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Integration of Medical and Biological Physics With General Physics: Advancements and Applications in Healthcare and Technology

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Annotation: The integration of medical and biological physics with general physics has led to significant advancements in healthcare and technology, yet a comprehensive framework bridging these disciplines remains underdeveloped. This study explores the intersection of physics, biophysics, and medical applications, highlighting the role of fundamental physical principles in understanding biological systems and improving medical technologies. Through an interdisciplinary review, we analyze the contributions of physics to medical imaging, radiation therapy, biomechanics, nanotechnology, and bioinformatics. Findings reveal that leveraging physics-based methodologies enhances diagnostic precision, treatment efficacy, and the development of innovative medical devices. The results underscore the necessity of interdisciplinary collaboration to address emerging challenges in healthcare. This research provides a foundation for future technological innovations and fosters a deeper integration of physics into biomedical sciences.

Keywords: Medical physics, biophysics, healthcare technology, medical imaging, nanotechnology, radiation therapy, biomechanics, bioinformatics.

Physics has become an essential basis for understanding biological systems from the microscopic organization of molecules, as a engineering base for many biotechnological processes on the design and use of medical devices. Development in medical technologies, such as computer modeling, use of information from medical imaging devices and novel treatment modalities, increases the importance of the interface of physics–medicine in practical applications. Nevertheless, the narrow connection with medical and biological physics is not sufficient because the recent developments and discoveries appear mostly at the intersections of different fields of science. For instance, progress in the molecular classification of cancers has been possible due to the introduction of the geometric method of data analysis developed for the needs of purely mathematical research. Likewise, recently in biology an important discovery was the finding of universal dependence in the self-assembly of proteins and RNA, discovered using concepts rooted in physics. On the other hand, recent studies in the growth of technological networks have shown that they share many statistical patterns with more complex systems such as biological networks. Therefore, to understand the growth mechanisms of such networks, the tools and methods of statistical physics must be expanded. Common goals and the necessity to face new challenges is the reason that on the occasion of the International Year of Physics the general aspects of the application of physics in biology, medicine and health are analyzed. Instead of exploring new methods and problems at the forefront of scientific research, a general perspective is offered on the application of physical principles in biological and medical systems and devices. This discussion is of a cross-disciplinary character and concerns physicists, now working in either biology or medicine, as well as biologists and medical doctors with a professional, though not specialized, physical background.

1. Introduction to the Interdisciplinary Field of Medical and Biological Physics

On the border between physics, chemistry, and biology, there is a multitude of phenomena and processes to be discovered that are not yet explored. Physics, despite its age if compared to newer biological and medical sciences, was and remains in many cases quite ahead of biology and medicine. At the bottom line, the function of living beings, from the simplest ones (living cell) to the most complex ones (human organisms), is regulated by a relatively small number of physical principles. These principles provide a common language to describe a wide range of vastly different phenomena, extending from the very small scale to the very large scale, and from rest to very high velocities. From the classical gigantic eclipse predictions of planetary phenomena by Newtonian physics to the very small scale predictions of quantum physics, the image of the world around humans is constantly enriched, clarified, and reshaped. By extension of the scientific imagery of the world, biology and medicine operated mostly within a “philosophical”, “morphological”, “naturalistic” (versus physical), and “phenomenological” concept of the “vita”, body, injury, physiology, diagnostics, therapeutics, and pathology.

Following the traditional metaphor of the half glass of water, another possible approach may naturally arise: “now the physical-technical capabilities potentially open the way to implement the “exhaustive knowledge on the structure and operation” of the living systems; questions and problems still remain at what the boundaries of the “reciprocal” interaction between physical and biological approaches are and, in particular, in what new directions experimental applications in biology are feasible using advanced techniques (noninvasive, nondestructive, in vivo, 3D), technologies (in-silico models development), and methodologies (physical principles to describe biological systems, from the infinitesimally small to the infinitely large scale) provided by physics are “useful and meaningful” [1].

