Executive Summary

Biotechnology offers technological solutions for many of the health and resource-based problems facing the world. The application of biotechnology to primary production, health and industry could result in an emerging "bioeconomy" where biotechnology contributes to a significant share of economic output. The bioeconomy in 2030 is likely to involve three elements: advanced knowledge of genes and complex cell processes, renewable biomass, and the integration of biotechnology applications across sectors. This book evaluates existing evidence and the characteristics of biotechnology innovation in order to estimate where the bioeconomy is today, where it could be in 2015, and more speculatively, what it might look like in 2030. It develops a policy agenda to help guide the use of biotechnology to address current and future challenges.

Several factors will drive the emerging bioeconomy by creating opportunities for investment. In addition to the use of biotechnology to meet the challenge of environmentally sustainable production, a major driver is increasing population and per capita income, particularly in developing countries. The latter trends, combined with rapid increases in educational achievement in China and India, indicate not only that the bioeconomy will be global, but that the main markets for biotechnology in primary production (agriculture, forestry and fishing) and industry could be in developing countries. Increases in energy demand, if combined with measures to reduce greenhouse gases, could create large markets for biofuels.

The emerging bioeconomy will be influenced by public research support, regulations, intellectual property rights, and social attitudes. Regulations to ensure the safety and efficacy of biotechnology products influence the types of research that are commercially viable and research costs. Pure regulatory costs are highest for genetically modified plant varieties (ranging from USD 0.4 million to USD 13.5 million per variety) and for the open release of genetically modified micro-organisms (approximately USD 3 million per release), such as for bioremediation to clean up polluted soils. In health, the future of regulation is not clear, with economic pressures and technical opportunities pushing the system in different directions. Intellectual property rights could be increasingly used to

encourage knowledge sharing through collaborative mechanisms such as patent pools or research consortia. Social attitudes to biotechnology will continue to influence market opportunities, but public opinion can change, for instance when biotechnology products provide significant benefits for consumers or the environment.

The report identifies two new business models for biotechnology that could emerge in the future: collaborative models for sharing knowledge and reducing research costs and integrator models to create and maintain markets. Collaborative models are relevant to all application areas. Their adoption, combined with new business opportunities for non-food biomass crops, could revitalise small dedicated biotechnology firms in primary production and in industry. Integrator models could develop in health biotechnology to manage the complexity of predictive and preventive medicine, based on biomarkers, pharmacogenetics, shrinking markets for individual drugs, and the analysis of complex health databases.

An estimate of the "probable" bioeconomy in 2030 adopts a "business as usual" approach to institutional factors such as regulation and builds on research into the types of biotechnology products that are likely to reach the market by 2015. The results suggest that biotechnology could contribute to 2.7% of the GDP of OECD countries in 2030, with the largest economic contribution of biotechnology in industry and in primary production, followed by health applications. The economic contribution of biotechnology could be even greater in developing countries, due to the importance of primary production and industry in their economies.

Ultimately, the impact of the bioeconomy on GDP in 2030 will depend on the interplay between governance, including the level of international cooperation, and the competitiveness of biotechnological innovations. Two scenarios are developed to explore alternative futures. One scenario describes how a change in the funding system for health therapies encourages rapid innovation in regenerative medicine. In another scenario, public attitudes could result in some biotechnologies not reaching their potential. An example is predictive and preventive medicine, where the advance of this technology could be limited by public resistance to poorly planned and intrusive healthcare systems. The scenarios also explore different technological outcomes such as growing competition between biofuels derived from biomass, algal biofuels, and electrical transport systems.

As highlighted in the scenario analyses, the social and economic benefits of the bioeconomy will depend on good policy decisions. The required mix of policies is linked to the potential economic impacts of biotechnological innovations on the wider economy. Each type of

innovation can have incremental, disruptive or radical effects. In many (but not all) cases incremental innovations fit well within existing economic and regulatory structures. Disruptive and radical innovations can lead to the demise of firms and industrial structures, creating greater policy challenges, but they can also result in large improvements in productivity. The extensive discussion of policy options examines challenges in primary production, health and industrial biotechnology, looks at cross-cutting issues for intellectual property and integration across applications, evaluates global challenges, and finally reviews the types of policies that are required over both the short and long term.

Primary production provides a diverse range of policy challenges. Examples include the need to simplify regulation, encourage the use of biotechnology to improve the nutritional content of staple crops in developing countries, ensure unhindered trade in agricultural commodities, and manage a decline in the economic viability of some sectors when faced with competition from more efficient producers. The main challenges for health applications are to better align private incentives for developing health therapies with public health goals and to manage a transition to regenerative medicine and predictive and preventive medicine, both of which could disrupt current healthcare systems. Industrial biotechnology faces multiple futures due to competitive alternatives from both outside and within biotechnology. Efficient policies to support many industrial biotechnologies will need to be linked to life cycle analysis standards to identify the most environmentally sustainable alternatives.

Obtaining the full benefits of the bioeconomy will require purposive goal-oriented policy. This will require leadership, primarily by governments but also by leading firms, to establish goals for the application of biotechnology to primary production, industry and health; to put in place the structural conditions required to achieve success such as obtaining regional and international agreements; and to develop mechanisms to ensure that policy can flexibly adapt to new opportunities.