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HOW TO IMPROVE THE FORMAL ANALYTIC REASONING AND SCIENTIFIC MOTIVATION IN THE INTELLECTUAL TRAINING OF MEDICAL STUDENTS

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A review article of the *The New England Journal of Medicine* (1) refers that almost a century ago, Abraham Flexner, a research scholar at the Carnegie Foundation for the Advancement of Teaching, undertook an assessment of medical education in 155 medical schools in operation in the United States and Canada. Flexner's report emphasized the nonscientific approach of American medical schools to preparation for the profession, which contrasted with the university-based system of medical education in Germany. At the core of Flexner's view was the notion that formal analytic reasoning, the kind of thinking integral to the natural sciences, should hold pride of place in the intellectual training of physicians. This idea was pioneered at Harvard University, the University of Michigan, and the University of Pennsylvania in the 1880s, but was most fully expressed in the educational program at Johns Hopkins University, which Flexner regarded as the ideal for medical education (1).

To Flexner, research was not an end in its own right; it was important because it led to better patient care and teaching. Indeed, he subscribed to the motto, "Think much; publish little" in contrast with today's "publish or perish" culture. Now research productivity has became the metric by which faculty accomplishment is judged; teaching, caring for patients, and addressing broader public health issues are viewed as less important activities (1). In view of today's subordination of teaching to research it should be assumed that scientific reasoning should be central in the intellectual training of physicians?, especially if we take in consideration that many have criticized medical education for emphasizing scientific

knowledge over clinical reasoning, practical skill, and the development of character, compassion, and integrity (1). Our answer is yes.

Although our present medical curriculum seems overweighed by the scientific aspects of medicine to the exclusion of the social and humanistic aspects and we need a better balance between knowledge, skills, and values, still it is necessary to improve scientific education to prepare outstanding physicians for the 21st century. Abundant theory and large bodies of scientific knowledge create the false impression to medical students that almost everything is already known. And, even worst, the avalanche of scientific knowledge does not imply better scientific reasoning. The final test of the efforts of medical students will be not what they know theoretically but what they are able to do in scientific and clinical reasoning. After 1960, as medical research became increasingly molecular in orientation, and especially after sequencing the human genome, our organism has been smashed into billions of fragments. As in the popular song “Humpty Dumpty” (Humpty Dumpty sat on a wall / Humpty Dumpty had a great fall. / All the king’s horses and all the king’s men, / Couldn’t put Humpty together again), Denis Noble, Professor of Physiology at the University of Oxford, wonders in his book “The Music of Life”: Can we put Humpty-Dumpty back together again? This is the challenge of modern physiology. Teaching physiology is to teach the “logic of life” and in consequence to educate in scientific reasoning. Since cognitive psychology has demonstrated that facts and concepts are best recalled and put into service when they are taught, practiced, and assessed in the context in which they will be used (3) our teaching approach in physiology is not formulated in context-free and value-neutral terms as is seen in many cases in the basic medical sciences, but centered in the context of medical education.

Learning the scientific style by performing programmed tasks on cause-effect relationships

Our first objective has been to dissect the variables involved in the functions described in every chapter of the text book of Physiology. Then, we propose a list of tasks, accessible through Internet (Fig. 1), to be performed by the students: 1) Definitions of variables. These definitions include the range of physiological variation. 2) Relationship between pairs of variables. The relationship must be justified by an equation or graphic. When it is not possible to show a quantitative relationship, a qualitative relation is proposed. 3) Main variables directly related (cause-effect) with one variable. 4) Causal relationships between variables in a group of variables chosen in the context of their clinical interest.

For instance, we propose the analysis of the variables involved in an elevation of blood pressure.

Question: Which are the main variables directly related with blood pressure?
Answer: Cardiac output and peripheral resistances.
Analytical result: Cardiac output is increased.

Next question: Which are the main variables directly related with the cardiac output?
Answer: Stroke volume and heart rate.
Analytical result: Stroke volume is increased.

Next question: Which are the main variables directly related with the heart stroke volume?
Answer: The filling pressure, the contractility, and the arterial pressure.
Analytical result: The filling pressure is increased.

Next question: Which are the main variables directly related with the filling pressure?
Answer: Venous return.
Analytical result: Venous return is increased.

