

Second Flexner Century: The Democratization of Medical Knowledge: Repurposing a General Pathology Course Into Multigrade-Level “Gateway” Courses

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Abstract

Starting in 1910, the “Flexner Revolution” in medical education catalyzed the transformation of the US medical education enterprise from a proprietary medical school dominated system into a university-based medical school system. In the 21st century, what we refer to as the “Second Flexner Century” shifts focus from the education of medical students to the education of the general population in the “4 health literacies.” Compared with the remarkable success of the first Flexner Revolution, retrofitting medical science education into the US general population today, starting with K-12 students, is a more daunting task. The stakes are high. The emergence of the patient-centered medical home as a health-care delivery model and the revelation that medical errors are the third leading cause of adult deaths in the United States are drivers of population education reform. In this century, patients will be expected to assume far greater responsibility for their own health care as full members of health-care teams. For us, this process began in the run-up to the “Second Flexner Century” with the creation and testing of a general pathology course, repurposed as a series of “gateway” courses on mechanisms of diseases, suitable for introduction at multiple insertion points in the US education continuum. In this article, we describe nomenclature for these gateway courses and a “top-down” strategy for creating pathology coursework for nonmedical students. Finally, we list opportunities for academic pathology departments to engage in a national “Democratization of Medical Knowledge” initiative.

Keywords

Flexner 2.0, Flexner 3.0, Flexner 4.0, health literacy, medical education, medical science, Second Flexner Century

Received May 04, 2017. Received revised June 09, 2017. Accepted for publication June 10, 2017.

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Introduction

Since 1996, faculty members from The University of Arizona College of Medicine's (COM) Department of Pathology have taught a modified medical school general pathology course as a campus-wide course offering for Master of Science (MS) students and Doctor of Philosophy (PhD) students.¹ Pathology department faculty members later adapted, and taught, a truncated version of the graduate student general pathology course to middle school and high school students in Tucson and Phoenix, Arizona.²

Low health literacy is a major challenge in the United States.³⁻¹¹ Three factors support our nascent 21st-century "Democratization of Medical Knowledge" initiative in the United States: (1) a growing literature pointing to influences of patient "health literacies" on their personal clinical outcomes from treatments of diseases; (2) published evidence that K-12 students, college students, and nonmedical graduate school students can handle medical science coursework, previously reserved for medical students; and (3) our studies showing that a typical medical school general pathology course can be repurposed, mobilized, and reinserted at multiple points in the US education continuum.¹⁻¹²

This is the fourth in a series of papers on our Democratization of Medical Knowledge initiative in which we further expand our classification of nonmedical school general pathology courses, describe our top-down multicourse authoring strategies, introduce tool kits used to enrich these nonmedical school courses with learning materials ordinarily available only to our medical students, and describe opportunities for academic pathology departments to participate in the Democratization of Medical Knowledge initiative in national leadership roles as creators, managers, and content experts (Appendix A).^{1,2,11}

Expanded Scope and Nomenclature for a Set of Gateway General Pathology Courses

A gateway course is, by definition, foundational in nature. It is often the first course in a string of related courses, taught at a progression of grade levels, on a particular subject.¹³⁻¹⁹ There are 4 major health literacies (plural): health literacy (singular)—basically the reading and writing skills needed to follow medical instructions, disease literacy, pharmacy (drug) literacy, and medical procedure literacy.^{3,7-11} Acquisition of disease literacy requires having, at a minimum, a rudimentary understanding of medical science.

We use the "Flexner" name as the stem for our course designations. This is in recognition of Abraham Flexner's critical role in the first modern revolution in medical education, beginning with the publication of his "1910 Flexner Report."²⁰ Flexner was an organizational genius and master educator who spent 2 decades leading the charge for reform of medical education in the United States in the early 20th century.²⁰⁻²³ Today, there are many incentives to move beyond the Flexner Report's recommendations and extend medical knowledge

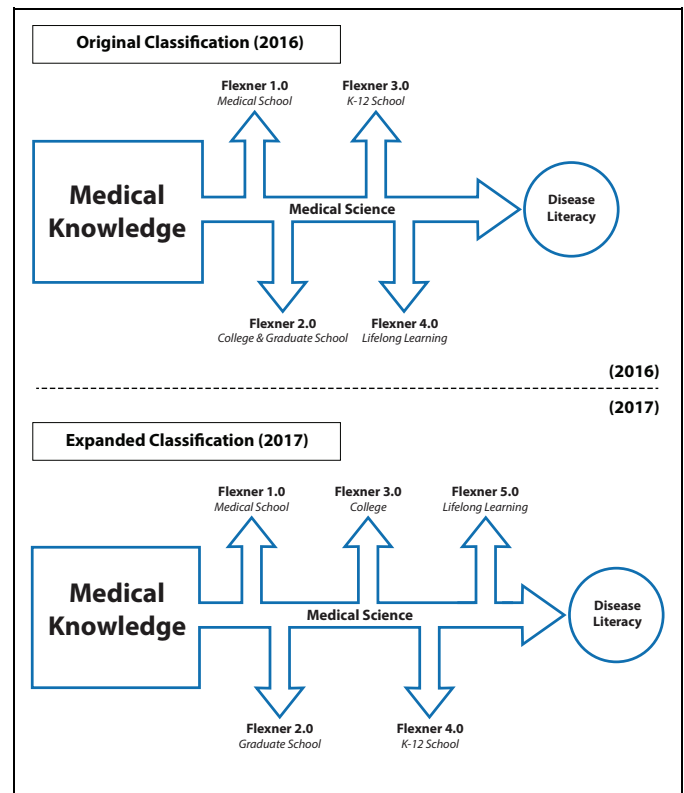


Figure 1. Interrelationships of a series of general pathology gateway courses, repurposed from a single medical school general pathology course. This compares the "Original Classification (2016)" (top) and "Expanded Classification (2017)" (bottom) naming schemes. The subclassification of courses is shown in Table 1. The "normalizing tool kits" are shown in Table 2.

throughout the entire US population, starting with K-12 students.² The pressures are multifactorial and include growing concerns over US patient preparedness for assuming increased responsibility for their own health care.^{4,24-26}

In previous *Academic Pathology* articles, we introduced a short form of our classification of general pathology gateway courses including names for our initial pair of courses for non-medical students.^{1,2} In this article, we introduce the nomenclature for the entire series of general pathology gateway courses (Figure 1 and Table 1). These courses have shared core content enabling the rereview of that content as students move up through a progression of education levels. The courses differ with respect to the amount and depth of course content on each topic, hours of in-class and out-of-class learning, and the hours of engagement in whole-slide imaging laboratories.

