Science & Society

Teaching of pharmacology in the 21st century: new challenges and opportunities

Josep-E. Baños, María Reverte and Fèlix Bosch

It is generally accepted that pharmacology was founded by Rudolf Buchheim (Fig. 1), Professor of Pharmacology at Dorpat (1846) and Giessen (1867). Buchheim is not known for his pharmacological studies but rather for his efforts to develop a new, independent discipline. In his seminal paper on the role of pharmacology to train physicians [1], Buchheim stated that pharmacology is strictly related to physiology and pathology, and should be taught through a clear understanding of the physiological processes that are modified by drugs. It is questionable whether Buchheim's thought, 'the role of pharmacology is critical to change drug therapy from mere empiricism to the scientific-based approach', [1] is still valid nowadays.

Evidently, the duties of pharmacology in Western societies have greatly changed since Buchheim's times. For example, the discovery of new drugs has permitted scientists to consider pharmacotherapy as one of the milestones of medicine in the past century. The understanding of these changes is better achieved if we consider the different stages that pharmacology has followed since the early work of Buchheim (Table 1). The appearance of the so-called lifestyle drugs [2] and the development of pharmacogenomics and proteomics [3] are some of these recently introduced changes. New times pose huge challenges but also provide many possibilities to develop the discipline.

Fig. 1. Rudolf Buchheim (1820–1879), Professor of Pharmacology at Dorpat and Giessen, the founder of experimental pharmacology. Reproduced with permission of Professor A. Wendel from the German Society for Experimental and Clinical Pharmacology and Toxicology.

Challenges in the third millennium: what and how to teach

The direct consequence of the success of drug discovery has been an endless increase of scientific information. But, at the same time, this fact could create some difficulties for university students because there is no realistic possibility of teaching all facts about all drugs to each student [4]. Moreover, if pharmacology is not taught only to health-care workers, what should be taught to each professional to permit adequate knowledge of this complex topic? On these grounds, it would be necessary to define a core of knowledge in pharmacology for every degree offered, according to the practice of each profession. The Education Committee of the British Pharmacological Society has formulated a core curriculum for Honours BSc in Pharmacology, and the Erasmus programme and Bologna declaration have recognized the need to develop comparable studies across universities in the European area of Higher Education.

How to harmonize the new sciences with the 'old' pharmacology will be a new challenge. Given the development of new sciences (molecular biology, immunology or genomics), it is naïve to think that modern pharmacologists can overlook some basic knowledge in these disciplines if they wish to take part in the pharmacology of this century. But it is also not realistic to think that the knowledge of the 'old' pharmacology can simply be forgotten as worthless to study new drugs, even if they are derived from proteomics or from biotechnology. In fact, pharmaceutical industries are increasingly asking for researchers with a pharmacological background rather than those with only molecular biology skills [5]. Knowledge and competence of pharmacologists will be recognized as essential to develop drugs optimally in the present century, regardless of the method from which they are obtained. Drugs are drugs, regardless of their origin, and students should be trained in the principles of pharmacology to understand how they work and to advance the knowledge generated by them.

For those involved in teaching, one question is of no less interest than those questions discussed above: how should relevant information, once chosen, be taught? Paradoxically, two strategies have been considered in the past few years as good options: (1) problem-based learning (PBL); and (2) computer-assisted teaching and the internet approach.

