netherlands: Meulenhoff; 1990.
69. De Waart, A. et al. Rapport van Sectie K. In Reinink, H. J. et al. (Ed.), *Rapport van de Staatscommissie tot reorganisatie van het hoger onderwijs* (page 247). Den Haag: The Netherlands: Staatsdrukkerij en – Uitgeverijbedrijf; 1949.
70. Rijksuniversiteit Utrecht. Studiegids 1980 (page 101).
71. Van Rijnberk, G.A. Nieuwe banen voor de geneeskundige opleiding. 6. Stemmen uit Oostenrijk. *Nederlandsch Tijdschrift voor Geneeskunde*. 1919; 63(Eerste Helft):1161-1165.
72. Deelman, H.T. Enkele vragen inzake het geneeskundig onderwijs. XX. Over de plaats van het onderwijs in de pathologie aan de universiteit. *Nederlandsch Tijdschrift voor Geneeskunde*, 1944; 88(I,1/2):3-6.
73. Groen, M. *Het wetenschappelijk onderwijs in Nederland van 1815 tot 1980. Een onderwijskundig overzicht. Vol. 1: Wetgeving. Civiel effect. Godgeleerdheid. Rechtsgeleerdheid. Indologie. Geneeskunde* (page 351). Eindhoven, Netherlands: Technische Universiteit Eindhoven; 1987.
74. Actualiteit. Artsen-opleiding. *Nederlands Tijdschrift voor Medische Studenten*. 1964;10:46-50.
75. Flexner, A. *Medical education. A comparative study*. (page 131, footnote). New York: The MacMillan Company; 1925.
76. Pekelharing, C.A. et al. Rapport der blijvende commissie voor het praktische en het aanvullende geneeskundig onderwijs, benoemd door het hoofdbestuur der Nederlandsche Maatschappij tot Bevordering der Geneeskunst, ingevolge het besluit der Algemeene Vergadering van Dinsdag 10 Juli 1906. *Nederlandsch Tijdschrift voor Geneeskunde*, 1909;53(Eerste Helft,6):361.
77. Buning, E.J., and Van Lingbeek, M.S. De geneeskundige opleiding. *Nederlandsch Tijdschrift voor Geneeskunde*. 1910;54(Eerste Helft):1489-1490.
78. Donders, F.C. Openingsrede van de zes-en-twintigste Algemeene Vergadering der Nederlandsche Maatschappij tot Bevordering der Geneeskunst. *Nederlandsch Tijdschrift voor*

Geneeskunde. 1875; 11(Tweede Afdeeling):229-248.
79. Koster, W. Hooger-onderwijs-belangen. *Nederlandsch Tijdschrift voor Geneeskunde*. 1903;(Eerste Deel,6):281-299.
80. Treub, H. Over medische studenten, medisch onderwijs en medische professoren in Nederland. Openingsrede van de twee-en-veertigste Algemeene Vergadering der Nederlandsche Maatschappij tot Bevordering der Geneeskunst. *Nederlandsch Tijdschrift voor Geneeskunde*. 1891;27(Tweede Deel,2):65-78.
81. Defares, J.G. Aanvulling van de medische opleiding met onderricht op exact-wetenschappelijk gebied. *Nederlands Tijdschrift voor Geneeskunde.* 1958;102(II,32):1569.
82. Oort, J. and Hooghwinkel, G.J.M. Onderwijs in wetenschappelijk onderzoek in de medische basisvakken. *Nederlands Tijdschrift voor Geneeskunde*. 1967;111(15):689-693.
83. Querido, A. Planning for the new medical faculty of Rotterdam. *J Med Educ*. 1970;45(6):393-402.
84. Binneveld J.M.W. and Vleesenbeek, H.H. *Medische Faculteit Rotterdam. Analyse van een experiment*. (page 83-85). Leiden, The Netherlands: H. E. Stenfert Kroese B.V.; 1976.
85. Van Rijnberk, G.A. School en leven. *Nederlandsch Tijdschrift voor Geneeskunde*. 1921;65(Eerste Helft,13):1674.
86. Halliburton, W.D. The importance of the infinitely little. *Lancet*. 1921(March 26):628.
87. Van Rijnberk, G.A. Efficiency. *Nederlandsch Tijdschrift voor Geneeskunde*. 1938;82(III,33):3932-3933.
88. Van Rijnberk, G.A. Onderwijsvraagstukken. X. “Efficiency”, het spook der toekomst. *Nederlandsch Tijdschrift voor Geneeskunde*. 1924;68(Eerste Helft,14):1491.
89. Petersen, H. Anatomie und Physiologie im vorklinischen Unterricht. Ueber die Rolle der Anatomie im Lehrgang des künftigen Arztes. *Klinische Wochenschrift*. 1928;7(39):1872-1875.
90. Van Der Werff Ten Bosch, J.J. Differentiatie in medisch onderwijs. *Nederlands Tijdschrift voor Geneeskunde.* 1973;117(6):230-233.
91. Sanders, H. De genees- en natuurkundige afdeeling van het Athenaeum Illustre en het voor haar gevraagde ius examinandi. *Nederlandsch Tijdschrift voor Geneeskunde*. 1874;10(Tweede Afd.,7):93-98.
92. Ter Kuile, Th.E. *De universitaire medische studie*. Amsterdam, The Netherlands: Scheltema & Holkema’s Boekhandel; 1906.
93. Thung, P.J. *Medical education in the Netherlands: Recent history and developmental trends*. (page 5). Leiden, The Netherlands: Universitair Medisch Centrum; 1970.
94. Tutarel, O. Geographical distribution of publications in the field of medical education. *BMC Medical Education*. 2002;2:3.

The Timing, Format and Role of Anatomical Sciences in Medical Education

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The Role and Value of Anatomy in the Medical School Curriculum

Many basic science and clinically oriented textbooks begin by addressing the anatomy of an organ, system or clinical area. Arguably, the reason the reader is introduced to the pertinent anatomy is that the structure of the body is fundamental to understanding all of the other basic and clinical medical sciences. The forerunners of today's anatomists systematically studied the human body. And by doing so, anatomists provided a framework for the other basic sciences to investigate the way the various parts of the body normally function and what happens when body functions are impaired.

Most people are likely to equate anatomy with gross anatomy, i.e., the macroscopic structure of the body as revealed through the dissection of the body. However, anatomy encompasses four sub-disciplines collectively referred to as the anatomical sciences. Two of the sub-disciplines, histology and embryology, are also concerned with the structure and organization of the body, but histology examines the microscopic structures that cannot be seen by gross inspection and embryology deals with both the gross and microscopic growth and development of the body from conception to birth. The fourth major sub-discipline, neuroanatomy, is concerned with the gross anatomy, microscopic anatomy and embryology of the nervous system. Because of the complexity of this system, neuroanatomy focuses on the brain, spinal cord and the peripheral nervous system.

In preparing to be a physician, medical students must study the four anatomical sciences to become conversant with the origin, structure and organization of the body. As students of the human body, medical students learn the names that have been given to the structures and organs that comprise the body, how the body takes shape from the embryonic tissues that are formed after conception, and how the organs are built from the cells and major tissues of the body. In studying the anatomical sciences, students begin to learn the language of medicine that will allow them to communicate with patients and discuss patient problems with other healthcare professionals. Furthermore, the experience of dissecting the body and examining the microscopic structure of the body with a microscope helps students cultivate observational skills and learn the importance of attention to detail. The dissection of a cadaver helps students develop strengths in effective learning strategies, independent learning, and professionalism qualities early in their medical education.[1]

Medical students readily grasp the relevance of gross anatomy to medicine. A course in gross anatomy and the experience of dissection is the vehicle that transforms naive onlookers into knowledgeable medical students and endows them with the recognition that they are part of the medical profession.[2] However, students are slower to recognize the importance of histology and embryology in their training despite the fact that impaired function primarily is realized through adverse effects on the development and microscopic organization of the cells that comprise the body. Students' attitudes towards these topics develop early in their training and remain with them because medical students often do not see the impact that histology and embryology have on the practice of medicine.

In a traditional medical school curriculum, awareness and greater acceptance of the importance of histology and embryology only comes as medical students progress through the curriculum and are exposed to other basic science subjects such as physiology and pathology. Diminished expectations arise because it is difficult for students to appreciate the details of histology and embryology when the two subjects are not correlated with clinical problems, i.e., with the practice of medicine. The difficulty that students have with histology and embryology is exacerbated by their work with unfamiliar structures that are visualized only at the microscopic level.

Unlike gross anatomy, students may lose the macroscopic perspective during observation of the much smaller samples of comparable structures at the microscopic level. In embryology, the students' task is complicated by having to visualize microscopic structures and understand the 3-dimensional changes that transform simple structures into complex shapes.

Another dilemma for students and instructors is that the entire knowledge base that medical students encounter is unlikely to be used by physicians after they enter the practice of medicine. The specific aspects of anatomy, histology, embryology or neuroanatomy that are used will most certainly depend on the physician's role as a researcher, educator, or caregiver. However, *basic concepts and practical aspects* of the anatomical sciences undoubtedly will be used by most physicians on a daily basis. For example, in performing a physical examination, the structure and function of the human body is understood at its most macroscopic level and gross anatomy and neuroanatomy provide a basis for understanding the patient interaction at this level. Also, an understanding of the body in three dimensions is inherently necessary to interpret information from a variety of imaging techniques including radiographs, CT scans (Computerized Tomography) and MRIs (Magnetic Resonance Imaging). Furthermore, students must learn the normal microscopic structure of tissues and organs because organ function cannot be assessed through the outward appearance of an organ. An appreciation for how the smallest components of an organ are affected by pathogens, toxins, drugs, environmental hazards and other factors cannot be understood without being familiar with the normal morphology of the cells and tissues.

In the case of neuroanatomy, knowledge of the normal morphology of the nervous system provides students with an anatomical basis for localizing lesions and interpreting disorders that produce clinical symptoms. The ability to understand how focal damage to the nervous system results in specific symptoms displayed by patients depends upon specific structures that transmit information in the nervous system and their location relative to one another. Like gross anatomy, intimate knowledge of the structure of the nervous system provides future physicians with the knowledge needed to interpret imaging data and make a diagnosis.

With respect to embryology, the future physician is provided with an understanding of the structural changes that occur during the prenatal period and the processes that establish gender and the body as a whole. Knowledge of the normal developmental processes that result in a functional adult is needed for one to understand the reasons for errors that lead to malformations and congenital disorders.

When and How Should the Anatomical Sciences Be Incorporated into the Medical Education Curriculum?

Medicine is as much art as it is science and one of the central questions that medical school educators must confront is whether gross anatomy, histology, embryology and neuroanatomy should be taught as stand-alone courses or whether there should be an amalgamation of the anatomical sciences and the other basic science disciplines and clinical medicine.

The anatomical sciences typically have been presented early in the education of students, e.g., within the first year of medical school. The visual aspects of each of the anatomical sub-disciplines provides a more tangible introduction to the body before proceeding to other basic medical sciences or clinical subjects. This is true even in a non-traditional curriculum.

If gross anatomy and histology are presented as stand-alone courses, the students are more likely to develop a deeper understanding of these disciplines in themselves, including the themes and variations in structure that are seen at both the macroscopic and microscopic level. If gross anatomy and histology are presented concurrently, students will also, at some point, be able to relate the microscopic structure of the organs and tissues to what they observe in the gross anatomy laboratory. Embryology, however, should probably be presented in combination with gross anatomy at least for those aspects of development that result in gross anatomical malformations.

By scheduling gross anatomy, histology and embryology early in their training, students are provided with the morphological basis for understanding of the content of their other basic sciences classes. The timing also allows students to relate the normal microscopic anatomy to disease processes at the cellular level. Neuroanatomy is highly specialized and specific to the nervous system. In this case, the gross structure of the body and histology of the tissues provide students with the underpinnings needed for understanding the relationship of the nervous system to the other systems of the body. Thus, the timing of neuroanatomy in the curriculum is more variable and tends to occur later than the other anatomical sciences.

As an integrated course, gross anatomy can begin early with the components of a traditional course being distributed to a number of organ-based modules. However, the laboratory component of gross anatomy often dictates when gross anatomy is taught. Practical considerations that affect the position of gross anatomy in the curriculum include the use of the laboratory by other courses, cadaver preservation, and faculty availability.

The many different fields of basic medical knowledge including the anatomical sciences can be brought together in an effective manner by relegating the information to organ or system-based modules. With such an approach, there is more opportunity to distribute baseline anatomical information throughout several years of training. Using this approach, everything is not concentrated at the beginning of medical school or within a semester of work. The time frame is more gradual and as a result the students have an easier time learning and assimilating the material. Some academic programs even combine traditional and organ-based aspects of medical education by offering a traditional gross anatomy course that is followed by an organ-based curriculum.

The integration of material should include the different basic medical science disciplines and the presentation and analysis of related clinical applications. The approach has numerous advantages for the educational process. In particular, the amalgamation of the art and science of medicine can engage students in the material more quickly by its close association with a clinical setting, the amalgamation can influence the type and amount of material covered by the faculty, and the amalgamation of basic science and clinical medicine can show students how the information they are learning is applied to patient care and diagnosis.

It may be helpful to integrate some instruction in anatomical sciences into year 3 and 4 clerkships as well to reinforce the relationship between structure and disease processes that underlie clinical disorders.

In either a traditional or an organ-based curriculum, laboratories in the anatomical sciences offer an experience that is unique in the education of medical students. The laboratories provide the opportunity for a different kind of problem solving, e.g., locating structures and relating anatomical information to clinical disorders. The interactions with faculty in a laboratory setting are frequent and more casual, making it possible for students to develop closer relationships with faculty. Students often are required to present information in laboratory about dissections or problem solving sets to their peers providing an opportunity for the students to learn cooperatively in small groups. In comparison to the setting of a large lecture hall, the students also are more likely to discuss the subject material in the setting of a laboratory. The opportunity for interactions increases a student's comfort level working as part of a team. It also helps develop communication skills, information sharing, and peer learning. Although the occurrence of laboratories associated with courses has decreased steadily[1], laboratories provide the opportunity to develop competencies that are essential in medical education.

Anatomy faculties are expected to do research and service as well as teach in courses that require significant amounts of time and resources. In reorganizing a curriculum, the tendency may be to eliminate laboratories or reduce the time set aside for laboratory in order to reduce contact time and reassign faculty resources. However, the laboratories complement didactic lectures and provide students with insights that can not be acquired in other ways. The dissection of a cadaver and reading microscope slides, for example, forces students to develop psychomotor skills, visualize in three dimensions, and deal with inherent variations that are commonly faced when examining actual specimens. In addition, the laboratories, which are interposed with lectures to reduce monotony, offer a different mode of learning that helps to reinforce the subject material.

Examples of Best Practices for Incorporating the Anatomical Sciences into the Medical Education Curriculum

Currently, each of the anatomical sub-disciplines is taught either as a stand-alone course or within an integrated organ or system-based module. A recent survey of courses in the United States[3] indicates that 79% of the gross anatomy courses are offered as stand-alone courses compared with 29% that are offered in integrated modules. Regardless of the format, 100% of the gross anatomy courses have a laboratory associated with them and the vast majority use some combination of student dissection and prosection. Some gross anatomy courses also supplement dissection with computer-based tutorials that facilitate visualization of 3-dimensional structures.

A little more than half of all of the histology courses in the survey occur as stand-alone courses (51%). The remainder of all the histology courses surveyed (49%) are integrated into the curriculum with other subjects.[3] The importance of microscopes and glass microscope slides in laboratory instruction is underscored by their use in all of the courses. A separate report supports this interpretation. In the survey of American and Canadian medical schools, 71.9 % of the respondents (histology course directors) specified that microscope and glass slides were being used in their courses.[4] It is important to note in this regard that a survey of osteopathic physicians report that practicing physicians need microscope skills.[5]

A stand-alone histology course provides an intensity of study and continuity of information that develops familiarity with the information and skills that extend beyond the recognition of microscopic structures. On the other hand, the compartmentalization of the material is one of the strengths of the systems-based approach. Smaller units of material facilitate learning because the students are not overwhelmed by morphological differences observed in the other organs. The organ-based approach also integrates normal and pathological changes in structure more effectively. The lack of continuity and emersion in the subject however can lead to some students not fully developing the microscope skills that would be acquired in a traditional histology course.

Perhaps one of the most significant changes in instruction in histology to occur over the past 2 decades is the use of computers to display digitized microscope images. The technology provides numerous advantages including 1) the elimination of the skills necessary for the operation of the microscope, 2) the use of a common set of exemplary images that help students learn identifying features, 3) the ability to view images anytime and anywhere a computer is available, 4) the elimination of microscope slide collections, and 5) a more simplified method of storing specimens, i.e., digital images versus glass microscope slides.

One of the more recent advances in technology have resulted in the use of microscope and/or virtual slides. Virtual slides are exact digitized images of entire histological slides and although the means used to examine a virtual slide is different from that used to examine a microscope slide the similarity provides the students with a realistic interface that poses the same challenges as reading an actual microscope slide, i.e. students must still learn to analyze and interpret the image information. [6,7] Thus virtual slides provide an experience that is close to or identical to that performed in a traditional microscope laboratory without the need for learning how to operate a microscope.

The impact that digital images have had on the histology laboratory can be measured by number of schools that employ them.[4] The gains in the use of computer technology are likely to lead to an enhancement of the materials used in the histology laboratory and greater flexibility in the way histological materials are accessed. If the latter is indeed the case, the debate over the use of computers in histology is more a matter of when and where the materials are acquired by students. However, even if the virtual slides can be viewed outside the confines of the school, students will continue to need curricular time set aside for formal laboratories that are staffed with instructors who can guide the students through the virtual materials, helping them to acquire the skills that are needed to analyze specimens, localize objects, and recognize structures. Access through the Internet could promote the development of web-based tutorials that could be made available to all schools.