2. Fundamental Principles of General Physics Relevant to Medical and Biological Applications

Physics is a fundamental branch of science that governs natural processes and interactions. Since everything in the universe is integrated and influences each other, it is reasonable to study all subjects with a holistic approach. Medical and biological physics focus on general physics integrated with healthcare and biological science. General physics is essential because the phenomena of medical and biological systems should be described by the fundamental laws of nature. Motion and structure of the human body are described by laws of mechanics as an application of general physics principles. Transfer and exchange of heat are also the concerned phenomena and are described by general physics principles termed thermodynamic. The surface of the human body is essentially electromagnetic and closely related to the basic principle of electromagnetism. Human sensation to the environment consists of mechanical, heat, and electromagnetic signals which interact inside and among themselves within a certain human organ. Understanding the fundamental principles is important to recognize how people sense the environment and react to the signals of it. The understanding might also be helpful in designing new technology or adjusting the environment related to human health, using the advantage of the least interaction angle of the applied physics principles to the human organ objects. Temperature contrast image was defined by monitoring the arrival time of the gas bolus arrival, while spatial resolution sensitivity distribution was defined by adjusting the electro-mechanical actuator aperture. Both of these purposed considerations and design might be helpful in new technology clinical application and evaluation. This approach described that a general physical principle and phenomena can be applied to medical imaging diagnosis.

In daily biomedical and public health, it is important to recognize the common health terms and phenomena from a general physical perspective that occurs in medical scenarios, community health situations, and health emergency events which are close to general physics principles. Geometric, wave phenomena, propagation model of disease being spread, basic model of a neuron cell, polygonal domain shape of a brain lobe, number of brain lobes, allergic reaction of the human body, signal alpha strength, displaying of medical scan image, wildfire behavior, and analysis method. Generally, it is described that biological and medical questions can be approached by the fundamental principle of general physics underlying all natural phenomena. In clinical medical practices, it is mentioned to dose and shield the radiation of the patient and physician to restrict human tissue from the damage of radiation or particles while also discovering the underlying treatment principle of the most organisms of a certain kind of illness. This is broadly described by the exponential law behavior. On health care quality and cost-effectiveness, it is about a cost compared to healthcare service that is received either healthcare facility or home-care service affected epidemiologically as an analogy heat conduction model by convection process. Offering flexible care such shares broad understanding of disease healing process, disease spread process and modeling, and principles of treatment. [2][3][4]

3. Biophysics: Understanding the Physics of Biological Systems

Biophysics is the field that seeks to understand the physical principles that govern the biological systems and the relations between these and the systems. This means that although much of the subject matter is biological, it is approached in a physics manner. Nature and physical forces behind the organization of the molecular structure, the interactions in it, and the energy transfer between molecules are sought, together with the collective dynamics of the biological systems and the interactions of the systems to the surrounding media. The scientific process of biology integrates the physical approaches in its newer data analysis methods; there is also good need of a complementary physical point of view to understand the more complex biological events and the related data as a whole. It has already been realised that a complex biological process can hardly be understood using a purely biological approach; in addition, this approach too often limits the perspective and insight. A fast technical development is also already leading to practical applications in the same research field, and examples of this are given throughout the paper. Bio-medical transducer technology is a good example of the electronic-biologic integration and has already led to widely used drug delivery systems and other drug administrating systems based on various automatic measurements. The devices controlling the administration of insulin are one of these successful examples.

Physical measurements, on the other hand, are basic in the study and modelling of the system. Some bio-physical measurements complement, some compete against, biological measurements. Because of the large diversity of the phenomena to be measured, the bio-physical measurements can widely vary from on-line single molecule measurements to population studies based on statistical image analysis. Sudden conversions also benefit from bio-physical insights, and tools as well. Biology is a very dynamic science, and it appears that the present problems are seen to be easier and easier while there is not yet a full understanding or explanation of the main principles behind the complex biological processes. There are still more mysteries in biology than in any other science, so there is certainly a lot to be done. When seeing one of the recent breakthroughs in biology as given, it is most important to keep in mind that in the frontier of biophysics there are still overwhelming problems in modelling very basic biological issues [5]. Treatments on cancer or other typical diseases are far on the horizon. Classic biophysics or biophysical methods are indeed closely related to physics-instrumentation only, but are rarely the frontier biophysics. Some of the available new methods are also quite mundane. Bio-medical systems- or circuitry are close to engineering, but as a rule involve less of the frontier physics in the development as compared to traditional p-instrumentation. On the other side, the role of physics in the explanation or understanding of physical laws in the biological phenomena is no more fundamental than the role of physics in the explanation of laws in electronics, chemistry, or geophysics. Physics as such has been mature for centuries, the newer knowledge being mostly in a more applied, technical or more exotic range. What is done currently is the applications of the more traditional knowledge to the biological data based on already observed physical laws. Those applications are, of course, also very important and useful, opening new fields of quantifying or mathematical approaches to the biological data. By far the most of contemporary efforts in biophysics are still of that kind. But unlike many other sciences, in which the frontier represents mainly improvements or extensions of existing theories or methods, the frontier biophysics is still awaited to solve some very basic issues in the line of physical laws underlying complex biological processes or to find new universal (and predictive) approaches, not only observations, of the biological data. As a guideline to speculate on some potential future breakthroughs in medicine resulting from more extensive integration of biophysics and practical medical practice, the following couple of examples are offered. [6][7][8]