Next question: Which are the main variables directly related with venous return?
Answer: *Vis a tergo*, *vis a fronte*, venous tone and rhythmic muscle contractions.
Result: Venous tone is increased.

Next question: Which are the main variables directly related with the venous tone?
Answer: Sympathetic activity.
Result: Sympathetic activity is increased.

Final diagram: Write down a cause-effect diagram relating all the results obtained.

The students perform electronic evaluations that follow the same paradigm.

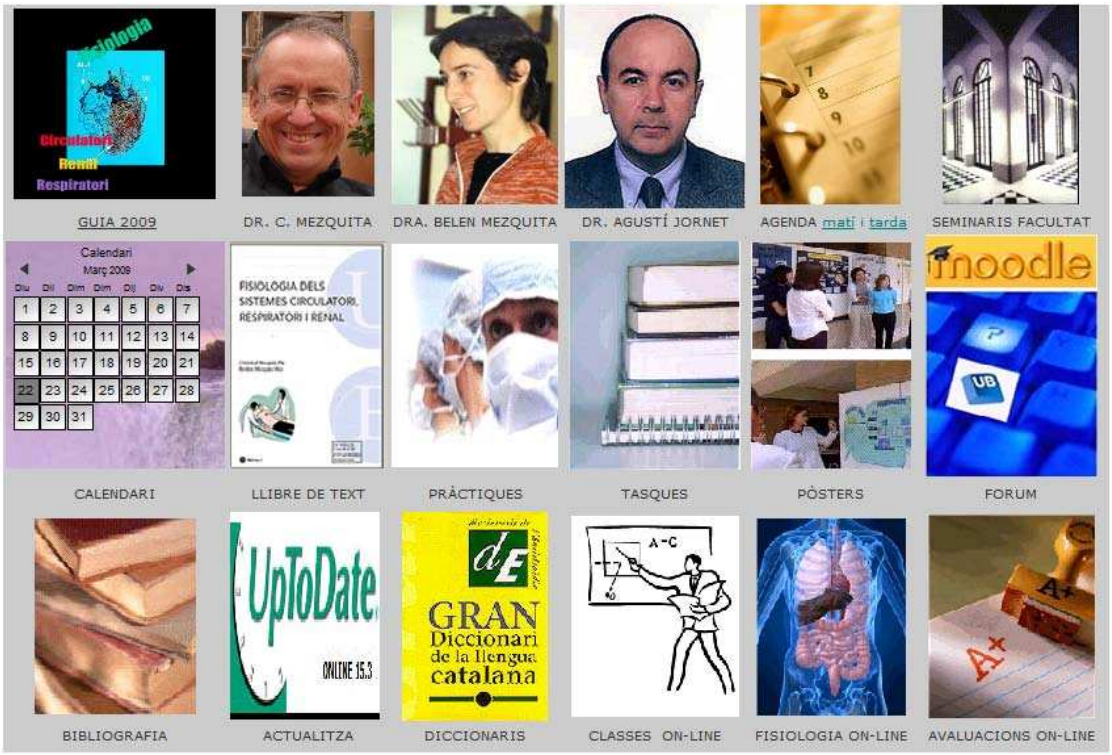

Fig.1. Tasks are accessible trough Internet: www.fisiologia.net

As an essential part of our approach to scientific education we reduce the amount of information given to the students and put the emphasis on the causal relationships between those variables that are the foundation of physiological functions. To build the relationships between the proposed variables, students use text books of physiology. For a limited number of questions we broad the scope using scientific journals in addition to the text book. Every year we propose a list of questions to the students about relationships between variables, which only can be solved using recent bibliography. The questions are selected from the topics discussed in the best scientific journals or from the articles recommended in the field of physiology by top leading scientists in Faculty of 1000 (www.f1000biology.com).

Students can access these questions through Internet (Fig. 2). First they work individually on some of the questions. The students search trough PubMed the scientific literature and look for an answer to the proposed question. Afterwards, they have to access the electronic journal where the selected article has been published and download it. It is mandatory to select an article published within the previous 12 months. This way we ensure that students work with the most updated data published on these topics.