For embryology, almost 80% of sampled programs have integrated embryology into modules. Most of the traditional embryology laboratories have been eliminated with only 7% of schools retaining laboratory sessions.[3]

Data from the American Association of Medical Colleges indicate that only 4 out of 109 medical schools in the United States and Canada list a course entitled Neuroanatomy.[8] The vast majority of medical school courses go beyond the traditional method of studying the anatomy of the nervous system by providing an integrated approach that incorporates many disciplines.

Thus, gross anatomy and histology continue to be offered as stand alone course to a large extent, whereas embryology and neuroanatomy primarily have been integrated into organ-based modules.

REFERENCES

1. Böckers, A, Jerg-Bretzke, L, Lamp, C, Brinkmann, A, Traue, HC, Böckers, TM. 2010. The gross anatomy course: an analysis of its importance. Anat Sci Educ 3: 3-11.
2. Netterstrøm, I, Kayser, L. 2008. Learning to be a doctor while learning anatomy! 2008. Anat Sci Educ 1: 154-158.
3. Drake, RL, McBride, JM, Lachman, N, Pawlina, W. 2009. Medical education in the anatomical sciences: the winds of change continue to blow. Anat Sci Educ 2: 253-259.
4. Bloodgood, RA, Ogilvie, RW. 2006. Trends in histology laboratory teaching in United States medical schools. Anat Rec (New Anatomists) 289B: 169-175.
5. Pratt, RL. 2009. Are we throwing histology out with the microscope? A look at histology from the physician's perspective. Anat Sci Educ 2: 205-209.
6. Dee, FR, Lehman, JM, Consoer, D, Leaven, T, Cohen, MB. 2003. Implementation of virtual microscope slides in the annual pathbiology of cancer workshop. Hum Pathol 34: 430.436.
7. Ogilvie, RW. 2007 Implementing Virtual Microscopy in Medical Education. http://www.iamse.org/development/2006/was_2006_spring.htm Accessed on March 9, 2010.
8. American Association of Medical Colleges. http://services.aamc.org/currdir/section4/start.cfm Accessed March 15, 2010.

The Role and Value of the Basic Sciences in Medical Education (with an Emphasis on Biochemistry)

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ABSTRACT

Biochemistry is one of the foundational or basic sciences that enable competent physicians to balance the art of medicine with rational, science-based medicine. It is important to the medical curriculum because it is a fundamental discipline for learning other foundational sciences, it teaches how scientific reasoning can be applied to clinical decision making, and provides a framework for solving clinical problems that require molecular insights. While Biochemistry is usually introduced into the first-year of the medical curriculum, competency in applying biochemical principles in the solution of clinical problems is best achieved when they are integrated vertically throughout the four-year curriculum and presented in a clinical context using active-learning strategies.

Medical students will be better prepared to learn, understand and apply biochemical principles if they have some prior exposure to some combination of biochemistry, cell biology, molecular biology and genetics during their undergraduate education.

Introduction

When Abraham Flexner began his evaluation of the medical schools in the United States and Canada in 1908, there were three different ways in which a student could receive training to be a physician: 1) apprenticeship with a practicing physician, 2) through a proprietary medical school, or 3) by a university-based medical school and associated hospital.[1] The publication of *Medical Education in the United States and Canada* (commonly referred to as the Flexner Report) in 1910 criticized the lack of science content and application of the scientific method in teaching diagnosis and treatment.[2] This resulted in the reform of medical education in the United States through the adoption by the Council on Medical Education in 1905 of the standard adopted that medical students would have two years of education in the sciences of human anatomy and physiology and two years of clinical training in a teaching hospital.[3] The implementation of this reform was completed in the 1930's.[1]

The sciences that constitute the foundation of medical practice

Since the time that scientifically-based medical education became the standard for training physicians, there has been an exponential increase in the scientific knowledge that a physician must understand and apply to diagnose and treat patients competently. In addition to training in human anatomy and physiology during the first two years in medical school, a present-day medical student also receives instruction in biochemistry, cell biology, embryology, epidemiology, genetics, histology, immunology, microbiology, molecular biology, neurobiology, nutrition, pathology, pharmacology and virology. These foundational or basic sciences enable the future physician to understand what constitutes the homeostasis of the healthy individual, the mechanisms by which that homeostasis is disrupted by disease, and how particular disease states may best be treated. A competent physician will be able to apply concepts from these foundational sciences and integrate new scientific knowledge and technology to rationally solve clinical problems presented by patients.

With new discoveries and advances in the foundational sciences increasing every year, the challenge for medical educators is to discern which of these advances together with current knowledge will help the medical student relate the foundational sciences to medicine and clinical practice. A recent study by the Association of American Medical Colleges and the Howard Hughes Medical Institute described the competencies in the foundational sciences that a physician entering residency should possess in order to be able to practice medicine grounded in scientific principles.[4] The report emphasized the importance of the natural sciences in medical education but also stressed that they should be presented in a way that students recognize their relevance to medical practice. These competencies, along with the accompanying learning objectives in the report, will serve as an excellent guide in helping medical educators present the scientific concepts that will prepare the medical student to practice science-based medicine.

The value and role of the foundational sciences in medical education

The ultimate goal of all of the foundational sciences is to prepare the student to take the greatest advantage of clinical experience available in their medical training. Regardless of their separate venues, foundational science education and clinical training are characterized by an extensive interdependency. The foundational sciences provide a high quality learning experience when they are correlated with clinical problem solving challenges. Likewise, clinical training becomes a high quality learning experience when it is fully supported by the foundational sciences.

The discipline of Biochemistry is but one of several foundational disciplines that describe the elements that compose the body and mind, how those elements function and how that function is regulated to maintain health. These disciplines further prepare the student to understand how that regulation is disrupted by disease. When effectively integrated with all the traditional disciplines, Biochemistry provides needed insight into the underlying mechanisms of both structure and regulation that occur at the cellular, tissue, organ, and whole system level. Effective integration requires attention to content, proper scaffolding of that content through increasing levels of complexity, and stage appropriate application to clinical problem solving.

Biochemistry plays several roles in the medical curriculum:

- It is a discipline fundamental to learning other foundational sciences in the medical curriculum; it provides a vocabulary and a way of understanding and thinking about that vocabulary.
- It teaches how scientific reasoning can be applied to clinical decision making.
- It provides direct background for clinical problems that require molecular insights.

Biochemistry is generally introduced early in the medical curriculum because many of the other foundational sciences utilize it. It develops general concepts such as regulatory cycles, signaling pathways, metabolic pathways, and structure/function relationships that serve as metaphors for learning in later courses. Physiology draws upon biochemical concepts to describe intra- and intercellular regulatory pathways, detergent action and enzymatic mechanisms of digestion and absorption, and proteins that function as motors to pump ions. Pharmacology employs concepts in protein-ligand relationships, regulation of synthesis and degradation of signaling molecules, and outcomes of altered regulation of metabolic pathways. Pathology utilizes molecular insights to explain storage diseases, the anatomical and physiological outcomes of vitamin and other nutrient deficiencies, regulation of cell cycle and cell death in the development of cancer, and the molecular explanations related to altered metabolism. Microbiology and immunology use concepts in protein structure in antigen-antibody relationships, active oxygen function in cellular immune response mechanisms, and molecular biology concepts involved in DNA transposition and gene regulation. Neurosciences make use of principles of gene regulation to describe the anatomical changes during neuroplastic adaptation, the biochemistry involved in neurotransmitter metabolism, and pathologic outcomes of membrane defects.

Scientific reasoning serves as the basis for clinical problem solving. It requires a fund of knowledge upon which to base hypothetical possibilities that can be tested. Thus, in its most general aspect, the process of clinical diagnosis is a guess based on the facts available. More precisely, it is a guess that is made more reliable when based on information provided by the foundational sciences. Biochemistry has a role in providing insight into the meaning of the data collected from the patient that concern molecular mechanisms. This involves an understanding of laboratory analysis of blood and other body fluids and an awareness of the possibility of involvement of metabolic pathways, of gene regulation, or of chemical messengers.

The signs and symptoms of disease occur in patterns. Many of these patterns are visible or obtained from the patient's medical history. Biochemistry contributes to a framework for recognizing patterns and establishing their likelihood as a diagnosis. This framework of molecular structure and function, regulatory relationships, and integration of pathways through which molecules are transformed makes it possible to think more clearly and reliably about clinical problems. Clinical therapeutic solutions are also aided by biochemistry insights because molecular mechanisms translate into physiological effects, e.g. pushing anti-inflammatory pathways through dietary changes results in a decrease in inflammation.

Incorporation of the foundational sciences into the medical curriculum

In general the foundational sciences should be integrated, both horizontally and vertically, in the medical curriculum and should be taught in a clinical context whenever possible. The vocabulary and core concepts that underpin all of the other courses should be introduced in year 1 and reinforced in year 2. These core concepts should be introduced in a clinical context with problem solving exercises so that the students gain experience applying those concepts to clinical decision making. The clinical years are the most appropriate place for the mastery of the detailed basic science concepts required for a full understanding of the clinical condition and treatment options for the patients with whom the students are working. This education strategy allows the students to appreciate fully the importance of mastering those detailed basic science concepts that most closely relate to patient care. Also, because students are learning these concepts in the clinical framework of a real patient experience they are more likely to retain and be able to apply these concepts in the future.

There are almost as many strategies for achieving horizontal and vertical integration as there are medical schools, but there are some fundamental principles for successful integration that apply to most of the integration models that exist.

In year 1, the primary emphasis for each of the foundational sciences should be on introduction of core vocabulary and concepts and showing the relationship of those concepts to health and disease. In the case of biochemistry, the core concepts are those cited in the above section addressing the value and role of the foundational sciences. The foundational sciences in year 1 should be integrated with each other so that clinical concepts can be introduced in the context of all of the relevant foundational sciences. For biochemistry, the most closely related foundational sciences are cell biology, molecular biology, genetics, nutrition and physiology.

While there are many ways in which integration of the foundational sciences can be organized, successful integration always requires that faculty work with each other in the planning and implementation of integration so that key concepts flow from one lecture to another. Since it is seldom possible for all related lectures to be organized sequentially, it is important that faculty make it clear to the students how the concepts that they cover are linked to others in the curriculum.

Finally, the foundational sciences are best integrated in a clinical context that requires clinical application of the core foundational science concepts. For the didactic portion of the curriculum, this can be achieved by organizing lectures around clinical cases. However, it is also important to involve the students in decision-making processes that utilize core foundational science concepts to solve clinical problems and to do this in an integrated manner to the extent possible. For example, clinical case exercises related to lysosomal storage diseases, glycogen storage diseases, cardiovascular disease and diabetes can be designed to involve core concepts that are associated with biochemistry, cell biology, molecular biology, genetics and nutrition.

The second year curriculum varies widely among medical schools, but it is important that the first-year and second-year faculty work together so that the core concepts from the foundational science curriculum in year 1 are integrated with the second-year curriculum. The first step in this process is an identification of the key concepts from the first-year curriculum that underpin the second-year curriculum. This helps to define those concepts that should be part of the first-year curriculum. It also allows a coordination of the first- and second-year curriculum so that there is appropriate review and expansion of important foundational science concepts in the second year curriculum. It can also be valuable to introduce clinical cases in the first year and revisit them in a more detailed manner in the second year.

Integration of the foundational and clinical sciences is the most challenging in the clinical years because much of the content is taught at the bedside and often at various locations. However, many clinical courses are now standardizing the clinical experience by defining lists of patients that every student must see and procedures that every student must master. In much the same manner foundational science and clinical faculty can work together to identify the key foundational science concepts which are important for student understanding of the clinical learning issues and should require mastery of those foundational science concepts. Typically, this would draw on the foundational science concepts learned in years 1 and 2 that are ideally suited for understanding the disease process being studied, but would go into a level of detail that would be inappropriate for a first or second year course.

From the perspective of biochemistry, examples of foundational concepts linked to clinical learning issues would be lipid metabolism and cardiovascular disease, metabolic regulation and endocrine disorders and metabolic pathways and genetic medicine. Once the key foundational science concepts related to clinical learning issues have been identified there are many ways in which these concepts could be introduced into the clinical curriculum in a standardized manner. Some examples include case presentations, simulated patients, online learning modules or self-instructional modules, but many other strategies have been successfully employed at various medical schools. Finally, it is essential that schools assess the application of foundational science concepts in a clinical context.

Examples of best practices for incorporating the foundational sciences into the medical curriculum

Diversity is a strength in the gene pool and it is a strength in the curriculum. In order for Biochemistry to play a proper role in the curriculum, it needs to be taught through a diversity of modalities that allow its fundamentals to be applied, either in learning more complex concepts or in application to clinical problems. While the traditional lecture has a strength in organizing and communicating facts and concepts, the absence of using that information to make a decision and act on it, e.g. dialog, drawings, reports, prevents the students from using an optimal whole-brain approach.[5] The temporal lobes that process the information in our long term memory are not designed to postulate possibilities and also make a logical choice among them. A whole-brain approach engages the prefrontal area to perform the latter task and draws on known information thus producing a highly effective use of the whole brain in learning. The modalities of Team-Based Learning and Problem Based Learning are two examples of teaching strategies that employ group problem solving to engage the whole brain including the limbic emotions that result when people work together.[6,7] This metacognitive approach has been recognized in a report by Bransford, Brown and Cocking as one of the three key essential elements for effective education that were identified by the National Research Council.[8]

Many teachers are now also employing active strategies during lecture to better engage the student. The use of hand-held audience response transmitters, "clickers," permit the instructor to make a formative assessment of the understanding of a concept as it is being taught and a "think-pair-share" method that has students talk briefly with a neighbor in response to a question about the topic being taught are two examples.

If an integration of Biochemistry with the other foundational sciences is to be effective, the integration itself must not be taken for granted. When a metabolic pathway or a signaling pathway is affected by a disease or a drug, then reference should be made to the integrative relationship in addition to the new information presented. This should persist into the clinical training as students discuss their patients during rounds. Also, opportunities for online acquisition of information and collaborative problem solving can help to reinforce this integration. Reports in the research literature do not confine themselves to single disciplines and students working in teams often see different applications of related disciplines to the benefit of the other team members.

Physician competency in the foundational sciences is best achieved when they are integrated with each other throughout the medical curriculum and effectively applied to solve clinical problems.

Prerequisite science components of the pre-medical curriculum

An in depth mastery of the foundational sciences is becoming increasingly important to prepare future physicians for the scientific advances that are rapidly changing the practice of medicine. At the same time there are pressures to shrink the curriculum time devoted to the foundational sciences. Thus, it is absolutely imperative that students enter medical school with a prior exposure to some combination of biochemistry, cell biology, molecular biology and genetics. This prerequisite will introduce undergraduate students to the vocabulary and basic concepts that they will be learning and applying in a more clinical context in medical school. Ideally, this undergraduate prerequisite will also teach students the basics of scientific reasoning. It should be recognized that the coverage of these topics is very uneven at the undergraduate level, so this prerequisite should not be considered as a replacement for these content areas in medical school, but rather a means to make learning in the medical curriculum more effective. Finally, as described in the 2009 AAMC-HHMI report, these topics would be best taught in an integrated manner at the undergraduate level so that students are exposed to the vocabulary and basic concepts of all four content areas equally, and so that the students learn how those content areas are interrelated.[4]

REFERENCES

1. Beck, A.H., STUDENTJAMA. *The Flexner report and the standardization of American medical education*. JAMA, 2004. **291**(17): p. 2139-40.
2. Flexner, A., *Medical Education in the United States and Canada*. 1910, New York, NY: Carnegie Foundation for the Advancement of Teaching.
3. *"Standard now Recommended" and "Ideal Standard"*. 1905, American Medical Association Council on Medical Education.
4. AAMC-HHMI, *Scientific Foundations for Future Physicians*. 2009, Association of American Medical Colleges: Washington, D.C. p. 1-43.
5. Zull, J., *The art of changing the brain*. 2002, Sterling, VA: Stylus Publishing, LLC
6. Michaelsen, L.K., et al., *Team-based learning for health professions education : a guide to using small groups for improving learning*. 2008, Sterling, VA.: Stylus Publishing, LCC.
7. Neville, A.J., *Problem-based learning and medical education forty years on. A review of its effects on knowledge and clinical performance.* Med Princ Pract, 2009. **18**(1): p. 1-9.
8. Bransford, J.D., A.L. Brown, and R.R. Cocking, eds. *How People Learn: Brain, Mind, Experience, and School*. 2000, National Academy Press: Washington, D.C.

Abraham Flexner: The Value of Medical Microbiology and Immunology as Foundation Sciences in Medical Education

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ABSTRACT

One hundred years ago a professional educator, Abraham Flexner, published a lengthy Report on the status of medical education in the United States and Canada. The Report underscored, among other criteria, the critical need for fundamental basic science courses including medical microbiology and immunology. In view of modern complexities, including threats of emerging pathogens, drug resistant microbes, bioterrorism, autoimmune diseases and cancer immunotherapy, we have examined anew the Flexner Report to assess the importance of Medical Microbiology and Immunology in medical education and their relation to clinical medicine.

The stage was set for change in medical education near the end of the 19th century. Medicine was undergoing a transformation as scientific understanding grew and the irrationality of some common techniques of the time led to their being discredited in the eyes of the public (e.g., bleeding and purging). The American Medical Association Council on Medical Education had recently completed a survey of US Medical Schools and was interested in reforming the teaching of medicine and standardizing the curriculum. In 1905 Andrew Carnegie, a self-educated man and firm believer in popular education, had founded The Carnegie Foundation for the Advancement of Teaching. One of the Foundation's goals was to provide support for change in American education policy by bridging the gap between teaching practice, evidence of student learning, the communications and use of this evidence, and structured opportunities to build knowledge.