4. Medical Imaging Techniques and Their Physical Principles

As a healthcare professional or even a patient, there is a wide range of medical imaging modalities that can cause confusion, due to each having its own physical principles. This term is a collection of medical imaging tools that share a common ability to obtain pictures of the anatomy or the physiological processes inside the patient, hopefully without causing damage in the process. Some of the common techniques are X-rays, Computed Tomography, Magnetic Resonance Imaging, Ultrasound, Positron Emission Tomography, and more. It is well clarified that in medical practice today, non-invasive exploration of the patient’s body is not possible without the wide range of help provided by medical imaging. Despite the variations in the techniques, all these imaging methods share similar physical principles. Traditionally they all detect and record the interaction of different forms of radiations with the body, forming images based on this interaction.

Once the patient’s body has been exposed to radiation, the recorded information is then used to generate images, or pictures of the body’s inner anatomy and/or physiology. The physical properties of the recorded images can vary, like contrast, resolution, and the information about the tissue being examined. In essence, these images work because of the accumulation of the body’s modulation of the recording radiation energy. It can be the absorption, attenuation, or scattering. On their own, even with the help of these images, the physical properties of these recorded energies are difficult to interpret or prove to be of any clinical use. To address this, different types of post-processing such as windowing leveling, averaging, subtraction, and digital algorithms have long been introduced to enhance the accuracy and proof of these images.

5. Radiation Therapy: Physics-Based Treatment Modalities

Radiation therapy, which is extensively employed in treatment of brain, head and neck, breast, lung, prostate, liver, pancreatic, esophagus, bones, muscle, and skin cancers among others. The physics behind radiation therapy, treatment planning, some widely used with increasing cadence beam delivery mechanisms, safety considerations, and imaging practices to verify the treatment plan and monitor patient positioning will be discussed. Moreover, a number of current and experimental treatment modalities that utilize high energy X-rays (photons), protons and other hadrons, electrons, and other less common radiation particles or rays and beams, all of which pertain to particle therapy, will also be discussed [9]. Particularly, proton applications in medicine will be highlighted.

There are more in depth topics on the physics of radiation therapy and its biological effects being looked at right now exclusively devoted to cancer treatment and research. However, an overview of the principles of this anti-cancer treatment with a broad reference to a few decades worth of supporting literature will be the outline. For any tumor larger than a few cubic millimeters, temperature, pH, and oxygen level of a cancerous growth and its surrounding tissue can directly affect the biological and physiological responses of the tumor cell structure to radiation. For over-expressed CT antigens like NY-ESO-1, the biological response of tumor cells during and after the cytocidal mechanism of radiation is particularly studied. In brief, the current fractionation approach usually entails a higher daily dose over a shorter treatment period where the timing and engineering of dose delivery must minimize damage to surrounding non-tumor tissues or critically functional organs. Despite how this information may unfold, it is essential to keep in mind physics’s special role of treatment planning, especially with respect to dose calculations, beam delivery mechanisms and safety considerations, as well as imaging’s role in verifying the treatment plan and ensuring the proper positioning of the patient throughout treatment delivery.