Lifelong learning, defined as the "ongoing, voluntary, self-motivated" pursuit of knowledge for either personal or professional reasons," https://en.wikipedia.org/wiki/Lifelong_learning, is represented in the "Expanded Classification" as "Flexner 5.0" (Table 1). It is important to understand that "disease literacy" requires a higher level of medical science knowledge than is expected for "health literacy."^{3,7-10} In the schematic representation of the "Original Classification (2016)" (Figure 1, top), the undergraduate college students and

Table 1. Nomenclature for Mechanisms of Diseases (eg, General Pathology) Courses.

Original Classification (2016)	Expanded Classification (2017)	Education Level
Flexner 1.0	Flexner 1.0	Medical school
Flexner 2.0	Flexner 2.0	Graduate school
	Flexner 2.A	Graduate school—lower level
	Flexner 2.B	Graduate school—upper level
	Flexner 3.0	College
	Flexner 3.A	College—lower level
	Flexner 3.B	College—upper level
Flexner 3.0	Flexner 4.0	Grades K-12
	Flexner 4.A	Grades K-8
	Flexner 4.B	Grades 9 to 12
Flexner 4.0	Flexner 5.0	Lifelong learning
	Flexner 5.A	Formal coursework
	Flexner 5.B	General resources
Flexner X.0	Flexner X.0	Alternative pathway*
	Flexner X.EC	Early college

*Flexner X.0 designations for a Flexner medical science course taught in an “alternative pathway” such as at an early college (Flexner X.EC; also see Figure 9).

nonmedical graduate students were lumped together. In the “Expanded Classification (2017)” (Figure 1, bottom), Flexner 2.0 now represents a nonmedical graduate student course and Flexner 3.0 represents an undergraduate college course instead of K-12 courses as shown in the “Original Classification—2016.”^{1,2} Flexner 4.0 represents “K-12 General Pathology” and Flexner 5.0 represents “Lifelong Learning.”^{27,28} The repository for “medical knowledge,” referred to in Figure 1, houses supplementary learning materials custom-tailored to highlight clinical relevance in this series of nonmedical school general pathology courses (Table 2).

Rethinking the Recommendations of the 1910 Flexner Report

Throughout the First Flexner Century, 1910 to 2010, a single education concept, biomedical teaching and research, dominated medical education. Flexner’s recommendation was that premedical and medical education be comprised of the specific prerequisite college science courses—college biology, chemistry, and physics—which would precede the taking of a specific group of preclinical medical science courses in medical school. Flexner designated medical school biochemistry, pathology, pharmacology, and bacteriology (ie, microbiology) as the essential medical science courses. Today, many medical educators regard this century-old linkage of the Flexnerian premedical science courses to current medical school preclinical science courses as unwarranted and a significant impediment to medical education reform.^{6,11,20,29-36}

Table 2. General Pathology Course Enrichment Tool Kits for Nonmedical School Learning Environments.

Category	File Name	Description	Remarks
1	Pictorial gallery	Classic images of diseased organs and tissues, with descriptions	Sets of 50, 100, and 250 PowerPoint slides (PPS)*
2	Visuals collection	Graphics, tables, schematics	Sets of 50, 100, and 250 PPS*
3	Illustration group	Medical illustrations	Sets of 50, 100, and 250 PPS*
4	Critical lists	Memorization lists, drills, games, and so on	Education-level appropriate packs
5	Patient cases	Patient vignettes, clinical pathologic conferences (CPCs), gross and micro autopsy cases	Store-and-forward or video streaming formats
6	“Adopt-a-Disease” jukebox	Student presentations to students and faculty at the end of the course	Student team presentations: etiology, pathogenesis, pathology, and clinical course

*Bronze (50 slides), silver (100 slides), and gold (250 slides) PowerPoint Slides (PPS).

Modernization of Premedical and Medical School Curriculums

Medical science coursework is underrepresented in US K-12 schools, especially in our society which expects the general public to assume increasingly greater responsibility for their own health care and that of their families.⁴ The minimization of medical science coursework throughout most of the US education continuum traces back to the 1910 Flexner Report. Flexner recommended that medical science be taught as “upper level” college coursework at a time when bachelor degree nursing programs and college-level pharmacy degree programs were barely on the radar screen.^{18,37} The US medical schools and their rapidly growing applicant feeder network of undergraduate colleges had a vested interest in maintaining the status quo for medical school premedical science course requirements. Adding new courses can be an expensive proposition.

In the year 2016, the Medical College Admissions Test (MCAT) examination, required for nearly all US medical school applicants, was updated by expanding the list of premedical college topics to be covered in their MCAT examination and changing its focus. The MCAT’s orientation shifted from fact memorization to problem-solving.³⁸ In order to create the 2016 MCAT examination, undergraduate colleges were spared the inconvenience and costs of expanding their premedical curriculum course offerings. Instead, the Association of American Medical Colleges (AAMC), which creates and manages the MCAT, decided to expand its own role in premedical

education. It turned to the Khan Academy, a leading not-for-profit innovator in distance education, to collaborate with AAMC's subject matter experts in creating Khan Academy brand online instructional materials and test preparation exercises for topics covered on the new MCAT examination.²⁹

Expanding Medical Science Curriculum Throughout the US Education Continuum

Our overall objective is to prepare patients, during their student years, for an expanded role in their own health care and that of their families and friends. We envisioned making it possible for students at each major step in the education continuum to have access to a logical progression of coursework related to the 4 health literacies, the unifying theme. (See below for a detailed discussion of how the course content was created.)

