Back to the future? Active learning of medical physiology in the 1900s

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Rangachari PK. Back to the future? Active learning of medical physiology in the 1900s. *Adv Physiol Educ* 31: 283–287, 2007; doi:10.1152/advan.00053.2007.—In the early 1900s, teachers of medical physiology faced a problem familiar to those teaching the subject in a contemporary setting: too much information, too little time, too many students in crowded rooms, and exams that discouraged real learning. They wanted students to question authority and demand evidence and thus be better prepared for medicine. Their solution was laboratory instruction. They felt strongly that useful information could not be obtained merely to bring students into laboratories and minimize didactic learning as they felt strongly that useful information could not be obtained merely from books. Thus, they were strong proponents of what we now call active learning.

TEACHING PHYSIOLOGY to the current generation of medical students is not an easy task. Burgeoning information in all the basic sciences forces teachers to be extremely selective in what they teach to ensure that future practitioners of medicine have acquired the necessary concepts and skills to deal with clinical problems. However, even a brief backward look at the teaching of medical physiology 100 years ago makes it clear that the problems facing teachers today are far from unique, although the means used in the past to deal with similar issues were rather different.

Consider the following quote taken from the preface to Alcock and Ellis’s A *Textbook of Experimental Physiology for Students of Medicine* (1), published in 1909:

> For some time past London teachers have felt that the Courses in Practical Physiology were unsatisfactory, in that sufficient regard was not given to future requirements of the student of medicine. The magnification of the office of examinations, which is the bane of higher education in this country, tends to the stereotyping of teaching, and makes it difficult to design courses with the natural object of improving the knowledge of the student. And yet if a man is to understand the problems of disease, he must first be acquainted with the workings of the healthy body. It is not sufficient, nor is it necessary, that he should know all that has been written on the subject. Rather must he aim at having such a mental image of the organs of the animal body, that the latter becomes to him, so to speak, transparent, and he is able mentally to picture the disorders of function, which he infers from the signs and symptoms utilized by the medical man for the purposes of diagnosis. This knowledge cannot be obtained simply from the reading of books.

The writer was Ernest Starling, Jodrell Professor of Physiology at the University of London, who had already made extensive contributions to that discipline. Clearly, his comments resonate well with those teaching physiology in contemporary medical schools. Only a few years earlier, he had introduced a new word into the scientific lexicon, hormone, based on his discovery of secretin along with his brother-in-law, Bayliss. He was a compulsive experimenter (12), and so when he examined the problem of teaching physiology, he drew attention to what to him and many others at the time seemed the most logical approach to teaching the subject properly: through experiments in the laboratory.

This brief essay will examine the teaching of medical physiology predominantly in England and North America from the perspective of a physiologist teaching similar students today. The issues of the past will be examined using current educational jargon: content, process, and evaluation. Finally, an attempt will be made to see modern teaching approaches from the vantage of a 19th century physiologist transported magically to a contemporary North American medical school.

Content

Although we may not appreciate it, the teachers of that period were also faced with an enormous content that they felt was essential for medical students to know. Wiggers (26), writing in the middle of the last century, wryly commented that the “volume of physiological information his generation was required to master as students was by no means small” and pointed to a series of textbooks of that period as evidence. Austin Flint Jr., Professor of Physiology at Cornell University Medical College, wrote in the preface (7) to his *Handbook of Physiology* that he had undertaken the difficult task “of selecting from the vast store of knowledge what may be taken as a fairly symmetrical and comprehensive presentation of human physiology, not too voluminous for students or for ready reference by active practitioners.” As standard texts on chemistry and physics contained little information on modern physiological chemistry, he included elements on ionization, dissociation, and osmotic pressure, which had an important bearing on modern views of physiological processes. His readers would have been aware that the recently instituted Noble Prizes had been awarded to both Van’t Hoff and Arrhenius for their fundamental discoveries. In fact, Van’t Hoff in the first Nobel Lecture in Chemistry had drawn attention to the relevance of his discoveries for physiology and medicine (24). Flint’s textbook contained 860 pages of very dense text with an atlas of histology. Over 130 pages dealt with various aspects of gastrointestinal function (salivation, digestion, secretion, and motility). Across the Atlantic, Michael Foster authored an “abridged” textbook of physiology in 1895 that had over 1,160 pages of text with about 100 pages dealing with various aspects of gut function. So the overloaded curriculum was a reality even then.