It has been reported that 10% of the world's medical schools are using PBL [6], and this method is also increasingly used in science and engineering schools around the world. For example, McMaster University is using this method to train undergraduate students in their Biology and Pharmacology programme [7]. PBL has received much attention from teachers of pharmacology because this method allows the possibility of putting drugs into the context of their clinical use. Furthermore, it permits the integration of knowledge of the different disciplines. As a consequence, students consider PBL seminars very useful, compared with traditional laboratory courses, to better understand pharmacology [8]. PBL greatly enhances the acquisition of effective self-directed learning skills, and students learn what the main resources are to gain knowledge in pharmacology. In addition, teachers really enjoy the PBL sessions [9] and it has been recognized that all these advantages do not limit the acquisition of factual knowledge, which is similar to that obtained with the traditional forms of pharmacological teaching [10]. Nevertheless, shortage of

 0165-6147/02/$ – see front matter PII: S0165-6147(02)02018-7

Table 1. Milestones in drug therapy and consequences for the building of modern pharmacology

Milestone	Consequence
Isolation of drugs from plants	Possibility to test substances to ascertain their biological effects: transition from *Materia medica* to experimental pharmacology
Organic synthesis	Availability of many substances to test their effects using pharmacological approaches
Dose–response relationship	Opportunity to become a solid quantitative science
Discovery of antibiotics	Recognition that a rational process can discover drugs: development of experimental pharmacology
Thalidomide's tragedy	Assumption of the need to prove the effectiveness and safety of drugs: development of clinical pharmacology
Maturity of biotechnology	Chemistry is not the only source of drugs: molecular biology and immunology are close to pharmacology in drug discovery
Self-medication as a way to promote general well-being	Drug industries develop targets to find lifestyle drugs: general population needs to be informed of the scientific features of drugs
Integrating genomics	Improvement of new strategies in drug therapy, discovery and testing

staff time, the perception that this method is staff-time intensive, and a lack of effective motivation are some reasons for the limited success of PBL [11].

It is becoming universally accepted that education of undergraduate students will be enhanced through the use of computer-assisted learning [12]. In pharmacology, several British groups have developed and used technology-based teaching and learning materials in undergraduate courses [13]. These methods have been shown to be as effective as lectures to provide factual knowledge [14] and promote effective independent student learning [15]. As constraints for the integration of these materials, the lack of time to develop supporting materials and a resistant culture against new procedures could be cited [11]. However, these problems could be overcome by the development of teaching and learning resource packs [13]. Interactive computer programs have also been used successfully to replace *in vivo* experiments on animals [16]. Finally, it is advised that teachers should never expose students to such programs alone without careful guidance and feedback.

The internet is increasingly perceived as an important resource of teaching. It offers a large number of pharmacological resources that can help students to find information regarding all drug topics. Moreover, a recent study has shown that >80% of European pharmacologists rate internet information as good to excellent [17]. Cracowski *et al.* [18] have developed a module for PBL in cardiovascular pharmacology using the World Wide Web. Most students found it useful as a pedagogic tool but only 40% reported it to be an effective method of teaching. These results demonstrate the interest of the method but also advise against a widespread and indiscriminate use of these technologies before they are established.

Opportunities in the third millennium: a tale of hopes and wishes

There are two important aspects that pharmacology, as a whole, should face this century. The first is its ability to convey the importance of pharmacological knowledge to our so-called post-modern society. The second is its role in the study of the new drugs developed after the application of the new sciences.

There is little doubt that drugs will be increasingly used in Western countries. The credulity of the society regarding the effectiveness of any drug, the commercial pressure of pharmaceutical companies and the readiness of many physicians to prescribe drugs will most probably increase drug use. Consequently, many professionals will need basic training in pharmacology to adequately face the new times. Whereas pharmacology was only taught to health professionals in the past, it is increasingly observed that students with a biological or technological background are receiving training in this discipline.

Students from journalism, economic sciences or even law sciences are more and more interested in pharmacology. For example, we have been offering an open course ('Medicines, Science and Society') to our university students, where the scientific and social bases of the drugs are explained (Box 1), and, unexpectedly, almost 100 students from diverse backgrounds have taken this course every year. We believe that this fact could reflect the interest of all students for attaining basic knowledge about drugs. Some debates, such as those on drugs of abuse, the effectiveness of 'miracle' drugs and environmental pollutants, are frequently deprived of scientific meaning by the poor level of understanding of pharmacology of governments, press and the general public [5].