Then, we select those students that had completed successfully the first part of the work to form groups of 3-6 members to prepare a poster or a multimedia presentation about the proposed topic. We give detailed instructions and a model to make the poster and the multimedia presentation. One of the students of the group is selected randomly immediately before she/he makes the presentation to the rest of the students. All the members of the group participate in the discussion.

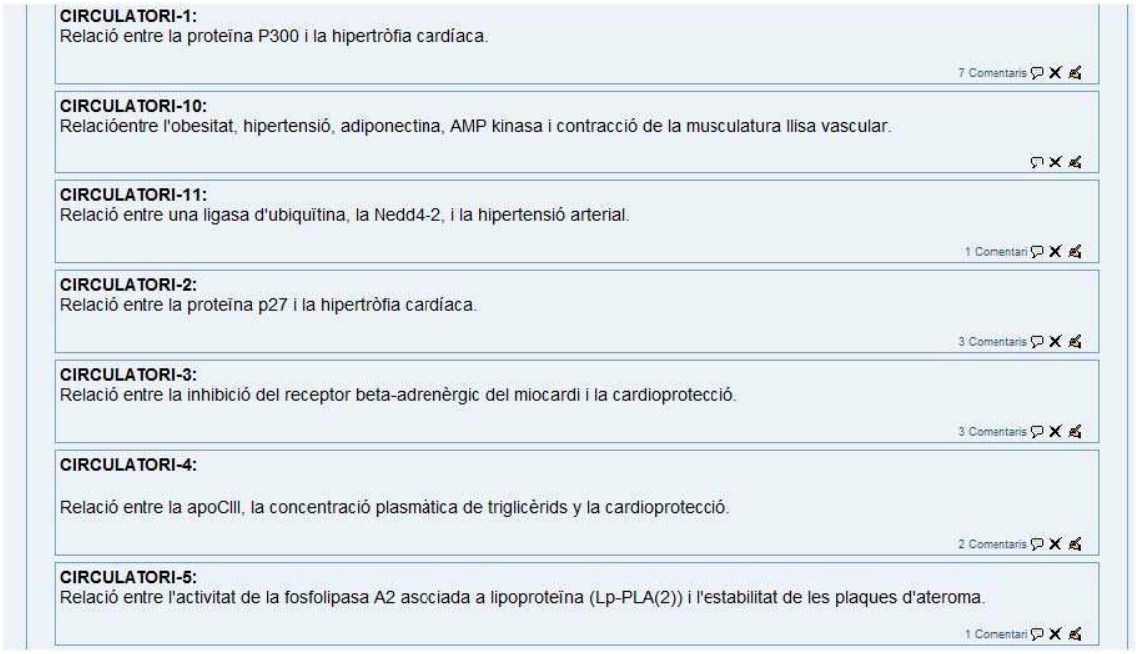

Fig.2: The list of questions to be answered after bibliographic search is accessible through the Moodle platform

Once the students have retrieved the article, they have to: 1) Answer the question proposed; 2) Briefly summarize the rational of the experiments performed by the authors to reach their conclusions, and 3) Write down the main bibliographic reference.

Through these activities we intend to develop the following competences: 1) Formal analytic reasoning, 2) Communication skills (oral, written, and electronic) and 3) Teamwork skills.

How to improve scientific education reading scientist's biographies, listening scientist's podcasts and playing scientist

In addition to Medical Physiology, we teach an elective in English called "Biomedical Discoveries". In this elective we use a different approach for scientific education. At the beginning of the course we give to every student the classic book on the major discoveries of the microscopic world "Microbe Hunters" written by *Paul de Kruif*. Every week the students read a chapter and become familiar with its contents. The author of the book says: "How I wish I could take myself back, could bring you back, to that innocent time when men were just beginning to disbelieve in miracles and only starting to find still more miraculous facts. How

marvelous it would be to step into that simple Dutchman's [Leeuwenhoek's] shoes, to be inside his brain and body, to feel his excitement … Reading "Microbe Hunters" the students can hear Robert Koch complaining "I hate this bluff that my medical practice is… it isn't because I do not want to save babies from diphtheria … but mothers come to me crying – asking me to save their babies- and what can I do? – Grope … fumble… reassure them when I know there is no hope… How can I cure diphtheria when I do not know what causes it, when the wisest doctor in Germany doesn't know?...