Shortly after The Carnegie Foundation for the Advancement of Teaching was created, Abraham Flexner (1866-1959), a secondary school teacher and principal for nineteen years in Louisville, Kentucky, joined its research staff. Based on a recommendation from the Foundation president, Henry S. Pritchett, and the executive committee, the trustees of the Carnegie Foundation commissioned Flexner in November of 1908 to study and report on the schools of medicine in the United States and Canada. In 1910, after having visited all 155 schools, he presented a comprehensive and written report entitled "Medical Education in the United States and Canada" to The Foundation.[1] The Flexner Report remains the single most critical event in the history of medical education in North America. It provided keen insights into the condition of medical education in the early 1900's while emphasizing the need for a scientific basis in medical education. It criticized the existing financial incentives that motivated faculty actions and medical school policies, and it prompted the American public to demand changes in the study and practice of medicine. It exposed the overall nonscientific approach found in medicine and the lack of standardization and inadequacies in medical education. Flexner was a firm proponent of students learning by observation and by doing. He believed that these experiences should help students develop the ability to reason and hopefully understand the background and significance of what they observed. To this end, Flexner proposed that US and Canadian medical schools adhere to the German university tradition of combining strong biomedical sciences with hands-on clinical training.

The medical school curriculum should, in Flexner's view, relate directly to several foundational subjects including anatomy, physiology, pharmacology, bacteriology and physical diagnosis. He felt that these subjects should occupy the first and second years of medical school and relate to the clinical work that occupied the third and fourth years of medical school. Without the scientific basis of medical education inherent in foundation courses, it would be difficult to educate the practitioner to any reasonable level of medicine.

Over the last century, medical education evolved under the framework of the Flexner Report. Modifications over the last twenty-five years have included significant efforts to overcome persistent factual minutiae, archaic assessment practices and regulator constraints. Nearly all medical schools have gone through a period of change by reconstruction of the "standard" curricula and programs. In many cases, curricular changes occurred hand-in-hand with changes in evaluative tools. Examination questions from the National Board of Medical Examiners have evolved from regurgitation of isolated minutiae to now requiring the integration of multiple basic and clinical science disciplines in the context of larger clinical scenarios. Proposed changes to these exams are likely to stress the integration and importance of basic sciences in the practice of clinical medicine.

It has been universally accepted that understanding the normal is the starting point for a comprehension and mastery of the abnormal and that understanding the normal requires a strong background in foundational sciences. The underpinnings of medicine, therefore, depend on the fundamental sciences that furnish "the essential basis of medical education"[1] and provide the student physician with an understanding of the practical importance of the scientific method. This information needs to be combined with a strong foundation in various non-science course work, behaviors, attitudes and skills. There continues to be considerable debate concerning the best way to restructure medical education in light of the exponential increase in scientific knowledge.

Medical education has been and continues to be complicated by turbulence in the healthcare industry. This instability has been linked to intense managed care pressures that force clinical faculty to bring in more income from patient care. In addition, basic science faculty members continue to feel increasing pressure to procure extramural grant support. These pressures impact and modify clinical and research endeavors and have often resulted in faculty having less time for teaching and ultimately negative changes in the curriculum. In some cases, schools have attempted to allow their faculty to specialize by developing predominantly educational positions for a handful of faculty. These medical educators facilitate the delivery of the curriculum along with traditional clinical and basic science faculty members. In other cases, schools have responded by merging classes between different health professions. Classes that combine medical students with physician assistants, dental students or students of other allied health professions attempt to address the disparate needs of the students. These changes, however, have lead to frustration on the part of faculty and stress on the curriculum.

To enhance the development of knowledge, values and skills in contemporary medical education, modernization practices have founded a new series of principles. These principles include concepts that match the way we teach with the way we learn. Current methods include peer evaluations, written assessments, self-assessment, standardized patient examinations, sophisticated simulations and substantial formative feedback. Many, if not all, medical schools have provided small group interactive sessions, interactive laboratories, and other forms of cooperative learning environments. Advances in computer science have allowed new and innovative methods of teaching, including immediate feedback and self-directed and interactive learning experiences. In addition, instructional methods include opportunities for active learning and independent study, both of which drive the concept of lifelong learning. There is little question that the incorporation of these principles has provided a firm basis for student learning.

Flexner underscored the critical importance of devoting adequate time to the teaching of the basic principles of science when he wrote in 1910 about how difficult it was to adequately cover this material in "already crowd[ed]…two years of the curriculum…assigned to them."[1] This observation, of course, has been confounded in 2010 by the monumental increase of information in microbial and immunological diseases and the potential impact of genomics and proteomics on infectious disease and biopharmaceuticals. By the very nature of information overload it is becoming increasingly difficult to find time for a meaningful discussion of the advances in microbiology and immunology while providing the necessary foundation for someone recently introduced to the discipline. Yet, in modern 21st century medicine there is a critical and real need for physicians to have a competent knowledge base in addition to the clinical skills and behaviors needed to competently deliver medical care. Departure from this base will unfortunately result in premature demise of the patient.

Resting on the foundation of Flexnarian principles are modern day courses, including medical microbiology and immunology. These courses use illustrations from the bacterial and immunological diseases of humans that play an important role in understanding medicine and healthcare. Under the medical microbiology and immunology umbrella there are essential requirements for advanced knowledge in the many aspects of microbes, diseases, and host defenses. For example, a change in the Earth's climate may result in an increase in arboviruses, and indeed there is a very real requirement for knowledge related to the agents of war and global terrorism and the innate and acquired defenses that are related to infectious diseases. Unlike the approach to understanding normal structure of the body in anatomy and physiology, medical microbiology and immunology focus on the abnormal, i.e., disease and disease processes, which at the end of the day are the essence and basis of medicine. As aforementioned, these sciences have been integrated in varied forms into the first and second years of medical school and provide a firm basis for a clinical understanding of the scientific method and the etiology of diseases. In addition, the concept of modern hygiene in clinical medicine was devised through an understanding of infectious diseases and the immune response to infection. A thorough understanding of medical microbiology and immunology requires not only knowledge of disease and disease processes and the interaction of microbes and their hosts (human and zoonotic), but also an understanding of the structure, function, and physiology of organisms fundamentally different from humans. It is appropriate therefore that these areas of science be integrated into the 'introductory' years of medical school, providing a sound basis for clinical medicine.

The academic requirements for entry into medical school have varied. In 1910 Flexner championed a strong knowledge of chemistry, biology, and physics. These requisites were to be obtained in a university educational setting. Interestingly, a recent cooperative report from the Howard Hughes Medical Institute and the Association of American Medical Colleges (HHMI-AAMC) has addressed these requirements.[2] The partnership convened a group, known as the Scientific Foundations for Future Physicians (SFFP) Committee, to assess the most relevant scientific competencies for premedical students prior to medical school admission.[2] In short, the SFFP Committee focused on overarching competencies rather than specified prerequisite courses. Premedical students are expected to demonstrate "observational and analytical skills and the ability to apply those skills and principles to biological situations."[2] With the ever increasing amount of knowledge and complexity of the concepts involved in medical microbiology and immunology, it is critical that students entering medical school have a high level of competency to "demonstrate both knowledge of and ability to use basic principles of mathematics and statistics, physics, chemistry, biochemistry, and biology needed for the application of the sciences to human health and disease."[2] The Committee, therefore, *shifted* the emphasis from direct courses to the acquisition of competencies "that equip an individual to learn medicine."[2] The SFFP Committee defined "a competency as the knowledge, skill, or attitude that enables an individual to learn and perform in medical practice and to meet or exceed the standards of the profession."[2] In addition the HHMI-AAMC emphasized "a greater flexibility in the premedical curriculum that would permit undergraduate institutions to develop more interdisciplinary and integrative science courses…."[2]

The SFFP Committee has provided and underscored eight well-defined "competencies *[including learning objectives]* deemed important for medical school education."[2] Included under this umbrella is an array of information related to medical microbiology and immunology. For example, Competency M4, Competency M5 and Competency M6 stipulate that the graduating medical student should be able to, respectively,

> "Apply the principles of the cellular and molecular basis of immune and non-immune host defense mechanisms in health and disease to determine the etiology of disease, identify preventive measures, and predict response to therapies." *[M4]*
>
> "Apply the mechanisms of general and disease-specific pathological processes in health and disease to the prevention, diagnosis, management, and prognosis of critical human disorders." *[M5]*
>
> "Apply principles of the biology of microorganisms in normal physiology and disease to explain the etiology of disease, identify preventive measures, and predict response to therapies." *[M6]*

Inherent in the learning objectives for these competencies are the roots for understanding scientific knowledge and the means to move forward with a *competency-based curriculum*. The report also noted a need for renewal of the curriculum and provides a format for the competency approach to medical education. A similar movement towards a competency-based curriculum has occurred in graduate medical education. The Accreditation Council for Graduate Medical Education (ACGME) has started to include the acquisition of curricular-based competencies as part of the accreditation of post-MD medical training programs within the United States.[3] At a minimum Flexner would be pleased with these changes, which in a sense provide support for modern day medical education and emphasize his focus on "*competency*":

> "From the foregoing discussion, these conclusions emerge: By the very nature of the case, admission to a really modern medical school must at the very least depend on a competent knowledge of chemistry, biology, and physics. Every departure from this basis is at the expense of medical training itself."[1]

In addition to scientific competency Flexner accurately reflects on the "scientific method" and the concept of life-long learning as aspects of professional competency:

> "The sick man's progress is nature's comment and criticism. The professional competency of the physician is in proportion to his ability to heed the response which nature thus made to his ministrations. The progress of science and the scientific or intelligent practice of medicine employ, therefore, exactly the same technique. To use it, whether in investigation or in practice, the student must be trained to the positive exercise of his faculties; and if so trained, the medical school begins rather than completes his medical education. . . A professional habit definitely formed upon scientific method will convert every detail of his practicing experience into an additional factor in his effective education."[1]

In modern day medicine student physicians are committed to life-long learning, using the scientific method to interpret and evaluate both scientific and clinical information. In addition, physicians stay informed about advances in medical knowledge and their integration into patient care by participation in continuing medical education, the technological availability of medical information and research endeavors. Flexner notes that:

> "Educationally, then, research is required of the medical faculty because only research will keep the teachers in condition. A non-productive school, conceivably up to date to-day, would be out of date to-morrow; its dead atmosphere would soon breed a careless and unenlightened dogmatism."[1]

In short, the educational strategies in medical microbiology and immunology in modern medical education provide solid support for professional and personal learning goals that lead to life-long learning and support the *"foundation"* of clinical medicine.

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REFERENCES

1. Medical Education in the United States and Canada. A Report to the Carnegie Foundation. Abraham Flexner. (1910). Retrieved January 20, 2010, from the World Wide Web: http://books.google.com/books?id=DYcaAAAAMAAJ&printsec=frontcover&source=gbs_similarbooks_r&cad=2#v=onepage&q=&f=false
2. Association of American Medical Colleges. (2009). Retrieved January 20, 2010 from the World Wide Web: https://services.aamc.org/publications/index.cfm?fuseaction=Product.displayForm&prd_id=262&prv_id=321
3. Accreditation Council for Graduate Medical Education. (2010). Retrieved January 20, 2010 from the World Wide Web: http://www.acgme.org/acWebsite/home/home.asp

Pharmacology – In the Face of Revisiting Flexner's View of Medical Education

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What are the sciences that constitute the foundation for medical practice?

Pharmacology is clearly one of the basic sciences that form the foundation for medical practice. Our understanding about how at the molecular, cellular, and tissue levels drugs elicit their effects on living organisms (pharmacodynamics) and how these organisms absorb, distribute, metabolize and eliminate (pharmacokinetics) drugs describes pharmacology as a hybrid science that borrows from other foundational sciences (*e.g.,* genetics, molecular biology, cell biology, physiology, biochemistry).

The value of pharmacology is to ensure a scientific basis for therapeutic decisions, and the establishment of benefit versus risk estimates that are based on an understanding of the complex effects of medicines on the body, including how drugs affect living systems and how the body affects drugs.

What are the value and role of the foundational sciences in medical education?

Schmidt and colleagues suggest that student learning occurs through a series of phases.[1] For medical education the first phase includes the development of an extensive basic science knowledge base. In the second phase, students are immersed in clinical situations in which they begin to associate signs and symptoms with particular diseases constructing a coherent clinical knowledge base. Through numerous patient encounters, physicians ultimately rely on pattern recognition against previously encountered cases in diagnosing disease. This is not to say that basic science knowledge is lost. On the contrary, the notion is that the basic science knowledge is encapsulated into the clinical knowledge[2]. Moreover, physicians revert to basic sciences knowledge when faced with an unfamiliar or challenging clinical problem.[3,4] Pharmacology is unique among the foundational sciences of medicine in that it follows students into their clinical years and beyond.

Pharmacology's clinical role and value are self-evident. Indeed its value as an integrative science is also clear. Pharmacology bridges the foundational and clinical sciences. General foundational concepts of pharmacology such as pharmacokinetics, pharmacodynamics and toxicology are grounded in foundational sciences of biochemistry, physiology and anatomy. Such concepts are fundamental to the understanding of therapeutics and to understanding of why one drug might be picked over another in a specific pathophysiological circumstance. Pharmacological identification of how drugs interact with the specific targets (molecular targets within foreign cells such as microbes or within specific cells of organ systems) is foundational science. Using this information to provide a general nomenclature to the major classes of therapeutic agents provides a framework for clinical use of drugs. Finally, an understanding of the scientific methods of evaluating the benefits and risks of drugs is a core concept of pharmacology as a foundational science. Bridges into clinical science occurs under many circumstances, for example: 1) when discussions about individual drugs occur in the context of treating a specific pathology with currently recognized first choices of therapy; 2) when details of approaches of therapy (specific combination therapies that optimize treatment in specific circumstances for example) become the focus; 3) when adverse reactions of drugs emerge during therapy; 4) when drug metabolism affects treatment outcomes. The application of the principles of pharmacology becomes the foundation for therapeutics. Thus, when the discussion of drugs is directed toward selecting a specific drug to treat a specific patient and determining an appropriate dosing regimen, pharmacology evolves into therapeutics and therapeutic decision making.

When and how should these foundational sciences be incorporated into the medical education curriculum?

Pharmacology is a dynamic science [e.g., compared to anatomy]. Without a foundational understanding of the mechanisms by which drugs act, it is more difficult to integrate new information about novel and existing drugs, make informed therapeutic comparisons, safely prescribe complex therapeutic regimens to patients, and discover new therapeutic approaches for the prevention and treatment of diseases. Even so, there is no single best answer to this question of when and how to incorporate pharmacology into the medical education curriculum.

Some believe that for pedagogical reasons, it is important for pharmacology to maintain a unique identity in the curriculum and not be lost through a process of "integration". Unfortunately, some faculty of pharmacology and other foundational sciences feel forced to attempt to maintain discipline identity and avoid integration not for pedagogical reasons but to avoid loss of autonomy, resources, and curricular time. An advantage to this approach is that the learning of the discipline is consolidated in time and effort. This potentially allows for continuity of learning. A disadvantage is that learning of fundamental concepts may be lessened since the student may have difficulty understanding concepts out of context. When science disciplines are somewhat isolated for introduction, use of examples of how the foundational concepts are important for clinical decision making is useful to students. This is relatively easily accomplished with pharmacology because of its natural bridging nature.

Other faculty feel that pharmacology can and should be taught throughout the medical education curriculum. They argue that an advantage of this approach is that fundamental concepts of pharmacology easily work into discussions of anatomy, physiology and biochemistry. For example, integration of pharmacological concepts of agonist and antagonist can easily coincide with discussions of natural ligands, neurotransmitters and hormones. Biochemical concepts of equilibrium and kinetics allow introduction of pharmacological concepts of potency, affinity, intrinsic activity, efficacy and half-life. Discussion of pathologies provides opportunity to begin introduction of potential treatment options with discussions of mechanisms of action of various drug classes. These two levels of introduction of pharmacology traditionally occur within the "preclinical" training. This allows students to begin a general understanding of why specific medications are used for specific circumstances. While pharmacology can be discussed in a more isolated manner, such as is done in a "traditional" curriculum, it can also be well integrated into system-based, organ-based and clinical presentation-based curriculum. A potential disadvantage of the more integrated approach is there is need for more coordination with other disciplines, which presents a considerable logistical challenge. This approach has the added disadvantage of fragmenting the discipline of pharmacology, sometimes to an extent that it is not prioritized by students.

Perhaps an optimal approach is to provide some dedicated focus to the learning of basic principles of pharmacology and to subsequently challenge students to apply these principles to the understanding of therapeutic agents that they will encounter subsequently in an integrated curriculum. Most pharmacologists agree that as a bridge discipline, pharmacology can be the central driving force for integration of curricula. The fact that several other foundational sciences contribute to the basis of pharmacology allows for help in directing what needs to be addressed in these other courses to facilitate learning of pharmacology as well as clinical science. A primary challenge in such an approach may be to continually monitor the pharmacology/therapeutics content and to continually assure that students are dedicating suitable time and energy toward pharmacology learning goals.

Regardless of opinions about the best pedagogical approach to use, pharmacology in the preclinical years can best serve preparing students for the clinic by ensuring that the concepts of drug action and how the body handles drugs are learned by the students in a manner that facilitates use and recall in the clinical years. Pharmacology being taught with a focus on clinical relevance can push pharmacologists out of their comfort zone. Moreover, pharmacologists are often concerned with venturing too far into therapeutics which is understandable since they most commonly have PhDs and, hence, lack the first-hand clinical experience to decide on appropriate choice of prescription for a patient. Still a student must understand how to transfer knowledge about drug action based on a good grasp of physiology, pathophysiology, and microbiology (in the case of antimicrobials) to how to treat patients. Rather than losing its place as a discipline pharmacology is in a unique position to encourage dialogue between basic and clinical scientists as a way to obtain the proper balance between important foundational concepts and clinical relevance.

During the pre-clerkship years, it is likely that assessment will help to drive the desired learning. During clerkship training, the motivation to learn therapeutic agents changes away from student assessment toward patient needs. Students are now helping to care for real people taking real drugs. Suddenly, it matters what drugs do and how they work. What may actually become less apparent during clinical training, however, is the relevance of recalling fundamental principles of pharmacology that were learned in the pre-clerkship years. Too often the approach to prescribing drugs becomes a technical exercise and the host of molecular underpinnings of the drug's action on the body and the body's action on the drugs become a distant memory from the past. This is the time when pharmacologists have an opportunity to re-engage students' minds and help them to recall the importance of fundamental pharmacological principles.