6. Physics of Medical Devices and Technology

The physics underlying medical applications and devices that provide continuity of care to the patient are discussed. Patient care often requires the use of various medical devices such as pacemakers, defibrillators, blood glucose meters, CT and MRI scanners, and nebulizers. The physics governing the operation of these and similar devices are discussed, where possible using as examples devices existent within the hospital campus. Technological details are provided over the general consumer overview of operation for patients, nursing, and complementary staff. Engineering and physics play an essential role in the design, function, and safety of medical and biological devices. Earth’s electrical potential difference to an arbitrary reference ground serves as an impromptu dielectric. A six-month review cycle and bi-annual physics validation of MRI scanners is necessary for continued performance and patient safety. Medical technologies serve to improve patient care and outcomes in a symbiotic biology-technology-investment context. Approval and deployment govern the use of medical devices within healthcare. The expectations of physics in biomedicine and biology of technology are brought into the introductory discussion of medical devices used or supervised by physics and engineering staff. With the launching of this themed issue, the intent is to take the reader from broad generalities, over individual technologies, to future hopes and expectations in contemporary and future healthcare. Healthcare providers and biomedical engineers are increasingly confronted with narrow safety margins, the potential for errors of misuse and patient harm. Emphasis on these technologies is meant as a timely reminder of the responsibilities inherent to the purchasing, application, service, repair, maintenance, and retirement of critical clinical tools. It is hoped that all visitors, including those purely interested in the physics or technology, will heed the calls to pay close and regular attention to the performance of the devices utilized throughout the network of patient care in hospitals and clinics. Content size may vary, but not to exceed 40 single-spaced pages, it is hoped to provoke regular review in this respect and perhaps more generally of the interface between human practitioners, and their biology and technology.

7. Nanotechnology and its Applications in Medicine

The interdisciplinary field of nanotechnology is rapidly growing, advancing and transforming the healthcare industry. It is defined by engineering at a small scale of nano-meter that bridges the gap between different scientific fields, enabling the understanding of matter on a fundamental level at a molecular grade and determining its physical and chemical properties. This control and understanding of the properties of matter at the nanoscale have given rise to technological developments in a broad range of fields. There is a substantial interest in applying such technologies towards medical and biological sciences, which form the field of Nanotechnology with Medical and Biological Physics. Due to the broad nature, this paper will address applications and advancements in healthcare and technology in medicine. Perhaps one of the most vital contributions is in nanomedicine, highlighted by gains in drug delivery, imaging, and diagnostics. At the nanoscale level, principles of the physical and chemical properties of structured materials change, offering the possibility of drastically enhancing their performance. Application of these principles enables the development of multifunctional particles with unique biological and physicochemical properties, currently in the form of nanoparticles, both colloidal and solid. Such particles can encapsulate therapeutic molecules including drugs, proteins, and genetic materials, safeguarding them from degradation and enhancing their transport in the body through targeted delivery to certain cells, tissues, or organs. This has the potential to evoke substantial enhancements in the efficacy of treatment whilst significantly reducing side effects. A variety of particles including quantum dots, fullerene, liposome, and dendrimer have been applied in nanotechnology-based healthcare services. Moreover, the surface of designed particles can be functionalized with diverse biologically active ligands, increasing their specificity for targeted drug delivery. Further surface modifications at the nanometric level can enhance the biocompatibility of engineered materials, promoting cell adhesion, inhibition of bacterial colonization, and modulation of immune responses. Other interesting applications of nanophased materials in medicine include the use of semiconducting materials for phototherapy, and the use of nanoencapsulation of gas molecules for ultrasound imaging. More futuristic possibilities include the utilization of nanorobots in complex medical interventions, autonomous diagnosis at the molecular level with nanosensors and nanoprobes, and the ability to engineer smart multifunctional particles to cross biological barriers. However, many challenges and ethical considerations such as the safety of nanoparticles in the human body, the potential long-term effect of engineered particles, environmental risks, and nanoparticles' ability to cross blood-brain and blood-placenta barriers still need to be resolved. [10][11][12]

8. Biomechanics: Physics of Human Movement and Function

Biomechanics is the study of the physical principles that govern the function of biological systems. Within the human system, it is the interplay of the physical laws of motion and force with anatomical structures that result in the functions of tissues, organs, and the organism. These more engineering-based studies of living have created an exciting new multidisciplinary area of research that applies the principles of mechanics across scales to investigate and understand the mechanical aspects of biological systems. The understanding of the mechanical behaviour of biological systems may provide a new insight into the intriguing aspects of biological systems better to the server, diagnosis, and therapy.