Students suffered this curriculum. In the years of 1886–1889, students at the University of Pennsylvania Medical School had a grueling schedule (http://www.archives.upenn.edu/histy/features/1800s/1889med/courses.html) in their first 3 years. In the first year, they had 38.5 h of instruction per week, which increased to 54.5 h in the second year. Anatomy
occupied the largest component in both those years (13 h/wk); they also studied chemistry, histology, materia medica, and pharmacy in the first year and had 1-h weekly lectures on general pathology and hygiene as well as attending general medical and surgical clinics. Physiology was taken in the first 2 years (3 h/wk) with a final exam in the second year. A well-equipped physiological laboratory was available, which was under the personal direction of the professor who had a demonstrator to assist him. At Harvard, students received 220 h of stated instruction in a collegiate year of 32 wk. If one added time spent in home study, it appeared that physiology occupied around a quarter of the student’s time (17).

Process

Since lectures were the primary mode of communication, teachers took them seriously. Many of the most eminent scientists of the day were regarded as outstanding teachers. Michael Faraday was a case in point. He was considered to be one of the greatest experimental physicists of his time (his magnificent discoveries in electromagnetism had ushered in a new age), and yet he also had an enviable reputation for his abilities to communicate scientific information to young and old alike (16). A lecturer, he noted, “should appear easy and collected, undaunted and unconcerned, his thoughts about him and his mind clear for the contemplation of his subject.” He advised them to pay particular attention to the manner of expression, so that the utterance should “not be rapid and hurried, and consequently unintelligible, but slow and deliberate, conveying ideas with ease from the lecturer and infusing them with clearness and readiness into the mind of the audience.” He felt that although some were able to express their thoughts extemporaneously, it may not suit everyone. Proper organization of thoughts allows for more attention to expression. Although writing out a lecture could help, Faraday was explicit in that he did not approve of merely reading it out. He felt quite strongly that a lecturer should do his best to hold the attention of the audience. As he expressed it so eloquently, “A flame should be lighted at the commencement and kept alive with unremitting splendour to the end.” This meant that there should be really no breaks to distract the audience and no digressions and wanderings either. Knowing that an audience’s attention span was limited, he disapproved of long lectures and felt that no lecture should be allowed to exceed an hour. Faraday felt that diagrams and illustrations would enhance the lecture, but these had to be used very carefully. He gave very precise instructions in terms of arranging apparatus and demonstrations so that they could have the best possible effect on the audience and also paid particular attention to the organization of the lighting and seats in the lecture room. The realities were far different. Porter (17) describes the poorly lit, badly ventilated rooms in which students listened to their lectures at Harvard. They squeezed themselves into hard benches and had little room to take proper notes.

Jacob Henle, a brilliant anatomist, pathologist, and physiologist, was an outstanding teacher, extremely popular with his students for his wit, liberal views, and polemical writings. It was said that on hearing of his appointment at Heidelberg, students who were ready to leave stayed on an extra semester for the privilege of being taught by him (23). In England, several of the early physiologists were highly regarded for their teaching. William Sharpey, at University College London, gave 154 lectures in the academic years of 1837–1838, with over 23 lectures on the topic of digestion. He updated his lectures continuously and would often inform students of studies carried out elsewhere. In 1836, he referred to Beaumont’s experiments carried out in North America, and his notes mentioned Beaumont’s table on the digestibility of food-stuffs (22). He also described to students new discoveries such as Claude Bernard’s observations of glycogen in the liver (11, 20, 22). In the United States, Bowditch, another eminent physiologist, was highly regarded as an enthusiastic and stimulating lecturer, since he gave polished lectures and used demonstrations to illustrate fundamental facts (15). There were exceptions, of course. Michael Foster, who was instrumental in transforming the teaching of physiology by introducing laboratory experiments, was an “appalling lecturer,” although he was very effective in small groups, which gave him the best setting for his charismatic powers (11). The same could be said of John Burdon Sanderson, who had had a natural facility to enthuse students and organized courses, but was not an impressive lecturer and often left his audience bewildered (20).

