EDUCATION IN BIOPHYSICS: SOUTH AMERICAN PERSPECTIVE

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After brief comments on the genesis and concepts of Biophysics, the education of Biophysics in South America is considered. This is done having taken into account the subject in the context of the state of Biophysics around the world and the particularities of the region. The strategies for booster the Biophysics activities at high level are consider and one of the programs, recently implemented, is described in detail. It is concluded that the more efficient approach to promote the Biophysics in South America is to benefit from the expertise of the best research groups of the region to develop strong post graduate programs on the discipline. The advantage of this approach, which is already implemented in the region, is discussed.

1. Introduction

To consider the perspective of Biophysics education in South America, we will briefly review its origin and its development as an independent discipline. Emphasis will be put in the *multi*disciplinary character of biophysics -rather than *inter*disciplinary- which is the most relevant aspect for teaching purposes. This characteristic is also of great importance in the teaching of Biophysics not only for a Degree or Post graduate program but also when it forms part of the curriculum of non-Biophysics degrees.

The perspective and strategies of teaching have to be different for each country on account of the particularities and history of the discipline in each of them. However, we consider that it is possible to use the existing capacity, localized in a number of centers of excellence to promote the discipline using an appropriate approach. South America, in spite of its diversity, has many aspects in common, including the language that make possible to consider the implementation of an associated program to improve teaching and promote research in Biophysics.

2. What is Biophysics?

Since we will discuss the education of Biophysics, it seems to be necessary to say some words of what Biophysics is. This becomes relevant since Biophysics is a relatively new discipline and it is still unclear for many people in its fields of their competence.

According to *Wikipedia* (http://en.wikipedia.org/wiki/Biophysics) a fast source of information nowadays, "*Biophysics is an interdisciplinary science that uses the methods of physical science to study biological systems*." A definition that states that Biophysics is an *interdisciplinary science*; we will come to this point later.

In general, all short definitions are pointed to the use of physical methods to solve biological problems but some differences arise. For instance, we can read that it is *physics* as applied to biological problems, or *biology* with an emphasis on the application of physical principles.

Volkenstein (1982) emphasizes that the statement that the aim of biophysics is to apply physical method to biology, which is the widest idea among biologists, is completely wrong. Being strict with the above definition, using a microscope to study cells will be considered biophysics, statement in which none would agree.

We can use a wide definition based also on an expression of Volkenstein. Biophysics research begins with a physical formulation of a problem relates with life phenomena. This definition seems appropriate since it covers different aspects of the field, irrespective of the method used, even coming from chemistry, mathematics, informatics, etc.

The above definition fits Biophysics and Biological Physics as well. We may ask about differences between biophysics and biological physics; in fact the answer is *none*.

The coexistence of these names comes from the history. At the beginning there was no clear distinction but gradually *Biophysics* became the preferred name originally for the Physiologists and Biologists in general, while Physicists preferred the name *Biological Physics*. We have the International Union for Pure and Applied Biophysics (IUPAB) and the Commission of Biological Physics in the International Union of Pure and Applied Physics (IUPAP). Looking to the activities and the contents of the congresses and conferences organized by both Unions, we can clearly see that, in spite of their names, both are dealing with the same subject.

Let us to finish the section with a quote of Fick (1904) that marks the essence of the discipline.

"*A vital phenomenon can only be regarded as explained if it has been proven that it appears as the result of the material components of living organisms interacting according to the laws which those same components follow in their interactions outside of living systems.*"-Adolf Eugen Fick.

2.1. The Early Steps

The classical division of Science created after the scientific revolution had a big impact on scientific development. Disciplines such as Mathematics, Physics, Chemistry and Biology were clearly distinguished and each of them grew with an independent identity. Mathematics provides to the rest of the disciplines valuable tools but, Physics, for instance was much more than a user of Mathematics making important contributions and inspiring several aspects of the discipline. This prolific interaction continues till today preserving the traditional name of each discipline.

As mentioned above, the development of a specific science sooner or later leads to interfaces with other disciplines. In principle, Chemistry deals with the transformation of matter while Physics does not; however, atomic reactions –clearly in the Physics domain- show that Physics also has to be applied inside the molecules. As the knowledge at the interface grows, the interfacing subjects from both disciplines give rise to new ones-in this case Physical Chemistry and Chemical Physics. These two new disciplines were at the beginning differentiated in their approaches and contents, Chemical Physics with more Physics approach and Physical Chemistry with more Chemistry orientation. Nowadays they are undistinguishable and only tradition maintains their individual names.

The interaction between Chemistry and Biology leads to the area of Biological Chemistry and Biochemistry, the activity in this area was intense and in short time they become independent disciplines. As in the case of Physics and Chemistry the two names coexisted today and their contents are hardly differentiable.

The genesis and evolution of Biophysics follow, in general, the same path, as it happens to be one of the youngest fields of science. Presumably, the beginning of what nowadays we call Biophysics, was in the 19^{th} century with the works of the Berlin school of physiologists assuming, according to Emil DuBois-Reymond that Physiology would "*dissolve into organic physics and chemistry*".

