THE ROLE OF MATHEMATICS IN BIOLOGY

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ABSTRACT
Mathematics plays a key role in many disciplines of science, primarily as a mathematical modeling tool. New innovations and developments in physics are by the influence of mathematics. Calculus was invented entirely for the use of physics. The importance of the role of mathematics in physics is understood by the existing discipline “mathematical physics” or "theoretical physics". One can think is mathematics has that same important role or even lesser important role in the field of biology and is mathematics and biology could possibly have anything in common. Even though physics and biology are very different sciences, mathematicians and biologists developed the "mathematical biology" or "biomathematics"as a recent discipline for the mathematical representation in biology to the theoretical and practical applications in biological, biomedical and biotechnology researches. In this paper we study the role played by mathematics in biology and analysis weather a considerable amount of mathematics courses need to be teach for biological science graduates.

Keywords: Mathematics, Biology, Mathematical models, Biomathematics.

INTRODUCTION

In early days an attempt was made to establish the mathematical biology as a new discipline, but it did not succeed (Keller, 2002). There were initiatives by mathematicians but there were no precedents. For example, theoretical models to describe the spread of diseases had been discussed by Bernouilli and the flow of blood in veins was the uppermost in Euler’s mind when he performed his seminal work on fluid mechanics (Euler, 1775).

Mathematical biology or biomathematics is a fast-growing well-recognized and the most exciting modern application of mathematics. This is an interdisciplinary research area with a range of applications in biology, biotechnology and biomedical science. The filed may be referred to as mathematical biology or biomathematics to stress the mathematical side or theoretical biology to stress the biological side. A variety of mathematical techniques are used in mathematical biology to model biological researches. Mathematical areas such as calculus, probability theory, statistics, linear algebra, graph theory, combinatorics, algebraic geometry, topology, dynamical systems, differential equations and coding theory are now being applied in this field.

Many topics from biosciences have been high priority on the global agenda; the fights against cancer and degenerative diseases of the brain, such as Alzheimer’s, Parkinson’s and ALS and the management of health threats such as AIDS. Society is waiting to get the research results for their better life. The emergence of models and the existence of large data sets that require quantitative analysis in biology gives a great opportunity for mathematics. The existing or already established methods in mathematics can be used to support biological problems but the quantitative analysis of the fundamental problems in bioscience definitely require new ideas and new techniques from mathematics. The most significant biological achievement of the 20thCentury is the identification of the DNA. This work was essentially done by Physicists, Chemists and Crystallographers. There has already been evidence of effective contribution between biology and mathematics. For instance, the modeling of epidemics and the study of signal propagation in nerves are the growing works of differential equations and studies of dynamical system in this century.

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Mathematical biology or biomathematics is a fast growing, well recognized and the most exciting modern application of mathematics. The use of mathematics in biology is important since biology becomes more quantitative. This new discipline has applications in biology, biomedical and biotechnology. The aim of this new discipline is the mathematical representations of the biological problems using a variety of mathematical theories and techniques. The mathematical biology has both theatrical and practical applications in research on biological, biomedical and biotechnological fields.

One significant work is currently done by Dr. Aver Friedman, distinguished Professor of mathematics and his research team at the Oberlin center for computation and modeling in Ohio State university is to find a cure for cancer (Margaret Putney, 2005). The objective of the research is to use a virus that attacks just the tumor while leaving the healthy cells alone. The cancer which mostly affected by research is a particular type of brain tumor known as glioma. The researchers are trying to find a virus that reproduces fast enough is able to avoid enough of the immune system to reduce the tumor. The researchers of this center found some parameters that would cause the tumor to be reduced. They passed their result to the biologists to create a virus that matches such parameters.

Another contribution of mathematics to biology is a mathematical modeling to address the biological process. The Mathematical Biosciences Institute in Ohio State university works on this field. The institute works on the explosion of biological data which was created by the technology to study biological systems. The data created a need to develop many mathematical models, statistical methods and computational algorithms. The mathematical models needed to encompass the biological process such as neurological and cellular problems. In neurological process, Parkinson’s disease is in the center of the modeling work. There are around 1012 neurons in the human brains. To understand properly their relationship with all of the other neurons they proved that the differential equations can be used for the models.

Ecology and evolutionary biology are the dominant fields of mathematical biology. Evolutionary biology has been the subject of extensive mathematical theorizing. Hanna Kokko, theatrical biologists and the professor in the department of biological and environmental science at the University of Helsinki says that much of biology relies on mathematics (Hanna Kokko, 2007). Evolutionary ideas are often complex and the logic of hypothesis proposed should be tested not only empirically but also mathematically.

