

BIOTECHNOLOGY FOR SUSTAINABILITY – AN INTERDISCIPLINARY SYNTHESIS

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The accelerating awareness of the Earth's finite resources, including its environmental quality, is becoming a powerful driver for industries and governments not only to fight the effects of pollution and global change but to minimize the anthropogenic accumulation of wastes and even prevent it at the source. Demands are mounting to replace conventional industrial processes by less- or non-polluting ones and to (re)use waste streams. During this more and more widespread shift the treatment chains of wastes from a host of human activities and from a long legacy of industrial history constitute a major technological challenge. As these treatments merge with environmentally benign industrial processes a truly sustainable economy will become an irreversible reality. In this emerging landscape there is an unmistakable trend towards a more extensive use of enzymes or whole-cell biocatalysts in industrial processes as these are inherently linked to a number of tangible benefits including lower consumption of energy and chemicals, i.e. features that make them "green" agents. Specific examples of such bioprocesses under investigation are highlighted in the first part of this talk, with emphasis on microorganisms and their oxidoreductive enzyme machinery that can be put to work in both biosynthetic/biotransformation processes (e.g. formation of bioactive intermediates) and in biodegradation applications (e.g. elimination of emerging micropollutants). The exploitation of novel biocatalysts needs to consider the scalability of the process and the application space can be mapped in terms of catalytic activity and stability by applying multivariate analysis and optimization methodologies. Multi-enzyme biocatalyst configurations in matrices and novel robust enzyme formulations by biomimetic methodologies are becoming possible by integrating principles from a range of disciplines including biocatalysis, chemical engineering fundamentals and nanotechnology. In addition, economics and management disciplines provide the conceptual armour to assess process/product profitability, discriminating between low-price high-volume applications (e.g. environment services) and high-price low-volume applications (e.g. chemoenzymatic synthesis of active pharmaceutical intermediates) for the same biocatalytic process. In the second part, the accent is placed on emerging areas with high potential to offer a paradigm shift in bioprocessing, such as phototroph biotechnology. Thanks to their sustainable capacity for solar energy conversion, phototrophic organisms like (micro/macro)algae and cyanobacteria represent almost one third of the total primary biomass generated on the scale of our entire planet, while at the same time being by far the most important carbon dioxide

consumers. The future establishment of a sustainable microalgal industry necessitates not only efficient and robust phototroph strains but large-scale, inexpensive and dependable photobioreactor systems. In addition to gaining further basic understanding on these organisms' metabolism, more technoeconomic interventions such as cutting down the construction and operational costs might emerge as the primary principle that should guide the development of future industrial photobioreactor systems. In parallel, an adaptation of the biorefinery concept to algae and other phototrophic microorganisms holds much promise for a future expansion of the bio-economy in an environmentally responsible and sustainable society.

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