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APPLICATIONS OF MATHEMATICS TO BIOLOGY

Xavier Street and Mulatu Lemma
College of Science and Technology, Department of Mathematics, Savannah State University, USA.

Corresponding author: *Mulatu Lemma
Email: lemmam@savannahstate.edu

INTRODUCTION:

Mathematics is positioned to play a major role in this effort, helping to discover the secrets of life by working collaboratively with bench biologists, chemists and physicists. The critical need, which has already begun, is the development of a quantitative body of theory for biology. This development of theory is expected to have the same impact on biology as it did on the sciences of physics, chemistry and engineering in the 20th century. This quantitative body of theory will be created by people with strong backgrounds in both biology and in the mathematical sciences. Because of its outstanding record of interdisciplinary research and training, the IMA is an ideal venue for this annual program at the interface between the mathematical sciences and biology .One application of mathematical models is in analyzing the workings of the mammalian circadian clock. About 20,000 synchronized neurons in the suprachiasmatic nucleus (SCN) control daily rhythms of physiology, metabolism and behavior

Applications

1. Application of mathematics to Ecology

Ecology is the study of the relationships between living organisms, including humans, and their physical environment; it seeks to understand the vital connections between plants and animals and the world around them. Ecology also provides information about the benefits of ecosystems and how we can use Earth's resources in ways that leave the environment healthy for future generations.

When one makes measurements on things, say the weight of elephants in a certain region, investigators usually aim to measure the weight of all the elephants or take a sample of elephants and try to extrapolate from the sample information about the population. When populations are large, it is hard to take measurements for all of its individuals. On the other hand, when one takes a sample it is often difficult to be "sure" that the sample is representative of the population. Are the elephants in American zoos "typical" or all elephants? In getting understanding of a collection of data, there are two fundamental concepts involved. One is the notion of a measure of central tendency--a single number that captures the values of one's data set. Common measures of central tendency are the mean (the sum of the measurements divided by the number of members in the population), the median (after arranging the data in increasing order, a measurement in the middle), and the mode (a measurement which occurs most often). Not surprisingly it is hard to capture a whole population with a single number, since one data set may have nearly all the values very close to say, the mean, while another population may have the same mean as the first population but be "spread out." So it is natural in addition to a measure of central tendency for a data set to also compute a measure of "dispersion." A dispersion measure tries to indicate how far spread out the data is about the number computed for its "central tendency." A typical example is to use the mean as a measure of central tendency and the standard deviation as a measure of dispersion about the mean. Another measure of dispersion for a set of data would be the range, the difference between the largest and smallest measurements. Having thought of the range, one might invent the measure of central tendency, the "mid-range" value--the value of the range divided by two. Population means and standard deviations and sample means, and standard deviations are the tools that mathematicians (statisticians) use to understand what is going on in comparing two populations. The general tools of the statistician are also the tools of the ecologist. Ecologists have invented a variety of "indices" to measure and get insight into living things. Mathematics is necessary in Ecology to compare the reasons that the organism inhabits a specific habitat, In the theory of evolution and natural selection, the Price equation (also known as Price's equation or Price's theorem) describes how a trait or gene changes in frequency over time. The equation uses a covariance between a trait and fitness, to give a mathematical description of evolution and natural selection.

$$\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)$$

2. APPLICATION OF Mathematics to Evolution

Evolution is the process by which different kinds of living organisms are thought to have developed and diversified from earlier forms.

Recall:

$$z = \frac{1}{n}\sum_i z_i n_i$$

$$z' = \frac{1}{n'}\sum_i z_i n_i'$$

Mathematical graphs are structures that represent the dynamic relations among sets of items: Individual items sit at the vertices of the structure; the lines, or edges, between every pair of items describe their connection. In evolutionary graph theory, individual organisms occupy every vertex. Over time, an individual has some probability of spawning an identical offspring, which can replace an individual on a neighboring vertex, but it also faces its own risks of being replaced by some individual from the next generation. Those probabilities are wired into the structure as “weights” and directions in the lines between the vertices. The right patterns of weighted connections can stand in for behaviors in living populations: For example, connections that make it more likely that lineages will become isolated from the rest of a population can represent migrations.

3. Applications of Mathematics to Genetics

Genetics is the study of genes, genetic variation, and heredity in living organisms.

Mathematical models are a useful tool for investigating a large number of questions in metabolism, genetics, and gene–environment interactions. A model based on the underlying biology and biochemistry is a platform for in silico biological experimentation that can reveal the causal chain of events that connect variation in one quantity to variation in another. We discuss how we construct such models, how we have used them to investigate homeostatic mechanisms, gene–environment interactions, and genotype–phenotype mapping, and how they can be used in precision and personalized medicine.

To explore the Hardy-Weinberg equation, we can examine a simple genetic locus at which there are two alleles, A and a. The Hardy-Weinberg equation is expressed as:

p2 + 2pq + q2 = 1

Where p is the frequency of the "A" allele and q is the frequency of the "a" allele in the population. In the equation, p2 represents the frequency of the homozygous genotype AA, q2 represents the frequency of the homozygous genotype aa, and 2pq represents the frequency of the heterozygous genotype Aa. In addition, the sum of the allele frequencies for all the alleles at the locus must be 1, so p + q = 1.