As a frame of reference, the attention of course-authoring teams is focused on the interaction between students, as future patients (eg, these students later in life), and their primary care providers sometime in the future. By receiving input from primary care providers while authoring the coursework, we try to ensure that the course creators understand the dynamics of the patient-provider interface and that their primary mission is to enhance the communication between patients and their doctors, sometime in the future.

Each Flexner curriculum will meet the education standards relevant to the level of education of the students. For example, the Flexner 4.0 general pathology course (Table 1) incorporates all 8 practices listed in the "Next-Generation Science Standards" for high school curricula that the National Research Council's *Framework* identifies as essential.¹⁸ Science, Technology, Engineering and Math (STEM) curricula are notoriously lacking in medical science content, other than student internships in biomedical companies. We previously recommended that an additional "M," for "medical science," be added to STEM (ie, STEMM).² The inadequacy of medical science coursework in our K-12 schools reflects the US National Research Council's recommended framework for K-12 science education, which we regard as being in need of upgrading.^{2,17-19}

Planning of a Series of General Pathology Gateway Courses

The following illustrations are graphic representations of the Flexner framework which we use to conceptualize and operationalize gateway courses at each level in the education progression. The 1910 Flexner framework, illustrated schematically in Figure 2, remains the basic framework for the education of medical students in the US today.

The 1910 Flexner Report was concerned with college and medical education but neither K-12 nor graduate (MS and PhD) education. Today, US nonmedical graduate students take their coursework in the first 2 years of graduate school, which corresponds to the first 2 years of medical school, labeled grades 1 M and 2 M on this medical school scale (Figures 3 and 4).

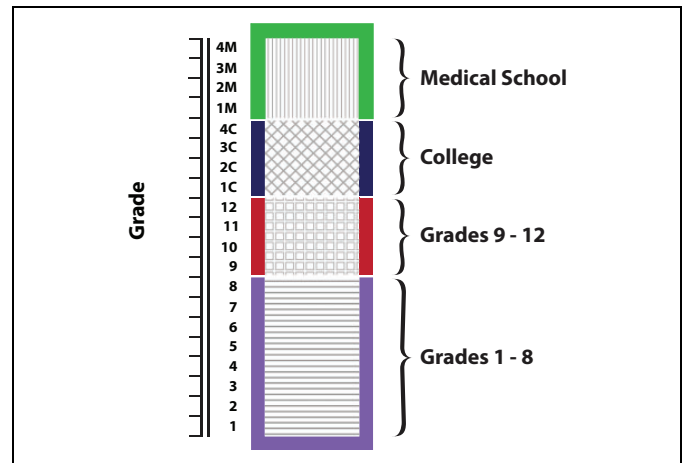


Figure 2. Flexner framework illustrated. The scale on the left represents the yearly progression of grades. Each of the 4 Flexner framework brackets (K-8, grades 9-12, college, and medical school) is shown in a standardized color. The bracketed grades are color coded: grades 1 to 8 are in purple; grades 9 to 12 are in red; college grades are in blue; and medical school grades are in green.

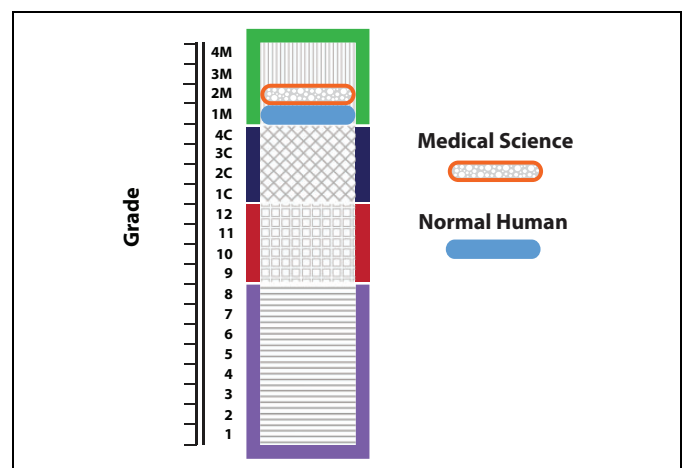


Figure 3. The placement of general pathology for medical students prior to entry into their clinical rotations in the third year of medical school. First-year medical school coursework (ie, the "normal human") is shown as a light blue capsule in the "1 M" year. The second-year (2 M) medical school general pathology course is contained within the orange capsule. Other medical science courses, including pathophysiology, pharmacology, and clinical microbiology, are collocated here as well (not shown).

The Flexner framework for medical education has "normal human" courses (ie, anatomy, histology, physiology, and biochemistry) positioned in the first year of medical school, with the medical science coursework (ie, pathology, pharmacology, microbiology, etc) taught in the second year of medical school (Figure 3). General pathology is the first module in the traditional year-long medical school pathology course.^{39,40} Today, nearly half of the US medical schools still use the original Flexner medical school course plan, shown here, whereas the others have adopted either an organ-based format or a hybrid combination of the 2 systems.^{12,41-44}

