TEACHING BIOPHYSICS. SUGGESTIONS FOR THE INTRODUCTORY LECTURE IN BIOPHYSICS

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Abstract. Some suggestions are sketched concerning the positive impact the introductory lecture on biophysics could have on the undergraduate students. The basic idea is that, especially with this occasion, the teachers have the opportunity to emphasize the role, importance and impact of biophysics on the approach of living matter. The introductory lecture should be a very impressive and challenging one, aiming to attract the students towards this fascinated field of life sciences. However, these suggestions do not preclude the possibilities offered by the other lectures to make short incursions into the past or present life of biophysicists and to emphasize their remarkable scientific achievements.

Key words: definitions, education, formation, journals, national/international congresses/societies.

INTRODUCTION

In the near past, the *Biophysical Journal* has had as one of its aims, besides promoting and stimulating fundamental and applied up-to-date biophysics researches, that to encourage the teaching and education in biophysics. *Biophysical Journal* has already published a series of very interesting but, in the great majority, focused papers on teaching some particular problems of biophysics [1, 2, 4–6, 8, 10, 13, 14] excepting a paper dedicated to strategies for recruiting and retaining minorities in physics and biophysics [15]. On the other hand, in the last years, this kind of papers were, unfortunately, absent.

The purpose of this paper is to suggest a possible introductory lecture mainly addressed to the undergraduate students or to those who are attending, for the first time, a course of biophysics. The reason of approaching this topic is the noticeable decrease of enthusiasm and interest of some capable young people to be engaged on physics and life sciences careers and who prefer more profitable positions offered by the job market.

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The first contact of the students with biophysics should be an unforgettable one, thus greatly contributing to definitely capture them on the way of biophysical research and/or higher education in the field of biophysics.

Teaching biophysics is not only a matter of mind (i.e. a correct technical presentation of the biophysics topics), but also a matter of attitude and responsibility.

Maybe some points to be signaled here are also common to the other introductory courses in life sciences but, having in mind the nature and future impact of biophysics on understanding living matter structure and operation, these points of view get specific aspects in the case of biophysics.

Teaching biophysics means inducing to the students the feeling of wonder and surprise for the order and beauty of the living matter organisation and operation and, also, the feeling of their utility in the challenging biophysical research. Indeed, the objective of biophysics is wonderful and tempting: the study and understanding of physical aspects of living structures and processes occurring inside them, by means of a powerful instrument: physics.

PRINCIPAL POINTS TO BE APPROACHED

In my opinion, the first lecture could be organised taking into account some of the steps suggested below, each one being accompanied by adequate, attractive and suggestive images and schemes.

OBJECTIVE AND PLACE OF BIOPHYSICS AMONG SCIENCES

First of all it is necessary to define the purpose and the objectives of biophysics and make it clear what its place and connection both with fundamental and life sciences are. Therefore, a picture illustrating the place and connection of Biophysics with other sciences, like that presented below, could be very meaningful for the students (Fig. 1).

Although during the past and even in the last decades a lot of definitions of biophysics were advanced [7, 9], maybe the more general one is that viewing biophysics as the "science aiming to investigate the structure and operation of living systems (and of their subsystems) with the aid of the concepts, theory and methodology of both experimental and theoretical physics". On the inside cover of *European Biophysics Journal*, under the *Aims and Scope* it is currently stated: "Biophysics is defined as the study of biological phenomena by using physical methods and concepts". Shortly speaking, applying physics to the study of living matter means...doing biophysics.

Among the other life sciences (e.g. biochemistry, biomathematics, bionics, bioengineering, etc.) biophysics has an important place, due to the huge power of physical methods in approaching life processes which, in essence, have as underground the physical phenomena occurring into biosystems.

Moreover, biophysics implies a very large palette of knowledge in biology, biochemistry, mathematics, condensed matter physics, electronics and computer science. Therefore, "biophysics is not a discipline proper like genetics, biochemistry and molecular biology, but is expected to promote interdisciplinary bridging " [7].