Pharmacology, more than many of the foundational disciplines is unique in that this clinical relevance carries over into the clinical years and beyond. Since higher level learning takes place in context, clinical training settings provide excellent opportunities to discuss advanced concepts of Pharmacology. Working with clinical colleagues, pharmacologists can help with instruction regarding therapeutics. Students oftentimes appreciate more the pharmacology when it is presented in students' clerkships.

What sciences could/should be pre-requisite components of the pre-medical (baccalaureate) requirements?

This question is daunting. The American Medical Association, the Howard Hughes Medical Institute and the American Association of Medical Colleges (AAMC) recently published commentaries on the recommendations for both pre-medical and undergraduate medical education in the areas of biological sciences.[5,6] A national committee of leading medical scientists and educators, formed by the AAMC, is actively reviewing the Medical College Admissions Test (MCAT).[7] The committee's work will take several years. The outcome of that work will not directly address the question of medical school pre-requisites but will undoubtedly influence how pre-medical programs are designed and how undergraduate advisers council pre-medical students about their course of study while obtaining their baccalaureate degrees.

This question of pre-medical requirements has haunted the discipline of pharmacology for a long time (including that part of the discipline concerned with basic science graduate education). At the extreme, some feel that pharmacology could be addressed in pre-medical training and, in fact, this has been the topic of discussion at many conferences. Indeed, there are some college-level pharmacology curricula but many of their students go on to work in the pharmaceutical industry or go to graduate school to pursue pharmacological sciences. With the exception of few notable elective college courses/tracks, no one has figured out how to overcome the politics, economics and imperatives related to pre-medical requirements so that pharmacology could become a major component of the undergraduate science curriculum (at least to the same degree as physiology and biochemistry). Generally, pharmacology is considered a "bridge" discipline of medicine, almost as much as pathology, and is probably better taught in the medical (or professional) school environment rather than shifting it to the undergraduate curriculum.

Looking at the pre-requisites of other sciences for medical school, some pharmacologists in medical education feel the pressure to help "unload" some of the scientific content of the medical education curriculum into the undergraduate learning period. Others feel the need to maintain a relatively un-specified undergraduate education that focuses on helping a person learn how to learn.

On one hand we live in an age of vast understanding of disease and remedy of disease at a greater and greater genetic and molecular level and so it seems that more advanced knowledge of those sciences is essential as prerequisites to medical school. This has encouraged some pharmacology educators to recommend biochemistry, cellular and molecular biology and genetics as pre-requisites. Others feel that a strong understanding of statistics is necessary to improve the use of evidence-based medicine in clinical decision making, public health and treatment regime assessments. On the other hand, the US Institute of Medicine strongly recommends that reductions in medical error need to be considered in all levels of training. This discussion suggests that behavioral science issues such as psychology, teamwork and communication are skills that should be important to entry to medical school. For very integrated medical education curriculum where pharmacology is taught in the first year of medical school, general biochemistry, human physiology and human anatomy would be best required as pre-requisites. In this setting the concepts of statistics and behavioral sciences could be helpful as pre-requisites but not absolutely needed.

Other pharmacology medical educators feel that while a common set of pre-medical requirements that included a wish list of basic sciences plus biostatistics and psychology might make our jobs at the undergraduate medical education level easier, it is unreasonable and even undesirable that students should enter medical school as clones. While some understanding of biological and chemical sciences is desirable, the argument is that medical education should avoid dictating so many pre-med requirements so as to narrow the interests of our future applicants. The "bent arrow" who graduates from college, has a career, and then enters medical school is a valued commodity because what this individual may lack in the immediacy of biological and chemical background, is more than made up for in their motivation, commitment and perspective on life and a career in medicine. Perhaps the best preparation for medical school is the curriculum that teaches a student how to learn and how to question.

What are examples of the best practices for incorporating the foundational sciences into the medical education curriculum?

There is little consensus or pedagogical evidence for best practices on incorporating foundational sciences into medical education. The “strong foundation” approach is repudiated by adult learning theory.[8] This has led to integration being the dominant approach currently. The effectiveness of this approach over others continues to be studied. Work by Novak et al looks at using a conceptual framework during medical learning and is not specific to pharmacology.[9] The study looks at second year medical students’ ability to retain scientific knowledge regarding metabolic alkalosis in the year after it was introduced. Those authors found that use of diagnostic schema or conceptual framework improved retention of knowledge. This would support the notion that integration of foundational sciences may help transference of knowledge into the clinical setting.

Some specific teaching methods are beginning to accumulate data suggesting ways to incorporate foundational sciences effectively in the medical education curriculum. A good example of best practice is the use of simulation. Many computer-based programs allow for students to practice the use of medications in a safe setting. For instance, Szarek and Winston have described the use of computer-controlled mannequins in a PBL curriculum.[10] They suggest that students are able to see the outcome or consequences of their drug choice in a safe environment with a preceptor. Simulation such as this offers a true integration of basic and clinical science at the “patients’” bedside. With respect to pharmacology specifically, recent publications suggested that students unanimously agree that learning through simulation is enjoyable[11,12]. Moreover, learning is facilitated and information is retained.[13] Simulation use, however, is not limited to pharmacology. Other disciplines that have demonstrated effective use of simulation in teaching include physiology and biochemistry[14-16]. Methods on the horizon include sophisticated computer simulations for drug action, the use of avatars, and the use of a patient monitor in the classroom to see effects of drug treatment.

Another best practice has been the use of team-based learning (TBL).[17] Using team-based learning to teach pharmacology compared to traditional methods to second year medical students improves student performance on a summative quiz.[18] Other teaching methods such as problem-based learning (PBL) have their proponents but there is little data as to their effectiveness over other approaches. Indeed there is evidence that PBL-trained students perform less well than students trained in conventional curricula.[19]

The answer to the question of best practices with measured outcomes in pharmacology may best be answered by considering how to reinforce pharmacology using state-of-the-art educational and cognitive psychology theories. For example Irby et al recently came out with recommendations on all medical education which included standardizing learning outcomes and individualizing the learning process, promoting multiple forms of integration, incorporating habits of inquiry, and improvement and progressive formation of professional identity.[20] Norman recently made helpful concrete recommendations on how to improve students’ ability to use a concept learned in one context to solve a problem in a different context (psychologists term this transfer).[21] Briefly, he recommends initial teaching using analogy imbedded in a problem, multiple teaching examples so students can identify similar concepts, followed by students practicing with multiple dissimilar problems spread out over time. Pharmacology medical educators might be aided by a national dialogue of pharmacologists involved in pre-clerkship and clerkship initiatives and the creation of a repository of examples of effective design strategies. The authors are unaware of any such dialogue or repository that specifically addresses pharmacology. This is a subject that could be addressed by national or international pharmacology organizations such as the American Society for Pharmacology and Experimental Therapeutics, Division for Pharmacology Education or organizations whose primary mission is to provide professional development for all who teach the sciences fundamental to medical practice such as IAMSE.

REFERENCES

1. Schmidt HG, Norman GR, Boshuizen HPA. A cognitive theory on medical expertise: theory and implications. *Acad Med.* 1990; **65**:611–21.
2. de Bruin ABH, Schmidt HG, Rikers RMJP. The Role of Basic Science Knowledge and Clinical Knowledge in Diagnostic Reasoning: A Structural Equation Modeling Approach. *Acad Med*. 2005; **80**:765–773.
3. Woods, NN, Brooks, LR, Norman, GR. The role of biomedical knowledge in diagnosis of difficult clinical cases. *Adv in Health Sci Educ*. 2007 **12**:417-26
4. Woods, NN, Neville, AJ, Levinson, AJ, Howey, EH, Oczkowski, WJ, Norman, GR. The value of basic science in clinical diagnosis. *Acad Med*. 2006 **81** Supp1: S124-7.
5. Emanuel, EJ. Changing premed requirements and the medical curriculum. *JAMA*. 2006 **296**:9, 1128-1131.
6. AAMC-HHMI Committee. Scientific foundations for future physicians. Committee co-chairs Alpern RJ, Long S. Washington, DC: American Association of Medical Colleges; 2009.
7. AAMC MR5: 5th Comprehensive review of the Medical College Admissions Test (MCAT). American Association of Medical Colleges: 2010. http://www.aamc.org/programs/mr5/start.htm [Accessed May 8, 2010]
8. Knowles M. The adult learner: a neglected species. Houston TX: Gulf Publishing Company; 1973.
9. Novak K, Mandin H, Wilcox E, McLaughlin K. Using a conceptual framework during learning attenuates the

loss of expert-type knowledge structure. *BMC Medical Education.* 2006 **6**:37.

10. Szarek JL, Winston I. Human patient simulators in medical students' preclinical curriculum; Thirunarayanan MO, Perez-Prado A, Integrating technology in higher education. Lanham MD: University Press of America; 2005.
11. Seropian M, Dillman D, Lasater K, Gavilanes, J. Mannequin-Based Simulation to Reinforce Pharmacology Concepts. *Sim Healthcare.* 2007 **2:**218–223.
12. Seybert AL, Kobulinsky LR, McKaveneya TP. Human Patient Simulation in a Pharmacotherapy Course. *Am J Pharmaceut Educ.* 2008 **78:**1-8.
13. Gordon JA, Brown DFM, Armstrong EG. Can a Simulated Critical Care Encounter Accelerate Basic Science Learning Among Preclinical Medical Students? A Pilot Study. *Sim Healthcare*. 2006 **1:**13-17.
14. Euliano, TY. Teaching respiratory physiology: clinical correlation with a human patient simulator. [Electronic version] *J Clin Monit Comput*. 2000 **16:**465–470.
15. Euliano, TY. Small group teaching: clinical correlation with a human patient simulator. [Electronic version] *Adv Physiol Educ*. 2001 **25:**36–43.
16. Nandate K, Abola, R, Murray WB, Whitfield C, Lang C, Sinz E. Simulation of Diabetic Ketoacidosis for Cellular and Molecular Basics of Medical Practice. *Sim Healthcare*. 2009 **4:**232-236.
17. Michaelsen LK, Parmelee DX, McMahon KK, Levine RE. Team-based learning for health professions education. A guide to using small groups for improving learning. Sterling, VA: Stylus Publishing; 2008.
18. Zgheib NK, Simaan JA, Sabra R. “Using team-based learning to teach pharmacology to second year medical students improves student performance”, *Medical Teacher*. 2010 **32**:105-107.
19. Patel VL, Groen GJ, Norman GR. Effects of conventional and problem-based medical curricula on problem solving. *Acad Med*. 1991 **66**:380–389.
20. Irby DM, Cooke M, O’Brien BC. Calls for reform of medical education by the Carnegie Foundation for the Advancement of teaching: 1910 and 2010. *Acad Med*. 2010 **85**:220-227.
21. Norman GR. Teaching basic science to optimize transfer. *Medical Teacher* 2009 **31**: 807-11.

Physiological Perspective of the Role and Value of Basic Sciences

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Introduction

It is important to state the central tenet of this paper: A firm understanding of the basic sciences is necessary for the intelligent practice of medicine. It is also important to acknowledge our inherent conflict of interest in writing this paper. As physiologists, we have chosen to make medical student education a major component of our professional career. Our bias is unavoidable, and to deny it would be to deny our professional identity.

As with most professionals, physicians function in multiple roles, including technologist, scientist, and humanist. Importantly, these roles are not mutually exclusive. This paper will advocate the role of the physiological sciences in developing the physician as scientist, but in doing so we do not seek to dismiss the other important roles of the physician, nor the contributions of the physiological sciences to those roles.

There are two aspects to the physiological sciences: physiology and scientist. Too often, the discipline is identified by the content (physiology) and not the role (scientist). The physiology aspect centers on a knowledge base which emphasizes principles of integration and control. The same efferent control system is responsible for shifting from the steady-state balance of homeostasis to an adaptive response which enables an organism to survive when the environmental situation changes. Physiological control emphasizes why, for example, the normal homeostatic heart rate of 72 beats per minute is inappropriate during aerobic exercise.

The scientist role of our discipline is equally as important in the development of a physician. This aspect of the preclinical curriculum is no less important than the knowledge fund, but it generally receives much less attention. Competent physicians must be able to evaluate research outcomes and incorporate them into their clinical practice. In the past 20 years, identifying the research which leads to best clinical practices has been formalized as "evidence-based medicine". Physicians in their role as scientists have to understand research processes and topics.

What Sciences Constitute the Foundation for Medical Practice?

The sciences that describe the body constitute the foundation for medical practice. This description exists at many levels: genetic, cellular, organ, organism, and population. The discipline of physiology describes function at each level from genetic to population. Most commonly, physiology is concerned with the function of organs and organisms. Physiology, however, does not exist in isolation. A proper understanding of physiology requires the context provided by the anatomical sciences, both gross and microscopic. In many allied health programs, instruction in anatomy and physiology are paired in recognition of this fact. Digestive and metabolic physiology are inseparable from biochemistry. Physiology, in turn, is a foundational science for other disciplines. The physiology of the various organs interacts with aspects of pharmacology and pathology. In a relatively recent development, the essential involvement of immune system mediators in both normal function and in disease is being better characterized. It is this interaction among the basic sciences that is emphasized in systems-based educational programs.

What is the Value and Role of Foundational Sciences in Medical Education?

Each of the basic sciences is a freestanding discipline in its own right with its own role and perspective. The anatomical sciences emphasize location in three dimensions, with the emphasis on both the details of an individual structure and its relationship to other structures in the body. Physiology deals with the same structures, but from a different perspective. Physiology emphasizes the organization and control of bodily function, both at the individual organ level and in dealing with the interactions between multiple organ systems. Such an approach has made it clear that organ system function varies over time. The body constantly balances the need for homeostasis with the ability to adapt to changing environment, such as caused by the introduction or the restriction of nutrients. These interactions are complex and are most commonly described in graphs and concept maps. It is not a coincidence that the most common x-axis used in physiology deals with some aspect of time. Physiology encourages students to embrace the huge quantities of data that are encountered in a typical patient presentation and to identify underlying themes that make sense of the observations. This ability to juggle data and context is essential when developing the hypotheses necessary to the clinical reasoning process.

The value of the preclinical sciences is that they promote an understanding of the body from multiple perspectives. There are times where the anatomical perspective provides insight and an enhanced ability to interpret symptoms such as localized pain. There are times that a physiological perspective is necessary to interpret a vital sign such as an elevated heart rate. Each of the preclinical sciences can make a similar argument, and it is the availability of the multiple perspectives provided by the basic sciences that allows a well-educated physician to interpret correctly complex clinical cases.

When and how should these foundational sciences be incorporated into the medical education curriculum?

Foundational sciences should be incorporated into the medical education curriculum in a manner which best facilitates their acquisition and retention. How to best facilitate acquisition and retention, however, is the subject of ongoing debate. On the acquisition side, learning theory shows that repetition enhances recall. Curricula should have planned redundancies, and the “spiral curriculum” exploits this approach. Layered on top of learning theory is the debate about the residual value of information that is learned and later forgotten. Something learned once, then forgotten, is often easier to learn the second time. Although some of the concepts in the preclinical years may be forgotten, they will be mastered more quickly upon second exposure in the clinics. On the retention side, one key tenet of adult learning theory is that information is retained best when it is integrated with prior information, and presented in the context in which it will be used. The problem-based and case-based approaches are designed in part around the ability to place knowledge in the appropriate context.

How to best achieve these aims for physiology has resulted in this discipline being represented in a wide variety of approaches to preclinical education. In the post-Flexnerian era, physiology was usually presented in a course during the preclinical years, occasionally combined with neurophysiology, endocrinology, or some other preclinical science. More recently, the evolution of integrated curricula resulted in the content traditionally defined as physiology often being a component of systems-based preclinical instruction. The lack of a single optimal curricular approach in US medical schools reflects both the complexity of the cognitive processes and the constraints in resources faced by each individual institution. The educational approach is optimized to the constraints (space, personnel other resources) faced by individual institutions.

What Sciences should be a Prerequisite of a Pre-Medical Curriculum?

The dividing line between the preclinical medical curriculum and premedical baccalaureate curriculum is artificial and arbitrary. The diversity of educational programs around the globe that do not include an undergraduate experience yet successfully prepare clinicians is evidence of this ill-defined boundary. Nevertheless, biology and chemistry certainly are core sciences necessary to pursue clinical training, and it is probably irrelevant if they are mastered as part of undergraduate training or the initial years of a dedicated medical curriculum. In preparation for physiology, an appreciation of the anatomical sciences and biochemistry provide a foundation on which physiological principles can be elucidated.

What are the Best Practices for Placing Foundational Sciences into the Medical Curriculum?

Educational research is fraught with inherent limitations. In terms of experimental design, confounders include the cohort effect and the Hawthorne effect. The cohort effect results from the fact that no two groups of students are identical, and consequently assessing the effects of an impact on one group of students versus another does not always yield clear differences. In addition, innovation alone enhances learning (see description of the Hawthorne Effect). Adding to the inherent design limitations of educational experiments, the desired outcome of a medical curriculum is exceptionally difficult to quantitate. Consequently, the best practices in incorporating the foundational science into medical education are defined pragmatically as those that work. In some environments, it is a faculty-centered model, such as the discipline-based approach proposed in the Flexner report. In other environments, it is a student-directed model such as problem-based learning. In all curriculum models, there is a constant tension between the breadth of content expectations, and the value of deep learning, all constrained by time limitations.

Conclusion

It is an interesting time to consider the role and value of basic sciences and medical education. The absence of an idealized model for medical education raises the question of whether the curriculum really has an impact. Many argue, for example, that our students' learning is independent of the curriculum, or in a worse case scenario, in spite of the curriculum. The Flexner model, which has guided the past century of medical education in the United States, is being increasingly challenged. In these uncertain times, it is important to remain grounded in the central duties of educators: to create an environment that enhances learning, to provide direction for the learners, and to model appropriate learning behaviors.