Biomechanics is seen in a lot of different fields, for example, studying the forces acting on the human joints to better understand disease states or how bones strengthening can fight osteoporosis, gait analysis to understand the mechanics of walking to inform prosthetic design, or simply how sports scientists use the field to enhance athletic performance or reduce injury. As we go about some daily life during the day, the body experiences forces that are then transmitted throughout the tissue progressively straining and deforming as they move. For pivotable, these can have harmful effects such as the strain energies from magnetic resonance imaging magnets abnormally straining the heart muscle as it contracts or the histological forced spinal traction separates the corticions in the knees causing damage to survive root. On the other hand, understanding and disturbing the mechanics of these strains and forces may be used to investigate and develop rehabilitation techniques ranging from birth size and geometry treatment of tissues to subsequent pharmacological interventions [13].

In sports science: a lot of injuries in the sports field comes from deliberate or accidental overloading of muscles, bones, or other tissues. The new imaging method using a tungsten granule allows for imaging at over 800,000 frames per second. In this example, the granules and angular ball speeds are measured throwing a basketball to give insight into how different playing techniques generate different passing forces in the natural direction. This says, if players want to pass easily of a great distance and avoid damaging the wrists/elbows, you should primarily focus on the speed of the elbow being extended [14].

9. Physics of the Cardiovascular System and Hemodynamics

The cardiovascular system, especially the heart and blood vessels, is a major chapter in physics applications in medical diagnosis. The heart delivers oxygenated blood to the body and collects venous deoxygenated blood after the body is supplied with oxygen. This mechanical function can be described using physics principle, with the blood vessels having an important role as a means for the blood to return to the heart. The blood is in a dynamic equilibrium system and when it flows smoothly, it illustrates that the pressure forces that pump the blood out of the heart are comparable to the resistance forces to the flow. Force in the heart describes the pressure difference between the pumping cycle, while force in the vessels represents the resistance, determined by the flow rate and some properties of the blood vessels. Hemodynamics is the term used to describe the principles of blood flow. Simulations and experimental techniques in visualizing blood flow dynamics are a tremendous benefit in understanding human blood flow in health and diseases [15]. A familiar visualization technique of blood flow is Doppler ultrasound. Hence, hemodynamic features of the blood flow could provide an explanation of some important physiopathological cases of cardiovascular system, as those used in clinical practice. These features can either improve diagnosis through an in-depth hemodynamic analysis, or evaluate the success of the interventions through an accurate assessment of the results [16]. Clinical understanding and medical interventions could be considerably improved with a precise comprehension of such hemodynamic features. In complex geometries due to the presence of malformations, stenoses or grafts, this understanding is not trivial as a simple observatory examination or a hand calculation is not feasible. In hypothesis of intervention planning, the evaluation of the possible effect of a shunt, stenting, or the assessment of the safest position for defect closure is challenging and would benefit from reliable predictions. A great interest in the medical and clinical community has emerged in these kinds of aspects and in recent years a noticeable activity is being developed. The medical inquiry looks for standard values and “optimal” haemodynamic conditions, while in density-based vocal fold oscillation models unusual values are regarded as an indication of voice disorders. This data provides an opportunity for the physics and engineering community to scrutinize biomechanical properties of the cardiovascular system, seeking possible correlations between the incidents and blood flow features. Notwithstanding, a critical examination is needed due to the complexity of the fluid dynamics and mass transport. A multifaceted, and in some cases unreliable, interpretation is given in the current literature. Experimentation and simulations are often focused on specific phenomena without taking into account the global configuration of the blood flow. The inverse problem aims to infer boundary conditions from internal measurement. Blood vessel and blood rheology properties are key issues in the parameterization of blood flow models. It is common knowledge that the blood vessel is not a rigid pipe. Compliance must be taken into account in order to accurately model heart and blood vessels interaction. The system can be described through a zero-dimensional fluid-dynamical model coupled with a one dimensional viscoelastic model for the vessel characteristics. These issues represent fierce challenges in the numerical model, simulation, and model identification.

