APPLICATIONS OF BIO PHYSICS – AN OVERVIEW

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Abstract:

Biophysics is a branch of science that uses the methods of physics to study biological processes. Physics uses mathematical laws to explain the natural world, and it can be applied to biological organisms and systems to gain insight into their workings. Research in biophysics has helped prevent and treat disease, advance drug development, and create technology to allow humans to live more sustainably and protect the changing environment. In the first half of the 20th Century, German scientists dominated the biophysics. They studied electromagnetic fields and light, and they became mainly concerned with studying the effects of radiation on living things. The popularity of biophysics rose when the Austrian physicist Erwin Schrödinger published the book *What is Life?* in 1944. This book was based on a series of public lectures that Schrödinger gave on explaining the processes of living things through physics and chemistry. In it, he proposed the idea that there was a molecule in living things that contained genetic information in covalent bonds. This inspired scientists such as James Watson and Francis Crick to search for and characterize the genetic molecule, and with the aid of Rosalind Franklin's x-ray crystallography research, they discovered the double helix structure of DNA in 1953.

Keywords: Biophysics, branch, science, methods, physics, study, biological, processes.

Introduction:

History of Biophysics Biophysics is a relatively young branch of science; it arose as a definite subfield in the early to mid-20th Century. However, the foundations for the study of biophysics were laid down much earlier, in the 19th Century, by a group of physiologists in Berlin. The Berlin school of physiologists included Hermann von Helmholtz, Emil DuBois-Reymond, Ernst von Brücke, and Carl Ludwig. In 1856, Adolf Fick, one of Ludwig's students, even published the first biophysics textbook. But technology in physics had not sufficiently advanced at this time to study lifeforms in a detailed way, such as at the molecular level.

By the mid-20th century, biophysics programs had sprung up and gained popularity in other countries, and from 1950-1970, biophysics research occurred at a faster rate than ever before. In addition to the discovery of DNA and its structure, biophysics techniques were also used to create vaccines, develop imaging techniques such as MRI and CAT scans to help doctors diagnose diseases, and create new treatment methods such as dialysis, radiation therapy, and pacemakers. Currently, biophysics has also begun to focus on issues related to the Earth's changing climate. For example, some biophysicists are working on developing biofuels from living microorganisms that could replace gasoline as a fuel.

Biophysics uses physics to explain and develop more information on living things. Common examples of these includes wearing glasses with corrective lenses for vision, and X-ray machines, which show the skeletal structure of a creature. Lasers are also part of biophysics, as well as an ultracentrifuge, which is a machine spinning at high speeds to separate a solution.

Biophysics has been used to explain fundamental (basic) processes in Biology. This includes, the diffusion (moving of particles from a point of high concentration to that of a low one) of gases, osmosis, and how lenses can be used to correct vision.

Osmosis has been best explained as water moving across a membrane from a source of water with higher concentration to a lower area. This makes it a type of diffusion, which helps create solutes. Solutes are proteins and ions that dissolve in a solvent (water). An example of osmosis can be seen in red blood cells. These contain many solutes like salt and protein. When placed into a solvent, the water will move to the area with the highest concentrate of solute.

Diffusion of gases is gas moving in random directions that result in them moving away from the area. The kinetic theory states that a gas is many particles (atoms/molecules) which are in a rapid moving randomly which causes many collisions with each other and with the walls of the container. So, diffusion of gases is pulling apart the gases and making the particles have more space between.

Biophysics has a long rich history, going back to the 18th century when an Italian physician, Luigi Galvani, started doing research on the nature of muscle contraction and nerve impulses. He found that electricity was constantly interacting with the muscles, and that work started off the entire biophysics properties, since electricity is part of nature. His discovery led to the creation of devices such as electrocardiograph (recording the electric impulses of heartbeats), electroencephalograph (recording brain waves), and the pacemaker (a device to keep heartbeats normal)

Biophysics is the field that applies the theories and methods of physics to understand how biological systems work.

Biophysics has been critical to understanding the mechanics of how the molecules of life are made, how different parts of a cell move and function, and how complex systems in our bodies—the brain, circulation, immune system, and others— work. Biophysics is a vibrant scientific field where scientists from many fields including math, chemistry, physics, engineering, pharmacology, and materials sciences, use their skills to explore and develop new tools for understanding how biology—all life—works.

