

This paper is an introduction to the following papers, which were presented at a colloquium entitled “Protecting Our Food Supply: The Value of Plant Genome Initiatives,” organized by Michael Freeling and Ronald L. Phillips, held June 2–5, 1997, sponsored by the National Academy of Sciences at the Arnold and Mabel Beckman Center in Irvine, CA.

Plant genomics and our food supply: An introduction

RONALD L. PHILLIPS* AND MICHAEL FREELING†

*Department of Agronomy and Plant Genetics and Plant Molecular Genetics Institute, University of Minnesota, St. Paul, MN 55108; and †Department of Plant Biology, University of California, Berkeley, CA 94720

A New Paradigm

“Protecting Our Food Supply: The Value of Plant Genome Initiatives,” a National Academy of Sciences Colloquium held June 2–5, 1997 at the Beckman Center in Irvine, CA, revealed a new paradigm based on the extensive similarities among the world’s food cereals and other grasses in terms of chromosomal gene content and gene order. Recent findings show that a gene on the chromosome of one grass species can be anticipated to be present in a predicted location on a specific chromosome of a number of other grass family species. In fact, the chromosomes of the various species, most of which differ in chromosome numbers, can be arrayed in concentric circles such that a radial line from the central species with the smallest genome—rice—will pass through regions of similar genic content in each of the other species. This concept has led the plant genetics community to view the grass family as a single genetic system. Recognition of these relationships has led to the exciting prospect of gaining sufficient genomic information from one species to understand much of the genetics of a broad array of species. The identification of genes controlling important pathways such as for insect resistance, isolation of genes of various types, determination of directional pathways of evolution and location of useful genes from exotic sources, decision making on biodiversity conservation, and many other applications in plant breeding will be easier because of the heightened understanding of genetic relationships. Similar results are emerging for all groups of species, plants and animals.

Reviews of the Human Genome Project, the *Drosophila* Genome Project, and the *Arabidopsis* Genome Sequencing Project provided insights on how to identify and prioritize the logical next steps needed to understand the genomics of plants. Many of the molecular genetic and bioinformatic tools in those programs can either be directly adopted or point the way toward needs specific for plants. The expectation now exists that within only a few years essentially all genes will be known in plants. The utility of this information may be even greater than with humans, because crosses among plants are a routine feature of plant breeding, and the genetic materials can be tested in the same or different environments. The value of plant genomics has been recognized by the private agricultural sector judging by its level of investment. These vast pools of plant genes will be invaluable resources for insertion into a wide array of crop plants via biotechnology. Publicly available research tools and data, however, were identified by meeting participants as a high priority. Many environmental contributions of plant genomics also became obvious, such as those resulting from the reduction in pesticide use via insect/disease resistant crops and better utilization of phosphorus in animals,

leading to less pass-through waste and subsequent pollution. The new possibilities for improving crop productivity and profitability, quality, food safety, the environment as well as the development of entirely new products all build on a long track record of using genetics to solve problems in agriculture. Biology will be the science for the 21st century, and our quality of life will depend on its prudent application in the food, feed, and fiber system worldwide.

Questions to be Answered

A colloquium such as this alerts plant geneticists and breeders to the surge of information on colinearity of genes, illustrates the identification of homoeologous genes and traits, and explores breeding opportunities based on comparative genetics. The first step, however, is to ask certain questions: (i) What do we know? (ii) How are we using the knowledge? (iii) Where are we going? We need to be discussing the value of plant genomics to protecting our food supply, given the expectation that the world population will double by 2050. Many experts believe that this doubling will require three times as much food because of increases in the standard of living and people’s expectations.

More basic questions also need resolving: (i) If we do learn the sequence of every gene in various organisms, do we need to know all of the allelic variations or should we concentrate on functions of classes of genes? (ii) Will the complete genome sequencing (including the repetitive DNA) of yet another species beyond *Arabidopsis*, humans, rice, *Drosophila*, mouse, and similar model organisms tell us anything new? (iii) How much beyond the coding regions should be sequenced? (iv) Are expressed sequence tags (ESTs) a good place to start? (v) How far can we extend genomic knowledge via comparative mapping? (vi) What are the needs specific to plants in the area of bioinformatics?

We also should ask some of the broader biological questions?: (i) Does colinearity of unique/low copy sequences reflect evolution or functional significance? (ii) Is the extensive amount of duplication within a genome there for performance, stability, or evolution? (iii) Why is there a lack of conservation of repeated sequences?

Agriculture and Plant Genomes

Plant genome research is more than biology; it is also about producing food for our planet. Agriculture accounts for about 18% of U.S. jobs, 15% of the gross domestic product, and 31% of exports. Estimates are that agricultural research provides a 35% return on the investment, and the value of agriculture is increasing rapidly as demand increases. The goals of agricultural plant science are to increase crop productivity, improve crop quality, and maintain the environment.

Traits of interest will include those related to crop protection to eliminate or reduce pesticides, prevent mycotoxin contamination, improve disease resistance to enable conser-

vation tillage, improve herbicide resistance to allow use of safer, more effective, and cheaper herbicides; stress tolerance in regard to shading, cold, hypoxia, heat, water use efficiency, nutrient use efficiency, high-density planting tolerance; and improve grain quality, influencing quantity and quality of oil, protein, carbohydrates, nutrients, and novel substances.

Genomics research will lead to new and innovative ways to achieve such trait improvement. The opinion of colloquium attendees seemed to be that if there is one single priority as the most important research investment, it should be genomics because it provides a critical focus and benefits all researchers. We grow about 200 crops for food, feed, or fiber, and almost all were introduced to the U.S.; they were modified genetically to be adapted to climate and consumer desires. Clearly, genomics can help in issues related to food safety, food quality, and food diversity. Genomics provides objectivity in breeding as never before possible; it allows hypothesis testing of quantitative genetics applications in plant improvement.

Biodiversity Issues

Amid the discussion of the applications of crop plant genomic information emerged the hope that increased knowledge of anchor crop species would make it possible to garner exotic,

useful genes from the wild—genes already engineered by natural selection. It would be ironic if, just when it were possible to actually capture those genes that work together to confer useful, much-needed traits such as salt resistance or drought tolerance, the exotic plants carrying these genes were extinct or lost. Thus, coupled with discussions on increasing our knowledge of plant genomes in crops was a marked interest in preserving species and gene biodiversity as sources of valuable genes for our future. Issues of plant genomic biology and issues of preserving and using evolved genetic diversity were linked and discussed as a single problem requiring a particularly long-range vision to keep in focus.

A Timely Colloquium

Although this colloquium was nearly 3 years in the planning, only a few months before the event Congress asked for a plan on how to have a comprehensive effort on plant genome research, especially for agriculturally important plants. An Interagency Working Group on Plant Genomes had been established under the National Science and Technology Council to identify science-based priorities for a plant genome initiative.