Another area of specialized research in mathematical biology is the genetic models and various models of the spread of infections. Cancer modeling and simulation, modeling the movement of interacting cell populations, modeling of the cell cycles are some of the models developed in the discipline of mathematical biology. Molecular set theory was introduced by Anthony Bartholomay. Molecular set theory is a mathematical formulation of the chemical kinetics of bio-molecular reactions in terms of sets of molecules and their chemical transformations. Its applications were developed in mathematical biology and especially in mathematical medicine.

Many universities in the western countries offers degrees in the field of biomathematics such as University of St Andrews offers B.Sc. (Hons) in Biology and

Mathematics, University of Dundee offers B.Sc.(Hons) in Mathematical Biology, University of Leeds offers B.Sc. in Biology and Mathematics and University of York offers M.Sc. in Advanced Mathematical Biology. These courses consists both mathematics and biology subjects. There is a need to offer a considerable amount of mathematics courses for biology graduates and biology courses for mathematics graduates in Sri Lanka to work in the field of biomathematics.

METHODOLOGY

We examine one biological model in which mathematics played major role in the problem. Chronic wounds represent a major public health problem worldwide. To determine the rapeutic strategies which help to heal ischemic wounds, a mathematical model were developed by Xue, Friedman and Sen (Avner Friedman, 2010). In this modeling process, a full thickness bipedicle dermal flap was developed first to isolate the blood supply from underneath the flap and from two long edges. One circular wound was developed in the center of the flap (ischemic wound) and another on the normal skin (nonischemic wound). The main variables involved in the wound closure phase of the healing process are several types of blood and tissue cells, chemical signals and tissue density. The model was formulated by using the system of particle differential equations in a partially healed domain.

The open wound is the circular region $0 \le r \le R(t)$, the partially healed wound is the annulus $R(t) \le r \le R(0)$ and the normal healthily tissue is the region $R(0) \le r \le L$. They assumed that the wound is circular but small incisions of size δ are made at the boundary $r = L$ with adjacent incisions separated by distance ϵ. Taking $\delta, \epsilon \to 0$ and applying the homogenization theory, each boundary condition $u = u_s$. The developed model is

$$(1-\alpha)(u-u_s) + \alpha \frac{\partial u}{\partial r} = 0.$$

Here α is a measure of ischemia; α near 1 means extreme ischemia. These results are agreement with the experimental results. The model now can be used as a tool to suggest biologically testable hypotheses for improved healing. So this reduces the need for guesswork and time-consuming animal testing.

RESULTS AND DISCUSSION

The above example model shows the role played by mathematics in a biological problem. This clearly indicated that a deep knowledge in both mathematics and biology is very important for the development of realistic models. A Continuous discussion between biologist and mathematicians is also needed during the modeling process. When the models are formulated by mathematicians, they will be passed to biologists for testing in real situations. During the testing process, factors involved in the problem will be examined using the model and patient data. So the factors will be evaluated using the patient data and model and compared. Any assumptions made during the modeling process will also be tested with patient data or realistic conditions. Improvement suggestions will be passed from biologists to mathematicians for development of better models. This process will continue for a number of cycles until a better model is formulated by both biologists and mathematicians. We should note that when biologists passes their requirements to mathematicians, the mathematicians should have knowledge in biology to understand the biologists' request. Similarly, when the mathematicians developed a model, the biologists should have mathematics knowledge to understand the model.

It clearly shows that knowledge in both mathematics and biology is very important to solve biological problems. This also indicated the importance of a discipline which is a combination of mathematics and biology. Since this new discipline deals with real problems and solve them in a realistic way, this new discipline, biomathematics, becomes popular among biologist and mathematicians.

CONCLUSION

The great alliance between mathematics and physics is well recognized universally. Both disciplines supporting each other. There are areas in biology which have advanced by mathematics, such as computational neuroscience, population dynamics, ecology, spread of disease and phylogenomics. In future, mathematics will be the future frontier of biology and biology is the future frontier of mathematics. Considering this new trend, important mathematics courses should be included in biology curriculum to understand the applications of mathematics and also a considerable number of biology courses should be included to mathematics curriculum to understand the biological problems. The new discipline, biomathematics, should be introduced in our undergraduate and postgraduate curriculum to produce our graduate with the latest research knowledge in biological stream.

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