The second great opportunity for pharmacology in the near future is its central role in testing new drugs that will appear in the coming years. Genomics and proteomics have raised unusual expectations about the possibility of finding many unknown proteins to be used in incurable illnesses. Although many pharmacologists do not believe that this new Holy Grail will offer a cure for every illness, most of them accept that

Box 1. The curriculum of 'Medicines, Science and Society', a course offered to all undergraduates of the Universitat Autònoma de Barcelona

- Historical aspects of drugs
- General concepts and terminology
- Introduction to pharmacodynamics: what drugs do to the body
- Introduction to pharmacokinetics: what the body does to the drugs
- Introduction to biopharmaceutics: how drugs are administered
- Drug adverse reactions
- The drug research process
- The randomized clinical trial
- The pharmacoepidemiological studies
- Ethical aspects in drug research
- Official regulation of medicines
- Sociological aspects of drug use
- Economic cost of drugs
- The placebo effect
- The therapeutic chain: the physician, the pharmacist and the patient
- The use of drugs in special populations: children, pregnant women and the elderly
- Drugs and driving
- Self-medication
- Lifestyle drugs
- Alternative drugs: herbal remedies and homeopathy
- Drug dependence
- Drugs and sports
- Sources of reliable information about drugs
- Drugs in the media
- Future trends in drug research

significant knowledge in molecular biology is already needed to cope with the present and future discoveries. There is no doubt that 'pharmacological thinking' is needed to adequately deal with the challenges that new substances will display [5]. It is probably easier for a pharmacologist to understand the principles of molecular biology than for a molecular biologist to grasp all the knowledge of pharmacology needed to correctly evaluate the new drugs [19]. Page *et al.* [5] suggest that only the application of *in vitro* and *in vivo* pharmacological tests will provide the required information about new products before their use in humans. For this reason, the new century might witness a rebirth of the discipline. For pharmacologists, change is not an option: it is a survival response [20].

Concluding remarks

Although Burks' opinion that 'the future of education in pharmacology is exceptionally bright' [21] might be considered as too optimistic, there are few signs for being pessimistic about the possibilities of pharmacology in the future. We believe that there is much work to be done and we have much to gain from the explosion of new knowledge and technologies. This should be accomplished without losing sight of the principles of the discipline of pharmacology.

Acknowledgements

We would like to thank Albert Badia, Ian E. Hughes and Patangi K. Rangachari for the review of the manuscript and their useful suggestions. We also thank Chuck Simmons for his help with the English of this article.