Many of the best teachers were proponents of what is now known as active learning. Henle made the microscope a tool for teaching the average student, and Ludwig, the inventor of the kymograph, was an inspired teacher in that same mold (5, 23). Jan Evangelista Purkyne was not only an outstanding sensory physiologist but was seriously concerned about teaching and learning (5). He examined learning at all levels as a process of discovery, which began in the earliest years and continued until the distinction between learning the known and defining the unknown vanished. The student who was felt to be a lifelong learner, to use current jargon, merged into the genuine investigator. His pedagogic ideas were strongly influenced by the Swiss teacher Pestalozzi, who emphasized the ways of learning (process) over what was actually learned (content). This was perfectly acceptable at the level of a child, but Purkyne recognized that knowledge was vital and so sought to restore parity between content and process. He would have sympathized with modern skeptics of problem-based or case-based learning, who fear that overemphasis on process may neglect recognition of crucial principles (25). Purkyne wanted the student to be more actively engaged in their own learning and to that end started including practical demonstrations in physiology courses as additions to his lectures. Soon, he moved beyond lecture demonstrations to involving students in his research projects. Although not all students took advantage of this option, it certainly fostered an investigative spirit that added to the ethos of research in the German university system. Purkyne was not alone in promoting active learning. The approaches utilized in the continent were transferred to England by William Sharpey and Michael Foster. Sharpey was one of the first to use the microscope as a teaching tool in Great Britain. He constructed an ingenious device that allowed him to present microscopical demonstration to students during his lectures (11, 22, 20). Visiting American scientists who caught the “German” disease transported it across the Atlantic. This gradually transformed the teaching of physiology to medical students, which in antebellum America was largely didactic (9). The notion of “learning by doing,” which became established at Johns Hopkins University, received a tremendous impetus when Abraham Flexner
wrote his scathing attack on the status of medical education in the United States and Canada (3).

The Flexner report created the framework for standardizing medical education and thus is perhaps the most important document in the history of medical education in North America (3). A would-be medical doctor in the early 1900s could choose three paths. He (rarely she) could opt to be apprenticed to a practicing physician or join a proprietary medical school or one of the university-affiliated medical schools. The results were extremely variable and quite scandalous. The Council of Medical Education of the American Medical Association sought to reform medical education. They wanted to standardize preliminary education and also implement an “ideal” medical curriculum. The Council of Medical Education asked the Carnegie Foundation for the Advancement of Teaching to conduct a survey of teaching practices. Henry Pritchett, the Carnegie Foundation President, commissioned Flexner to undertake the survey. He favored strongly the university model, which included 2 years in the basic sciences followed by 2 years in clinical rotations in a teaching hospital.

Laboratory instruction in experimental physiology was seen as the solution to mere passive learning. Ludwig’s invention of the kymograph introduced graphical recordings into experimental physiology, and these approaches were applied in teaching laboratories as well. Purkyne’s role in promoting laboratory instruction has been mentioned above. England lagged behind France and Germany in physiology due to numerous factors (11). A determined effort by Sharpey was needed to make England a leader in physiology. Part of this effort involved importing continental approaches to teaching physiology. Laboratory teaching began in the late 1860s with an elective course at University College London. The Royal College of Surgeons introduced the requirement that practical classes in anatomy and physiology be a requirement for licensing, and this became generally adopted. So, by the end of the 19th century, laboratory courses and exams had become acceptable for training future physicians (11), and, as Fraser and his colleagues wrote in the A Laboratory Manual of Experimental Physiology (10), it “is now recognized as a fundamental subject in the curriculum of the medical student and as one having a most important place in the training of the student of biology. In the medical course, the physiological laboratory serves as the portal to the clinic.” Starling’s views on experiments in the teaching of medical students were mentioned at the outset. The program of instruction became well established, and Davenport describes his own experiences when he went to study physiology at Oxford in the late 1930s (6).

However, the medical curriculum was crowded, as noted above, and it was quite impossible to find the time required to do all the experiments. So, Fraser and colleagues (10) felt that the experiments must be selected with great care so that “the experience which the student gains in their performance may guide him aright in building up his knowledge of this subject.” Alcock and Ellison’s textbook (1) described a variety of experiments ranging from muscle, circulation, digestion, and respiration to the blood, secretion of urine, temperature, the special senses, and the nervous system. Students at Toronto and Buffalo used Fraser et al.’s laboratory manual (10), which included experiments on contraction of intestinal smooth muscle as well. MacLeod, who played a major role in the discovery of insulin, gave demonstrations on the innervation of the salivary glands and the control of the pancreatic secretion as well as experiments on salivary secretion and gastric juice. For Porter at Harvard, neuromuscular physiology was the central focus. As he expressed it grandly, the “physiology of muscle and nerve is in large measure the physiology of all living tissues, so that a man learned in this one field is in effect already acquainted with the general principles of physiology” (4).