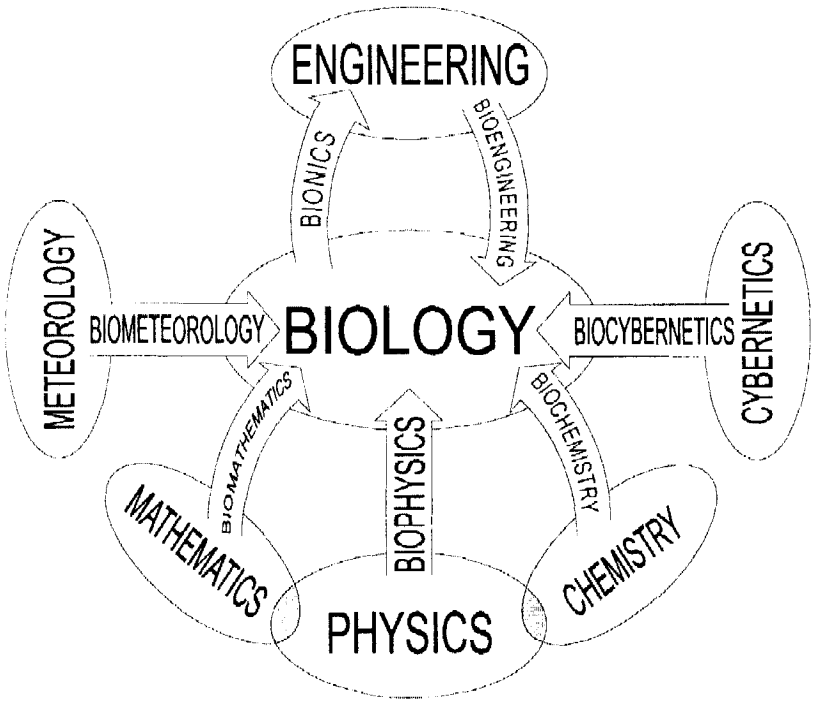

Fig. 1. – The scheme of connections among biosciences, fundamental sciences, and some of the applied sciences (modified after Popescu [12, 13]).

An interdisciplinary approach of biological phenomena is more and more obvious, as it was emphasized by the director of the National Institute of Health, Bethesda, on the occasion of the 100-th anniversary of the American Physical Society: "it is to also consider the more immediate need to transport intellects across disciplinary boundaries" [16]. Biophysics, by its area and objectives, fully responds to this imperative desideratum.

THE MAIN BRANCHES OF BIOPHYSICS

One could continue with a short and attractive presentation of the biophysics evolution and of its branches, emphasizing that biophysics is already a mature and universally accepted science.

One could define and shortly describe the branches of biophysics, having in mind as criteria, on the one hand, *the level of living matter organization* and, on the other hand, *the branches of physics* from which biophysics is extracting its own methodological substance and power.

Thus, after the first criterion the main branches of biophysics are [11, 12]:

a) *Quantum biophysics* (at sub-molecular/molecular level), which quite substantially overlaps quantum biochemistry, but its affiliation to biophysics seems to be naturally justified;

b) *Molecular biophysics*;

c) *Supra-molecular* and *cellular biophysics;*

d) *Complex system biophysics* (e.g. the biophysics of biological analysers).

Taking into account the other criterion, namely, the branches of physics, one could speak of:

a) *Biomechanics* with the sub-domains as bioacoustics, biorheology, and haemodynamics;

b) *Biothermodynamics* (bioenergetics of respiration, energetics of muscle contraction and membrane transport);

c) *Bioelectricity* (nervous impulse propagations, global electrical activity of different tissues and organs);

d) *Physiological optics*;

e) *Photobiophysics* (photosynthesis and bioluminescence);

f) *Radiation biophysics* (the interaction of living matter with different ionising and non-ionising radiations);

g) *Theoretical and computational biophysics.*

One could remind that in the scientific literature can already be found, plenty of monographs, textbooks/course books, and chapters of books having the titles of the branches of biophysics, e.g. *biothermodynamics* [3]. On the same line of evidence, one could mention the issue of the journal *Proteins: Structure, Function and Genetics (Supplement 4, 2000)* having the subtitle *Biothermodynamics in the year 2000.*

I shall mention that Biophysical Journal includes among its main permanent sections the following ones: *Photobiophysics, Cell biophysics, Theoretical and computational biophysics* and *Biophysical techniques.*

In this manner the students could create themselves a pertinent and global image on the whole domain encompassed by biophysics.

It is important to stress that, due to the vastness and variety of problems approached by biophysics, one person cannot afford to succeed in approaching but a limited number of biophysics topics. Therefore, it is necessary for each of the students to realize his/her somehow restricted future place in the large but coherent activities of biophysics researches, having however the consciousness that his/her efforts will certainly contribute to the development and completion of the whole domain.

EDUCATION AND FORMATION IN BIOPHYSICS

There is a diversity of ways of higher education and formation of young people in the field of Biophysics, varying from country to country and sometimes, in a given country, even from one university to another.

As much the formation/education of the biophysicists is concerned, usually one can start either from biology or from physics, at different levels of study: undergraduate, graduate or doctoral ones. Therefore, the formation of the new generations of biophysicists is the shared privilege of physics and biology.

In my opinion, based on an experience of more than 25 years of teaching biophysics, firstly at the Faculty of Medicine in Bucharest (1975 – 1981) then at the Faculty of Physics in Bucharest (1981 – present) and, especially on the tradition of our department involved in formation of biophysicists in Romania, it is more productive and time saving *to start biophysics education with physics and mathematics* and to continue with biology, genetics and other specialised life sciences, rather than to begin with biology and then to continue with physics. It is easier to graft biological concepts and information on a physics and mathematical background, which is more difficult to create and consolidate later.