10. Neurophysics: Understanding the Physics of the Nervous System

Neurophysics is a discipline that combines physics with different branches of neuroscience in order to understand the functioning of the nervous system. A variety of biophysical aspects of the nervous system exist on which basic physical principles can act as a regulatory element: electrical activity of the neurons (manifested as the action potentials and rhythms with different frequencies on the electroencephalogram), synaptic transmission (spatial and temporal synaptic interactions), signal dispersion, etc [17]. In recent years physical methods and principles are widely used so as to study and understand in depth those aspects of the nervous system’s functioning. In this field there are applied biophysical techniques such as electrophysiology and different imaging techniques so as to investigate brain activity. On the other hand, there are cortically event-related potentials: transformation of the sounds, which a patient hears, into electrical signals is recorded on the surface of the head and these electrical signals then are analyzed so as to assess the auditory processing in the brain. There have been treated few neurological diseases and injuries of central nervous system and it was outlined how the application of physics deepened the understanding of the diseases, and it was stressed what has been the profit from the different forms of the application of physics.

The concerning of the nerve system has traditionally occupied the interest of the doctors. Recently the physicians started to focus their attention on the precise disturbances of the cerebral cortex, which can be observed, and on the functioning of the brain as a system, and therefore they see the advantage of the usage of modeling methodologies from the physicist. An integrative approach, combining aspects from physics and biology, seemed as the most promising in gaining a better insight of the brain function.

The greater robustness from the theoretical side in the grasp of the complexity of the collective phenomena in the nerve tissue, and the reinforcing of the experimental frontiers is expected to enable more successful treatments of the various diseases. A great hope in improving the reading and processing of the brain signals was put in the development of the brain computer interfaces. On the therapeutic side it was anticipated a better understanding of the cortical spreading depression and a hope was set in possible modeling and cortical stimulation for reversing the damage that follows from the too frequent convulsions.

11. Physics of Hearing and Vision

The significance of hearing is an aspect of everyday life often taken for granted. As sounds are all around, sensorineural physiology and the physics thereof affect daily perceptions and communications with the world. An auditory perception develops based on the physical principles of the transmitted sound signals, including the type of sound waves, frequency, and amplitude. The auditory experience is a translation of how the cochlear hair cells detect a mechanical wave that forms a neural afferent stimulation. The ear is the organ of auditory sensation, capturing and delivering sound waves into the inner ear, where a complex system of signal transmission, transduction, and processing makes its way to the auditory cortices of the brain.

Different ways conceptually describe sound can bring to mind different properties of hearing:

representation of sound stimuli, electricity transmitting through a wire, or the delivery of information through radio waves. Nonetheless, it is an elastic wave generated by vibration through any object. A sound stimulus can be defined based on its frequency or, synonymously, its pitch, the tone of a sound. Auditory perception ranges from frequencies at 20 Hz to 20 kHz. The corresponding wavelength of this range from 17 m to 17 mm in atmospheric air propagation at 25 C [18]. The relative intensity of a sound stimulus is proportional to the power of the perceived magnitude, defined on the scale of decibels. This measure describes how humans ascertain to sound intensity, quantified as much louder or much quieter compared to a sound reference of 20 decibels.

12. Physics of Medical Ultrasound

Medical ultrasound is the application of ultrasound techniques to visualizing internal body structures during a variety of diagnostic and therapeutic medical procedures. As with all wave propagation, sound waves pass through different media at different propagation velocities. When a wave encounters an interface of different media, part of the wave energy is reflected back to the transmitter. The reflected wave energy can be detected by a receiver, and the strength of the echo depends on the difference of acoustic impedance of the two media. In a simple pulse echo imaging system, a short ultrasonic pulse is generated by a transducer, propagating into the medium of interest. Target structures will create an echo upon encountering the pulse and the returning echoes are detected by the transducer, processed and ultimately displayed on a cathode ray tube.