We may consider the research of Adolf Eugen Fick, a pupil of Ludwig and follower of the Berlin school of thought as one of the landmarks of the discipline. Fick makes use of a physical and mathematical approach to solve biological problems and their results have had high impact. A remarkable man, Fick began study of mathematics and physics at Marburg but soon switched to medicine; he work as physiologist, ophthalmologist and physician. Interested in a rigorous study of movements of fluids in the human body he formulated in 1855 what is today known as the *Fick's law of diffusion*, that has a high impact not only in biology but in physics and chemistry. He developed a direct method to measure the cardiac output, called the *Fick principle* and invented the *tonometer*, an instrument to measure the ocular pressure. His book *Die medizinische Physik*, published in 1856 (Bischof 1996), in spite of its title, is probably the first book of Biophysics.

In 1921 a book published on the discipline (Burns 1921) seems to be the first one bearing the name *Biophysics* in its title. In the same year the first Germany university institute devoted to biophysics founded in Frankfurt was renamed as "Institute of Biophysics" in 1934.

2.2. The Growing Identity of Biophysics

During the early period all the development of the new discipline was through contributions to physiology mostly on thermodynamics and mechanical aspects of muscular contraction and the electrical behavior of the nerve impulse. Around 1920 the radiation effect on the living organisms was introduced as a part of the field. This topic attracted the attention of several researchers and it was dominant in the discipline during the beginning of the so called nuclear age. Although radiation studies are now a small part of biophysics, the applications are relevant to the radiotherapy and is serves as an emergent area named Medical Physics.

We want to remark that for many students and researchers coming from biology, Biophysics teaches a lot of intellectual procedures coming from physics that were carried into the biological field were the strategic simplifications of highly complex processes as a master methodology. This intellectual aspect of Biophysics is characteristic, and complements the experimental and mathematical approaches. Examples of the presence of these strategic simplifications in the undergraduate courses are, among others, the equivalent circuit for cell membranes, and the Einthoven triangle for electrocardiogram or the radiobiological models based on target theory for irradiated cells survival.

In the second half of the XX Century, the resolution of the crystallographic structure of DNA in 1953 by Watson and Crick and the resolution of the three-dimensional structure of the myoglobin in 1958 by Kendrew and Perutz, open a new aspect of the biophysics research. The molecular aspect of the life was then part of the Biophysics, integrated by several branches.

Contemporary biophysical research includes many emergent areas, and the future scope of Biophysics is hard to predict considering the strong tendency toward innovation of our science. Neural networks theory was born inside biophysics at the beginning of the decade of 1940, and let us mentions in passing that many of the foundational papers on neural computation published during 1970s and 1980s were included in the Proceedings of the National Academy of Sciences (USA) in its biophysical section. The creation of the Internet and of the World Wide Web led at the end of the 1990s to important contributions on communications networks in papers published mainly by physicists. Today, many biophysical approaches to the topology and dynamics of metabolic networks (a fundamental issue in the understanding of normal and pathological cell physiology) are actively investigated by many biophysicists around the world using these new approaches.

2.3. ***Multi*disciplinary Versus *Inter*disciplinary Character**

Biophysics is currently named as an interdisciplinary science. Following the definition of the Oxford English Dictionary, *interdisciplinary* means: "*Of or pertaining to two or more disciplines or branches of learning; contributing to or benefiting from two or more disciplines*". We may compare with, *multidisciplinary,* defined as "Combining or involving several separate academic disciplines". The latter does not differ too much from the second meaning of interdisciplinarity, although a subtle difference can be found when it is compared with the first definition. Let us consider both terms based on the meaning of the prepositions.

Inter('*between*', '*among*') -disciplinary, define Biophysics as a discipline in between Physics and Biology; on the other hand Multi('*more than one, several, many*') - disciplinary , will locate it as sharing knowledge of different sciences.

We may consider the Biochemistry face as a discipline between Chemistry and Biology. Along the time it developed a proper methodology and emerged as an independent, although interacting, discipline that can be called interdisciplinary according with our definition.

Biophysics research uses tools and concepts from Biology, Physics, Chemistry, and Mathematics. It redefines problems outside the normal boundaries reaching for solutions based on a new understanding of complex situations.

Is there any practical benefit of the definition? We believe that, besides the interest, having a precise characterization of the discipline will help in understanding the teaching approach. We will come back to this point.

2.4. Why Biophysics as Independent Discipline?

Biophysics being a discipline of relevant applications to other branches of Science, such as Physiology, Biochemistry, Biotechnology, Medical Physics, and others, we may ask why we take it as an independent discipline instead of letting it remain as part of any (or all) of them.

This alternative will compartmentalize the discipline diluting the synergic effect of the multiple contributions of other subjects making a sub-area with less creative opportunities.

Acting as an independent discipline, preserving its multidisciplinary character and not just a mix up of several concepts, is more productive and can bring to other sciences new useful knowledge.

From the point of view of teaching, the latter approach will produce a biophysicist that will be able to teach for the biophysics students the broad field, and also, when teaching for other students, not only shows the particular applications for a particular degree but also conveys the essence of biophysics rather than mere technical applications.

