OpenPicoAmp – open-source lipid bilayer membrane amplifier for hands-on learning of biophysics

V. Shlyonsky[1], F. Dupuis[1] and D. Gall[1]

[1]Université libre de Bruxelles, Dept. of Physiology and Pharmacology, 808 Route de Lennik, 1070, Bruxelles, Belgium

Biophysics education can be promoted by the availability of low cost and engaging teaching materials. To address this, we developed an open-source lipid bilayer amplifier which is appropriate for use in introductory courses in biophysics or neurosciences concerning the electrical properties of the cell membrane such as capacitance and unitary ionic currents. The amplifier is designed using the common lithographic printed circuit board fabrication process and off-the-shelf electronic components. A more advanced version of the amplifier is also proposed, with a bandwidth and noise characteristics comparable to that of commercial amplifiers and therefore suitable for ion channel research.

The traditional lecture is still the standard pedagogical method for teaching science at the undergraduate level, although it has been shown that more active approaches are more efficient especially in large-enrollment courses [1-2]. In addition, it is now challenged by the development of massive open online course, or MOOC. This evolution should reinforce the interest in extensive hands-on learning sessions as they provide a way to improve learning which cannot be obtained by the online methods [3]. Hands-on learning sessions are also relevant in the "flipped classroom" approach which is an inverted teaching structure where instructional content is delivered outside class, and engagement with the content is done in class, under teacher guidance and in collaboration with peers. Instead of giving the same explanations over and over, the teacher can capture his explanation once on video or audio, and spend energy and time individualizing instruction [4]. This provides a way to cope with large class sizes and reach students who are at varying levels of understanding and skill.

In undergraduate basic science courses, the hands-on learning sessions can take the form of laboratory sessions where of a series of challenging questions and tasks require students, divided in small groups, to practice reasoning and problem solving while provided with frequent feedback from fellow students and from the instructors. To implement this approach there is crucial need of engaging teaching materials. Entry-level neurophysiology equipment used for teaching neuroscience is in the range of thousands of euros and experiments may require the use of living animals. Here we propose an open-source lipid bilayer amplifier which is appropriate for use in introductory courses in biophysics or neuroscience. We also describe a simple experimental protocol which is currently performed by undergraduate medical students during their training in basic neuroscience at our institution. The related costs to build the amplifier and the bilayer chamber are below 200 euros and the experiments do not involve the use of animals.

One way to show that you understand how something works is to build it. As we are able reconstitute a neuronal cell membrane at the molecular level using the so-called black lipid membrane technique (BLM) [5], we can say that we understand how neurons produce electrical signals. The planar lipid bilayer method allows to build an artificial cell membrane and examine pore forming molecule functionally at the single-molecule level. The laboratory session we propose in this paper allows the students to observe directly these elementary currents produced by the activity of a single pore forming molecule, such ionic channels being the key players in the generation of the neuronal electrical activity.

The reactions of the students to the lab sessions are positive and their learning outcomes are clearly improved by this hands-on approach. In the framework of this project, the lab equipment was built by a lab technician as medical students do not have a training in basic electronics in their curriculum. Students from other disciplines, like physics or engineering, have this prerequisite training. Therefore, they could be directly involved in the building of the equipment and this would provide an additional valuable learning experience. The electronics design is licensed under a Creative Commons Attribution Share-Alike license, which allows for both personal and commercial derivative works, as long as this paper is credited and the derivative designs are released under the same license. We hope that the proposed experiment will be used as a teaching tool in other institutions, allowing fruitful exposure of undergraduate students to biophysics or neurosciences.

References

[1] D.C. Haak, J. Hille Ris Lambers, E. Pitre and S. Freeman, “Increased structure and active learning reduce the achievement gap in introductory biology,” Science, vol. 332, pp. 1213–1216, 2011.

[2] S. Freeman, S.L. Eddy, M. McDonough, M.K. Smith, N. Okoroafor, et al., “Active learning increases student performance in science, engineering, and mathematics,” Proc Natl Acad Sci U S A, vol 111, pp. 8410–8415, 2014.

[3] L. Deslauriers, E. Schelew and C. Wieman, “Improved learning in a large-enrollment physics class,” Science, vol. 332, pp. 862–864, 2011.

[4] C.G. Prober and C. Heath, “Lecture halls without lectures–a proposal for medical education,” New Engl J Med, vol. 366, pp. 1657–1659, 2012.

[5] P. Mueller, D.O. Rudin, H.T. Tien and W.C. Wescott, “Reconstitution of cell membrane structure in vitro and its transformation into an excitable system,” Nature, vol. 194, pp. 979–980, 1962.