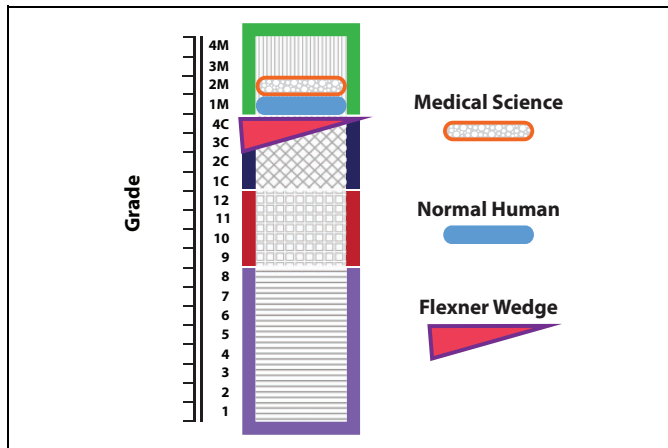


Figure 4. Flexner framework with a “wedge” (our invention) preventing the vertical diffusion of pathology coursework down into undergraduate colleges or K-12 schools. The Flexner framework with the metaphorical “Flexner wedge” is shown at the interface between the fourth college year (4 C) and the first year of medical school (1 M). The wedge blocks the back diffusion of medical science coursework into lower grade levels

In Flexner’s times, a metaphorical barrier arose spontaneously at a natural education boundary, partitioning undergraduate college and medical school and blocking access to medical science curricula by undergraduate college students. The exclusive intellectual property ownership of pathology coursework, by medical school academic pathology departments, was locked down, institutionalized, and guarded from poaching by other university disciplines, according to the ordinary rules of university governance and traditions, and then reinforced by accrediting organizations. The exclusivity of pathology is a linchpin of the medical profession’s guild status, even today. It is noteworthy that pathology is one of the few medical science courses to which the other health professions’ schools (eg, nurses, pharmacists, etc) are routinely denied access. On the other hand, as seen through the lens of Interprofessional Education and Collaborative Practice, the denial of access to pathology courses for nursing and pharmacy students, enforced by their deans, not the medical school deans, is a significant obstacle to assembling high-level interdisciplinary teams, including medical doctors, nurses, and pharmacists, to deliver complex health-care services. This should be remedied.⁴⁴⁻⁵¹

There are examples of successful repurposing of a medical school general pathology course at multiple grade levels in the US education continuum. Figure 5 shows the transposition of general pathology into a Flexner framework for nonmedical graduate school education, outlined in gray at the top.^{1,2} The terminal degrees, MS and PhD for Flexner frameworks “C” and “D” may be granted either by medical schools or by nonmedical graduate schools. Starting in 1952, a competing model for medical education was introduced at Case Western Reserve Medical School, in Cleveland, Ohio.⁴³ This is an organ-centric curriculum model. With the Case Western Reserve Medical School model, normal structure and function, and diseases and their therapies, are taught together, sequentially, 1

organ system after another (Figure 6—Flexner frameworks A, B, C, & D). The general pathology content for individual organs comingles with “normal human” course content. Typically, teaching is delivered by multidisciplinary faculty teams. At the University of Arizona COM, we now have had over 20 years of experience teaching general pathology to nonmedical first-year graduate school students in both the biological and physical sciences. The Flexner framework for nonmedical graduate students essentially duplicates that of medical students (Figure 7) except for the use of a gray-colored bracket on top of the Flexner framework for the nonmedical graduate school students, in place of the green bracket used to designate medical schools (compare with Figure 3).

Other configurations for derivatives of our medical school general pathology course have been successfully deployed. For example, a 3-week version of the Flexner 2.0 general pathology course was implemented successfully at Bard High School Early College in Newark, New Jersey (Figure 8). This version of the course was taught in June 2016 as an “X-term” intensive course. There were 42 contact hours spread across 3 weeks. Some sessions were video-conferenced in from the University of Arizona COM in Tucson, Arizona. The success of the course illustrated the flexibility of the Flexner 2.0 course, in this example being repurposed as a “Flexner X.EC” course in an alternative education pathway (early college; see Table 1).^{11,52}

As a last example of the flexibility of the general pathology course, here, in grade 1 H through 7 H, students may take a blend of BS and MD courses (Figure 9). Currently, there are 42 BS/MD programs in the United States (Figure 9). Such schools might provide interesting environments for the relocation of most of a medical school’s medical science coursework earlier in the students’ curriculum, perhaps even into the second and third year of a 6- or 7-year combined degree program, as is commonly found in European medical schools today.⁵³

Top-Down Authoring Process for a Series of Education Level-Appropriate General Pathology Gateway Courses

We approached developing a series of courses by first imagining a set of buckets, one for each education level-appropriate course (Figure 10). We then identified a core of high priority information, from the medical school general pathology course (Figure 11, red cylinders), that was placed in every bucket, to be shared among the courses, even at the earliest level. Finally, we added additional medical school pathology content in a stepwise fashion, such that the Flexner 2.0 course for nonmedical graduate school students would cover 85% of the total medical school course content (Figures 10 and 11). The learning objectives for each course were also tailored in a stepwise fashion, reflecting both consistency and expansion through the education continuum. Appendix B shows a comparison of learning objectives for the first lecture in the neoplasm block to be delivered at a series of grade levels. We previously published a detailed outline for the initial lecture in the neoplasm block, which serves as a frame of reference for these learning objectives.¹