THE NEUROSCIENCE PERSPECTIVE

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What Sciences Constitute the Foundation for Medical Practice?

The Flexner Report clearly showed the practice of medicine has its foundation in the basic sciences. Empirical observations gave way to scientific inquiry as technological advances took place. Anatomy, chemistry and physiology can, arguably, be considered the original basic sciences that spawned histology, biochemistry, cell biology, microbiology and pathophysiology. More recently, pharmacology and the rapidly expanding field of genetics are now considered essential basic sciences for the study of medicine. Neuroanatomy is a traditional basic science that was a natural outgrowth of the study of gross anatomy. The authors recognize that since the 1970's many medical "neuroanatomy" courses have transformed into "neuroscience" courses that incorporate new found knowledge derived from immunohistochemical and molecular techniques. Therefore, the traditional neuroanatomical study of spinal cord pathways, the brainstem, cerebellum, diencephalon, basal ganglia and specialized cortical functions is now supplemented with our growing molecularly-based knowledge of neurotransmitter and receptor functions and their interactions with newly developed pharmaceuticals. As shall be mentioned later, a neuroanatomy course that is heavily weighted towards neuroscience does not necessarily benefit the undifferentiated undergraduate medical student.

What is the Value and Role of Foundational Sciences in Medical Education?

This fact was firmly established 100 years ago by Dr. Flexner and is still valid for the future of medicine. Although neuroscience research is rapidly advancing our knowledge base, there is still a need for traditional neuroanatomy to be a substantial part of any "neuroscience" course. As an organ system that pervades the entire body, it is *sine qua non* neuroanatomy be a part of any medical curriculum. Furthermore, the study of neuroanatomy promotes the development of deductive reasoning skills that are needed to practice medicine, because basic neuroanatomical knowledge, without the use of CT scans or MRI, can still be used to determine the site of a central or peripheral nervous system injury. Perhaps even more important, deductive reasoning can be used to decide if a set of symptoms and signs are explained by a lesion seen on an imaging study.

To date, most of the advances in neuroscience knowledge, other than some of the pharmaceutical aspects, have yet to be translated into bedside practice. Despite the large amount of neuroscience research being performed (the 1990's were even declared "The Decade of the Brain"), the central nervous system (CNS) continues to resist efforts to reverse spinal or cortical injuries and CNS repair remains enigmatic. Neurologists and neurosurgeons, even though they now have the ability to visualize CNS anatomy more clearly than ever via CT, MRI and fMRI techniques, are still frustrated in their inability to offer effective treatment for many patients. However, the future holds much promise as our fundamental understanding of so many previously untreatable diseases, e.g., multiple sclerosis and Parkinson disease unfolds from the weight of millions of research dollars.

The topic of neuroscience can be introduced at any point during the first two years of a four-year medical education, or early in year three of a six-year curriculum. Since this topic constitutes a complete organ system, it can be a stand-alone course in medical schools that have a "traditional" discipline-based curriculum, as well as in those that use an integrated or organ system-based curriculum. The length of neuroscience courses in the United States varies from a full 18-week semester, where it is taught concurrently with three or more other courses, to an eight-week full immersion course usually running concurrently with an "art-of-medicine" course, e.g., introduction to clinical medicine or physical diagnosis.

Ideally, a neuroscience course should partially overlap with a gross anatomy course. Simultaneously teaching the head and neck portion of gross anatomy while the neuroscience course is presenting the brainstem makes for an integrated approach to learning cranial nerve function. This method eases the student's ability to take the peripheral/functional aspects of cranial nerves, taught in gross anatomy, across the subarachnoid space into the brainstem where the neuroscience course presents the typical strokes that impair cranial nerve function. This approach greatly enhances the integration of the two courses. In addition, neuro-histology, -embryology, -radiology and -physiology can be incorporated into the neuroscience course at the appropriate points to help the student integrate these disciplines with the nervous system. In some medical schools, behavioral science is also taught as a part of a neuroscience course; if this is the case, the hybrid neuroscience course is usually presented early during the second year of a four-year curriculum.

The authors have found that even before a neuroscience course has started, presenting clinical scenarios involving peripheral nerve injuries during the extremities portions of a gross anatomy course sets the stage for the study of the CNS. All too often, peripheral nervous system injuries are left to the purview of gross anatomy courses and texts, and are not adequately covered in neuroscience courses and texts. It is important to recognize that the peripheral nervous system should not be ignored in a neuroscience course, since reviewing typical peripheral nerve injuries reinforces the neurology concepts needed for passing medical board examinations and, more importantly, makes for a more competent medical resident and physician.

Probably more than most basic science disciplines, the study of the nervous system lends itself nicely to teaching via clinical scenarios. The somatotopic organization within the central nervous system allows logic to be applied in determining the site of a lesion or the functional deficit resulting from a central or peripheral nervous system injury. Knowledge gained from a neuroscience course can be directly applied to clinical scenarios, even before the medical student has had exposure to their clinical rotations, since the student should have acquired the ability to diagnose common CNS or peripheral nervous system injuries.

What Sciences should be a Prerequisite of a Pre-Medical Curriculum?

Although many of the basic sciences have a foundation course presented at the undergraduate level, e.g., biochemistry, cell biology, physiology, histology, genetics, and, occasionally, comparative anatomy, there are not as many universities that have an undergraduate neuroanatomy/neuroscience course. If it is offered, the subject is usually taught from a neuroanatomical approach. (It should be noted that many universities offer a variety of graduate neuroscience courses.) Is an undergraduate neuroscience course necessary for success in medical school? That is difficult to determine. The opinion of the authors is "no", since a medically-oriented, neuroanatomical approach to the subject is not conceptually difficult, and "lesion hunting" is a logical process that can be easily grasped by the highly motivated medical students. If a medical neuroscience course is more molecular- vs. anatomical-based, the prevalence of undergraduate cell biology and biochemistry courses should provide a sufficient background to apply the concepts to the nervous system.

The experience of the authors shows that what's lacking in many medical matriculates is a basic knowledge of cranial nerve function and head and neck embryology that would make understanding the brainstem unit of a neuroscience course easier to grasp. Therefore, a robust undergraduate comparative or human anatomy course would be more beneficial to a greater variety of health-related professions students than a neuroscience course whose approach is more molecular in nature. Furthermore, an embryology course, that is classical vs. molecular in nature, would not only teach how the dermomyotome is formed and is inexorably linked to it's spinal nerve, it would also teach brachial arch formation and their cranial nerve supply. Another added benefit of studying classic embryology would be the study of sectioned material, e.g., the 10mm pig embryo, so that students have practice in mentally forming three-dimensional reconstructions. Experience in using the "minds eye" would be of great benefit when medical students, residents and physicians examine CT scans and MRI's.

What Are the Best Practices for Placing Foundational Sciences into the Medical Curriculum?

There is probably no other basic science course that has a more varied curriculum in medical schools around the world as a neuroanatomy/neuroscience course. The gamut ranges from solely a traditional neuroanatomical approach, to a mainly neurophysiological/molecular approach, with any blend of these two extremes. The large number of texts whose content ranges from basic neuroanatomy, to clinically-based applications, to molecular/physiologic approaches attest to this. Over the past two decades, the basic neuroscience concepts needed to prepare a well-trained, undifferentiated, undergraduate medical student has been eroded by an approach to the subject that is too in depth and geared more for graduate students than medical students. The authors feel this too detailed approach to the material is more prominent in neuroscience than most other basic science fields. Therefore, in order to prevent the continual addition of large amounts of new content, neuroscience course directors must avoid adding additional information to their courses that is not clinically applicable at the current time. Until there are major breakthroughs in translational neuroscience research, knowledge of complex molecular events can't save a patient's life.

Unlike gross anatomy courses, it is not essential that the anatomical aspects of the nervous system be taught using cadaveric material. There are numerous neuroanatomy atlases that provide the images necessary to learn CNS anatomy. Furthermore, images of cadaveric material are now supplemented with CT scans and MRI images that give the undergraduate medical student an excellent exposure to neuroradiology. Laboratory sessions for neuroscience courses should, ideally, be organized around a neurosystems approach that uses clinical cases to reinforce the didactic portion of the course. For example, Radiology faculty and residents can present clinical cases using CT scans and MRI's. Pathology faculty and residents can bring neuropathological specimens to present an introduction to neuropathology and provide visual reinforcement for the various lesions that produce CNS deficits.

Neuroscience has an advantage over most basic science courses in that it can be taught almost exclusively from a clinical perspective. Once students have mastered the basic neuroanatomical pathways, cortical regions and CNS blood supplies, a functional deficit can be presented to students for them to localize the lesion within the central or peripheral nervous systems and vice versa, a nervous system lesion can be presented to the student and they can describe the functional deficit. The authors feel it is imperative that any neuroscience/neuroanatomy course be presented from a clinical approach so that a general practitioner can know when to triage a patient and send them to an emergency department or trauma center. It must also be remembered that only a small percentage of medical students select neurology or neurosurgery as their residency choice. Therefore, it is even more important to teach the subject from the perspective of what is needed by a primary care physician and not a neurologist, neurosurgeon or graduate student.

Another way to consolidate neuroscience knowledge for medical students is to have patients presented during Neurology Grand Rounds that have "classic" neurological problems that can be understood by freshmen medical students, e.g., upper or lower motor neuron lesions, Parkinson disease, or Horner syndrome. During the presentation the neurologist can explain the reasoning and tests ordered based on the differential diagnosis, while the neuroradiological and neuropathological aspects of the case can be presented by a radiologist and pathologist. Seeing these patient presentations literally brings neuroscience to life and is readily appreciated by the medical students. If live patients can't be used, then videos of patients can be provided (only if the patient has signed the appropriate consent forms!). Our experience supports live patients as a far superior learning experience, especially when a clinician takes on the challenge of seeing the patient with an unknown problem in front of the medical students. The physician/patient discourse on how the patient history and physical exam leads the clinician to localize the lesion and obtain the diagnosis reveals to the students the logic of the clinician's thought process.

Testing the student knowledgebase is important and examinations should preferably use clinical scenarios. Short National Board of Medical Examiners (NBME)- or United States Medical Licensing Examination (USMLE)-style vignettes can be written that use only prose or are supplemented with a neuroanatomical or neuroradiological image. Using this method of testing helps ensure you are gauging the depth of student understanding vs. their ability to regurgitate memorized facts.

In the United States, the USMLE and American Association of Medical Colleges (AAMC) want to blur the artificial split between the basic sciences and clinical rotations. Medical curriculum committees need to determine ways the basic sciences can be reinforced in the clinical years, and more clinical exposure provided to freshmen and sophomore medical students. It has already been mentioned that it is relatively easy for patients with classic neurological deficits to be presented to first and second year medical students during Neurology Grand Rounds or other clinical sessions within the neuroscience course. Placing neuroscience material into the third and fourth years of medical school, without occupying an inordinate amount of basic scientist time, can be accomplished by providing video recordings of essential or confusing neuroscience topics (e.g., spinal cord pathways, autonomic nervous system function, the pyramidal and extra-pyramidal motor systems) that can be viewed by the junior or senior students during their neurology and/or neurosurgery rotation. Neuroanatomical topics would not need updating once a perfected presentation is archived, but neuropharmacological topics would require updating as new breakthroughs in treatments become available. Furthermore, the use of on-line neuroscience-related resources, e.g., MedEd Portal (managed by the AAMC) could be accessed by medical schools around the world. It is critical that this information be primarily review material and not new basic science information for the students. For instance, students in the clinical years have to learn the intricacies of treating strokes and facial nerve palsies, and if they have not learned to recognize them beforehand, the task will be overwhelming.

Finally, the authors are concerned about who will be qualified to teach the fundamental sciences in the near future. Now that many Ph.D. graduates have been trained in molecular techniques, there will be a natural desire for these new faculty to teach the neurosciences within their comfort zone of using a molecular approach to the subject and, unfortunately, sometimes overemphasizing their area of research. It is not unusual to receive neuroscience course evaluations where students state that many of the lecturers talked more about their research interests vs. adequately covering the lecture objectives. This problem is not unique to neuroscience since it's happening in many other basic science fields, e.g., physiology. The problem will continue to grow in the United States and, perhaps, other countries because there are few new Ph.D. graduates who have a comprehensive understanding, or even a basic overview, of their discipline. So it is critical at both the local and national levels to have clinicians and basic scientists work together to fashion the best framework to educate our future clinicians in neuroscience. Only together can we strike the best balance of what they need now and what they may need to know in the future as research leads to new treatments.

Role of Basic Sciences in 21st Century Medical Education: An Asian Perspective

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Introduction

Historically, the development of western style medical education in several countries of Asia was closely linked to the establishment of medical schools and initiated quite early in the 20th century by the colonial governments that ruled these countries at the time.

Medical Education in Asia: Our Colonial Heritage

Asian countries such as Hong Kong, India, Malaysia, Myanmar, Singapore and Sri Lanka all inherited the British system of medical education. Others, such as Cambodia, Laos and Vietnam, inherited the French system, whereas medical education in Indonesia was closely linked to the Dutch system.[1,2]

The US medical education system had a strong influence in Korea (South), the Philippines, Taiwan and Thailand mainly because of the strong military arrangements existing in these countries; it also had some influence in China mainly through the work of the early Christian missionaries (for example, establishment of the Peking Union Medical College in Beijing, then known as Peking).

Although medical education in Asia had been strongly influenced by British, French, Dutch and the US systems of medical education, many countries of Asia have now become less dependent on their past colonial links. Much of Asian medical education is now based on *global trends* which provide evidence of best practices (i.e. Best Evidence Medical Education) in curriculum design and delivery.

Role of the Basic Sciences in 20th Century Medical Education: A Case of Self-Serving Science without Boundary Markers

The role of the basic sciences in medical education advanced and flourished greatly in the early period of the 20th century following the submission of the Flexner report. Many Asian medical schools also incorporated the basic medical sciences into their undergraduate curriculum by adopting and adapting various systems of western medical education.

The Flexner Report

In 1910 Abraham Flexner, a research scholar from the Carnegie Foundation for the Advancement of Teaching, submitted a highly influential report on the state of medical education in medical schools of the USA and Canada.[3] Flexner advocated that medical education in the USA and Canada should, not only be university-based, but also be strongly underpinned by a scientific foundation (basis) of medical practice. Flexner had envisaged that medical students would readily acquire basic science knowledge, concepts and principles through learning of the basic medical science disciplines in their early ‘pre-clinical’ years and, subsequently, can apply scientific thinking and scientific skills in understanding and resolving medical problems encountered in their clinical education.

Flexner’s report provided the main impetus for designing the undergraduate medical curriculum with a foundational pre-clinical phase, aimed primarily at providing medical students with the scientific basis (foundation) of medical education, followed by “…*a clinical phase of education in academically oriented hospitals, where thoughtful clinicians would pursue research stimulated by the questions that arose in the course of patient care and teach their students to do the same*”.[4] Flexner’s advocacy led to the rapid establishment of basic science departments in medical schools, as well as to the intensive recruitment of basic scientists to teach the basic medical sciences.

Thus, the Flexner advocacy unintentionally created two distinct phases in medical education, commonly referred to as the pre-clinical and clinical divide.

Initial Impact of the Flexner Report: Emergence of Departmental Silos

Flexner's recommendation strongly influenced curriculum reforms around the world, including much of Asia. For many decades following the report, medical schools adopted and implemented the concept of a pre-clinical ('scientific') and clinical phase in medical education, resulting in a highly discipline-specific curriculum design which neither promoted nor encouraged cross-talk between and across the medical disciplines, i.e. there was a lack of curriculum integration across the medical disciplines. Instead, each discipline had its own vested interests to protect, and this widened the pre-clinical/clinical divide further. As a consequence, departmental silos became firmly entrenched and responsible for the delivery of highly discipline-specific basic science knowledge to medical students in the pre-clinical years. Interestingly, the late Miller (1961), one of the doyens of medical education, had already cautioned about the need to ensure "*unity in diversity*" in medical education.[5]

"*Each department is responsible for some part of the education of a medical student, but no department should forget that it is no more than a part of the whole which is responsible for the education of a whole student and the fulfillment of the overall objective.*"

Basic Sciences in 20th Century Medical Education: Serious Emerging Concerns

Several educational shortcomings arising from the increasing pre-clinical / clinical divide soon became more apparent. Firstly, the delivery of basic science knowledge in medical education became driven more and more by the academic content of each discipline, as well as the research initiatives of the basic science teachers. Thus, much of basic science teaching focused on in-depth scientific facts rather than on the relevance of the discipline to and in the context of contemporary medical practice. Clinical teachers also complained that students seemed to have a poor grasp and recall of and, therefore, the inability to apply basic science knowledge, concepts and principles acquired in the preclinical years to medical problems encountered in the clinics.[6] These issues are well described by Pawlina.[7]

"The lack of clinical relevance, lack of integration, and the division of pre-clinical and clinical instruction caused dissonance and dissatisfaction among clinical teachers and students alike."

Medical education in Asia was also confronted with the same predicament, as it had inherited the same problems and shortcomings associated with the oft lamented creation of the 'pre-clinical / clinical Divide'. So medical schools in Asia also seriously considered the need for further reforms and refinements in their undergraduate medical curriculum to address the concerns highlighted.

