6. Innovations in plant breeding

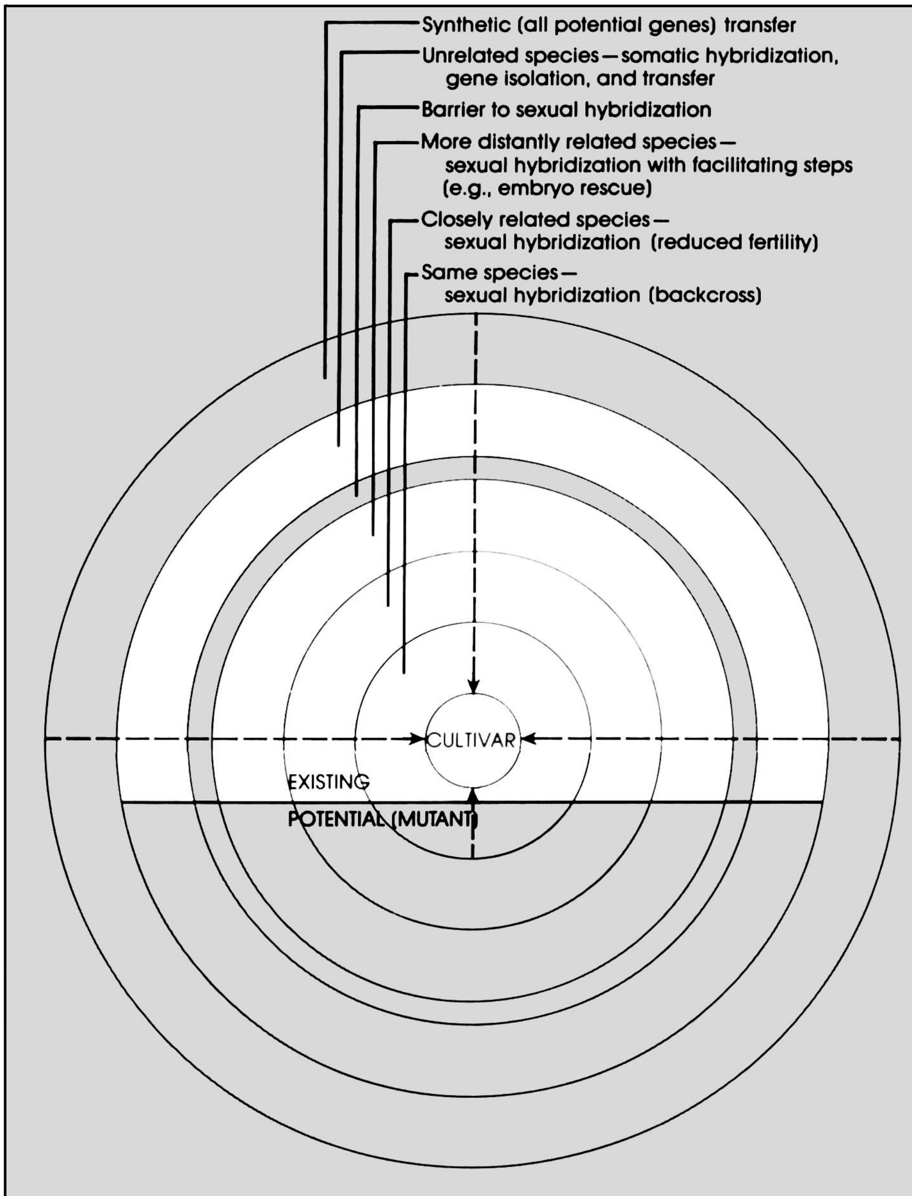
New concepts in whole-plant genetics

Thomas J. Orton,
Assistant Professor, Vegetable Crops, Davis

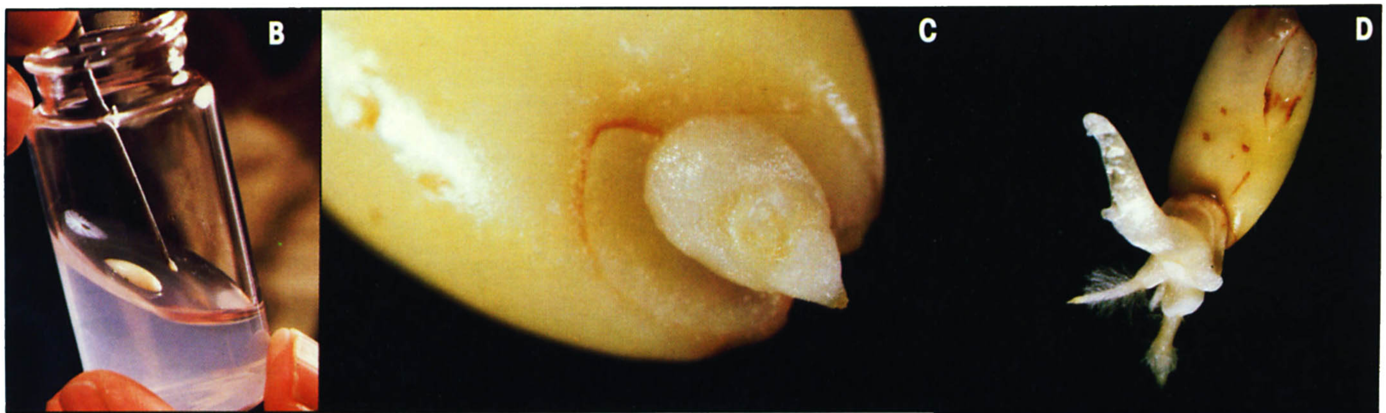
In the excitement surrounding accomplishments in the manipulation of tissues, cells, and genes over the past ten years, one might get the impression that plant breeding research at the whole plant and population levels has been filed away and forgotten. On the contrary, several exciting developments in breeding technology have surfaced during this same period.