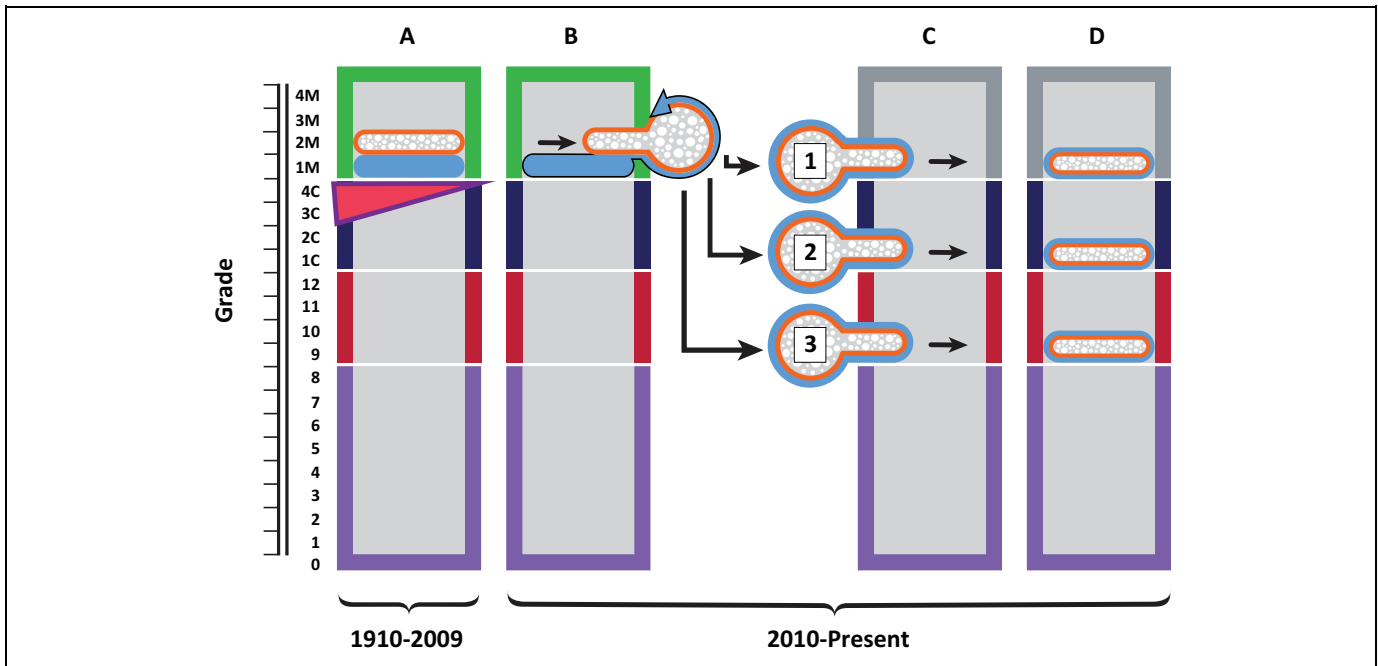


Figure 5. Transposition of general pathology coursework after withdrawal of the imaginary Flexner “wedge” (A). In framework B, medical school general pathology course is extracted carrying with it a light blue coating (see arrowhead, in framework B), representing essential first-year anatomy, histology, physiology, and other essential nonpathology course content. Potential reinsertion points include box 1—as a first-year graduate school course; box 2—as a first-year college course; and box 3—as a first-year high school course, shown here at the ninth grade level. The terminal degree illustrated in Flexner frameworks “C” and “D” are granted either by medical schools or nonmedical graduate schools (gray framework, C and D, top).

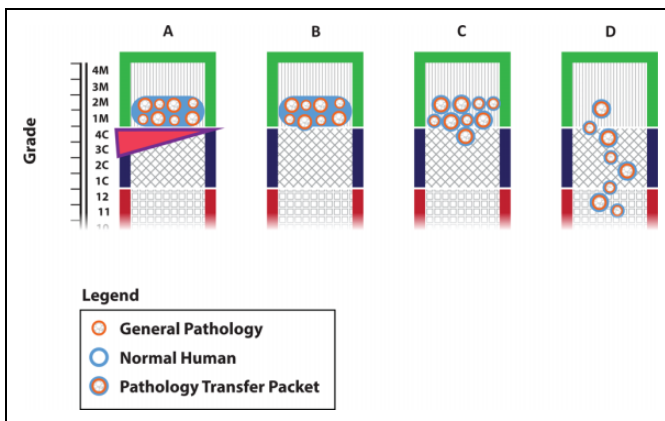


Figure 6. Organ-centric medical education model. Organ system-specific units include normal organ content (blue) and pathology content (orange spheres; frameworks C and D). These organ system-specific units self-organize with normal human content into mobile “pathology transfer packets” (C) that can individually relocate elsewhere in the education continuum (D). General pathology content for individual organs (orange spheres) congregate with “normal human” course content shown as a continuous blue phase (Flexner frameworks A and B). Removal of the wedge (B) results in the downward diffusion of “pathology transfer packets” including their thin blue rim of normal human content (C).

Our pathologist-driven, top-down (ie, derivative) curriculum building approach maximizes the repurposing and reutilization of medical school course materials in successive

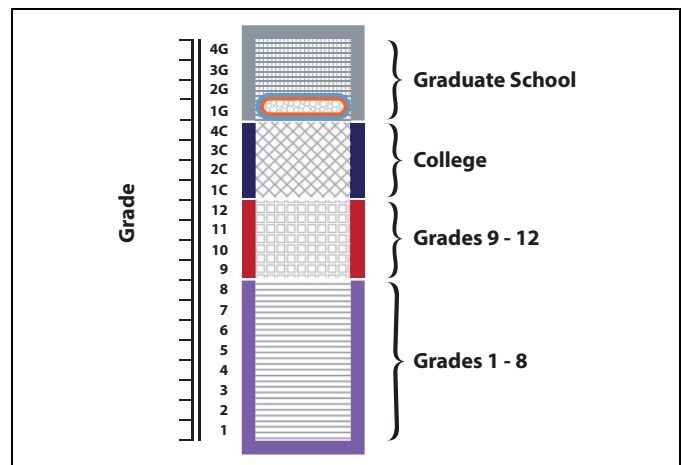


Figure 7. Flexner framework illustrating general pathology as a course for nonmedical graduate students. Here, the general pathology course is shown as a first-year nonmedical graduate school course. The top bracket is gray for graduate schools.

generations of the course. Our plan anticipates that students would take general pathology 1 to 3 times as they progress through multiple levels of the education continuum.

