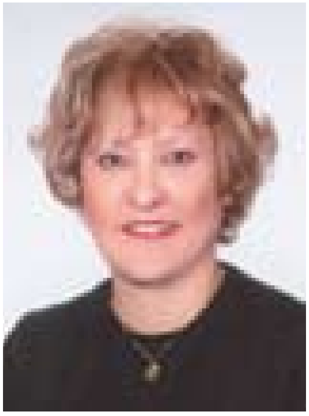
Biobracing the future with smart microbes: towards bioindustrialisation



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Bioindustry has been referred to as a cluster of companies producing engineered biological products, their supporting businesses and their classification on the basis of end markets such as therapeutics, diagnostics and bio-products for agriculture and bioremediation. Bioindustry also supports high technology applications for the creation of new energy sources and linkages to microelectronics and nanotechnology [1].

Fascinating examples of bioindustry are emerging (e.g. LifeTech Ruhr, Germany and Bio-industry Park-Canavese, Italy [2, 3]) as biotechnological companies, research establishments, training and further education institutions, technology centres, service providers and communal economic sponsors join forces. The aim is to accelerate and optimise biotechnological product development from the idea to its marketing on to industrial mass production for bioprocessing, biomems, bio-IT and proteomics [2]. The Australian bioindustry established in early 2000s has recently been reinvigorated under the umbrella of AusBiotech and supporting bioscience precincts [4] for national, State and territory based activities [5, 6].

Such national and international bioindustrial developments have now made microbiology “a subject of great intellectual excitement and one of huge practical utility” [7]. Microbially derived technologies have become a major driver for the growth of bioindustries and the influence of microbial biotechnology will increase substantially in the future as new products and processes with major economic and social implications are developed.

Within the millennium, the gradual depletion of some fossil fuel supplies, particularly oil, will result in a need for research to develop alternative energy sources including biological fuel generation [8-10]. Biofuels can be produced from microbially mediated operations using renewable resources, and microbial fermentation and biotransformation processes can economically produce organic acids, industrial solvents and biopolymers [8-10]. Many of these microbial products are used as chemical feedstock and functional ingredients in a wide range of industrial and food products [8-10].

Microbiological systems that capture or produce renewable resources and also prevent or clean up environmental pollution are also being developed [e.g. Bio-design Institute, Arizona State University, USA] by combining microbiology, molecular biology and chemistry with engineering [11]. The aim is the utilisation of microbial ecosystems to reclaim polluted water, generate energy from waste substances, and improve public health and sustainability. Microbial fuel production can now contribute to the meeting of world energy requirements [8] and generation of biofuels. As a result, application of microbially derived bioprocesses is now emerging as an important field for the industrial microbiology.

Even electricity can be generated using microbial systems [8, 9, 12]. A microbial fuel cell has recently been developed [Pennsylvania State University, USA] to break down organic matter and produce hydrogen and electricity through the process of electrohydrogenesis [8, 9, 12]. The microbial fuel cell incorporates exoelectrogenic bacteria that, in the process of oxidising organic matter, transfer electrons outside their cells to the anode and release protons into the solution they grow in. By adding a small voltage to the fuel cell, hydrogen gas is produced with yields well in excess of those obtained by water electrolysis [8, 9, 12]. It is claimed such systems can be used on farms to reduce transport costs and energy expenditure by producing hydrogen gas from farm by-products [8, 9].

Furthermore, recent research shows that the use of phototrophic microorganisms, or their photoactive systems, could directly convert sunlight to electricity, such as the artificial membranes incorporating bacteriorhodopsin-based systems from archeans e.g. *Halobacterium halobium* [9].

There are even reports on bacteria replacing silicon chips to make faster and smarter computers [9]. Conventional computers store information on thin wafers of silicon that cannot hold enough information or process information fast enough for applications of artificial intelligence or robotics [9]. In contrast, it is claimed that the light activated bacteriorhodopsin-chip moves much faster than the flow of electrons and will be able to store more information than a silicon chip and process the information faster, more like a human brain [9].

Russian scientists have reported on the production of a bio-processor for military radar and the US military use similar protein chips in their combat planes [9]. In the event of a crash, a deactivated cooling system destroys the chip, keeping classified information from being stolen [9]. It is expected that eventually these smaller, faster and higher-capacity chips will make it possible to develop computers that perform functions closer to human intelligence (e.g. act as eyes for blind people) [9].

Microbial activities are employed in the degradation of man-made xenobiotic compounds within waste streams and in the bioremediation of environments contaminated by hazardous materials [8, 10]. Microbial-based 'clean technology' is also being increasingly used in the desulphurisation of fuels and the leaching of metals from low-grade mineral ores and wastes [8, 10]. Environmental biological control is a further area where microorganisms are used in an effort to reduce our reliance on synthetic chemical pesticides [8, 10]. A wide range of microorganisms is cultivated to produce biomass or cell products for the control of fungal, insect and nematode pests on agricultural crops [8, 10].

Bacteriophages are becoming a fascinating tool not only in the above-mentioned applications but also in biomedicine [13-15]. The bactericidal activity of bacteriophages has long been instrumental in treating human infections as an alternative or as a complement to antibiotic therapy. Nowadays, endolysins (i.e. phage-encoded enzymes that break down bacterial peptidoglycan at the terminal stage of phage reproduction cycle) are used successfully to control antibiotic-resistant pathogenic bacteria in animal models, making endolysins effective antimicrobials with potentially important applications in medicine and biotechnology [16].

Moreover, the relative ease with which entire bacteriophage genome sequences can now be elucidated has had a profound impact on the study of bacteriophages [4]. Phage research has also fuelled other biotechnological applications such as phage display technologies recently harnessed in a multidisciplinary approach for the generation of novel nanotechnologies [13-15]. They have further been exploited as delivery vehicles for protein and DNA vaccines, as gene therapy delivery vehicles, and as tools for screening libraries of proteins, peptides or antibodies [16].

A fascinating article titled *Bacteriophage therapy: an historical perspective on the clinical efficacy of bacteriophages in therapy and prophylaxis* highlighting the evolution of phage therapy use at the Eliava Institute in Tbilisi, Georgia since its establishment in 1923 will be published in the next issue.

From now on, with the application of the 'unrivalled armory of knowledge' deriving from advancements in microbial biotechnology, our greatest challenge for the future will lie not so much with advancing the field of microbiology as with making it more "truly accessible to the general public in all its intellectual vigor and beneficial practicality" [7].

Leading experts from Australia and overseas in the outlined areas of Bio-industry have contributed to the present issue and I cordially thank them all for stressing the importance of ongoing global efforts towards the recognition of microbially-derived bio-industrial advancements.

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