The development of Science in the present times makes the borders between disciplines quite blurred. Many disciplines have at present important biological interface, requiring some special skill to contribute to the advance in the discipline in the multidisciplinary area. This situation requires appropriate teaching schemes and contents for different disciplines.

Besides the classical presence in Medicine, as a necessary support for Physiology, the requirements of new degrees, as Bioengineering, Biotechnology, Biomedicine, Environmental studies, and others, represents a new challenge in the teaching design.

This aspect is of absolute relevance for underdeveloped countries since the new disciplines nay have great impacts in the modernization of the production processes, more efficient uses of their resources, and the diversification of activities.

We have to bear in mind that the variation among underdeveloped countries is huge and their problems are not necessarily common. Whereas some countries need to direct their meager resources in increasing basic education and literacy, others -like many South American countries- are on the way to develop strong scientific systems. Therefore to plan any action it is important to consider the variability in order to apply the correct strategy for each particular situation.

3. Biophysics Education

The important contribution of Biophysics and its recognized identity leads, naturally, to the implementation of courses dealing with the discipline. These courses have to be adapted to the different curricula, as we mentioned before. We will briefly review the situation especially in South America.

Let us mention a ubiquitous example. The transport of matter through the body is not only governed by the simple diffusion but by more complex mechanism as well, such an active transport, facilitates diffusion, and others. The necessary tools to give acceptable explanation require the use of other approaches beside the biological ones. Mathematics, Physics, and Chemistry come concurrently to help the biological problems.

To deal with these requirements many Universities incorporated independent courses on these subjects. The name of *Biological Physics* or *Biophysics* is used depending of the characteristic (and taste) of each University.

This situation also occurs with other sciences and particularly with Biology with Chemistry and Physics, which is of main interest in the present context.

Looking back we can see that some subjects that are nowadays belonging to Biophysics were included in courses of Biology, particularly in Physiology, what is clearly understood due to the origin of the first studies. When the transport through membranes started to be analyzed in more detail, the active transport, facilitated diffusion and other phenomena that require concepts of Physics and Chemistry, were taking mostly on Biochemistry.

The studies of the structure of bio-macromolecules takes public knowledge after the diffusion of the work of James D. Watson and Francis Crick who, using x-ray diffraction data collected by Rosalind Franklin, made a model of the deoxyribonucleic acid (DNA) proposing a double helix structure (Watson 1953). The impact of this work overshadows the work of Max Perutz, mentor of Watson, and John Kendrew on the three dimensional structure of myoglobin and hemoglobin (Kendrew 1956, Perutz 1960). However the first resolution of these structures opens a new avenue for the understanding the structure and function relationship of proteins.

Biophysics enters a new era incorporating the area of macromolecules at atomic resolution with the consequent broadening of the teaching field, particularly in Europe and the USA.

3.1. The Current Situation in the Under-Developed Countries

The educational needs of under-developed countries differ considerably from the developed ones, mainly in terms of the overall capacity and emphasis on the effort that has to be invested in the different levels. Bearing in mind the severe needs to increase literacy, higher education has an important role in the process. To produce local university graduates is one of the ways of pushing the process forward. Clearly, the

Universities have, in the first place, to be focused on some relevant professions, in which medicine, for instance, cannot be absent, but many other professions have helpful impact to accelerate the development, such as Engineering in its different specialties, Chemistry, Biochemistry and Biotechnology, architecture, and, obviously, the preparation of good level teachers. Even if we want to reduce to minimum the number of subjects to be included, we cannot avoid Mathematics and Physics as basic support for all the rest. In this minimal list Biophysics will not be included as a specific course but certainly as a subject for many of them, to provide an appropriate teaching it is necessary to generate some source to provide quality teaching on the specialty.

This scenario is common to many regions; however we will restrict the analysis of the situation to South America.

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the definition of Biophysics. Moreover present a collection of topics relevant to Biophysics and an interesting chapter on 'False Biophysics'].

Biographical Sketches

J. Raul Grigera got a degree in physics at the University of La Plata. Argentina and do his PhD mostly in the University of Groningen on the study of water in biological systems. He becomes a Professor of Biophysics of the School of Science at the University of La Plata (1973). Is now Emeritus Professor of that University and Research Member (highest rank) of the Argentinean National Research Council (CONICET). He has been Director of the Institute of Physics of Liquids and Biological system (IFLYSIB) belonging of the University of La Plata and CONICET for more than 20 years. He was member of the Council of IUPAB where, as convener of the Task Force of Education and Capacity Building, works on the improving of Biophysics in undeveloped Countries using different approaches. He funded the Latin American Post Graduate Program of Biophysics. He participates in the Commission for Biological Physics of IUPAP as a Member and Secretary. His scientific contribution is mainly on the field of water in biological systems (protein hydration, water simulation, cold denaturation of protein and the role of water, and others). Is Fellow of the Royal Society of Chemistry, the American Physical Society, the Institute of Physics and the John Simon Guggenheim Foundation.

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