Basic Science Teaching in 20th Century Medical Education: The Tipping Point

"*Too often Ph.D.- basic scientists have set themselves apart from their M.D. colleagues and the clinical activities of the health center and acted more or less as isolated research institutes, to the extent that the question is now often raised, Do we indeed need the basic scientists? …… Their lectures are accurate but sterile and insensitive to the legitimate needs and interests of medical students.*"[8]

Abrahamson' another doyen of medical education, specially drew attention to "*curriculosclerosis…[as]…an extreme form of departmentalization…[which]…in its disease state, becomes a stifling, inhibiting influence on normal development and function of the curriculum.*" [9] By mid to late 20th century, and even into this new millennium, there emerged a persistent chorus of highly critical comments expressing mainly dissatisfaction with the role of the basic sciences in medical education which reached the tipping point! [10-13]

A global consensus then emerged that there should be a thorough re-evaluation of the role of the basic sciences as the scientific foundation of medical education in the 21st century. Indeed the timing is appropriate, considering the fact that the year 2010 is one century (100 years!) after the Flexner report was first published. [4,8,12-16]

ROLE OF THE BASIC MEDICAL SCIENCES IN 21ST CENTURY MEDICAL EDUCATION: FLEXNER RE-VISITED AND RE-AFFIRMATION OF ITS FUNDAMENTAL ROLE

The role of the basic sciences in 20th century medical education came under much flak mainly because of a lack of contextualization and, therefore, relevance in the delivery of the basic sciences to medical students in the pre-clinical years. Much of the teaching then seemed to have ignored the clinical significance of the respective basic science disciplines to the practice of clinical medicine. As a consequence, students found it difficult to apply and to recall their basic science knowledge when they enter into clinical education This unsatisfactory state then became a highly contentious issue in medical education.[6,7] However, "*The critical relevance of basic science to medical practice is emphasized by all of the accrediting agencies*"..[17]

Medical Education Reforms: Asia in Pursuit of a More Globalised Medical Curriculum

There is global consensus that the highly discipline-specific, non-integrated and divisive curriculum of 20th century medical education is neither adequate nor appropriate for the educational preparation of today's medical students to become tomorrow's competent, caring and ethical doctors of the 21st century. Consequently, many reforms in medical education have been initiated and implemented over the past few decades, particularly in the U.K., U.S.A. and Canada.[18]

Medical schools in Asia have also been in search of a more appropriate curriculum model for the education of their students in the 21st century. In the past two decades or so, medical education in much of Asia adopted and adapted many of the curriculum reforms implemented in U.K., U.S. and Canadian medical schools. For example the *SPICES* curriculum model, proposed by Harden, Sowden and Dunn in 1984, which emphasizes student-centered, problem-based and integrated learning had strong appeal to and was readily adopted by many Asian medical schools.[19]

Several other pedagogical initiatives implemented and adopted globally have also strongly influenced curriculum reforms in medical education in Asia. The initiatives include the concept of an outcome-based education, and well-defined outcome-based statements on professional competencies which medical students must acquire.[20] These outcome-based statements have been crafted, documented and implemented by some leading medical schools and professional organizations like the ACGME, CanMEDS and the GMC (see Medical Teacher, 2007 for a more detailed description).[32] Furthermore, the Global Minimum Essential Requirements (GMER) project in collaboration with 8 leading medical schools in China, the establishment of three FAIMER Regional Institutes in India and the conduct of the Essential Skills for Medical Educators (ESME) course annually, since 2006, at the Asia-Pacific Medical Education Conference (APMEC) held in Singapore have all contributed to the curriculum reforms undertaken in many Asian medical schools.[21, 22]

Another major force strongly influencing the design and delivery of medical education in Asia is the intensive drive to globalize healthcare in several Asian countries as an economic imperative. This has created a medical tourism industry with an estimated worth of US$60 billion and growing.[23] In order to impress and attract international patients with their high standards of clinical care and practice, international accreditation by Joint Commission International (JCI) serves as the yardstick.[24] Thus, in order to sustain and enhance the trend in globalized healthcare, medical education in many Asian countries will now be more closely aligned to the western system of medical education, in fact towards a more globalized curriculum.

Flexner Re-visited: Re-Affirmation of the Role of the Basic Sciences in 21st Century Medical Education

"…*a comprehensive understanding of the basic sciences is* ***essential*** *for the future of medicine as a profession, as physicians will be expected to contribute to the development of* ***clinically relevant*** *basic science understanding and to bring this knowledge to the bedside through the development of new diagnostic and therapeutic options for patients."*[17]

"*Given that medicine is rooted in fundamental scientific principles, both human and biological sciences must be learned in relevant and immediate clinical contexts* ***throughout*** *the MD education experience."*[25]

"*The graduate will be able to apply to medical practice* ***biomedical scientific principles****, method and knowledge…."* [26]

In the last decade or so, there has been strong re-affirmation of the fundamental and critical role of the basic sciences in 21st century medical education. [15] (see quotations above). Moreover Cohen, in reviewing Flexner's recommendations, has also clearly expressed that *"…commitment to the scientific foundations of medicine… remain as valid as ever*."[27] In the recently published AAMC-HHMI report it was also pointed out "…*that the basic science content in the medical school curriculum has not kept pace with the expanding scientific knowledge base of medicine and fails to reflect accurately the importance of the sciences in the practice of medicine*."[28] Other national and international reports have also addressed the critical role of the basic science as the building blocks of medical science and their vital role in the effective practice of medicine. [25, 26]

The re-affirmation of the fundamental and critical role of the basic sciences in 21st century medical education poses a major challenge to medical education around the world; it raises the important question 'How should the medical curriculum be re-designed to effectively deliver the basic sciences as the scientific foundations of medicine in the 21st century'?

ROLE OF THE MEDICAL BASIC SCIENCES IN 21st CENTURY MEDICAL EDUCATION: SHIFTING THE EDUCATIONAL PARADIGM

Just as there is a need for an educational paradigm shift from the highly teacher-directed instruction (teaching) to student-centered learning (learner-centered education), [29,30] there is also now an urgent need for a major paradigm shift from the teaching of intensive, in-depth and non-contextual scientific facts in the basic medical sciences to student acquisition of scientific competencies resulting from the learning of basic science knowledge, concepts and principles relevant to and in the context of 21st century medical practice, i.e. in the context of the diagnosis, treatment and prevention of disease in the 21st century. [7,25,26, 28,31]

Thus, there is now strong re-affirmation and global consensus that the basic medical sciences are even more important than ever before as the scientific foundation of 21st century clinical medicine. However, basic medical science educators around the world must have clear understanding and insights of the paradigm shift required to deliver basic science knowledge, concepts and principles to medical students in 21st century medical education. It is only in this context and with such prevailing mindsets that the significant and critical role of the basic sciences can be sustained and its health ensured in 21st century medical education.

Design and Delivery of the Basic Medical Sciences in 21st Century Medical Education: What Should Students Learn?

In the document Tomorrow's Doctors, the section on 'Outcomes for graduates' ('Outcomes 1') specifically refers to 'The doctor as a scholar and scientist' under which it is clearly stated that "*The graduate will be able to apply to medical practice biomedical scientific principles, method and knowledge relating to anatomy, biochemistry, cell biology, genetics, immunology, microbiology, molecular biology, nutrition, pathology, pharmacology and physiology.*"[26] These sentiments are reflected in the HHMI-AAMC report on the Scientific Foundations for Future Physicians.[24]

An outcome-based approach should therefore be applied to select relevant course content from the individual (or combination of) disciplines specified in the GMC document.[32] The relevant content selected should ensure an adequate basic science knowledge base to facilitate student learning for the acquisition of scientific competencies required as the scientific foundation of medical practice in the 21st century.

The inclusion of the "traditional" basic science disciplines in the current listing by the GMC and also considered essential for medical education in the 21st century, raises the issue whether there is a need to're-engineer' (re-structure and re-organize) the 'traditional' basic science departments at the risk of some disciplines becoming even 'extinct'- at least in name? [33]

Design and Delivery of the Basic Medical Sciences in 21st Century Medical Education: How should Students Learn?

How should we design learning strategies in the basic sciences for medical students to learn and acquire the desired scientific competencies? Cohen stated that "*all medical schools should adopt promising pedagogical innovations to enrich the learning experience for students* [including] *underscoring the relevance of 'basic science' topics by integrating pre-clinical and clinical education throughout the curriculum.*"[23] Today, the design of any learning strategy in medical education should be aimed primarily at creating learning experiences for students to analyse, integrate, evaluate and to apply scientific knowledge and information. Such a pedagogical approach can be expected to facilitate and enhance student acquisition of critical thinking and reasoning skills, problem-solving and decision-making skills, as well as self-directed learning skills (and, therefore, laying the foundation for lifelong continuing self-education). These skills are also the main hallmarks of scientific competencies which, if successfully acquired, will equip medical students with the intellectual capacity to understand the relevance of and apply basic science knowledge, concepts and principles to clinical practice and, therefore, to have the enhanced ability to explain or resolve medical problems encountered in the diagnosis, treatment and prevention of diseases. Wilkerson, Stevens and Krasne have already emphasized the importance of designing learning experiences for students based on sound pedagogy to enhance more effective integration of the basic sciences with clinical medicine. [6]

Indeed, several well-established and pedagogically sound learning strategies are already available for designing such learning experiences for students, either in *large* group or *small* group settings.[6] The underpinning educational principle in all these learning strategies is to engage students actively in an interactive teaching-learning process, i.e. in 'discussion pedagogy', so that students will actively involve themselves in the social construction of knowledge with peers.[34-,37] Of course, learning in *small* group settings will also have the advantage of providing students with opportunities for *collaborative learning* and for the acquisition of *social* skills, including *interpersonal* and *team-work* skills, as well as *communication* skills, so essential to medical practice in the 21st century.[38]

Thus, the use of interactive teaching-learning strategies to deliver basic science knowledge in 21st century medical education can be expected to address the two major shortcomings of 20th century medical education, namely, poor student recall of basic science knowledge in the clinical years, and the lack of ability of students to apply knowledge of the basic sciences to medical problems encountered in the clinics.

Design and Delivery of the Basic Medical Sciences in 21st Century Medical Education: How should the Learning for Students be Organized?

How then should we organize (or design) student learning of the basic science disciplines in 21st century medical education? Today, medical educators and professional organizations strongly advocate greater integration of the basic sciences with the clinical disciplines in the curriculum design of the 21st century. This will require a paradigm shift, from the predominantly compartmentalized type of teaching of the basic sciences (mainly in the preclinical years) to more integrated learning of the basic sciences with the clinical disciplines, i.e. "…*to optimally integrate the sciences into the[clinical] years of medical school education*."[27]

HOW CAN WE OPTIMISE THE INTEGRATION OF STUDENT LEARNING OF THE BASIC SCIENCES WITH CLINICAL MEDICINE IN 21ST CENTURY MEDICAL EDUCATION?

Although many medical schools around the globe (including much of Asia) have already implemented curriculum reforms to update basic science knowledge and to ensure greater clinical relevance of the basic science disciplines to medical practice, medical students in the clinical years still seem to have poor retention of and, therefore, lack the ability to apply basic science knowledge, concepts and principles acquired in the preclinical years. [4,6,17,39,40]

Since "*The basic sciences will continue to have a fundamental role in the development of physicians of the twenty-first century*",[17] there is now an urgent need to facilitate and enhance student retention of basic science knowledge, concepts and principles delivered to the students in the preclinical years. In this context then, medical educators need to seriously consider designing new and innovative curriculum structures which will ensure, not only the clinical relevance, but also result in better understanding and student retention of basic science knowledge in the clinical years. There is strong consensus that appropriate integration in the teaching-learning of the basic medical sciences with clinical medicine will achieve the desired outcome.

The question now becomes: How best can we optimize integration of the basic sciences with clinical medicine for student learning in 21st century medical education?

OPTIMIZING THE INTEGRATION OF THE BASIC MEDICAL SCIENCES WITH CLINICAL MEDICINE

In the past several decades, curriculum reforms with the primary aim of enhancing integration of the basic sciences with clinical medicine have been initiated in many medical schools around the world, including many medical schools in Asia. However, the process of integration varied greatly among the medical schools with significant differences in design structure, including: time allocation, sequencing, electives or compulsory courses, and pedagogy.[40]

The early efforts at integrating the basic sciences with clinical medicine did not have as strong an appeal and impact in the world of medical education, as did problem-based learning (PBL) following its first implementation by McMaster university medical school about four decades ago.[41,42] More recently, however, several new approaches have been well documented, and these are likely to receive more attention and to be adopted and adapted by other medical schools around the world, including Asia. We describe several of these.

An Early Lesson from Harvard Medical School

In 1985 Harvard Medical School implemented a hybrid curriculum using a block structure, combining PBL with limited lectures and laboratories, instead of the usual concurrent courses. Moreover, in designing the blocks, partnerships between basic science teachers and clinical faculty were strongly encouraged. The Harvard block structure facilitated student integration of the basic sciences with clinical medicine with strong evidence of continued retention of basic science knowledge by the students in the clinical years.[6,43]

University Of Pittsburgh School of Medicine (UPSOM), Pittsburgh, Pennsylvania

In 1995 UPSOM developed the Integrated Life Science (ILS) program as a back to the basic sciences approach for medical students to re-visit the basic sciences during the clinical years when the students will be more clinically mature. Thus, the innovative program was developed primarily to integrate the biomedical sciences with clinical medicine and promote an understanding of the application of the scientific method in clinical thinking and appraisal of the literature. The program serves also to illustrate how collaborative teams of clinicians and scientists translate new scientific knowledge into changes in medical practice.[40,44]

The UPSOM ILS curriculum therefore highlights the advantages of initiating the back to learning of basic sciences when medical students have had at least one year of clinical exposure after which, in the view of Spencer, et. al., [40] medical students are more receptive to re-learning of clinically relevant basic science knowledge, concepts and principles, because their "*…clinical reasoning and analytical skills are more mature…[and so] students gain a more meaningful understanding of the pathophysiology of diseases and targeted therapeutics*."[40]

David Geffen School of Medicine At University of California, Los Angeles (UCLA)

"*Recognizing the limitations of its own traditional, departmentally based curriculum, the medical school…challenged its **basic science faculty members** to **sit down with** their **clinician colleagues** and craft a **new, fully integrated pre-clerkship curriculum** that would present '**no content without context**'.*"[6]

In 2003, the David Geffen school of medicine launched its "Human Biology and Disease" (HB&D) pre-clerkship curriculum aimed primarily at integrating the "*..traditional biomedical sciences…with social and clinical sciences*." The HB&D curriculum is essentially "*…an integrated foundational curriculum…*" using a block and thread structure consisting of "*…nine sequential block courses over 2 years, each block traversed by five disciplined-based threads…*" and running for "*…either 8 weeks or 5 weeks of classroom and clinical study followed by 3 days for an integrated examination and a 4 day break*." A weekly structure for each block consists of PBL tutorials, lectures (maximum of 10h a week), a clinical session (3-4h), and a formative assessment at the end of each week; the total contact time is 24 h.[6] A significant point to note about the David Geffen school of medicine's fully integrated HB&D pre-clerkship curriculum is that the curriculum and instructional methodologies were based upon established principles of learning theory designed to achieve deep learning, promote the application of science in clinical care enhance self-learning behaviors. [6]

Mayo Medical School

"*We have made the transformation* ***from*** a *'****course-based****' curriculum, where students are 'exposed' to content (material is 'covered') with relatively little emphasis on integration or student retention* ***to a block-based*** *curriculum, which* ***integrates*** *normal structure, normal function, and pathophysiology of disease."*[17]

The Mayo medical school implemented a change from a course-based curriculum to a block-based approach involving an integrated normal structure/function and Pathophysiology of disease with an emphasis on the scientific foundation of the disease process.[45,46] A principle focus is on a longitudinal curriculum. [17]

Leiden University Medical Center (LUMC) Integrated E-Learning Course in Pharmacology

"*…we propose a* ***model*** *for* ***integrating*** *a basic science in the medical curriculum via the* ***implementation*** *of efficient and effective* ***e-learning***.[47]

Dubois and Franson recently described an interesting approach they used to integrate their pharmacology program.[47] The LUMC e-learning program was initiated in 1999 and is based on the development of the Teaching Resource Center (TRC) Pharmacology Database which provides links to the Dutch national formulary This association promotes integration of basic pharmacology and pathophysiology with clinical application.[47,48]

The LUMC integrated e-learning program (TRC Pharmacology Database) provides a good example of a successful and strategic e-learning model that promotes and facilitates the integration of basic science knowledge and concepts into clinical medicine through the use of information-communication technology (ICT). However, apart from careful and diligent planning with a project team, the authors also cautioned that the e-learning initiative *"…is a serious undertaking which has many parallels with curricular changes*" and, therefore, ensuring buy-in by all stakeholders will be just as important

CONCLUSION

The role of the basic sciences as the scientific foundation of clinical medicine gained much prominence and status after Abraham Flexner submitted his seminal report in 1910. The report highly influenced the curriculum design and delivery of medical education, not only in the U.S.A. and Canada, but also across much of the world, including Asia. However, by the mid 20th century, serious concerns were raised about the lack of clinical relevance and poor student retention of basic science knowledge and concepts delivered to medical students in their early preclinical years.

Today, in this new millennium and one century after the Flexner report, the critical and fundamental role of the basic science disciplines in medical education has re-emerged, with strong endorsement from influential medical bodies like the AAMC-HHMI of the U.S.A., the AFMC of Canada and the GMC of UK. However, a paradigm shift is now required: From students receiving intensive instruction of in-depth scientific facts derived from disciplinary courses, to student acquisition of scientific competencies required for the development of the desired habits of mind, behavior and action for medical practice in the 21st century. The importance of this shift in approach is highlighted by the thoughts of Pickering:

"…method is remembered when facts have been forgotten, and method can be used in a new situation where there are no, or too few facts. The students learn how to learn and can go on acquiring knowledge for the rest of his life." (Sir George Pickering; 1958)

The teaching of basic science knowledge, concepts and principles must, therefore, be aimed at inculcating in students the methods of science and scientific thinking. Thus, courses must now be designed to integrate across the medical disciplines, and departmental silos must not be allowed to impede the integration process. Course integration should ensure student re-learning of the basic sciences in the clinical years, perhaps, after one year of clinical exposure when students have reached a more "mature level" clinically. The design of integrated courses should be strongly underpinned by current learning concepts and principles. Importantly too, the positive outcome of pairing a basic scientist with a clinician in developing, organizing and teaching in the integrated courses should be given priority. ICT can also be exploited to advantage in designing integrated courses for medical student learning. Simulation-based learning should also be considered in this light.