One premise upon which the need for cellular and molecular approaches has been based is that plant breeders have exhausted existing pools of genetic variability, and progress has consequently diminished. There is little evidence to substantiate the existence of such limitations for most crops. Moreover, it is premature to conclude that sexually accessible variability has been depleted when the existing collections are rarely, if ever, comprehensive. New variability, for example, in soybean and rice introductions (among others) from the People's Republic of China will more likely sustain performance increases in the foreseeable future than will new cellular/molecular approaches.

As the following articles show, the idea of expanding the pool of accessible genes by overcoming natural isolating mechanisms between species remains a possibility; hybrids between species can be synthesized and chromosomally altered to produce dramatic economic gains, as with strawberries; it is now possible to sexually engineer wheat lines containing desired genes from related species simply by adding or substituting whole chromosomes. In other research, crosses between the cultivated tomato and a salt-tolerant wild species have produced breeding lines with some salt tolerance. Preliminary observations suggest that cold tolerance is another possibility. To date, 14 genes for disease resistance have been transferred from wild species into cultivated tomato varieties. Cell culture of interspecific hybrids has been successfully applied to facilitate the flow of genes among species related to tomato, barley, and cabbage. Altogether, exploitation of genes from wild germplasm sources has barely begun.



Range of genetic variability available to plant breeders for crop improvement. Beginning from the inner circle, accessible variability can be transmitted to the cultivar from successively distant sources. While the overall range of variability increases as the genetic distance increases, the difficulty of performing the transfer also increases.



To produce wheat-barley cross, embryo is excised from immature barley endosperm (A) and is replaced by frail hybrid embryo (B) produced by hand pollination. The endosperm serves as nurse tissue for the hybrid (C). About 70 percent of the embryo cultures may give rise to plants (D), but of 270 plants obtained by this process at Davis, only 20 were true wheat × barley hybrids (E, center; spike at left is wheat; right, barley).

A major factor limiting the rate of progress in plant breeding has been low heritability. This occurs frequently in complex traits such as yield and quality, which are controlled by a large number of genes and are environmentally unstable. Plant breeders and physiologists are cooperating in an effort to overcome this problem by breaking a complex character down to components, and ultimately to the actual molecules that mediate the expression of the character. By selecting for the components of a character or for its underlying molecular constitution, breeders hope to reduce complexity and environmental impact, allowing for faster progress.

Areas currently being explored for application of this approach are yield, quality, salt and drought tolerance, water-logging tolerance, chilling tolerance, disease and insect resistance, and self-incompatibility phenotypes (which are used in F_1 hybrid production). For example, in processing tomatoes the major component of yield is volume of finished product (sauce, paste, catsup) per unit of cultivated area. In breeding for harvest yield alone, much of the progress observed results from increased water content, which must, in turn, be eliminated by the processor. The solution has been to maintain or increase the economic yield of processing tomatoes (solids) while decreasing water content. The alternative character used by breeders as a selective criterion is sugar (soluble solids) concentration, which is negatively correlated with water content. By combining this character with additional selection for gross yield, uniform maturity, thick skin, and firm flesh, it has been possible to make more rapid progress in improving this crop than in the past.

Another approach to solving the problem of low heritability, recently developed at the University of California, is the use of electrophoretic variation as an alternative selection criterion in tomatoes.

One strength of cellular and molecular genetic approaches is the possibility of performing selection with chemicals or physical conditions on extremely large populations of haploid individuals in a small space and over a short time. Numerous schemes have been devised to select desirable genetic variation with respect to nutrition, stress tolerance, herbicide resistance, and disease resistance. Until now, variant cells selected *in vitro* have only rarely been translated into functionally equivalent whole plants. Recent studies show that it may be possible to circumvent some of the problems associated with selection of cultured cells by substituting whole plants. For example, chemicals have been used to screen barley seedlings exhibiting increased nutritional value. Other experiments have shown that pollen can be responsive to selection *in vivo*, opening up the possibility for screening large populations of haploid individuals.

Plant breeding has brought about drastic changes in plant architecture or genetic makeup, revolutionizing production and marketing methods. Recent examples include determinate growth habit for mechanical harvesting, disease-resistant cultivars, and hybrid varieties. New ideas are constantly emerging, such as techniques to permit the selection of plants with multiple tolerance genes ("horizontal" resistance) as opposed to often unstable single gene ("vertical") resistance. Dwarf fruit trees are being developed that will produce more with lower management and harvesting costs.

Although genetic engineering for crop improvement holds great promise, plant breeding and other aspects of whole plant genetics are also becoming increasingly sophisticated. Advances in breeding technology guarantee that plant breeders will continue to make valuable contributions to agriculture.

Wheat-barley hybrids

Chao-Chien Jan
Calvin O. Qualset
Jan Dvorak

Some crop plants have simple inherited characters that would be desirable if transferred to another crop. Our current work on transfer of resistance to the barley yellow dwarf virus (BYDV) from barley to wheat is an example of a simple modification to the embryo culture method that produced hybrid plants from two difficult-to-hybridize species.

BYDV is an aphid-transmitted virus that occurs on many grasses, including forage grasses and cereal grains. Discovered in Cali-