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Nanomedicine: Technologies Impacting on Tomorrow's Medicine

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The introduction to "The $1000 Genome" article, published few months ago in Chemical & Engineering News [1], beautifully captures the topic of the present editorial: **The human genome project is long done, and the entire genome is sequenced. We know the order of adenines, guanines, cytosines, and thymines. End of story, right? Wrong. It's only the beginning. The challenge now is to find a way to integrate genomic information into health care.**

Indeed, the rapidly growing disciplines of genomics and proteomics are boosting the discovery and development of novel drugs by allowing the molecular components of cells to be subjected to comprehensive high-throughput screening and analysis. The first targeted genomics-based therapies own their success from the fact that specific pharmacogenetic profiles differentiate patients having a greater chance of responding well to a particular drug. For instance, hundred of thousands of DNA polymorphisms can be identified and precisely ordered on a map which can be used to correlate an individual's genetic information with the probable response to therapy. Existing data reveal that some single nuclear polymorphisms in gene enconding Toll-like receptors (TLR) are responsible for severe forms of septic shock [2] and the polymorphisms responsible for glucose-6-phosphate dehydrogenase deficiency predict an increased risk of renal failure and hemolysis in response to certain drugs [3]. The impressive development of the technology in the last decades (e.g. DNA chips) [4], offers us today powerful tools to quickly test an individual's numerous DNA polymorphisms. The time of multiple, laborious, and expensive genetic tests is gone.

Nevertheless, the inability of genomics to address the protein level in sufficient detail is a crucial shortcoming, since it is at this level that most disease processes develop. The field of proteomics will require the development of new sets of analytical tools that allow the characterization of complex interactions between proteins and other biological molecules, and how these phenomena are translated into dynamic and macroscopic events. These tools will exploit technologies being developed outside the biological sciences and particularly within the physical sciences and engineering. The newly born area of nanosciences in which biology and the physical disciplines come together is beginning to materialize as a force that will revolutionise the entire field of medicine.

Applications of nanotechnology for treatment, diagnosis, monitoring and control of biological systems have been recently named by the National Institute of Health "nanomedicine" [5]. More precisely, nanomedicine refers to medical treatment at the level of single molecule or molecular assemblies that provide structure, control, signaling, homeostasis, and motility in cells, i.e., at the nanoscale (100 nm or less) [6]. The National Institute of Health Roadmap's "Nanomedicine Initiatives" predicts that the medical research will fruitfully benefit over the next decade from nanotechnology. The initiatives under scrutiny include non-invasive monitoring of parameters of homeostasis such as blood glucose, cheap genome sequencing, nanoscale laboratory-based diagnostic and drug discovery platform devices,…

Today, efforts in assessing the glucose level in patients with diabetes mellitus are tremendous and represent the major driving force for biosensor development [7]. Despite the various commercially available solutions, the "ideal" monitoring is still a challenge. Such "ideal" device should be user friendly, and operate continuously by means of a closed-loop system consisting of a pump and a sensor coupled with a control unit that would provide the required amount of insulin.

The development of new methods aiming to drive the cost of sequencing of an individual human genome to below $1000 is another key topic in nanomedicine [8]. Not only companies are racing for cheaper genome sequencers; in fact, many of the novel technologies are firmly grounded in nanotechnology academic research. For example, at Univesity of Illinois, Urbana-Champaign, G. Timp and coworkers are drilling synthetic inorganic nanopores sized to fit single nucleotides through multilayered silicon structures in which two semiconducting plates are separated by a dielectric layer [8]. DNA passing through the nanopore induces an electrical signal at the semiconducting plates. The idea is to distinguish the bases by their dipole moments. The nanopore sequencing technology promises to read long stretches of DNA without the need for expensive optical detectors and amplification methods.

Clearly, the declining cost of genome sequencing is modifying both the way biologists hunt for disease genes and the way medical professionals diagnose and treat disease. In fact, we are now entering a new era of personalized medicine enabled by interdisciplinary research. Advanced Point-of-Care (POC) technologies are at the heart of personalized diagnosis, in which predisposition to a disease is detected

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at an earlier stage and treatment is tailored to the patient's individual needs. Very recently, Acrongenomics, Inc. and Molecular Vision, Ltd. have announced a joint collaboration [9] intended to accelerate the development and commercialization of POC diagnostic devices for personalized medical testing. The project is intended to support the development of novel POC devices for on-the-spot diagnosis of diabetes management, STDs (Sexually Transmitted Diseases), cardiovascular diseases and substances of abuse, based on the BioLED technology developed by Molecular Vision, Ltd.

With diagnostics and therapeutics converging in today's healthcare market, the synergies between the nascent fields of genomics, proteomics, and nanotechnology hold promise to tackle the tough technical challenges associated with personalized medicine.

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