Figure 11 shows approximate percentages of medical school pathology content that each Flexner course would contain. (This is not drawn to scale.) These estimates are based on classroom contact hours, with 1 hour in a whole-slide image laboratory being equivalent to 1 hour of lecture. The Flexner

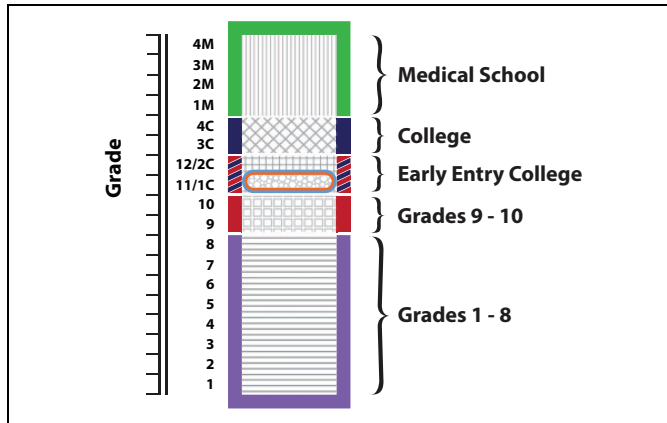


Figure 8. Modified Flexner framework representing a general pathology course adapted for use in an early entry college. The course was taught in June 2016 as an “X-term” intensive course, with 42 contact hours across 3 weeks, earning 3 college credits. The success of the course illustrates the flexibility of the Flexner 2.0 course, in this example being repurposed as a “Flexner X.EC” course in an alternative pathway (see Table 1).

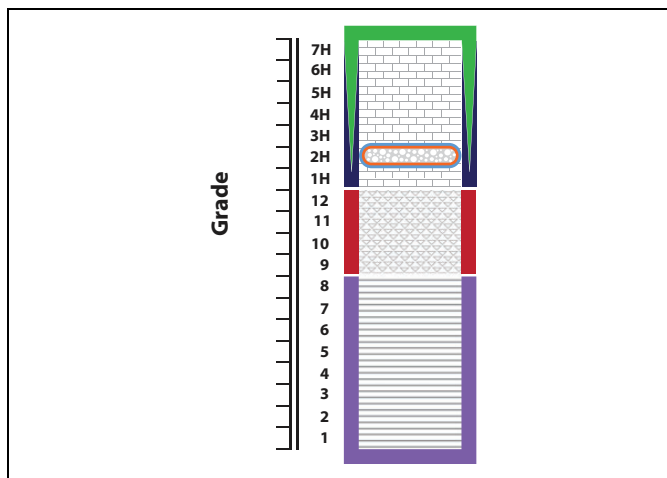


Figure 9. Flexner framework showing a 7-year hybrid BS/MD curriculum (1-7 H) with general pathology inserted at the “2 H” level. Blue marks undergraduate college course content and the green marks medical school coursework.

2.0 and 3.0 courses have approximately 2.4 times as much content as the Flexner 4.0 course (85% vs 35%) since both courses included 13 two-hour whole-slide imaging laboratories and lectures on the interpretation of laboratory results.^{1,2} The outermost green rim, seen only in the medical school Flexner 1.0 course, included time spent on “doctoring” issues (eg, medical ethics, clinical vignettes, medical imaging, etc).

Normalization of Medical School and Nonmedical School General Pathology Course

Medical students benefit from the rich educational environment and access to a wide variety of special learning

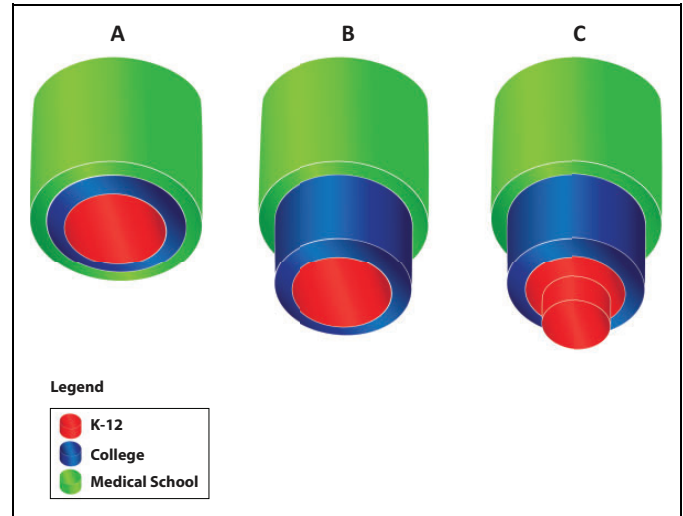


Figure 10. “Top-down/step-down” strategy for creating a family of medical science courses. Content for a series of general pathology courses, derived step-wise from a single body of knowledge (top). A (left), Representation of the medical school general pathology course. B (middle), Derivation of the college-level general pathology course (blue and red cylinders). C (right), Derivation of the K-12 general pathology course (red) from the college-level course. Not drawn to scale.

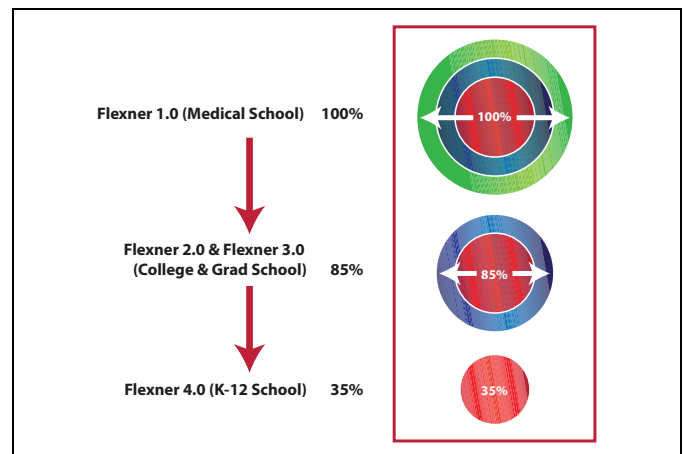


Figure 11. “Top-down/step-down” strategy for creating education-level appropriate courses. Percentages represent contact hours in lectures and laboratories. Illustration is not drawn to scale. “Top-down” refers to extraction of course material from medical or graduate school versions of the mechanisms of diseases course; “step-down” refers to progressive simplification of course material. Step-down from Flexner 1.0 to 2.0 reflects removal of clinical diagnostic and therapeutic materials; step-down from Flexner 2.0 and Flexner 3.0 to 4.0 reflects the removal of whole-slide imaging laboratory exercises, further simplifications of the content, and some deletions of optional topics in order to retrofit the course into the K-12 time slots. In our experience, this step-wise downsizing of the medical school general pathology course required the iterative resetting of priorities in order to achieve grade-appropriate and level of difficulty-appropriate clones of the original medical school gateway course, while retaining the patient–doctor interface focus. It is necessary that health education experts are involved in the process. Not drawn to scale.

opportunities that a medical school campus provides. In order to help create a level playing field for the nonmedical school students, we developed online toolkits that enrich their learning experiences and fill some of the gaps caused by their distance from a medical school campus.