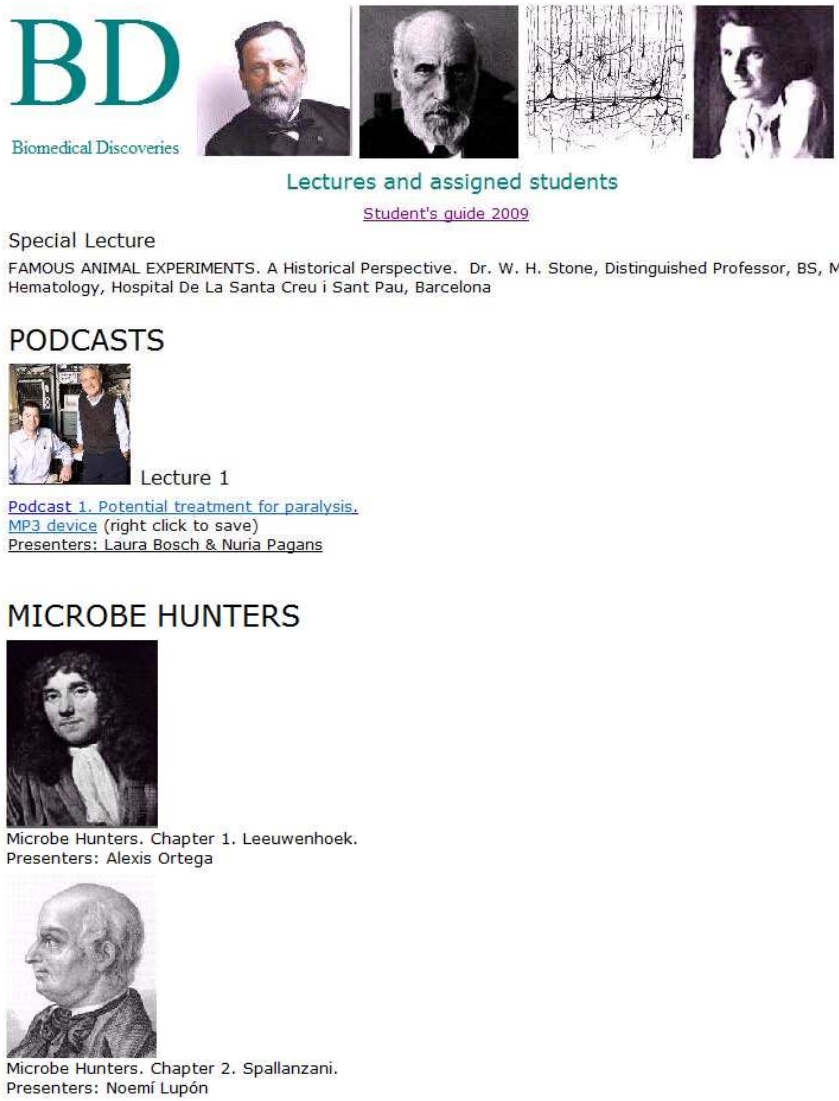

Fig. 3: Podcast and chapter assignments for students of "Biomedical Discoveries" are accessible through Internet

In addition to reading a chapter of the book every week, students read and listen to the podcast programmed for each week on hot scientific topics. To become familiar with the content of the podcasts, students listen to the audio and read the transcripts several times using Internet or MP3 devices.

During the classes a couple of students, previously selected, play the role of the scientist of each chapter of "Microbe Hunters" and the podcast being interviewed by the rest of the students.

- The interviewee is briefly presented by the teacher.
- Two students play the role of the interviewee.
- Students are randomly chosen to make questions.
- The interviewees answer the questions.

During the class we project videos on the scientific approach to the problems of global medicine. You can access the list of topics and student's assignments at (Fig. 3) http://www.fisiologia.net/TOPICS.htm

Finally it is very important for the scientific education of medical students to have the opportunity to work for a period of time in a lab bench. Students can attend every year at the Medical School of the University of Barcelona a "Week of Science", reading posters on the research projects going on in our labs, attending scientific seminars and visiting the labs. For those students that have been working in our laboratories or abroad, our Medical School offers during this "Week of Science" the opportunity to present their work and to receive some scientific awards such as the "Gemma Rosell Romero Award".

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