find out more about the cell and its proteins. And to cover our collective embarrassment that we should forget anything so obvious, we have invented new words; proteome, phenome, the functional genetics initiative.

The proteome program is being formulated as a protein analog of the genome program because that program is familiar. But in reality, the proteome program takes up where DNA sequencing and genetics leave off. The technologies of two-dimensional gel separation, peptide HPLC, capillary electrophoresis, and mass spectrometry can collectively characterize the proteins in cells at a rate comparable to that achievable for gene sequencing. Partial protein sequences can be linked to the growing gene databases to identify them at that ultimate genetic level. We can scan a cell for its protein composition in a few days, compare it to dozens more in a week. This is in itself a powerful technology, one that answers the question about what genes are actually doing in cells, at least in biochemical terms. This, however, should only be the beginning.

Proteins are about function, about dynamics. The X-ray structure of a protein is a cartoon of what it is like (albeit sometimes a very useful cartoon). To name a protein a "7-transmembrane-helix G-protein-coupled receptor" sounds like a description of its function. It is not, any more than a description of something as a "circularly delimited solid of low thickness-to-diameter ratio" tells you what you can achieve with the wheel. Biological function is about relationships and interactions, because life is a process, not a product. Here the proteome program can go beyond statics into dynamics, and look deeper into the macromolecular structure of the cell to see what it is doing. Even current technology can attempt to achieve this: a combination of flow cytometry with the analytical techniques I mentioned above could provide the protein equivalent of the biochemists' stop-flow experiment, so valuable in the days when enzyme kinetics were fashionable. The phenome could provide the links between the new genetic maps and the metabolic wallpaper that has been yellowing for too long. In short, the proteome program has the potential to return us to real biochemistry.

This will be enormously valuable, in scientific and commercial terms. The past two decades have taught us that DNA is just the foundation. The proteome will build on it. With the maturity that those 20 years have given the biotechnology enterprise, we should expect the proteome to yield more products, more understanding, and a new platform on which to build further in the future.

The new words—phenome, functional genetics, proteome—will promise far more than they can deliver—everything always has. But what they can deliver will be powerful indeed if they, like genetics, are taken as new beginnings, and not ends in themselves. ///

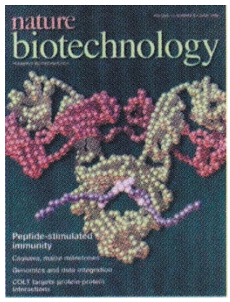
nature biotechnology

Please send letters to:
Nature Biotechnology
345 Park Avenue South
New York, NY 10010-1707, USA
Fax: +1 212 696 9635
E-mail: m.francisco@natureny.com

Cassava R&D: A public investment

To the editor:

The June 1996 issue of *Nature Biotechnology* carried research reports (**14**: 726, 731) of breakthroughs in cassava genetic transformation. Reflecting on these advances, the editorial "Transforming the root of the problem" (14:677) has accurately identified a "root" problem for cassava research: vitalizing the linkages for "grabbing hold of innovations and transforming them into useful products." The difficulties cited apply not only to biotechnology but to all efforts to enhance cassava's value for food security and economic development.



But cassava is NOT in danger of becoming "the wrong kind of icon for biotechnology." On the contrary, Cassava has a young but dynamic integrated R&D cycle of market research, priority setting, strategic and applied research, technology transfer, and feedback.

The breakthroughs reported were not achieved in isolation. The reporting labs are among the founding members of the Cassava Biotechnology Network (CBN). CBN, founded in 1988, has over 600 members including biotechnologists and applied researchers in 25 cassava-growing countries, the international centers CIAT in South America and IITA in Africa, as well as in 13 economically advanced countries. Through efforts such as CBN, the donor community is working to make sure that cassava research— including biotechnology—is effectively targeted and delivered. Cassava genetic transformation research, for example, addresses specific objectives identified by CBN through interaction with farmers, processors, and researchers, including processing quality, nutritional value and safety, and production sustainability.

The concern of the author of the research news analysis (14:702), about inadequate transfer of biotechnology research to developing countries and their crops, is valid but underestimates both existing accomplishments and the attention in fact being paid to these issues in cassava R&D. For example, tissue culture methods for conservation and exchange of cassava genetic diversity have been transferred to over 20 countries; this develops a base of skills and infrastructure prerequisite to genetic transformation research.

The editorial on "the root of the problem" is correct, however, when it implies that the cassava R&D cycle is underfunded (hopelessly so, concludes the editorial) in view of cassava's importance to so many in the world, including some of the poorest farming communities and nations. Funding for cassava research (a small fraction of that spent on other major world crops) comes from contributions from national governments, bilateral and multilateral donors, and private foundations. CBN fully agrees with Indra Vasil in calling for more international funding for biotechnology research on crops important to developing countries, in developing countries. It is important to remember that this call must be made not only to the international donors but also to the voting public of the donor countries. The public in economically advanced countries are almost entirely unaware of issues in cassava, food security, and agroeconomic development. We have a big job of popular education to do.

Will cassava R&D ever be even partially self-sustaining, through investment by processing firms or farmers themselves (e.g., as are maize and soybean research)? In the long term, potential for some degree of self-funding exists, if research efforts succeed in (1) providing sustainable and predictable yield stability to cassava farmers for food security, and (2) adding value to cassava products, while maintaining cassava's productivity and low production cost. These accomplishments would provide cassava farmers with a cash market for production above household needs, create rural employment, and provide incentive for private investment in cassava production, processing, and marketing.

Until such time, cassava R&D remains humanitarian aid and public investment in economic development. By working together to make best use of scarce resources, the cassava R&D community has delivered useful technologies (e.g., new products, biocontrol of insect pests, improved drought tolerance, increased yield with high quality, tools for genetic diversity conservation and use).

Cassava research has and will continue to have "significance beyond the merely technical."

Ann Marie Thro
Cassava Biotechnology Network
Cali, CA
(A.Thro@cgnet.com)