Finally, basic science teachers should take heed of the caveat from Norman who, in a recent editorial, urged them not to yield to temptation no matter how important they may perceive their disciplines to be.[49] This, then, is the ultimate challenge to basic science teachers who must respond positively and must not repeat the self-serving scientific excesses of the past. Only then can basic science teachers ensure the continued good health and status of the basic sciences in medical education for the 21st century, and only then can they consider that it has 'passed the litmus test.'[7]

REFERENCES

1. Amin Z, Khoo HE, Gwee MCE, Koh DR and Tan CH (2004). Profiles of Asian Medical Schools. Part I: Southeast Asia. Published by: Editorial Committee, Medical Education Unit, Dean's Office, Faculty of Medicine, National University of Singapore
2. Amin Z, Khoo HE, Gwee MCE, Koh DR and Tan CH (2004). Medical Education in Southeast Asia: Emerging Issues, Challenges and Opportunities. *Medical Education*; 39: 829-832.
3. Flexner, A. (1910). Medical Education in the United States and Canada: A Report to the Carnegie Foundation for the Advancement of Teaching. New York: Carnegie Foundation for the Advancement of Teaching.
4. Cooke Molly, Irby DM, Sullivan W, Ludmerer KM. (2006). American Medical Education 100 Years after the Flexner Report. *N Eng J Med*, 355: 1339-1344.
5. MILLER GE (1961). The Objectives of Medical Education In: *Teaching and Learning in Medical School*, 1961; Ed. Miller G.E., Cambridge, MA: Harvard University Press.
6. Wilkerson LuAnn, Stevens CM, Krasne Sally (2009). No Content Without Context: Integrating Basic, Clinical, and Social Sciences in a Pre-clerkship Curriculum. *Medical Teacher*, 31: 812-821.
7. Pawlina W (2009). Basic Sciences in Medical Education: Why? How? When? Where? *Medical Teacher* 31: 787-789.
8. Glew RH (1981). Do We Need The Basic Scientists? *Perspectives in Biol Med*, 25: 149-154.
9. Abrahamson S (1978). Diseases of the Curriculum. *J Med Ed* 53:: 951-957.
10. Friedman CP, Purcell E, De Bliek R (eds) (1983). The New Biology and Education: Merging the Biological Information, and Cognitive Sciences. Josiah, Jr. Foundation, New York, 1983.
11. Boud D, Feletti G (1997). Changing Problem-based Learning. Introduction to the Second Edition. In: The Challenge of Problem-Based Learning, 2nd Edition, Chp. I, pp. 1-14, Boud D and Feletti G (Ed), Kogan Page, London.
12. Rajan TV (2006). Making Medical Education Relevant. *Chron High Educ*, 52:20
13. Whitcomb, ME. (2006). Medical education reform: is it time for a modern flexner report? *Acad. Med*. 82:1-2.
14. McCrorie, P (2000). The Place of the Basic Sciences in Medical Curricula. *Med Ed*, 34: 594-595.
15. Fishbein RH (2001). Origins of Modern Premedical Education. *Acad Med*, 76: 425-429.
16. Dienstag, JL (2008). Relevance and Rigor in Medical Education. *New Eng J Med*, 359: 221-224.
17. Grande JP (2009). Training of Physicians for the Twenty-first Century: Role of the Basic Sciences. *Med Teacher* 31: 802-806.
18. Irby DM, Wilkerson LuAnn (2003). Educational Innovations in Academic Medicine and Environmental Trends. *J Gen Intern Med* 18: 370-376.
19. Harden RM, Sowden S, Dunn WR (1984). Some Educational Strategies in Curriculum Development: the SPICES Model. *Med Educ* 18: 284-297.
20. Harden RM (2007). Outcome-Based Education: The Future is Today. *Med Teacher* 29:625-629.
21. Schwartz MR, Wojtczak A, Zhou TF (2004). Medical Education in China's Leading Medical Schools. *Med Teacher* 26: 215-222.
22. Chacko TV (2009). FAIMER Regional Institutes: Meeting Faculty Development Needs of Mid-level Educators. Programme Handbook, 6th Asia Pacific Medical Education Conference, 19-22 February, 2009, Yong Loo Lin School of Medicine, National University of Singapore, Singapore, pp. 38-39.
23. Jones CA, Keith LG (2006). Medical Tourism and Reproductive Outsourcing: The Dawning of a New Paradigm for Healthcare. *Int J Fertil Women's Med* 51:251-255.
24. Crone RK (2008). Flat Medicine? Exploring Trends in the Globalization of Health Care. *Acad Med* 83: 117-121.
25. AFMC (The Association of Faculties of Medicine of Canada, 2009). The Future of Medical Education in Canada: *A Collective Vision for MD Education*, An AFMC Project. 49 Available from www.afmc.ca/fmec. Accessed 10/30/10.
26. GMC (2009). General Medical Council, U.K. Tomorrow's Doctors. Outcomes and Standards for Undergraduate Medical Education. Available from http://www.gmc-uk.org/tomorrowsdoctors. Accessed 10/30/10
27. Cohen JJ (2008). Chairman's Summary of the Conference. In: Hager, M (ed), *Revisiting the Medical School Educational Mission at a Time of Expansion, Charleston, SC*, Josiah Macy, Jr. Foundation; 2008.
28. AAMC-HHMI (2009). Association of the American Medical Colleges and the Howard Hughes Medical Institute Report of Scientific Foundations for Future Physicians Committee, Washington DC. Available from *http://www.hhmi.org/grants/pdf/08-209_AAMC-HMI_report.pdf* Accessed 10/30/10
29. Barr RB, Tagg J (1995). From Teaching to Learning- A New Paradigm for Undergraduate Education. *Change*, 27 (Nov/Dec): 13-25.
30. Ludmerer KM (2004). Learner-centered Medical Education. *New Eng J Med*, 351: 1163-1164.
31. Medical Teacher (2009). Special Issue on Basic Sciences. *Med Teacher*, vol 31
32. Medical Teacher (2007). Outcome-Based Education theme issue. *Med Teacher* 29.
33. Bunton, SA (2006). Recent Trends in Basic Science Department Reorganizations. Analysis in Brief (AAAMC), 6(1). Available from: www.aamc.org/data/aib. Accessed 10/30/10.
34. Christensen CR (1991). Premises and Practices of Discussion Teaching. In: EDUCATION for JUDGMENT The ARTISTRY of DISCUSSION LEADERSHIP, Chp.2, pp 15-34, Ed. Christensen CR, Garvin DA and Ann Sweet, Harvard Business School Press, Boston, Massachusetts.

35. Kauchak DP, Eggen PD (1998). *Learning and Teaching: Research-Based Methods*. Boston, Mass.: Allyn & Bacon.
36. Anderson RD (2007). Inquiry as an Organizing Theme for Science Curricula. In: Abell, SK and Lederman, NG (Eds.), Handbook of Research on Science Education, (pp. 807-830). Mahwah, NJ: Erlbaum.
37. Tomorrow's Professor Listserv (2007). The Constructivist View of Learning. TP Message 498: 1-3. The Stanford University Center for Teaching and Learning (http://ctl.standford.edu).
38. MEYERS C & JONES TB (1993). Small Group Teaching. Promoting Active Learning Strategies for the College Classroom, Jossey-Bass Publications, San Francisco.
39. Ling Y, Swanson DB, Holzman K, Bucak s (2008). Retention of Basic Science Information by Senior Medical Students. *Acad Med* 83 (Suppl 10): S82-S85.
40. Spencer AL, Brosenitsch Teresa, Levine AS (2008). Back to the Basic Sciences: An Innovative Approach to Teaching Senior Medical Students How Best To Integrate Basic Science and Clinical Medicine. *Acad Med* 83: 662-669.
41. Wilkerson LuAnn, Gijselears WH (19960. Bringing Problem-Based Learning to Higher Education: Theory and Practice. *New Directions for Teaching and Learning*, no. 68, Winter 1996.
42. Gwee MCE (2009). Problem-Based Learning: A Strategic Learning System Design for the Education of Healthcare Professionals in the 21st Century. Kaohsiung *J Med Sci*, 25: 229-237.
43. Moore G (1994). The First Curriculum: Content and Process. In: New Pathways to Medical Education: Learning to Learn at Harvard Medical School, Eds. Tosteson DC, Adelstein SJ and Carver ST , Harvard University Press, Cambridge, MA.
44. Kanter SL, Wimmers PF, Levine AS (2007). In-depth Learning: One School's Initiatives to Foster Integration of Ethics, Values and the Human Dimensions of Medicine. *Acad Med* 82: 405-409.
45. Davis M, Amin Z, Grande J, O'neal A, Pawlina W, Viggiano T, Zuberi R (2007). Case studies in outcome-based education. *Med Teacher* 29: 717-722.
46. Jelsing EJ, Lachman N, O'neal AE, Pawlina W (2007). Can a Flexible Medical Curriculum Promote Student Learning and Satisfaction? *Ann Acad Med Singapore* 36: 713-718.
47. Dubois EA, Franson KL (2009).Key Steps for Integrating a Basic Science throughout a Medical School Curriculum Using an E-Learning Approach. *Med Teacher* 31: 822-828.
48. Franson KL, Dubois EA, van Gerven JMQA, Cohen AF (2007). Development of Visual Pharmacology Education Across an Integrated Medical School Curriculum. *J Vis Commun Med* 30: 156-161.
49. Norman G (2007). Editorial: How Basic is Basic Science? *Adv in Hlth Sc Edu* 12: 401-403.

The Role and Value of the Basic Sciences in Medical Education: The Perspective of Clinical Education - Students' Progress from Understanding to Action

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Introduction

It is understandable that the role of basic science in the medical school curriculum should be re-examined at a time when, on the anniversary of the "Flexner report," decades of change in the practice of medicine, and anticipated changes in the delivery of health care over the coming decades are in the forefront of discussion.[1] The national movement toward redesign of medical school curricula can only be accelerated in these circumstances. Therefore, there is an urgency to reexamine all the premises of medical education, including the role of the foundational sciences for the practice of medicine in the curricula of the 21st century. This essay will explore the essential role of basic science in students' progress toward independence as their responsibilities move from understanding into action.

Why all the concern about basic science?

In a way, it seems counter-intuitive, or even absurd to ask whether acknowledge of basic science is of central importance to the practice of medicine. How is it, then, that present concerns arise?

One concern comes from faculty. As recently noted in a collaborative statement from IAMSE on the role of basic science in medical education "there is tension between the time needed to teach an ever-expanding knowledge base science, and the time needed for increased instruction in clinical application and it behavioral, ethical and managerial knowledge and skills needed in preparation for the clinical experiences".[1]

The concern also comes from a new generation of task-oriented students: "many students still have genuine doubts about the value of basic sciences to which they had been exposed."[2] And it comes from leaders in science themselves in the recent report from the Howard Hughes Medical Institute (HHMI). "In recent years the scientific knowledge important to learning and practice of medicine has changed dramatically, while the approach to science education in the premedical and medical curricula has essentially remained unchanged".[3]

Sweeney goes further and argues that the curricular problem "to basic scientists is that much of clinical medicine remains unnecessarily unscientific", and therefore "Until clinical medicine itself changes, the utility of science in the training of a physician will remain difficult to demonstrate." [4]

There are several questions: whether basic science is relevant to education in medicine, or just whether science needs to be taught in a different way? Or perhaps, given the explosion of scientific information, it is a question of what needs to be taught and when?

Finnerty et al1. posed – and answered - five questions on the 100th anniversary of the Flexner report: what are the sciences that constitute the foundation for medical practice? What is the role of science in being ready for practice at different stages of training? When and how should the foundational sciences be incorporated into the medical school curriculum? (What instructional methods and what assessment tools?) What sciences are prerequisites to enter medical school? and what are examples of best practices? The purpose of this paper is to reflect on these questions from the perspective of a clinical educator, and initially on the broader question that underlies these: how does basic science knowledge contribute to the competence of a physician? This is an opinion piece, but key supporting literature will be cited.

In what way does basic science fit into competence as a physician?

Addressing how basic science is incorporated into the practice of medicine depends upon basic assumptions about what medical practice is, or more specifically, what the “competence” of an individual physician means. One accepted definition of competence was offered by Epstein and Hundert: "the habitual and judicious use of communication, knowledge, technical skills, clinical reasoning, emotions, the values and reflection in daily practice for the benefit of the individual and community being served".[5] A similar approach is embodied in the "six general competencies" into which the Accreditation Council for Graduate Medical Education (ACGME) which divides competency: medical knowledge, interpersonal and communication skills, professionalism, patient care, system-based practice and practice-based learning.[6] In both of these models competence is seen as a multidimensional construct in which knowledge is given a prominent role, and a knowledge of basic sciences (normal human structure and function, and mechanisms of disease and therapy) is explicit.

The Epstein definition situates competence in the specific, local context in which the physician provides care for a specific individual patient or community. These six aspects (or seven, Epstein) into which competence is divided are applied to a specific patient. As an alternative to this “analytic” model in which competence is refracted into six domains, there is a “synthetic” model combining knowledge, skills and attitudes in which this may be said more concisely: "competence is bringing to each patient in your practice what the patient requires, and nothing extraneous”.[7,8] This emphasis on a specific situation and the role of the individual within that situation may an essential consideration, since what science is required will depend on the practice (specialty, context and scope of practice) of the individual. With the changing and increasing levels of responsibility of medical students and residents, the problem can be framed more developmentally as we ask what students are expected to bring to the required situations (courses and clerkships) at a specific levels of their training. Additionally, as the student moves toward graduation and has chosen a specialty, this formulation fosters more flexible learning the basic science (individual study and electives).

Growing competence as a movement from understanding into action

Clinicians are used to seeing the medical school curriculum (whether four years as in the United States, or six years as in other parts of the world) as "preclinical" and "clinical". In this framework a course in the first year or two of medical school is a preparation for what happens later. Typically, there is not a strict separation, and in recent decades, early clinical training in medical interviewing, physical examination and diagnostic reasoning have been included in "introduction to clinical medicine" or "doctoring" courses. Another way of looking at this progress from the initial years of medical school to subsequent years is to characterize the students' task. This can be done rather simply by conceptualizing the process as a movement from understanding into action; for instance, we might say that initially they are responsible for understanding and explaining what is happening with their patients (from a point of view of mechanism), and later they are responsible for moving toward diagnostic and therapeutic planning. As will be discussed below, this has implications for what basic sciences must be mastered at each stage of the process.

Does science aid understanding and action?

In the past two decades there is a growing body of literature on how basic science fits into the practice of medicine, and how the competence of students develops. Most of this literature focuses on the task of diagnostic reasoning ("making a diagnosis") rather than the broader concept of clinical decision-making which includes diagnostic and therapeutic planning, and shared decision making with patients and families. Since initially students are given responsibility for thinking through problems, but not for unsupervised care of patients, this has been an appropriate first focus for educational research.

Is basic science knowledge required for developing diagnostic reasoning? This was assumed in the original "Flexner model" in which two years of basic science was seen as a prerequisite for learning clinical medicine. The domain of medical knowledge was seen as two separate types of knowledge, one a knowledge of mechanisms (normal structure and function and derangements of these), and the other a knowledge of clinical medicine (the manifestations of disease).[9] (Please see also Patel and Woods for current reviews of learning theories as they relate to basic science in medical education.)[10,11]

It has become a commonplace that clinicians do not “use” basic science in their decision-making, and rely rather on pattern recognition. This general observation of medical students in their own conversations with teachers has been supported by "think-aloud protocols" in which physicians are asked to explain how they arrived at their conclusions. However, this surface observation has been clarified by structured observations that clinicians with a high level of expertise have "compiled" knowledge or "encapsulations" in which their knowledge of basic science is tacit, and below the surface of their conversation.[12,13] Studies have shown that experts do, in fact, use a knowledge of basic science mechanism in solving more difficult problems.[14]

Another concern is that medical practice may not require a true understanding of basic science to support analytic reasoning, since the vast majority (75%) seen by practitioners in their own discipline is, for them, routine. In these simple situations diagnosis may simply require a non-analytic thought process (pattern recognition), and management only requires a practice guideline. In fact, there is a growing sentiment that clinical epidemiology applied to principles of prevalence of disease and a specific population may be as important to successful diagnosis as a grasp of basic mechanisms.

The general principle of management by large clinical trials for both diagnosis and therapy, so-called "evidence-based medicine" (EBM), may be replacing, I have observed, mechanism of disease and mechanism of therapy as the preferred subject for discussion by residents on work rounds. Such an approach, in which EBM is preferable to pathophysiologic analysis, could be more cost-efficient and therefore more in tune with what health care policy leaders see as a priority in practice and education.

Where does basic science fits into practice?

In discussion of straightforward cases, clinicians do not articulate a use of basic science in clinical reasoning because their knowledge is compiled or encapsulated and because the cases are routine and simple. However, and here we come to the essential point, what separates physicians from other health care workers, such as physicians assistants and those who must follow algorithmic care, is the ability to manage more difficult problems. In this respect, medical education must train those who not only follow practice guidelines, but who can write such guidelines and who have the authority to deviate from, or "violate" practice guidelines (personal communication, Ralph Jozefowicz). As noted before by Finnerty, if physicians are to be more than technicians, then an understanding of science is essential.[1]

Basic Science as Curricular Method and not simply as syllabus

Scientists argue, and clinicians are inclined to agree, that in addition to the a knowledge of scientific facts, the very study of science develops effective thinking skills, a ready skepticism about observations and studies, and a habit of rigor and honesty in interpreting data. In this sense basic science is more than a list of topics to be covered (syllabus) but is part of a structured experience (curriculum) that leads toward eventual independence.[15] But this distinction between begs an important difference between two disciplines that differently value understanding and action. The methods of science are designed to lead to understanding, and employ clarification studies (*experimenta lucifera* in the terms of Francis Bacon); whereas the practice of medicine requires a praxis, or method of action that looks for benefits through studies that are “fruitful” enough to justify one course of action over another (*experimenta fructifera*).[16,17] These should be complimentary, of course. But they reflect a difference of intention that may make it hard for medical school teachers to work together.[4]

There is supporting evidence that expert physicians, in dealing with difficult cases do rely on understanding of basic mechanisms.[14,18] When "solving" routine or simple cases, expert clinicians in endocrinology and cardiology relied on quickly processed, non-analytic reasoning and pattern recognition.[9] When, however, out of routine, they verbalized the knowledge of mechanism that helped them solve problems. Moreover, in some studies when specifically asked about disease mechanism, expert physicians do in fact have a grasp of principles and mechanism superior to students.