Teachers setting up laboratory courses were conscious of the inherent problems. It was unlikely that the average medical student would get sufficient number of results, there was the problem of securing living materials, and teachers had to strike a proper balance between proper direction and stifling originality (10). Nevertheless, as Porter emphasized, “the way of the physiologist was not really all that peculiar. The method of getting a real education is the same from the kindergarten to the specialist. The principle is to train ‘for power’—and not for information” (17). By this, he presumably meant the ability to deal directly with the problems to be encountered. He noted that “The power of dealing with nature can no more be learned from books, lectures and a few more or less effective demonstrations than football can be learned by reading about the game and occasionally sitting on the fence a hundred feet from the eleven at practice” (17).

Porter played a significant role in transforming laboratory instruction at Harvard. He was convinced that medical students should have first-hand laboratory knowledge if their learning was to go beyond “mock physiology based on mock anatomy” (17). He was quite scathing of lecture demonstrations, which were often given in crowded rooms where students could rarely make out details properly. Even when such demonstrations were given in smaller groups, there was inadequate time for students to grasp the details. Clearly, different approaches were needed. In the 1870s, Bowditch had created the physiological laboratories at Harvard, and when Porter assumed this responsibility, he revamped them to promote routine laboratory experiments. He was critical of didactic teaching, rote learning, and memory drills. From his perspective, laboratory experiments were primary for the “development of mind rather than the imparting of information” (4), and so didactic sessions were entirely secondary. His approach to physiology teaching thus reversed the relations between lectures and laboratory experimentation: “In the old the student rests upon the dictum of the professor and the textbook. In the new he relies upon the fundamental experiments done with his own hands.” He felt that his students should no longer ask “Who is the authority for that statement” but “What is the experimental evidence?” (4). To revamp the laboratory, he needed to scale up the instruments and scale down the costs. In 1899, there were over 200 students in physiology at Harvard and working in pairs required the purchase of a 100 kymographs from Germany, which not only cost close to $20,000 but required several months to deliver (2). So a classical American solution was used: the quantity production of quality instruments by the newly created Harvard Apparatus Company with the original capital raised by Harvard President Eliot. Porter’s version of the kymograph cost only $16 and was light enough to be lifted by one hand (4). By 1906, the instruments manufactured by the company were used in over 200 laboratories (162 instruments in the United States and 43 instruments in foreign countries such as Syria, Russia, Japan, and Australia). This is also an
indication of the fair degree of uniformity in experimental physiology instruction in a global sense.

**Evaluation**

The teacher of physiology was constrained by the examination system even then, as Starling’s earlier comments showed. Nevertheless, rules and regulations did have some unexpected benefits. The change in licensing requirements for surgeons was mentioned earlier. This apparently trivial change in the examination statutes of the Royal College of Surgeons in 1870 had enormous consequences for laboratory training in physiology. The new requirement was that candidates should have taken practical courses in physiology “consisting of not less than thirty meetings of the class,” where they themselves had been “individually engaged in the necessary experiments, manipulations etc.” (11). When this was adopted by the University of London the following year, it transformed Victorian physiology. Not only did all medical students have to do practical experiments, but they needed teachers, and the number of studentships, demonstratorships, lectureships, and other junior positions increased (11). Aspiring physiologists suddenly began to find positions available for them. This led to growth of research in that discipline, with British physiologists making increasing contributions to the growth and development of physiology.

The examinations in physiology were of the standard essay type, which remains in vogue still in many countries. When Charles Eliot was elected President of Harvard in 1869, he was appalled by the incompetence of the average medical practitioner and decided to institute a series of reforms to ensure that medicine was based on a sound scientific basis (15). One of these included written examinations to test the student’s knowledge. In physiology, students wrote a 2-h exam followed by an oral exam of 6-min duration. Table 1 provides some indication of the sorts of questions that students at Yale were expected to answer (http://info.med.yale.edu/library/exhibits/yalemed1/newcurriculum.html). Porter (17) was very critical of this approach as it seemed quite divorced from practical work. Students then were no different than now. Many only studied at examination time and tried to size up the lecturer. If he was supposed to “follow Foster” or some other textbook, they too did the same. They “excused their idleness in the lecture hour by resolves of industrious reading of the omniscient Foster at some future time” (17).