Table 2 lists our supplemental medical education learning materials. Access to these materials has been important to our successes in teaching nonmedical school general pathology. The learning materials can be created in academic medical centers' departments of pathology. Other general pathology gateway course enhancements, provided to nonmedical school cohorts at our COM, included field trips to our COM Simulation Laboratory and organ demonstrations in the hospital morgue. Another popular offering in K-12 schools is our "Adopt-a-Disease" program, which brings a "virtual" clinical experience into the off-site middle school and high school classroom (Appendix C).

Repurposing of Medical School General Pathology as Multigrade-Level Gateway Courses

Why repurpose a medical school general pathology as the course of choice to serve as a model for a series of gateway medical science courses? Our rationale is that this popular general pathology course has a long track record as being an effective "touchstone" course that links the medical sciences to patient diseases through the teaching of basic mechanisms of diseases, using K-12 classroom-adapted teaching materials rich in visual learning experiences.¹² In our experience, offering nonmedical students general pathology as their gateway course for medical science studies promotes the understanding of mechanisms of diseases that affect all organ systems and opens the door to the medical science world. In our experience, general pathology seamlessly takes its place at the head of a queue of the medical science courses, such as college-level, pharmacology, biochemistry, and microbiology. It did for the past century for medical students, and it does so now for students across the board. Also, of all of the basic science courses in a medical school, general pathology uniquely excels in its offering of visual learning experiences. This matches up well with medical practice, which has a large visual component in many specialty areas.

Medical Knowledge and Health Literacy

The Democratization of Medical Knowledge enterprise, as discussed in this article, has as its central tenet the proposition that sufficient medical science education could be added throughout the US education continuum creating the prospect of patients, now and in the future, achieving lifelong health literacy, disease literacy, pharmacy literacy, and medical procedure literacy, with all of the accompanying benefits in terms of personal and family health care.⁵⁴⁻⁶⁶ In order to reach this goal of gaining competency in the 4 major health literacies, our proposed initial intervention is the insertion of a flexible

gateway course on mechanisms of diseases, general pathology, at multiple points in the US education continuum.

Importance of Understanding Disease Context Within Health Care Teams That Include Patients

Achieving the Democratization of Medical Knowledge throughout society would necessarily require a sufficiently educated patient population. Currently, there is a critical need to elevate the education level of the US general public in order to have everyone play their own ideal role as "patient" in their virtual patient-centered medical home.^{67,68} One hallmark of success would be to have future patients possessing sufficient medical knowledge to enable their fluent and precise communication with their health-care providers, something that is often sadly lacking today. Without a satisfactory level of competency in the health literacies, including the critically important disease literacy, patients are all too frequently left at sea without a sufficient understanding of the context in which their diseases are being treated.

Important to our successful adaptation of general pathology courses to the K-12 and college levels was the maintenance of a strong, essential link between our Flexner courses with our pathology and laboratory medicine practices. We marketed the fact that pathologists are medicine's content experts on "mechanisms of diseases." Our access to superb teaching materials, both for classroom teaching and for demonstrations of diseased organs in the hospital morgue, and the willingness of pathologist educators to teach in these courses, proved to be invaluable assets for our innovative nonmedical school pathology education programs at The University of Arizona. The high comfort level of pathology staff members, both MD pathologists and PhDs, in providing both classroom presentations and staffing laboratories for community-based students was noted and appreciated by students at all levels.

Opportunities for Academic Pathology Departments—Taking Medical Science/Health Literacy Education to Scale

Our next challenge will be to take this to scale and make medical science education widely accessible throughout society. We can discuss this through the lens of an academic pathology chair in the United States. To accomplish this, we propose that the national network of academic pathology departments, comprising the Association of Pathology Chairs (APC), expand its role as subject matter experts beyond the walls of medical schools and claim the mantle of medical science experts for the entire education continuum in the United States. We propose that medical school pathology departments partner together to engage in a national collaborative "business," which would create a national network of training academies for the next generation of K-12, college, and nonmedical graduate school medical science educators. In our view, it is desirable that academic pathologists seize the opportunity to lead the endeavor to extend mechanisms of diseases education, as an entry

point for health literacy education, into all levels of US schooling.⁶⁹

Such opportunities for academic pathology departments might include the following:

1. Assume leadership roles in designing and promoting disease literacy education in K-12 schools, in undergraduate colleges, health profession degree programs across the board, and in nonmedical graduate schools.
2. Provide teaching materials and course content for K-12, college programs, and graduate student programs.
3. Recruit organizations, such as the Senior Fellows Organization of the APC, with a potentially interested membership to create and teach coursework on mechanisms of diseases to broader segments of the population, including students in K-12 schools, community colleges, baccalaureate colleges, and graduate schools.
4. Create a network of APC-accredited regional academies with a mission of preparing K-12 science teachers to bring medical science coursework into their schools. Model programs, focusing on other subject areas, such as training academies for K-12 instructors in business and finance, are currently available.⁷⁰
5. Establish a commission to develop recommendations for creating an educator workforce to teach general pathology to K-12 students. University professors are content experts. K-12 teachers are experts on pedagogy. Which group could provide the better candidates for teaching roles in this novel general pathology workforce? Over the short term? Over the long haul?
6. Following the lead of the American Academy of Arts & Sciences, as described in their publication, “Science and the Educated American: A Core Component of Liberal Education,” develop guidelines for the health literacies education of the “Educated Patient of the Future,” the imaginary occupant of the “patient-centered medical home.”⁷¹

