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Editorial overview: Synthetic plant biology: the roots of a bio-based society

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Humanity faces three major challenges in the 21st century: food security, availability of renewable energy, and environmental degradation. These three challenges are inter-linked and plants will be essential in counteracting them with science-based solutions (Figure 1).

All our food is derived from plants, either directly or indirectly via animal production. The process of photosynthesis enables plants to convert solar energy into chemical energy in the form of biomass that may be converted into renewable biofuels. Due to climate change, the need to develop sustainable robust agricultural systems is of utmost importance to avoid continued destruction of previously arable land (Figure 2). Inter-disciplinary research, including constructive engagement and dialogue with politicians, bio-ethicists, the general public and other stakeholders, is obviously essential in addressing these complex challenges, but excellent research within plant biology is going to be instrumental. This calls for increased investment in plant research. Likewise, plant researchers around the globe need to take charge in spurring the interest of young talented students to choose plant biology as their favorite discipline.

We are privileged by the numerous technological advances that we have at our disposal. Entire genome sequences of crop plants are now available at reasonable cost, transcriptome libraries and proteomics facilitate studies of developmental and environmental impacts, and bio-imaging techniques based on electron microscopy and mass spectrometry facilitate elucidation of plant plasticity. Nevertheless, the challenges to be addressed remain highly complex and interlinked, while the multidisciplinary approaches that are required dictate new ways of collaboration to ensure that basic and applied research is interconnected with engineering, and advanced in ways acceptable to the end users and thus to the benefit of society. It is ironic that the technological advances that formed the basis for the Green Revolution in the 1970s, such as the use of synthetic fertilizers, chemical control of herbivores and diseases, mechanization and the development of semi-dwarf high-yielding crop varieties, resulted in overproduction of foods in the industrialized world, created economic imbalances that caused governmental and private investment in plant research and production to decrease, especially within the EU. As a consequence, what has been achieved is tiny in comparison with what could have been done. More humans are alive today than have ever died, and we are in a situation where we have to make up for two decades in which solid foundations to address the challenges we are now facing could have been built. A similar overshoot in plant productivity in the years to come is highly unlikely. A burgeoning middle class, a wealth-related switch towards animal products, and the use of plant crops for bioenergy production renders the demand for crop products and biomass immense (Figure 3). In addition, plant biologists and breeders will face the

Figure 1

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Painting by Peter Bruegel the Elder entitled 'The Harvest' from 1565. The painting illustrates the labor intensive harvest progressing in a wheat field. The panoramic view testifies that monocultures have been an important part of food production for centuries and transform the landscape. Note that the height of the wheat plants almost matched the height of the harvesters. As part of the Green Revolution in the 1970' the expression of semi-dwarf genes resulting in less tall plants greatly increased yield.

increasing challenge of developing new crop varieties that are able to cope with the extreme weather changes associated with the expected changes in global climate (Figure 4).

This volume of Current Opinion in Plant Biology provides an overview of current research in areas that are expected to provide science-based solutions to these challenges. Future directions of the research within these areas are outlined as an inspiration to other researchers.

Molecular breeding is the most direct way to gain access to a desired phenotype and the available tools continue to evolve under the selection pressures of cost, precision and scope. Effective genetic screens to identify the single plant within a large natural population that carries a specific desired trait and advances within genetic engineering technologies are important complementary approaches. Plastid transformation is a less established technology with great promise, and the review by *Bock* describes the recent technological developments that have greatly increased the power of the approach. This is reflected in the extensive and diverse range of applications summarized in the article, leading the author to conclude that the commercialization of the technology is imminent (Figure 5). It is particularly helpful that plastid DNA is not transmitted through pollen in most species, enabling plastid transformation to offer biological containment of the traits introduced.

Reconfiguring the plant cell extracellular matrix has emerged as a major objective for the biofuels sector and four papers review progress in this area. First, researchers from the *Bacic* laboratory discuss the unprecedented complex challenges facing plant breeders and biotechnologists in their efforts to engineer designer walls. Changing individual components poses a challenge in itself since the changes have to be compatible with wall assembly and re-modeling, and with feed-back loops monitoring cell wall integrity following biotic and abiotic