Table 1. Selected examination questions in physiology at Yale University (June 1891)

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<th>Question</th>
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<tr>
<td>1. What are the chemical changes that take place when a living muscle enters into a contraction?</td>
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<td>2. Discuss the reflex actions of the spinal cord.</td>
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<td>3. What do you understand about the latent period of a muscular contraction? What are the principle causes affecting the degree of muscular contraction?</td>
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<td>4. What do you understand about inhibitory nervous action? Illustrate using two or more examples.</td>
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<td>5. Explain the accommodation of the eye to objects at different distances.</td>
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<tr>
<td>6. Describe the various tracts of the spinal cord and explain how they have been determined.</td>
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[Modified from http://info.med.yale.edu/library/exhibits/yalemed1/newcurriculum.html.]

**Between Then and Now**

In recent years, the Harry Potter novels have familiarized us with magical devices. One particularly interesting device, called the “Time Turner,” is used by a model student to gain more time so that she can overload on her courses (19). By turns on a magical hourglass, she is able to transport herself back in time so that she can have her hours back again so that she can do several courses at once. If, by the use of a similar device, an eminent Victorian physiologist were to transport himself forward to our world, he would be amazed at the voluminous information confronting baffled medical students as they try to make sense of physiology. He may vaguely that recall Porter had written to President Eliot at Harvard in 1904 that the majority of men entering medical schools then could not observe phenomena or record them accurately, as their “natural power of observation” and “lively curiosity regarding the world” was “not infrequently dulled by years of memorizing in the secondary schools” (4). He would wonder whether modern schools had made much difference to the preparation of students entering the medical profession. He would realize that even today active engagement of the student was crucial if they were to understand the voluminous information available to them in a meaningful way. He would examine modern textbooks and wished that teachers of his time could have had the facilities now available to include colorful explanatory diagrams and photomicrographs to render their books less wordy. He would recall that Austin Flint Jr. had to go to great lengths to ensure that his textbook was well illustrated (7).

If our visitor wandered into current lecture halls, he would find them as crowded as they were in his time. He would certainly be envious of modern technologies and the marvels of projection systems but wonder whether students gleaned much more now than in the past. He would like to observe the behaviors of the lecturers to see whether they would use any of the dictums recommended by Faraday for effective lecturing. He would wonder if there were any teachers like William Sharpey, who took so much effort to know not only the names of his students but also their personal circumstances, even though they often numbered several hundreds (11, 20). He may see numerous students using laptop computers in wired classrooms, but whether they were seriously taking notes or surfing the net would be hard to tell without closer inspection.

Our transported physiologist would be puzzled by some of the evaluation formats used. He may find some of modern educational jargon quite unfathomable and wonder if any of that seriously enhanced student learning. He would wonder whether the use of multiple-choice questions would be able to capture the nuances of thought that the old-fashioned standard essay exams were supposed to do. He would recall that Walter Cannon had introduced electives and tutorials at Harvard in a more intensive format to aid in the “sending into medicine of men with scientifically trained minds” (15). Although he would relish the use of tutorials for getting students engaged in their own learning, he may not be entirely sold on problem-based learning and wonder whether everyone would be able to get the general principles without more direction. What would be particularly disturbing to him would be the gradual erosion of laboratory instruction from a number of medical schools (13, 6, 25). He would read with some concern Davenport’s detailed analysis of that decline and be perturbed at comments made...
that “the basic sciences have grown too much, and too far from clinical concerns, to be usefully approached by medical students in the manner of graduate students. They must be limited...” (14). He would recall that the aim of teachers of medical physiology in his own time was to select elements specifically so that students would become better physicians! They then felt that their solution to the problem was eminently sensible. He would recall the emphatic words of Porter, “the force now making for reform is irresistible...the mass of knowledge in every department of medicine has grown so huge as to overwhelm both professor and student. The only refuge lay in thorough mastery of the scientific method. The medical student must acquire power rather than information” (2). He would watch with wry amusement teachers of today wrestle with the same issues and wonder at the fate of the newer solutions to the same problems. He would love to transport himself forward another century to see if problem-based learning, project-based e-learning, self-directed learning, or all those approaches, which seem so novel now, would be brushed aside by impatient teachers as they reinvent the wheel. As he makes several turns of the hourglass to return to his ethereal realm, he would mutter to himself “Plus ca change, plus la reste le meme chose.”

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