Addition of a Medical Science Component to the US Health Literacies’ Definitions

We acknowledge that our education intervention, the insertion of general pathology into K-12 classes and nonmedical university curriculums, designed to increase the robustness and value of the health literacy concept, would need vigorous testing with long-term outcome studies to justify its permanent inclusion in the standard US school curriculums. However, we have a sense of urgency in making this proposal. There is considerable evidence that the artificial and remediable deficiencies of medical science education in US schools throughout much of the education continuum may be manifesting themselves downstream with negative impacts on patient health care. This could contribute, downstream, to the high death rates from medical errors in US adults.^{24,25} These are pressing issues.⁷²

Appendix A

Second Annual Fred and Janet Sanfilippo Visiting Professor Lecture

An early version of this article was presented at Johns Hopkins Medical School’s Pathology Grand Rounds, as the “Second Annual Fred and Janet Sanfilippo Visiting Professor Lecture,” held in the historic Hurd Hall, in Baltimore, Maryland, on April 4, 2016, and in recognition of the associations of the Flexner brothers with Johns Hopkins University. This lecture is posted on the web as “The Sanfilippo Lecture,” at the Johns Hopkins School of Medicine’s Department of Pathology’s web page (last accessed on May 30, 2017),⁷³ and is permanently archived at the University of Arizona.⁷⁴ <http://pathology.jhu.edu/department/training/prospectives.cfm> (last opened on June 6, 2017).

For his evaluations of medical schools appearing in the 1910 Flexner Report, Abraham Flexner, a graduate of Johns Hopkins undergraduate college, used Johns Hopkins Medical School as his aspirational school against which all other US medical schools were measured. His brother, Simon Flexner, MD, had trained in medical research in the Department of Pathology at Johns Hopkins Medical School, before being recruited as director of the Rockefeller Institute for Medical Research, in New York. Professionally, Abraham Flexner was an outsider, a high school teacher of the Greek and Latin languages for the first half of his career as an educator, prior to his authoring of the groundbreaking 1910 Flexner Report. He had little formal training in science, except for a few college courses, and none in medicine.²²

Appendix B

Example of “Top-Down” Authored Sets of Learning Objectives for “Neoplasia I” Lecture

Comparisons of Learning Objectives for a Grade-Level Series of Flexner Courses (Sample: “Neoplasia I” Lecture)

Flexner 1.0 course (medical school)

1. Compare and contrast molecular and genetic mechanisms that underlie cancers.
2. Explain the actions of oncogenes and tumor suppressor genes.
3. Distinguish between benign and malignant tumors, by their gross and microscopic appearances and behaviors. Understand the significance of the terms “well differentiated” and “poorly differentiated” as they relate to tumors. How do benign tumors cause problems?
4. List the 4 most common cancers in men and women in the United States, as well as the 4 most lethal cancers in men and women.
5. List the 3 most common cancers in children.

6. List the 3 primary modalities for delivering cancer therapies.
7. Discuss the diagnostic tests for breast cancer and lung cancer.

Flexner 2.0 course (graduate school): See “neoplasia I/pathology 515” (Appendix B)¹¹

1. Compare and contrast molecular and genetic mechanisms that underlie cancers.
2. Explain the actions of oncogenes and tumor suppressor genes.
3. Distinguish between carcinoma and sarcoma and their tissues of origin and benign counterparts.
4. Distinguish between benign and malignant tumors by their gross and microscopic appearances and behaviors.
5. Understand the significance of the terms “well differentiated” and “poorly differentiated” as they relate to tumors.
6. List the 3 most common cancers in men and women in the United States, as well as the 3 most common lethal cancers.

Flexner 3.0 course (undergraduate college—2017 terminology)

1. Define benign tumor, cancer, carcinoma, sarcoma, and metastasis.
2. Distinguish 4 differences between benign and malignant tumors.
3. Describe 3 routes for metastatic spread of cancer.
4. Describe 3 common modalities for diagnosing cancer.
5. List the 3 most common lethal cancers in adult women and men.
6. Identify the number 1 risk factor for cancer.

Flexner 4.0 course (K-12 high school)

1. Define tumor, neoplasm, cancer, and metastasis.
2. Describe 4 differences between benign and malignant tumors.
3. Describe 3 routes for metastatic spread of cancer.
4. Name the most common cancer in adults and in children.
5. Identify the most common risk factor for cancers in women; in men.

Appendix C

“Adopt-a-Disease” Exercises

The “Adopt-a-Disease” exercises provide students away from medical facilities with a “virtual” clinical experience. The

student teams are each assigned a disease to research. The students search YouTube for videos of patients or their caregivers discussing their disease and select the one they think most effectively represents the disease category that they are researching. Student teams then make a class presentation at which they imagine what it’s like to live with their assigned disease. Student presentations follow a template covering: etiology, pathogenesis, pathology, clinical course, and public health implications of the disease assigned to their team.

Authors’ Note

Early phases of this work were carried out at Phoenix Union Biosciences High School, in downtown Phoenix, Arizona, and at the nearby T-Health Institute (eg, Institute of Advanced Telemedicine and Telehealth), the Phoenix division of the Arizona Telemedicine Program, located in downtown Phoenix. The Arizona Telemedicine Program is headquartered in Tucson, Arizona. Anna R. Graham, MD, Professor Emeritus in Pathology at the University of Arizona–Tucson, participated in early work on this project as *Scholar-in-Residence* in the Arizona Telemedicine Program and made major contribution to the design and testing of the gateway general pathology course for K-12 students.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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