References

1 Buchheim, R. (1876) Ueber die Aufgaben und die Stellung der Pharmakologie an den deutschen Hochschulen. *Arch. Exp. Pathol. Pharmakol.* 5, 261–278
2 Gilbert, D. *et al.* (2000) Lifestyle medicines. *Br. Med. J.* 321, 1341–1344
3 McLeod, H.L. and Evans, W.E. (2001) Pharmacogenomics: unlocking the human genome for better drug therapy. *Annu. Rev. Pharmacol. Toxicol.* 41, 101–121
4 Achike, F.I. and Ogle, C.W. (2000) Information overload in the teaching of pharmacology. *J. Clin. Pharmacol.* 40, 177–183
5 Page, C.P. *et al.* (1994) Wither, whether and whither pharmacology. *Trends Pharmacol. Sci.* 15, 17–19
6 Spencer, J.A. and Jordan, R.K. (1999) Learner centred approaches in medical education. *Br. Med. J.* 318, 1280–1283
7 Rangachari, P.K. (1994) Quality education for undergraduates in pharmacology: a Canadian experiment. *Trends Pharmacol. Sci.* 15, 211–214
8 Des Marchais, J.E. (1999) Nouvelles approches pédagogiques adaptées à l'enseignement de la pharmacologie, des activités centres sur l'étudiant. *Therapie* 54, 171–181
9 Antepohl, W. and Herzig, S. (1999) Problem-based learning versus lecture-based learning in a course of basic pharmacology: a controlled randomised study. *Med. Educ.* 33, 106–113
10 Michel, M.C. *et al.* (2002) Comparison of problem- and lecture-based pharmacology teaching. *Trends Pharmacol. Sci.* 23, 168–170
11 Markham, T. *et al.* (1998) Survey of methods of teaching and learning in undergraduate pharmacology within UK higher education. *Trends Pharmacol. Sci.* 19, 257–262
12 Greenhalgh, T. (2001) Computer assisted learning in undergraduate medical education. *Br. Med. J.* 322, 40–44
13 Hollingsworth, M. *et al.* (1999) Implementing technology-based teaching and learning in pharmacology. *Br. J. Pharmacol.* 128, 303P
14 Dewhurst, D.G. and Williams, A.D. (1998) An investigation of the potential for a omputer-based tutorial program covering the cardiovascular system to replace traditional lectures. *Comput. Educ.* 31, 301–317
15 Dewhurst, D.G. *et al.* (2000) Independent student learning aided by computers: an acceptable alternative to lectures? *Comput. Educ.* 35, 223–241
16 Dewhurst, D. *et al.* (1996) An interactive computer program to replace *in vivo* experiments on rat blood pressure for teaching undergraduate students. *Altern. Lab. Anim.* 24, 707–714
17 Salkovic-Petrisic, M. *et al.* (2001) Usage of the Internet pharmacology resources among European pharmacologists: a preliminary investigation. *Fundam. Clin. Pharmacol.* 15, 55–60
18 Cracowski, J.L. *et al.* (2001) Using a WWW-based module for problem-based learning in a cardiovascular pharmacology course. *Acad. Med.* 76, 394
19 Habermann, E. (1994) Education in pharmacology. *Trends Pharmacol. Sci.* 15, 175–176
20 Hughes, I.E. (1996) Teaching pharmacology in the UK: a view from academia. *Trends Pharmacol. Sci.* 17, 32–34
21 Burks, T.F. (1986) Undergraduate education in pharmacology and toxicology in the USA. *Trends Pharmacol. Sci.* 7, 207–210

Josep-E. Baños*
Fèlix Bosch
Dept of Pharmacology, Therapeutics and Toxicology, School of Medicine, Universitat Autònoma de Barcelona, 08193-Bellaterra, Spain.
*e-mail: JosepEladi.Banos@uab.es
María Reverte
Dept of Physiology and Pharmacology, University Institute of Educational Sciences, Universidad de Salamanca, Salamanca, Spain.

Book Review

A cart in search of a horse

Brain Drug Targeting: The Future of Brain Drug Development
by W.M. Pardridge, Cambridge University Press, 2001. £65.00 (hardback)
(xvii + 353 pages) ISBN 0 521 800 773

Brain disorders are the most prevalent disorders in Western society and chronic brain disorders rank highest in economical burden on health funding, which increases as life expectancy rises. Therapeutic approaches to brain disorders require drugs with two main characteristics: (1) specific therapeutic solutions should be designed for a specific brain disorder; and (2) the drug should be deliverable to the brain. The brain is protected from the circulating blood by the blood–brain barrier (BBB), which comprises endothelial cells lining blood vessels in the brain; these endothelial cells differ from those in surrounding peripheral blood vessels because they possess tight junctions. The BBB limits most passive paracellular transport of non-lipophilic drugs and hence active transport of nearly all molecules into the brain is required. Because only 2% of the available drugs can cross the BBB, major effort is needed to enhance brain targeting and delivery of drugs. Invasive strategies are employed when drugs cannot be transported through the BBB; these are delivered either by intracerebral infusion or implants, or by intracarotid infusion, along with physical BBB disruption. *Brain Drug Targeting* focuses on the delivery across the BBB of molecules that have potential therapeutic and restorative benefits in brain diseases and that lack