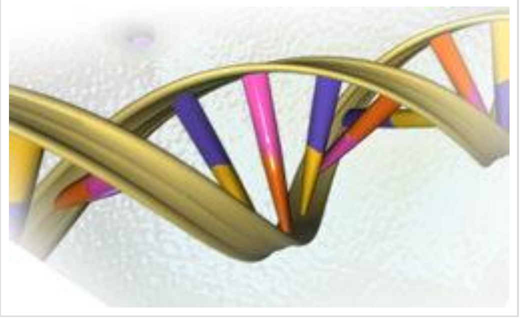
Biophysics: The Bridging Science

Physical scientists use mathematics to explain what happens in nature. Life scientists want to understand how biological systems work. These systems include molecules, cells, organisms, and ecosystems that are very complex. Biological research in the 21st century involves experiments that produce huge amounts of data. How can biologists even begin to understand this data or predict how these systems might work?

This is where biophysicists come in. Biophysicists are uniquely trained in the quantitative sciences of physics, math, and chemistry and they are able tackle a wide array of topics, ranging from how nerve cells communicate, to how plant cells capture light and transform it into energy, to how changes in the DNA of healthy cells can trigger their transformation into cancer cells, to so many other biological problems.

What Do Biophysicists Do?

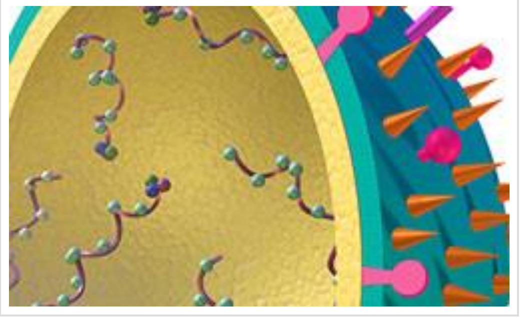
Biophysicists work to develop methods to overcome disease, eradicate global hunger, produce renewable energy sources, design cutting-edge technologies, and solve countless scientific mysteries. In short, biophysicists are at the forefront of solving age-old human problems as well as problems of the future.



Data Analysis and Structure

The structure of DNA was solved in 1953 using biophysics, and this discovery was critical to showing how DNA is like a blueprint for life.

Now we can read the sequences of DNA from thousands of humans and all varieties of living organisms. Biophysical techniques are also essential to the analysis of these vast quantities of data.



Computer Modelling

Biophysicists develop and use computer modeling methods to see and manipulate the shapes and structures of proteins, viruses, and other complex molecules, crucial information needed to develop new drug targets, or understand how proteins mutate and cause tumors to grow.

Molecules in Motion

Biophysicists study how hormones move around the cell, and how cells communicate with each other. Using fluorescent tags, biophysicists have been able to make cells glow like a firefly under a microscope and learn about the cell's sophisticated internal transit system.

Neuroscience

Biophysicists are building computer models called neural networks to model how the brain and nervous system work, leading to new understandings of how visual and auditory information is processed.

Bioengineering, Nanotechnologies, Biomaterials

Biophysics has also been critical to understanding biomechanics and applying this information to the design of better prosthetic limbs, and better nanomaterials for drug delivery.

Imaging

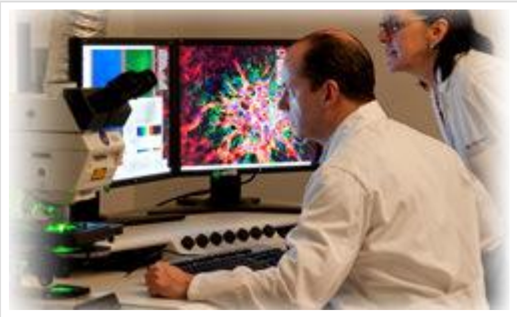
Biophysicists have developed sophisticated diagnostic imaging techniques including MRIs, CT scans, and PET scans. Biophysics continues to be essential to the development of even safer, faster, and more precise technology to improve medical imaging and teach us more about the body's inner workings.

Medical Applications Biophysics has been essential to the development of many life-saving treatments and devices including kidney dialysis, radiation therapy, cardiac defibrillators, pacemakers, and artificial heart valves.

Ecosystems

Environmental biophysics measures and models all aspects of the environment from the stratosphere to deep ocean vents. Environmental biophysicists research the diverse microbial communities that inhabit every niche of this planet, they track pollutants across the atmosphere, and are finding ways to turn algae into biofuels.

Where Do Biophysicsists Work?

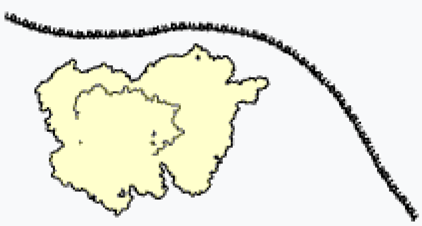


Biophysicists are teachers and researchers in biology, physics, engineering, and many other fields. They work in universities, hospitals, tech startups, and engineering companies developing new diagnostic tests, drug delivery systems, or potential biofuels. Biophysicists develop computer models to find out why a new flu strain eludes the immune system or they make 3D models of new protein structures to better understand how they work. They practice law in specialized fields like intellectual property, write about science for print and online publications, and work in government to advise legislatures. Those who are trained in biophysics have unlimited career possibilities.