At this point we can address the fundamental challenge raised by Sweeney that the practice of medicine is not scientific, that is, not completely based on a data driven recognition and manipulation of cause and effect. The implication is more than the traditional formulation that medicine is a combination of both art and science. It is that in applying principles to individual patients, it is the individuality of the situation (such as co-morbid diseases and social setting) that take precedence. These complicating factors outrun available ‘evidence-based medicine’. This brings us to an even deeper difference between the disciplines of science and clinical medicine.

Ultimately, physicians must act, even in complex circumstances for which large-scale, multi-center clinical trials can only give a rough approximation of a course of action. In this setting, where "data" are not available to dictate a course of action, the physician must use professional skills to achieve a patient-centered decision; but even within the physician him/herself, the cognitive process is one of dealing with uncertainty and managing complexity. It is in this area of complexity and uncertainty where the recent studies of Patel (cited above) and others are most useful in supporting utility of having a basic understanding of disease and pharmacology mechanism available in memory.

What basic sciences are the foundation of medical practice?

A specific syllabus in human biology is available in extreme detail from the Content Outlines for Steps 1 and Step 2 (Clinical Knowledge) for the US Medical Licensing Examination, and principles have been reviewed extensively by Finnerty et al; these will be reviewed here only in broad outlines and general principles.[1,19] The three "Ps" are closest to the surface: physiology, pathology and pharmacology for all cases/patients, with microbiology and biochemistry dominating for diseases from the internal or external ecology, and from nutrition. Anatomy is essential for localized symptoms (for instance, pain and swelling).

Using the general definition of competence as the ability to bring to the situation (patient) what is required, the level and kind of understanding required depends on the specific problem at hand, and the competent physician must be able to move "downward" (deeper) from a consideration of organ systems within the body to more detailed levels of mechanism and granularity (cellular and genetic mechanisms, and molecules), or "upward" to a broader, bio-psycho-social framework (such as substance dependence and family dynamics), moving from person to family and from local environment to society, and even, as required by the individual patient, to a health-care delivery model system level (see Figure 1). Therefore the individual physician must have access to a wide repertory of foundational sciences available from molecular biology and genomics, too physiology and organ histology, to behavioral psychology, to epidemiology and biostatistics.

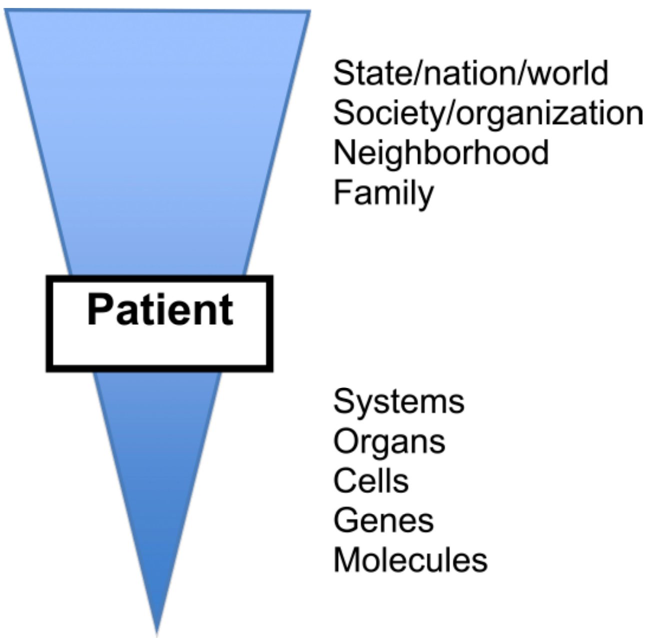

Figure1. Levels of understanding of the mechanisms in processes, tests and therapies in human health and disease.

What is the role of sciences in medical education?

One role is practical, related to where the student is in his/her progress towards independence, and the other is theoretical in supporting the development of rich, knowledge encapsulated in the memory of the student, and accessible as needed for complex or unexpected problems.

During medical school students are gradually given more responsibility in the care of real patients as they acquire more "competence" for their level of training. Overall, students move from understanding to action. Action in the face of uncertainly takes more than knowledge, and is a task that cannot easily be embraced within a cognitive model in which a student's understanding alone is required. Can basic science play a role in the formation of professional character, in which behavioral and social concepts are more fundamental?[20]

The progress of students from understanding to action can be extracted implicitly from the ACGME competencies in which the first three items - residua of the knowledge-skills-attitude model of Bloom - knowledge, communication skills and professionalism, are prerequisites to being given clinical responsibility.[21] The single most important competency, patient care, with its two pendants (system based practice and practice-based learning and improvement) then follows.

This progression from understanding to action is even more explicit in one specific formulation, the reporter-interpreter-manager-educator" framework.[7,22] In this framework basic science supports the students' gathering and explaining clinical findings on their own patients. Knowledge of the anatomy of the abdomen, for instance, is essential for diagnosing right upper quadrant pain; knowledge of the normal physiology of water regulation is essential for understanding polyuria and polydipsia; knowledge of normal and abnormal histology supports learning to interpret patterns of liver associated enzymes. The knowledge is not there for its own sake, but to support the responsibility that the student will be given. The use of clinical vignettes in which to embed the basic science questions in USMLE, Step 1, reflect this linking of cognitive expertise to a potential role for students in patient care.

The timing of basic science content areas

Some clinical problems are of sufficient importance and prevalence that they must be understood as prerequisites for any core clinical clerkship that the student happened to be on. For instance, how the body regulates blood pressure often underlies common, life-and-death situations and should be an absolute prerequisite for starting clerkships. How the body protects itself against dehydration and hypoglycemia -- when patients are unable to eat or drink -- puts the regulation of osmolality, and the biochemistry of glucose homeostasis on the list of prerequisites which help earn the right to take care of patients. On the other hand, learning iodine metabolism and thyroglobulin synthesis could probably be deferred until a student saw a patient in in the clerkships with thyrotoxicosis or thyroid nodule

How do we teach basic science?

The "how" is to be answered by two tests of success, which are of equal importance: one, can the students retrieve the essential facts from memory and apply them to the patient at hand; and two, is the student driven to answer the question "Why?" So, teaching methods are not aimed solely at students' memory, but at their intuitive search for explanations - Is there an emotional need to explain signs and symptoms through mechanism? If not, we, the faculty, have probably failed in this essential goal.

While differential diagnosis of clinical problems, such as bloody diarrhea, can be memorized as part of illness scripts, there is evidence that support by pathophysiologic understanding of mechanism supports longer term retrieval from memory.[15,23] Whether in lectures, small-group teaching or one-on-one, the teacher probes the student's ability to unify the surface features of (symptoms, signs and laboratory findings) with underlying mechanisms.

As students move from understanding into action, and into management of common problems, a knowledge of microbiology and pharmacology becomes more and more essential, and is essential for all training in each specialty of medical practice. But are specific learning needs the same for learners at different levels? Do students need to grasp all problems at the same level as specialists? Endocrinology fellows are more apt to be thrilled by adrenal synthetic pathways than surgeons, and the actions of tyrosine kinase inhibitors in chemotherapy more needed by oncologists. The problem may be resolved by deciding the specific expectations for the role of the learner at each level, i.e., what level of competence is expected.

Prerequisites for entering medical school

In the pre-medical school curriculum students should have demonstrated to themselves and faculty that they are familiar with the terminology, methods and content of science. It may be as important that they see "science" as a process of rigorous observation and hypothesis testing than as a fixed body of knowledge to be cherished. Among several recent discussions, Lambert and others proposed a revision of legacy pre-med requirements, including a shift from organic chemistry to biochemistry, from calculus to statistics and substituting no cell biology and physiology for physics.[24] Additionally, they support a decrease in total contact hours in collegiate science, and a shift to more individualized learning of science during medical school

Almost all authors and scientists still espouse a general education in humanities: "undergraduate years are not and should not be aimed only at preparing for professional school. Instead, the undergraduate years should be devoted to creative engagement in the elements of a broad, intellectually expansive liberal arts education".[3] Consensus also strongly supports college experiences which would allow students to express themselves clearly to teachers, peers and patients. Some basic training in logic and reasoning (less and less available with the decline of formal requirements in the philosophy department) and in written and oral communication (how to write a paragraph) are also desirable. Finally, some preparation to deal with patient-centered issues (behavioral modification, clinical psychology and family dynamics, and sociology) is probably more important than calculus.

What are some best practices for incorporating basic science education into medical school curricula?

In Pre-clerkship courses

Schmidt and Rikers offer useful principles to guide education in the pre-clerkship period.[13] Basic science should be taught to support the development of encapsulating concepts; not simply left to the students themselves but supported by integrated teaching (such as in an organ system approach); students should work with patients early in the curriculum; students should have exercises to reflect and elaborate on problems of patients (with a tutor/coach or in small groups) to develop knowledge structures.

Whatever the course's format "providing students with the appropriate theoretical knowledge gives them the means to create a coherent picture of the case when the clinical features become disorganized".[11,20] In the pursuit of realistic clinical scenarios, science course directors should avoid the tendency to provide complicated clinical scenarios (paper, simulated or real) whose clinical details might distract students from grasping the essential mechanism and pathophysiology underneath. I have proposed elsewhere that competence in my own discipline of internal medicine is the ability to embrace complexity, but act with simplicity"; but it is important to remember that beginning students are struggling to embrace simplicity.

On Clinical rotations

One important precept is that incorporating basic science training into the clinical years may need faculty development for teachers, so that the link between science and the clinical decisions is "made explicit, concise and clear".[11] Employing Ericsson's concept of deliberate practice – repetition with feedback from a master teacher – a best practice would be the teacher who asks and expects students to have asked themselves "why?" this patient has the symptoms at hand. This teacher makes the articulation of mechanism in explanation and therapy a routine practice.[25] This, too, will often require a faculty development effort, since this not habitual with faculty who are often supervising residents and patient care at the same time, and so naturally focus on action rather than understanding.

Many schools have incorporated early clinical contact with patients in the first year of medical school, and now a growing number have a formal return to science during the clinical years. A formal return to science may now be considered a "best practice". The "double helix" curriculum of the University of Rochester is one model that articulates the close relationship of these two domains of knowledge throughout the four years.[26]

Spencer and others provide a comprehensive summary of formal basic science education in US medical schools based on the AAMC curriculum directory and each school's own website.[27] As of 2007, 19% of US schools (up from 13% in 1985) included basic science after the clerkships for an average duration of four weeks. Specific formats and sessions are described as well as some common content areas (advanced pharmacology and pathology; resuscitation, neoplasia and molecular medicine).

In such a "formal return" to the study of basic science, there is some support for allowing the curriculum to meet the needs and desires of individual students, giving more flexibility and allowing more interdisciplinary work. For instance, from a selective panel of basic science senior seminars or mini-courses, a student going into surgery might choose three modules from anatomy and one from physiology; a student going into pediatrics might choose three from physiology at one from anatomy.

The recent HHMI report prefers to formulate learning objectives for students as "competencies" which are demonstrable by students rather than as areas to be covered by faculty.[3] Such phrasing moves the pedagogy from teacher-centered (what was presented) to student-centered (what skills were acquired), and may also be considered a best practice. This report also provides "eleven overarching principles" to inform science teaching, among which are that students should have not just a grounding in knowledge but, as importantly, in how that knowledge evolves; the report endorses the role of science in forming professional values such as curiosity, skepticism, objectivity and scientific reasoning. The HHMI report does not propose increasing the number of requirements for entry to medical school; instead it recommends substituting more relevant requirements for others that are less relevant to the practice of medicine".

New Developments

Educators should be aware that a revised standard for accreditation (ED 11) requires that "the curriculum of the educational program must include content from the biomedical sciences that supports students' mastery of the contemporary scientific knowledge, concepts and methods fundamental to acquiring and applying science to the health of people had to the contemporary practice of medicine".[28] It is the new annotation for this requirement that is remarkable in its phrasing to make it clear that departmental a (or scientist-based) approach to syllabus should not be a barrier to integrated learning all "it is expected that the curriculum will be guided by clinically-relevant biomedical content from, among others, the disciplines that have been traditionally titled anatomy, biochemistry, genetics, immunology, microbiology, pathology, pharmacology, physiology, and public health sciences".[28]

CONCLUSION

Teaching basic science should be incorporated into a larger concept of progress toward independence than that 'knowledge is an essential competence'. Educational leaders should be aware that a growing body of evidence supports the teaching of basic science as an essential step in solving complicated or unusual clinical problems, and not be discouraged by the fact that clinicians do not routinely mention the basic science facts that underlie our diagnostic reasoning. Little attention has yet been paid to articulating the role of basic science in teaching therapeutic management, but this author believes that teachers should continue to insist on an understanding of mechanisms as at least as important as epidemiologic studies and EBM. We should be aware that students are often still achieving understanding in a setting in which their teachers are focused on action (whether or not understanding is complete). Successful incorporation of science into medical practice through education depends on the effort to make this step an explicit priority.

REFERENCES

1. Finnerty EP, Chauvin S, Bonaminio G, Andrews M, Carroll RG, Pangaro LN. Flexner revisited: the role and value of the basic sciences in medical education. Acad Med. 2010 Feb;85(2):349-55
2. Weatherall DJ, Science in the undergraduate curriculum during the20th century, Medical Education, 2006, 40, 195 – 201.
3. Howard Hughes Medical Institute, Scientific Foundations for Future Physicians, AAMC, 2009.
4. Sweeney G, The challenge for basic science education in problem-based medical education", Clin Inest Med, (1999), 22, 1v-22.
5. Epstein RM, Hundert EM, Defining and Assessing Professional Competence, J Amer Med Assoc, 2002, 287, 226 -235.
6. Accreditation Council for Graduate Medical Education, http://www.acgme.org/outcome/comp/compmin.asp, accessed 11April 2010.xxix
7. Pangaro L, A New Vocabulary and Other Innovations for Improving Descriptive In-training Evaluations, Academic Medicine, 74: 1203-1207, 1999.
8. Pangaro L, Investing in Descriptive Evaluation: a vision for the future of assessment. Medical Teacher. 22(5), 478 - 481, 2000.
9. Patel VL, Evans DA, Groen GJ, Reconciling basic sciences and clinical reasoning, Teach Learn Med, 1989, 1: 116-121.
10. Patel VL, Yoskowitz NA, Arocha JF, Shortliffe EH, J Biomedical Informatics, 2009, 42, 176 – 197.
11. Woods NN, Medical Education, 2007, 41, 1173 – 1177.
12. Bordage G. Elaborated knowledge: a key to successful diagnostic thinking. Acad Med 1994;69:883–
13. Schmidt HG, Rikers RMJP, Medical Education, 2007, 41, 1133- 1139.
14. Patel VL, Groen GJ, Arocha JF, Memory and Cognition, 1990, 18, 394 – 406
15. Pangaro LN, A Primer of Evaluation, Guidebook for Clerkship Directors, 3rd edition, Fincher RM, Alliance for Clinical Education, 2005.
16. Bacon F, "Novum Organum", Francis Bacon: Novum Organum - With Other Parts of The Great

Instauration, Paul Carus Student Editions) [Paperback, Carus, 1994
17. Cook DA, Bordage G, Schmidt HG. Description, justification and clarification: a framework for classifying the purposes of research in medical education. Med Educ. 2008 Feb;42(2):128-33.
18. Woods NN, Brooks LR, Norman GR, The role of biomedical knowledge in diagnosis of difficult cases, Adv in Health Sci EDuc, 2007, 12:417-426.
19. USMLE Website http://www.usmle.org/
20. Torre DM, Daley BJ, Sebastian JL, Elnicki DM, Overview of Current Learning Theories for Medical Educators, Amer J of Medicine 2006, 119, 903 – 907.
21. Bloom, B.S. (Ed.) (1956) Taxonomy of educational objectives: The classification of educational goals: Handbook I, cognitive domain. New York; Toronto: Longmans, Green.
22. Pangaro LN, A Shared Professional Framework for Anatomy and Clinical Clerkships, Clinical Anatomy, 2006, 91: 419-428.
23. Woods NN, Neville AJ, Levinson AJ, Howley EHA, Oczkowski WJ, Norman GR, The value of basic science in clinical diagnosis, Acad Med, 2006, 81, S124-S127.
24. Lambert DR, Lurie SJ, Lynes JM, Ward DS, Acad Med, 2010, 85, 356 – 362.
25. Ericsson, K Anders, Deliberate Practice and the Acquisition and Maintenance of Expert Performance in Medicine and Related Domains. Academic Medicine. Research in Medical Education Proceedings of the Forty-Third Annual Conference November 7-10, 2004. 79(10) (Supplement):S70-S81, October 2004.
26. University of Rochester website, http://www.urmc.rochester.edu/education/md/prospective-students/curriculum/, accessed 15 July 2010
27. Spencer AL, Brosenitsch T, Levine AS, Kanter SL, Back to the basic sciences: An innovative approach to teaching senior medical students how best to integrate basic science and clinical medicine, Acad Med, 2008, 83, 662 – 669.
28. Liason Committee on Medical Education, The structure and Function of a Medical School, http://www.lcme.org/functions2010jun.pdf

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Erratum

In the Commentary "*Using Basic Science to Develop an Innovative Program in Complementary and Alternative Medicine*" by Hakima Amri and Aviad Haramati (Issue 20-2, pages 48-55), figure 3 was missing. The figure has been added and the pages have been republished on the JIAMSE website for your reference.

We apologize for this error.