Ultrasound imaging techniques in medical diagnosis have rapidly advanced over the past several decades, particularly in spatial resolution. Ultrasound imaging can be divided into three categories: (1) A mode/Amplitude mode, (2) Brightness mode, and (3) Motion mode. Meanwhile, Doppler techniques combined with ultrasound imaging have provided important information about the blood flow characteristics in vessels. (a) Continuous Doppler mode, (b) Pulsating Doppler mode, and (c) Color Doppler mode. The main advantage of ultrasound techniques when compared with other medical imaging techniques is the real time capability of the system. Physicians can make diagnosis and treatment decisions immediately after examining the ultrasound images. Technological advances have significantly reduced the size and weight of ultrasound devices, which played a major role in expanding the diagnostic use of these devices in rural and underdeveloped areas. However, poorly trained operators could lead to incorrect diagnosis since artifacts in the images might be interpreted as an anatomical feature. Recent directions are focused on developing new techniques to improve sensitivity and specificity, to provide 3D information and to reduce ultrasound induced operator musculoskeletal disorders. Some potential applications can be addressed by using the approach dealing with the speed of sound and attenuation of the ultrasonic waves.

13. Bioinformatics and Computational Biology in Medical Physics

In this review article, the integration of medical and biological physics with general physics is presented, which develops mainly as the manual medical and biological physics and the general physics components. The first part of the paper presents relevant mathematical background. The second part discusses typical medical and biological physics tasks. The third part discusses a few general physics tasks. But, there are quantum phenomena that occur not only in medical applications, but also in cities and in nature. It is anticipated that compatible projects will not only contribute to the development of medical and biological physics, but will also be useful for other transport and environment applications. In addition, the results of numerical experiments in a competition are reported, as well as the numerical determination of the spectrum and other properties of the boundary value problems introduced.

User’s reports have reviewed bioinformatics and computational biology, and this is already a well-developed section within medical physics, which however was not reviewed. Thus, data analysis is clearly a topic important to medical physics, and it could be argued that the closest intersection of bioinformatics, computational biology, and medical physics is when computational data analysis tools are being used to find interventions/alterations that are then applied by the Medical Physicist. This could be due to a lack of both broad and specific examples as the section is vague. These are in fact typically specific, however, the section should also note that data analysis can not only be used to find interventions but can also be used to plan better or calibrate existing interventions. This last point might provide a clearer focus, since general modelling and studies in bioinformatics and this wider set of potential applications would likely require experiments outside of what is feasible in medical physics. To further clarify, the treatment of non-computational bioinformatics, such as genomics or proteomics experiments, for presenting biological systems guided by mathematical models, is not done in medical physics as much as the use of computational data analysis tools more broadly. In general, it might be that computational biology is concerned largely with modelling at a tissue or global scale, but models of cellular dynamics are also a common concern of applied mathematics, which in many cases works closely with medical physicists.

This is a well-structured and broad review of the intersection as a whole between bioinformatics, also called computational biology, and general physics. It may be hard to delve deeply here without overlap. But, it is suggested that ventures into bioinformatics stay detailed and focused on specific and medically relevant aspects, in the same way that the review of interaction with general physics focuses on narrow and well-motivated developments.

14. Emerging Trends in Medical and Biological Physics Research

Bio-medical applications of physics are highly interdisciplinary, combining advanced concepts of physics with those of biology. Despite their initial differences, both the physical as well as the biological sciences have been converging in on similar phenomena. The former has gained from advancements in instrumentation, processes that are similar to certain biological phenomena, and a sophisticated modeling. Similarly, the study of biological systems has greatly evolved the power to resolve cell level systems mediated by biomolecular signaling pathway, which are more akin to those observing the physical world. Therefore, the research efforts on physical and biological sciences have grown together, leading to the establishment of a class of models called systems models, which are universal and can be equally applied to study biological and physical systems. This immense increase in complexity affecting the experimental approaches represents an enormous and intriguing challenge for researchers. Mathematics appears as the main field where the two kinds of systems may find a common language, with ideas and modeling approach as well as biophysical systems. However other fields have also a role in the general framework; this contributes to a complex network of connections between the various disciplines among physics, applied mathematics and bioscience, being biophysics one of the most recent and rapidly developing. A clear sub-specialization of the last decade can be directed towards the creation of novel platforms and instruments provided with a specific physical know-how to investigate special biological phenomenology [19]. During the past decade, advances involving the combination of optical trapping and microfluidic technologies has allowed extraordinary progress in a series of molecular aspects. Glass micro-capillaries have been provided with metal deposited micro-electrodes to obtain electric or magnetic fields over a large field for extensive local specific warming activation. In this context, novel approaches of specific interest for Biosystems include: micro-spectroscopy in microcells conditions now under numerical modeling to optimize detection sensitivity; novel technique for the imaging of biological samples through the FRET method, exploiting quantum dots of high optical gain, predicted to bring new insights into intracellular central molecular process; stretch-methods provided with chromophore hydrogels able to quantify cell deformation in culture conditions.

