Investments in physics technology and education are key to the future success of medicine

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Physics is fundamental to many of the technologies used across medicine today, yet it is often forgotten -- and certainly neglected -- that physics has made important contributions to health ever since the birth of medicine 5000 years ago. This is despite the fact that the contributions of physics to human health have been recognised at the highest level -- eg, in Nobel Prizes (Röntgen won the first Nobel Prize for physics in 1901 for his discovery of X-rays).

Physics is the science that underpins all other sciences. Its range extends from the largest of objects (the cosmos) to the smallest (at sub-atomic level), from the longest periods of time (the life of the universe) to the briefest (the momentary existence of some of the smallest sub-atomic particles). Physicists ask fundamental questions about the world - including about the body, disease, and the nature of life. Physics may be largely invisible to most of us, but it is at the heart of our society and our understanding of health. To quote Ernest Rutherford: "All science is either physics or stamp collecting."

There are almost too many contributions from physics to medicine to list. They include: diagnosis (X-rays, nuclear medicine, clinical PET scanning, magnetic resonance spectroscopy, magnetoencephalography, high-intensity focused ultrasound with MRI); treatment (radiotherapy, minimal-access surgery, interventional MRI, photonics, scaling theory); and a combination of the two for, as one example, planning and monitoring treatment. These contributions will grow as the molecular mechanisms of disease are better understood and as new technologies enable the investigation of these molecular processes in vivo.

In an era of post-genomic medicine, physicists have an increasingly vital part to play in the discovery of new diagnostic techniques and treatment modalities. One example is nanomedicine. Nanotechnology enables the manipulation of individual molecules and tiny quantities of liquids. There are substantial diagnostic and therapeutic opportunities for the controlled delivery of such minute amounts of substance - eg, in Alzheimer's disease. Investments in technology and education are essential for such innovations to flourish.

Furthermore, the successful realisation of personalised medicine will depend upon a different way of thinking in medical research and practice. Personalised medicine is the application of genomic and molecular data to better target the delivery of healthcare, facilitate the discovery and clinical testing of new products, and help determine a person's predisposition to disease. In place of the hitherto successful reductionism of the biological sciences, systems science, rooted in principles of physics, will be needed to enable the development of strategies for personalised health care to flourish in the future. Diseases are inherently complex and are not amenable to sometimes simplistic reductionist thinking. A fuller understanding of the complexity of living systems will be needed before substantial advances in personalised care can take place. The human body is not simply the sum of its components. Ageing is a good example. A fundamental theory of ageing, longevity, and senescence might be constructed by bringing together ideas from thermodynamics, statistical physics, and information theory, as well as the data derived from genomic and metabolic studies.

Speaking about the 21st century, Stephen Hawking said that "I think the next [21st] century will be the century of complexity." Indeed, medicine in the future is more likely to become an information science, where huge quantities of complex biological data are analysed by techniques such as machine learning to discover patterns and principles. The influence of physics on medicine will make healthcare predictive, preventive, and personalised. There is an urgency to this work. The revolution in information technology in medicine is already amassing vast quantities of data. An opportunity exists that must not be wasted. Substantial investments will be needed for training and educating medical physicists for this potential to be realized. This will include ensuring the safe, as well as the effective, implementation of new physics-based health technologies.

Recommendations from the Series

-- Research investment: The physical sciences need sustained government commitment and investment if the full health dividend of physics-based research is to be achieved. Success in the life sciences depends upon success in the physical sciences. Many advances in medicine have depended upon discoveries in physics that have yielded unexpected spin-offs (eg, MRI). Who can say, for example, what medical benefits will accrue from the results of projects such as the Large Hadron Collider?

-- Medical education: A revolution is happening in the contribution physics is making to the health sciences. Physics—and its impact on research through, for example, systems science—should receive stronger recognition in the undergraduate medical curriculum and in postgraduate education if doctors of the future are to be literate in a new era of physics-based scientific and medical discovery. Universities might also consider more physics-oriented qualifications for entry into medicine, emphasising quantitative and mathematical skills. A more numerate medical profession will be needed to take advantage of the full contribution physics will make to healthcare.

-- Multidisciplinary science for health: There must be closer collaboration and integration between the physical and life sciences through a new model of interface science, in which multidisciplinary teams from both sectors work closely in a shared research environment (the experience of the Institute for Medical Science and Technology in Dundee, Scotland, has shown the benefits of this approach). At present, collaborations tend to be opportunistic or fortuitous, diminishing the contribution that physics research can make to human health and healthcare.

-- Physics in schools: Every school should aspire to provide a high-quality physics education for its children. Young physicists need to be nurtured to ensure a supply of talented scientists who can take advantage of the opportunities for health-related physics research in the future. Schools should declare and implement their passion for physics in order to foster the right environment for committed students of physics to develop.

Medical physics: The choice of medical physics as a career should be seen, promoted, and recognised as a vocational discipline.

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