Medical technology has advanced tremendously because of research into biophysics. Computerized axial tomography (CAT) scanning, magnetic resonance imaging (MRI), and positron-emission tomography (PET) have given researchers sight into the complex bodies of creatures, including humans. Today, these are used in a day to day environment, but just under 50 years ago, we would not be able to even fathom technology such as this.

Biophysics has helped us advance tremendously by incorporating aspects of biology with physics. It began so long ago, and only recently have we taken true advantage of it, but we have certainly made up for lost time with all the wonderful medical tools and advancements that have been made. It's something that will seemingly be needed for years and years to come.

typically addresses biological questions similar to those in biochemistry and molecular biology, seeking to find the physical underpinnings of biomolecular phenomena. Scientists in this field conduct research concerned with understanding the interactions between the various systems of a cell, including the interactions between DNA, RNA and protein biosynthesis, as well as how these interactions are regulated. A great variety of techniques are used to answer these questions.



A ribosome is a biological machine that utilizes protein dynamics

Fluorescent imaging techniques, as well as electron microscopy, x-ray crystallography, NMR spectroscopy, atomic force microscopy (AFM) and small-angle scattering (SAS) both with X-rays and neutrons (SAXS/SANS) are often used to visualize structures of biological significance. Protein dynamics can be observed by neutron spin echo spectroscopy. Conformational change in structure can be measured using techniques such as dual polarisation interferometry, circular dichroism, SAXS and SANS. Direct manipulation of molecules using optical tweezers or AFM, can also be used to monitor biological events where forces and distances are at the nanoscale. Molecular biophysicists often consider complex biological events as systems of interacting entities which can be understood e.g. through statistical mechanics, thermodynamics and chemical kinetics. By drawing knowledge and experimental techniques from a wide variety of disciplines, biophysicists are often able to directly observe, model or even manipulate the structures and interactions of individual molecules or complexes of molecules.

In addition to traditional (i.e. molecular and cellular) biophysical topics like structural biology or enzyme kinetics, modern biophysics encompasses an extraordinarily broad range of research, from bioelectronics to quantum biology involving both experimental and theoretical tools. It is becoming increasingly common for biophysicists to apply the models and experimental techniques derived from physics, as well as mathematics and statistics, to larger systems such as tissues, organs,[6] populations[7] and ecosystems. Biophysical models are used extensively in the study of electrical conduction in single neurons, as well as neural circuit analysis in both tissue and whole brain.

Medical physics, a branch of biophysics, is any application of physics to medicine or healthcare, ranging from radiology to microscopy and nanomedicine. For example, physicist Richard Feynman theorized about the future of nanomedicine. He wrote about the idea of a *medical* use for biological machines (see nanomachines). Feynman and Albert Hibbs suggested that certain repair machines might one day be reduced in size to the point that it would be possible to (as Feynman put it) "swallow the doctor". The idea was discussed in Feynman's 1959 essay *There's Plenty of Room at the Bottom*.[8]

Some of the earlier studies in biophysics were conducted in the 1840s by a group known as the Berlin school of physiologists. Among its members were pioneers such as Hermann von Helmholtz, Ernst Heinrich Weber, Carl F. W. Ludwig, and Johannes Peter Müller.[9] Biophysics might even be seen as dating back to the studies of Luigi Galvani.

The popularity of the field rose when the book *What Is Life?* by Erwin Schrödinger was published. Since 1957, biophysicists have organized themselves into the Biophysical Society which now has about 9,000 members over the world.[10]

Some authors such as Robert Rosen criticize biophysics on the ground that the biophysical method does not take into account the specificity of biological phenomena.[11]

While some colleges and universities have dedicated departments of biophysics, usually at the graduate level, many do not have university-level biophysics departments, instead having groups in related departments such as biochemistry, cell biology, chemistry, computer science, engineering, mathematics, medicine, molecular biology, neuroscience, pharmacology, physics, and physiology. Depending on the strengths of a department at a university differing emphasis will be given to fields of biophysics. What follows is a list of examples of how each department applies its efforts toward the study of biophysics. This list is hardly all inclusive. Nor does each subject of study belong exclusively to any particular department. Each academic institution makes its own rules and there is much overlap between departments.[*citation needed*]

- Biology and molecular biology – Gene regulation, single protein dynamics, bioenergetics, patch clamping, biomechanics, virophysics.
- Structural biology – Ångstrom-resolution structures of proteins, nucleic acids, lipids, carbohydrates, and complexes thereof.