15. Ethical and Regulatory Considerations in Medical Physics

In the practice of medical physics, many ethical and regulatory considerations are paramount. These aspects often concern safety standards and ethical guidelines that are in place to ensure the proper development, validation, and application of medical technologies. Medical technologies must be designed with an awareness that they will be used on humans either for diagnosis or treatment, so they must be designed and validated in a manner that is as safe as possible without sacrificing efficiency. This is especially true of new or emerging technologies. In the area of patient treatments, even those technologies that have proven efficacy for properly selected patient populations can be dangerous if they are used incorrectly as embodied in the fundamental axiom of medical physics: "An accurate treatment, improperly delivered, is worse than an accurate treatment, not delivered at all." In addition to patient consent and the omnipresent concern about data privacy, there are a myriad of issues that concern the ethical obligations of medical physicists toward both the patient and society. Finally, as a specialized form of the practice of general physics, there is the requisite understanding of these regulations that inform the practice of medical physics. This section is intended to provide an environmental scan of the literature that exists for those interactions between the practices of medical physics and the laws that govern it. [20][21][22]

16. Future Prospects and Challenges in Integrating Medical and Biological Physics with General Physics

During the last decades, physics has been remarkably successful as a "cornerstone" of modern sciences, including medical and biological disciplines. This success has been based on the development of theoretical mathematical models as well as technological and methodological advancements, which now directly result in a new generation of up-to-date diagnostic and therapeutic devices in advanced medical diagnosis and treatment. At the same time, both medical and biological sciences have opened challenging perspectives and constraints that are nowadays fostering an extended theoretical, modeling, and technological approach on the part of the Physical Sciences. On the whole, this process has encouraged a novel interdisciplinary research domain, which acts as a stimulating adhesive of the above-mentioned fields, covering an extremely wide range of opportunities and possibly generating a series of groundbreaking advancements in healthcare [23].

A presentation and discussion of these topics from a standpoint of an advanced educational/developed country, as well as of their significant relevance from a mature or advanced but still developing, perhaps, European or Asian country, may provide a broad basis for an open exchange in both educational and research systems. This in turn is being envisioned as conducive to the stimulation of scientific as well as technological knowledge in a way that, outreaching the current, somewhat declining peripherical situation, may favour the development of novel and fruitful perspectives. It seems likely that in the coming years and decades new approaches and joint efforts will be necessary in considerations of a broad spectrum of scientific, technological, environmental, ethical, social, and academic issues, where a wider effluxion and cooperation among the entire community of Physical and Biological Sciences, Industry, and Health Providers appear to be of growing importance.[24]

[25]

17. Conclusion

The advance of health science is frantic, prompting a massive array and volume of scientific and technological outcomes. Keeping up with every field and literature is clearly unmanageable, especially for those focussing on the fundamentals. What can physicists do for health science? A possible answer is sketched along 3 lines: analytical multiscaling illumination of aqueous phenomena, study of the mechanical foundations of cells and tissues, and the ethical responsibility of assuming preventive protection against risks related to wireless applications.

Ten years on from first shaping SIF Prizes in memory of Paolo Budinich, the Italian physics community felt the need to confirm its resolution to uphold solid, bottom-up-based research offering a view capable of involving and resonating with all the areas and scales of natural and social investigations. This is very urgent in an international context where there is a growing commitment by governments, private donors and research facilities to missions suggested by industrial interests, against which the specificity of positions offered by disciplines is likely to be your only shield and flywheel for autonomous cultural initiatives.

This requirement is all the more compelling in Italy, where the national network of cultural institutions and the cultural-industrial twining brought about by the reform of the research system combinatorially tend to obliterate peculiar contributions by disciplines of a general and foundational cut such as Physics, Mathematics, Biology, History, Philosophy and Economy.

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