As for education in biophysics, one can notice that biophysics is an object of study in all medical, biological, pharmacological, and veterinary faculties, aiming to familiarize the students with some basic knowledge of biophysics useful in their future specific activities.

SOME HISTORICAL ASPECTS OF BIOPHYSICS

The presentation of some historical aspects could raise students' interest for the biophysics and especially it could induce into them the conviction that they could attain the performances of their predecessors themselves.

One could inculcate into the students' mind the determination to put in action their real potentiality in view of a future successful scientific accomplishment.

Examples of a few crucial moments of biophysical discoveries, some of them awarded with Nobel Prize, will positively impress and stimulate the students. One could remind, for instance, the challenging ideas of Schrödinger (exposed in his famous book *What is Life?*), the real contributions to genetics of the physicist Delbrück (who attracted many other physicists to biology), the Hodgkin-Huxley model of action potential propagation, the determination of myoglobin 3D structure by Kendrew and Perutz, the secondary structure determination of nucleic acids by Watson and Crick, etc. as outstanding and incentive scientific achievements.

Of course, there are a lot of other beautiful and instructive examples which could be presented too.

BIOPHYSICS ALL AROUND THE WORLD

It is important to call attention of the students on the existence all around the world of specialised research institutes, university centres or departments, where topics of biophysics are approached, starting from (sub)molecular level and reaching the complex biological systems.

Also, it would be valuable to present and shortly describe the organization of biophysics, at the local and global scale, that is the existence of national, regional (e.g. *European Biophysical Societies' Association, EBSA*) and of other international biophysics associations. It is important to say that, in principle, the national organizations are affiliated to the *International Union for Pure an Applied Biophysics* (IUPAB) which is organizing every three years an International Biophysics Congress (e.g. the first one was held in 1961 at Stockholm, the last one in 2002 at Buenos Aires, while the future one is to be held in 2005 at Montpellier, France).

As a rule, the national and regional associations of biophysics affiliated to IUPAB are organizing periodic scientific meetings, too. They are publishing periodical journals in biophysics, some of them currently accessible online (e.g. *Biophysical Journal, European Biophysics Journal*), favouring the scientific exchanges and dissemination of the newest discoveries and findings, thus stimulating the future researches in biophysics and in connected fields. The conclusion is that nowadays, there is a worldwide biophysics network in which each biophysicist is a significant piece, playing an important role as a potential contributor and equally as a fervent disseminator of biophysical approaches of living matter.

UTILITY OF BIOPHYSICISTS. ARE THEY NEEDED?

Finally, it is necessary to emphasize the numerous opportunities offered by the biophysics training programmes to those engaged both in fundamental and applied biophysical research.

On the job market in the life sciences, the biophysicists seem to be very much appreciated and preferentially employed, due to their multidisciplinary education, offering them a great flexibility and a large interface to other domains.

These are the reasons why many universities have developed important long term programmes of education, formation and research in biophysics, starting with the undergraduate level and continuing with the doctoral and, finally, with research postdoctoral positions.

One could only say that biophysics is currently contributing to decipher the space structure of macromolecules involved both in normal and pathological functions (e.g. the structure of prion involved in the controversial mad cow disease). The 3D structure of a macromolecule is just as important as its chemical composition, and one of the greatest challenges in biology is to understand how

one dimensional molecule folds in a functional space structure. If the physical process of protein folding is completely understood, it will be possible to create an algorithm to predict their 3D structure, starting from their amino acid sequence. This would allow to design more specific drugs in view of a more efficient and faster therapy.

The contribution of biophysicists and of biophysical techniques in the further exploring of Human Proteome, in the near future will be also a notable successful objective.

Three arenas of biology in which the skills of physicists and of their close cousins (among which, of course, the biophysicists) can be most productively used, are [16]: a) the methods for examining the physical and chemical properties of single macromolecules and single complexes of large molecules; b) the interpretation of complex data sets and the process of development and differentiation (why, for example, some cells develop into muscle tissue, while others become brain cells); c) the developing of a "radical physical explanation" (in the sense of Delbrück's goal) for cell function.

CONCLUSION

The way towards biophysics research is long and hard but very tempting and promising. By its challenge, purpose and methodology, biophysics will certainly be a *sine qua non* component of the life sciences of this new century. Its potential achievements, that will very soon become concrete applications in the real life, are the warranty of a wonderful and full reward of the biophysicists endeavour.

One can emphasize that biophysics, in a coherent synergy with the other life sciences and with advent of the fundamental sciences, will assure a successful approach and a much more profound understanding of the rules that govern the miraculous process of life on Earth.

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