Virtual *versus* Real Laboratories in Life-Science Education: The "Virtual Physiology" and "cLabs" Programs.

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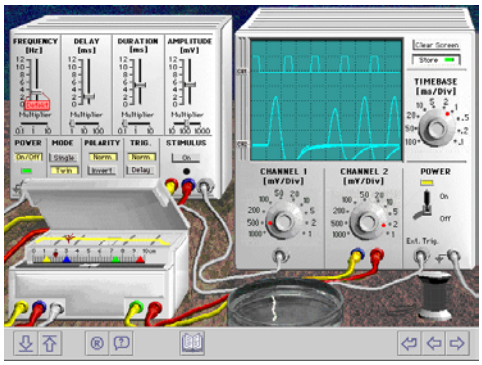
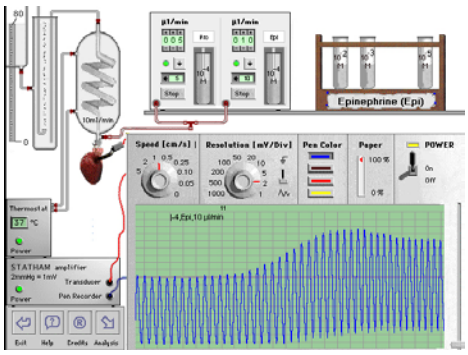
Since several years, teaching programs of the "Virtual Physiology" series, consisting of SimNerv, SimMuscle, SimHeart, SimVessel and SimPatch, are successfully used in practical physiology and pharmacology courses in medical, biological and related faculties at several hundreds universities and high schools all over the world. In many, probably most cases, these virtual laboratories have replaced the real experiments, for example, with the frog sciatic nerve and gastrognemic muscle or with isolated heart and smooth muscle preparations (gut, blood vessels) of rats and guinea pigs. This is also the situation at the Medical Faculty at the University of Marburg where the "Virtual Physiology" programs have been developed. (distributed since several years by Thieme Publishers, Stuttgart/NewYork). Starting point was students protests against the killing of animals for their education which, in the mid 90ies, led the Physiology professors in Marburg to resign in continuing with real animal experiments.

The "**Virtual Physiology**" programs offer very realistic lab environments on the computer screen where the students can do the experiments almost like in the real world: all settings of the virtual devices are freely adjustable and a mathematical algorithm guarantees the physiologically adequate reactions of the preparations even considering the biological variance, i.e. no student will have a preparation which is the same as his/her neighbour's.

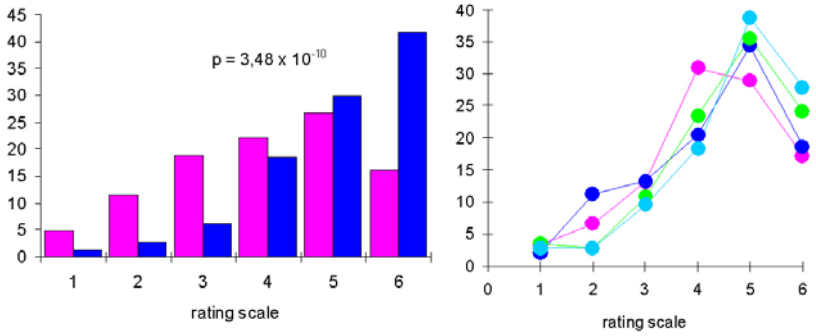




Virtual Physiology: left: **SimNerv**: determination of the refractory period using an isolated frog sciatic nerve. right: **SimHeart**: examination of epinephrine effects on an isolated rat heart in a Langendorff set-up.

While these programs originally might have been seen as only minor substitutes of the real labs it turned out in the course of teaching that they also have major didactic advantages. We have noticed that the students are much more active in the virtual than in the real animal labs. They are doing the experiments without the negative emotions from the killing of animals and without fear to destroy the preparation. The tutors impression is that the students find it interesting and stimulating to work with these programs which was recently confirmed by a students evaluation of "SimNerv".

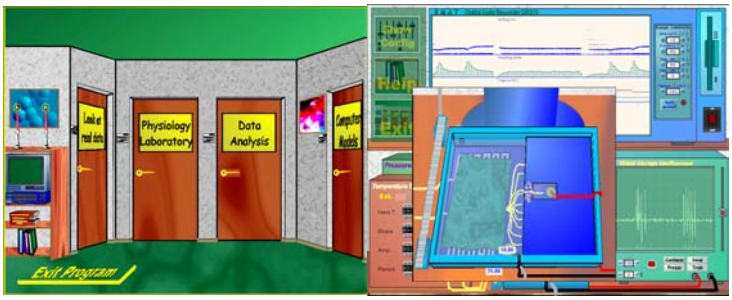
In comparison to the real experiment, most of the students assumed that they may even have learned more using 'SimNerv'. Excellent positive results (>80%) were also obtained when 'SimNerv' was compared to other training experiments. The students felt that "SimNerv" essentially helped to increase their understanding of nerve physiology and showed an obvious interest in the development and use of further simulation programs (see figures).