- Biochemistry and chemistry – biomolecular structure, siRNA, nucleic acid structure, structure-activity relationships.
- Computer science – Neural networks, biomolecular and drug databases.
- Computational chemistry – molecular dynamics simulation, molecular docking, quantum chemistry
- Bioinformatics – sequence alignment, structural alignment, protein structure prediction
- Mathematics – graph/network theory, population modeling, dynamical systems, phylogenetics.
- Medicine – biophysical research that emphasizes medicine. Medical biophysics is a field closely related to physiology. It explains various aspects and systems of the body from a physical and mathematical perspective. Examples are fluid dynamics of blood flow, gas physics of respiration, radiation in diagnostics/treatment and much more. Biophysics is taught as a preclinical subject in many medical schools, mainly in Europe.
- Neuroscience – studying neural networks experimentally (brain slicing) as well as theoretically (computer models), membrane permittivity, gene therapy, understanding tumors.
- Pharmacology and physiology – channelomics, biomolecular interactions, cellular membranes, polyketides.
- Physics – negentropy, stochastic processes, and the development of new physical techniques and instrumentation as well as their application.
- Quantum biology – The field of quantum biology applies quantum mechanics to biological objects and problems. Decohered isomers to yield time-dependent base substitutions. These studies imply applications in quantum computing.
- Agronomy and agriculture

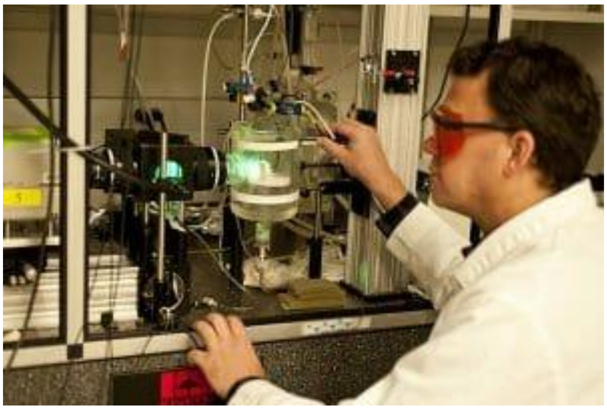
Many biophysical techniques are unique to this field. Research efforts in biophysics are often initiated by scientists who were biologists, chemists or physicists by training.

Areas of Biophysics

Biophysics is incorporated into many diverse areas of biology. Some research topics in biophysics or involving biophysics include:

- Membrane biophysics: the study of the structure and function of cell membranes, including the ion channels, proteins, and receptors embedded within them.
- Computational/theoretical biophysics: using mathematical modeling to study biological systems.
- Protein engineering: creating and modifying proteins to advance synthetic biology. Often used to advance human health in the form of new disease treatments.
- Molecular structures: biophysics studies the molecular structures of biological molecules including proteins, nucleic acids, and lipids.

- Mechanisms: using physical mechanisms to explain the occurrence of biological processes. Some physical mechanisms include energy transduction in membranes, protein folding and structure leading to specific functions, cell movement, and the electrical behavior of cells.



Here, a biophysicist in a U.S. Food and Drug Administration lab is studying the electrical activity of the heart as related to pacemaker and defibrillator use.

Biophysics Major Some universities offer undergraduate Bachelor of Arts or Bachelor of Science degrees in Biophysics, while others only offer a Biophysics degree at the graduate level (i.e., a master's and/or doctorate degree). Biophysics degrees are heavily focused on physics and biophysics courses, and usually those who major in biophysics are required to take numerous math and chemistry classes as well. At the undergraduate level, one can expect to take courses in general and organic chemistry, calculus, mechanics, linear algebra, and biochemistry. Other possible courses include cell biology, genetics, molecular biology, statistics, and computational biology, among others. Another important component of many biophysics degrees is research; some programs require research in a laboratory to be done for a certain number of semesters, culminating in a senior research project. The specific courses offered in a biophysics major program can vary from university to university, but majoring in biophysics will adequately prepare a student to begin their career in biophysics research.

If a student is interested in biophysics but their school does not offer a biophysics degree, there are often comparable programs found in other majors that include much of the same courses. Majoring in physics is another good option, and one may consider adding another major or minor in biochemistry, chemistry, or biology depending on research interests and the programs offered.

Biophysics Conclusions:

The most common career options for biophysicists include research, teaching, or a combination of both. A master's degree is generally needed to become a biophysics teacher, lab manager or research associate, while a PhD is necessary in order to be the principal investigator of a research laboratory. Principal investigators design experiments and oversee all of the research being done in a lab, while lab managers and research associates have a more supporting role and assist the principal investigator in carrying out their research. Those with bachelor's degrees may obtain positions as research technicians, which are also important in the laboratory. Research technicians carry out a lot of the benchwork of scientific experiments, allowing the principal investigator time to write scientific papers, research proposals, and grants.

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