CBPF-CS-004/95

How to Start in Biophysics[1]

G. Bemski
Centro Brasileiro de Pesquisas Físicas
Rua Dr. Xavier Sigaud, 150
22290-180 – Rio de Janeiro, RJ – Brazil

Abstract

This lecture discusses the relation of physics and biophysics and the ways in which physicists start working in biophysics.

Key-words: Biophysics

[1]Based on a lecture at: "School of Biophysics", International Center of Condensed Matter Physics, Brasília – February 6-15

The history of biology is quite different than that of physics. While physics together with mathematics and chemistry is an exact, an relatively old science, biology is considered to have started with Darwin in the 1850's. There was no good reason for the two to meet, even if on occasions gifted individuals were involved in work which more recently we could call biophysics. One should probably mention among them: Leonardo da Vinci (physiology), Galvani, T. Young (color vision, theory of light), J.R. Mayer (conservation of energy), Tyndall (optics), Helmholtz (hearing, vision, etc.) electrophysiologists such as Cole and Bronk and others. Even so, they belong principally to the period after 1800.

For the physicists involved since Newton in mathematical formulation of basic laws and in the studies of motion of bodies, their interactions, behavior of gases, liquids and solids, living matter was conspicuous for its absence. I believe that this was due to a great extent to two interrelated facors:

1) the tremendous complexity evidenced by biology;

2) belief that the living matter obeys some additional laws, beyond those discovered in physics. Such belief went in general under the name of vitalism.

This latter belief is not surprising and seems to be part of a general principle that problems (phenomena) which are not understood, are either not discussed, or considered to be due to new, yet to be discovered laws. Niels Bohr, as late as 1933 was wandering about the: "Diversity of life which is far beyond the grasp of scientific analysis".[1]

Today these discussions have stopped, but the problem of complexity remains, and until recently kept many physicists away from biology.

It took two events to start bridging the gap between the two sciences. One was the appearance in 1945 of a little book by Schrodinger: "What is life?" in which he discusses the mysterious stability of biological structures from one generation to next.[2] The second one was the discovery by Crick and Watson of the functioning of the nucleic acid and of the genetic code.[3] Here, at last, the physicists saw a phenomenon on a scale which was understandable. Molecular biology was born, and modern biophysics with it.

Biophysics is one of the several interdisciplinary sciences of the 20th century, together with biochemistry, astrophysics, geophysics, etc. Their appearance is due to the explosion of research in sciences in general, and the resulting necessity to limit each field and to specialize.

A student interested in physics has an obvious choice to make: the Physics Department at a university. The same is true about many other fields. However a person wanting to enroll in biophysics encounters problems. On undergraduate level very few universities in

Brazil or abroad, offer a Biophysics course. It is usually argued that it is more important that he should learn physics, since biology may be acquired later on, being a conceptually easier science.

On the graduate level there exists a dilemma in Brazil, where the specialization in biophysics is frequently done in the Physics Institutes. This restricts the students interested in getting a higher degree to those who have an undergraduate degree in physics, eliminating in practice all other students, many of whom would certainly become very good biophysicists.

There is a further weekness in this state of affairs. The curricula, both on the undergraduate and graduate level, do not offer an easy contact and interchange of courses with other departments. In the case of biophysics it is absolutely indispensable that a student should take a thorough course in chemistry (organic and inorganic) and in biology.

The example of the U.S. universities maybe useful. In many of them there exists an easy exchange of courses among the deparments, and the graduate students are guided by a committee of professors from different departments, which helps the student to select the interdisciplinary curriculum which best suits him. A similar system could easily be implanted in Brazil.

Physics in biology is obviously an enormously wide field which is only now beginning to expand and we are probably living in a transition period, in as far as the entrance of physicists into biophysics. It may be of interest to classify such physicists into various groups which I will attempt to do next.

1) An important group of scientists; physicists, or chemists by education, who developped, or otherwise worked with powerful experimental techniques and decided to use these techniques in biological problems. A classical case is x-ray diffraction, invented and used by von Laue and Bragg in solid state physics. This technique in the hands of Perutz and Kendrew was employed somewhat later to obtain maps of single crystal proteins [4,5]. Similarly, Wüthrich used NMR to obtain three dimensional maps of macromolecules in solution [6]. EPR, invented in 1945 by Zavoisky [7], has been used 10 years later by other physicists to obtain detailed structural information concerning the heme planes in hemoproteins[8]. Many more examples could be listed i.e. optics, in which techniques invented with pure physics in mind, were used by their inventors on biological material. For these reasons physics is often considered by biologists as inventor and supplier of experimental techniques.

2) There exists a small, but important group of well known theoretical physicists who

became interested in a specific biological problem, without however leaving physics.

3) A number of physicists who immersed themselves in biology, became biologists with their physics background. A good example is Delbruck who worked on bacteriophages with Luria [9]. It is believed that the strict training in physics makes such people into "solid" biologists.

4) Important groups of physicists approached specific problems in biology. Examples are: Hopfield working on neural networks [10], Frauenfelder on the dynamics of proteins [11], Feher and others on photosynthesis [12]. In all these, and other cases of experimental and theoretical work, fundamental biological problems are being solved with the insight of physicists.

5) Linus Pauling deserves to be mentioned in a category all by himself. His brilliant contribution to biology and chemistry span an area from the chemical bond to structure of proteins to molecular diseases.

6) Final, and numerous group of physicists was attracted to biology, tried its hand on smaller problems, often at first, in a less than organized way.

The future will probably restrict the approaches which consist of physicists "jumping into biology". The increased sophistication of the enormous field of biophysics will require increased specialization which will have to come from thorough studies at the university level. Biophysics will become more and more a field of its own, like physics or chemistry.

References

[1] N. Bohr (1933), "Light and life", Nature **131**, 421-423.

[2] E. Schrodinger (1945), "What is life?", Macmillan, N.Y.

[3] J.D. Watson, F.H.C. Crick (1953), "Molecular structure of nucleic acids – A structure for DNA", Nature **171**, 737-8 and **171**, 964-7.

[4] J.C. Kendrew (1950), "The crystal structure of horse met-myoglobin", Proc. Roy. Soc. A **201**, 62-88.

[5] M.F. Perutz (1965), "Structure and function of hemoglobin", J. Mol. Biol. **13**, 646-668.

[6] K. Wüthrich (1986), "NMR of proteins and nucleic acids", J. Wiley & Sons, N.Y.

[7] E. Zavoisky (1945), "Paramagnetic relaxation of liquid solutions for perpendicular field", J. Phys. USSR, **9**, 211-217.

[8] D.J.E. Ingram, J.E. Bennett (1955), "Paramagnetic resonance in phtolocyanine, hemoglobin and other organic derivatives", Disc. Faraday Soc. **19**, 140-146.

[9] M. Delbrück (1950), "Viruses 1950", Calif. Inst. of Technol., Pasadena.

[10] J. Hopfield (1994), "Neurons, dynamics and computation", Physics Today, **47**, 40-46.

[11] H. Frauenfelder, S. Sligar, P.G. Wolynes (1991), "The energy landscape and motions of proteins", Science **254**, 1598-1603.

[12] G. Feher, J.R. Allen, M.Y. Okamura, D.C. Rees: Structure and function of bacterial photosynthetic reaction centers (1989), Nature, **339**, 111-116.

[13] L.C. Pauling (1970), "Encyclopedia Britannica, vol. 17, 482.