Students evaluation of SimNerv (examples): left: evaluation of whether or not the students consider virtual experiments as useful alternatives to real experiments: percentage of answers prior (pink) and after (blue) their work with SimNerv which led to an additional, statistically highly significant shift (t-test: $p=3.5 \times 10^{-10}$) toward still more positive values (6 is the most positive and 1 the most negative value for SimNerv). right: students interest in further simulation programs in practical exercises (red), in lectures and seminars (green and blue) and for home studies (light blue).

These evaluation results together with our own positive impressions and numerous enthusiastic replies also from other users have stimulated us to develop an advanced series of virtual computer labs ("**cLABs**"). While the "Virtual Physiology" series, apart from SimPatch, deals with classical students experiments, the "cLabs" series additionally allows to do experiments that would be to difficult for most students to be physically carried but can be realized in a virtual lab.

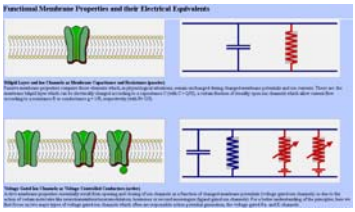
One of these programs, "**cLABs-SkinSenses**" is made in the tradition of the Virtual Physiology programs. It offers a realistic virtual lab for neuronal impulse recordings from thermo- and mechano-sensitive nerve fibres from the frog's skin. The students have to characterize the unknown receptors according their imulse recordings from the afferent nerves during thermal and mechanical stimulation of the skin. Additional modules provide data analysis tools and also offer the possibility to look at real data (published, for example, in Braun et al., Nature 367: 270-273, 1994) or to run computer programs which try to explain the ionic mechanisms of the transduction processes (e.g. Braun et al., Biosystems 71: 39-50, 2003).

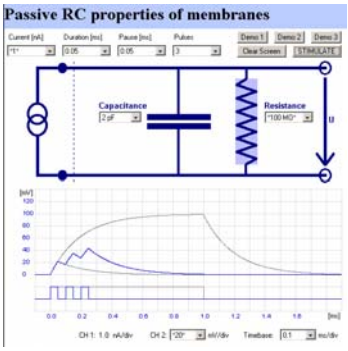


cLabs-SkinSenses: offers different modules (left) for the examination of stimulus encoding of thermo-and mechanosensitive skin receptors. The Physiology Lab (right) comprises a chart recorder, an oscilloscope and stimulus devices for impulse recordings from afferent skin nerves (here magnified with an view through the microscope).

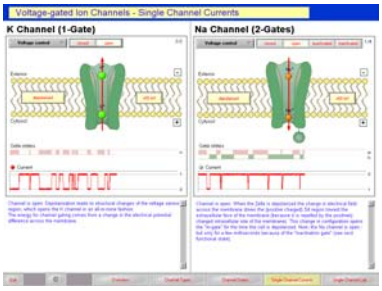
Another software package, "**cLABs-Neuron**", provides a series of animations and simulations for a teaching basic neurophysiology which also includes virtual labs for single-channel patch-clamp recordings as well as for whole-cell voltage- and current-clamp experiments. These programs again can be used for practical exercises as well as for lectures and seminars. Moreover, the modular structure with detailed tutorials (in German, English and Chinese, other languages in preparation) makes them well suited for home-studies. Part of the animation and simulation modules are freely available for experimentation at the cLabs homepage www.clabs.de.

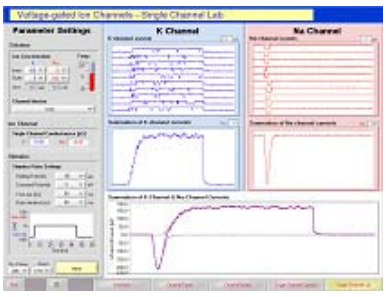
Functionally relevant **membrane properties** are illustrated together with their electrical equivalents. Main characteristics of passive membrane properties can be examined in a simple "RC-lab".



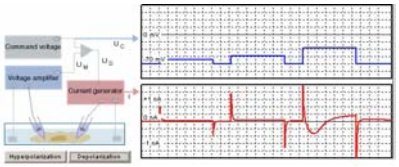


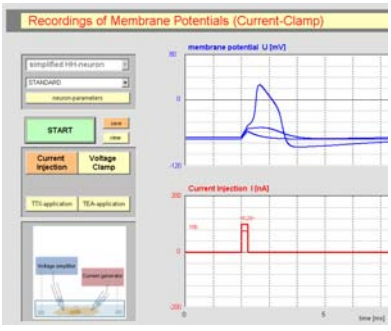
Gating mechanisms of main types of voltage activated **ion channels** are explained and a virtual single channel lab allows current recordings with a manifold of parameter settings.





The concepts of **current- and voltage-clamp recordings** are explained. Manuals and protocol form are provided for students' experimentation in the virtual laboratories. The teachers have access to a Neuron-Editor with easy control of the correctness of the students results





At the Medical Faculty of the University of Marburg the previous animal labs in Physiology courses have been completely replaced since several years by the "Virtual Physiology" labs, accomplished by newly developed exercises for students self-experimentation. For the next semester, we are planning also to include the cLabs-Neuron programs to offer a comprehensive Neurophysiology series of practical exercises consisting of **cLabs-Neuron** for the teaching basic text-book Neurophysiology and **SimNerv** to teach laboratory and clinical skills which shall be followed by students self-experimentation at the ulnar **Nerve** and with **EEG** recordings.