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Biosensors and bioelectronics

Dear Readers

Bioelectronics embodies the exploitation of biological or biologically-inspired molecules as an integral part of an electronic devices and biosensors are the analytical embodiment of this art. The world market for biosensors, in 2009, was just under US$13 billion, with nearly nine tenths of that still accounted for by glucose measurement. This extraordinary dominance by a single biosensor type is driven by the exceptional needs of people with diabetes combined with the success of biosensors in meeting their demands for an appropriate product. The overall *in vitro* diagnostics market is currently considered to be worth around $40 billion, while recent estimates suggest that the theranostics (companion diagnostics) market is potentially worth a staggering $72 billion. Diabetes is the fastest growing chronic disease in the World, with Asia now home to four of the five largest diabetic populations and 2% of the World‘s population afflicted. Heart disease and stroke kill around 17 million people each year, accounting for one-third of all deaths globally. By 2020, they will be the leading cause of both death and disability worldwide, with fatalities projected to increase to greater than 24 million by 2030. Infectious diseases account for over 16% of worldwide deaths, comprising those associated with poverty such as malaria, HIV/AIDS and TB (1/3rd of world population infected and 2 million deaths) and epidemic & emerging diseases such as meningitis, cholera, yellow fever, flu and antibiotic resistant infections. Around 12% of deaths worldwide are from cancer (Africa 4%, North America 23%; UK 24%), while approximately 11 million people worldwide are diagnosed each year with cancer (45% are in Asia). In addition, society needs to make adequate provision for the proper care of an aging population, the demographic time bomb, with the proportion of people in the world aged ≥60 yrs old expected to rise from the current 10%, to 22% by 2050. Current global healthcare spending is more than $5 trillion per year and is growing fast (15% of GDP for USA, 8% of GDP for Europe). While clinical diagnostics has tended to dominate commercial products in the bioelectronics area, there has been consistent and significant investment in the use of biosensors for defence and security. Indeed, one of the earliest biosensors to be developed was based on acetylcholine esterase for the electrochemical detection of nerve gases. Today we find a diverse range of biosensors based mainly on optical, electrochemical and piezoelectric transducers for direct detection of threat agents, military heath care, policing and environmental contamination. Another early application of biosensors was for environmental monitoring epitomised with the modest but successful BOD (Biochemical Oxygen Demand) market pioneered in Japan. Defence and environmental protection converged with the emergence of pesticide monitors based on acetylcholinesterases and the molecular biologists furnished us with a range of new whole-organism based sensors, tracing their heritage back to exploitation of the Lux gene. The other key application area for biosensors has been food quality and safety with a variety of devices being marketed to ensure the integrity of our food.

These combined needs of the individual with societal and economic pressures will force a paradigm change in the way analytical problems are managed, with the future focus on prevention, diagnosis and less expensive, decentralised technologies; in many cases these will be a matter of individual consumer choice. Home testing has been revolutionised by the introduction of colorimetric test strips, electrochemical biosensors, lateral-flow immunoassays and the recent commercialisation of self-implantable glucose biosensors. The completion of the Human Genome project has enable rapid advances in molecular diagnostics and pharmacogenetics, unravelling new pathways and revealing novel potential biomarkers. While personalised medicine is still in its infancy, the poor efficacy of many current pharmaceuticals is a strong driver for combining diagnostics with therapy. Molecular diagnostics to enable better administration of anticoagulant therapy, predict drug metabolism and detect mutations that identify patients likely to respond to cancer therapy, have already met with notable success. Moreover, the combination of diagnostics with pharmaceuticals not only furnishes immense clinical benefit, but provides a new financial model to drive forward the development of new sensors. The wider concept of securing the well being of the individual is served by "lifestyle" sensors with individuals increasing choosing to self monitor themselves, the food they eat and the environment they exist in. Meanwhile, society continues to seek ways to protect the general population from threat and disease with remote monitoring, grid-based sensing and predictive algorithms. The integration of biological or biologically-inspired sensing elements with electronic transducers that lies at the heart of biosensor technology promises potential solutions to these multifarious diagnostic challenges. Interdisciplinary research constructing multi-scale structures in order to organise functional materials in nanodevices and the marriage of top-down and bottom-up fabrication methods paves the way to arrange complex molecular nano units, to electronically address them and integrate them into functional devices. With over 6,000 papers published on biosensors in 2009, a plethora of patents and a myriad of new product development announcements, we see visions of the future including exploitation of nanotechnology, smart materials, synthetic biology and the creation of plastic bioelectronics. The future may not be entirely clear, but emerging new paradigms in biosensors and bioelectronics promise to furnish a stimulating interdisciplinary environment rich in new innovations to benefit society.

With kindest regards,

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