4. Application of Mathematics to Immunology

Immunology is the study of the immune system and is a very important branch of the medical and biological sciences. The immune system protects us from infection through various lines of defence. If the immune system is not functioning as it should, it can result in disease, such as autoimmunity, allergy and cancer. It is also now becoming clear that immune responses contribute to the development of many common disorders not traditionally viewed as immunologic, including metabolic, cardiovascular, and neurodegenerative conditions such as Alzheimer’s.

Statistical analysis is only one of the many tools that mathematics can provide to immunology and, in general, cannot offer mechanistic explanations. Mathematical and statistical methods enable multidisciplinary approaches that catalyse discovery. Together with experimental methods, they identify key hypotheses, define measurable observables and reconcile disparate results. Mathematical modelling will become increasingly important in immunology. It is precisely because intuition is insufficient beyond a certain level of complexity that analysis of the immune system must become more quantitative. Immunology is an excellent field for the application of mathematics, because it has a long tradition of important theories (clonal selection, immune networks, danger signals, …) and great thinkers. Still, there are impediments to a marriage of mathematics and immunology. One is that the technical languages of the disciplines are very different. It would be useful for experimental immunologists to have some basic understanding of mathematical modelling, its usefulness and limitations; it is also crucial that modellers learn the required immunology and the experimental systems they are modelling. That is, we must overcome the third problem identified above. On the other hand, there are examples of successful collaborations between experimental and mathematical immunologists. Often, but not exclusively, these partnerships are more fruitful when collaborations are initiated at an early stage of a given study.

The body uses heat to kill invading viruses and bacteria, so the heat equation described below is used to eliminate invading organisms.

$$\begin{aligned} \partial_t Q(V) &= -\int_{\partial V} \mathbf{H}(x)\cdot\mathbf{n}(x)\,dS \\ &= \int_{\partial V} \mathbf{A}(x)\cdot\nabla u(x)\cdot\mathbf{n}(x)\,dS \\ &= \int_V \sum_{i,j} \partial_{x_i}\left(a_{ij}(x)\,\partial_{x_j} u(x,t)\right)dx \end{aligned}$$

5. Application of mathematics to Physiology

Physiology is the science of life. It is the branch of biology that aims to understand the mechanisms of living things, from the basis of cell function at the ionic and molecular level to the integrated behavior of the whole body and the influence of the external environment. Research in physiology helps us to understand how the body works in health and how it responds and adapts to the challenges of everyday life; it also helps us to determine what goes wrong in disease, facilitating the development of new treatments and guidelines for maintaining human and animal health. The emphasis on integrating molecular, cellular, systems and whole-body function is what distinguishes physiology from the other life sciences.

Physiology deals with the function of the human function, which deals with hormones, which are regulated and described by mathematical applications. Mathematics is a powerful tool for quantifying complex relationships, it is important to find educational approaches that can impart to physiology (and medical) students a deeper understanding of how mathematics can be applied to studying complex living systems. Mathematics calculations are used in anatomy and physiology to provide additional insight into the information provided by the measurement of physiological quantities. The following exercises use a range of mathematical formulae that model various anatomic and physiological processes. The exercises also provide you with the opportunity to implement your general knowledge of rates, ratio and proportion. While the calculations themselves are not intended to be arithmetically difficult, the examples are presented within a health science context and involve specialist terminology relating to human anatomy and

Microscopes have two sets of lenses: the eyepiece lens (which you look through) and the objective lens (which is placed just above the specimen being viewed).

The eyepiece lenses have a magnification of 10X.

The 4 objective lenses have magnifications of 4X, 10X, 40X and 100X

References

"AMS :: Feature Column :: Mathematics and Ecology." *American Mathematical Society*, www.ams.org/publicoutreach/feature-column/fc-2015-09.

Batzel, Jerry Joseph, et al. "Bridging Different Perspectives of the Physiological and Mathematical Disciplines." *Advances in Physiology Education*, 1 Dec. 2012, journals.physiology.org/doi/full/10.1152/advan.00074.2012.

Castro, Mario et al. "Mathematics in modern immunology." *Interface focus* vol. 6,2 (2016): 20150093. doi:10.1098/rsfs.2015.0093

Nijhout, H Frederik et al. "Using mathematical models to understand metabolism, genes, and disease." *BMC biology* vol. 13 79. 23 Sep. 2015, doi:10.1186/s12915-015-0189-2

"Population Biology." *Population Biology*, glencoe.mheducation.com/sites/dl/free/0078757134/383928/BL_04.html.

Rennie, John, and Quanta Magazine. "Mathematics Shows How to Ensure Evolution." *Quanta Magazine*, www.quantamagazine.org/mathematics-shows-how-to-ensure-evolution-20180626/.

Welsh, David K et al. "Suprachiasmatic nucleus: cell autonomy and network properties." *Annual review of physiology* vol. 72 (2010): 551-77. doi:10.1146/annurev-physiol-021909-135919