
GOLDEN GENES AND WORLD HUNGER: LET THEM EAT TRANSGENIC RICE?

Craig Holdrege (nature@taconic.net)

Steve Talbott (stevet@oreilly.com)

One of the casualties of technology-dominated life has been the tradition of conversation around the dinner table. Whatever words we do exchange at mealtime are more likely aimed at the minimal coordination of our centrifugally driven lives than at sustaining the richly patterned textures of meaning conversation can evoke.

But our abandonment of conversation extends far beyond the dinner table. Our broader social relations, and also our dialogue with the natural world, have contracted toward mere informational exchange, leaving us bereft of larger patterns of meaning. When you lose the shifting, multiply-focused, metaphoric, and life-supporting qualities of conversation, what you have left is the attempt -- useful as far as it goes -- to formulate well-behaved problems susceptible to well-defined solutions. To do this you must employ the narrow, precisely formed language of manipulation and control -- a language we have come near to perfecting. While this language may offer little in the way of understanding or meaningful engagement with the other, it does bring the very real satisfaction of more or less effective power.

If the impressive drive toward effective power has taken special hold in any one scientific discipline, surely it is genetic engineering. And if this drive can display beneficent potentials, how better to do it than by placing a daily bowl of genetically engineered "golden rice" on the dinner tables of millions of Asian children, thereby saving them from immense suffering?

This hope, many researchers believe, is now nearing fulfillment. But a full conversation around that envisioned bowl of rice has yet to occur. And until it does occur, we will have no means to assess the technical achievements represented by the bowl. In what follows we venture some preliminary contributions toward such a conversation.

Beyond Frankenfoods -----

Transgenic golden rice does not yet fill the bowls of hungry Asian children. But the possibility that it will is the bright hope of scientists and biotech companies beaten down by the consumer backlash against the rapid and largely covert introduction of genetically modified organisms into global food supplies. The advertisement for golden rice, widely broadcast, is that it avoids all the pitfalls associated with the ill-fated "Frankenfoods" that so unsettled the buying public.

What lends this new, experimental rice its golden color is the presence of beta-carotene within the part of the kernel -- the endosperm -- that remains behind (normally as "white rice") after milling and polishing (Ye et al. 2000). Beta-carotene is a precursor of vitamin A; the human body can use it to form the vitamin. This is important because millions of children, especially in Asia, suffer from vitamin A deficiency, which can lead to blindness.

By most accounts the virtues of golden rice are many:

** It is not the product of profit-seeking biotech companies. The research, funded by the Rockefeller Foundation, the Swiss government, and the European Union, was performed at Swiss and German universities.

** The researchers stressed that, once the rice proves viable in field plantings, it will be freely distributed. No patents will block access to the rice by third-world farmers. (Just recently a slightly revised version of this promise has emerged: the scientists announced that they had reached a licensing agreement with the giant pharmaceutical company AstraZeneca and a smaller German company, Greenovation. The companies will donate seeds to developing countries and sell seeds to developed countries. Donated seeds will be distributed to government-run centers that will pass the seeds on to farmers. As long as the farmers do not earn more than \$10,000 annually from the sale of golden rice, they need not pay any royalties. See *Financial Times*, May 16, 2000; *Associated Press*, May 16, 2000)

** Rice naturally makes beta-carotene and other carotenoids, which are present throughout the plant -- except in the endosperm. The genetic manipulation producing golden rice is simply designed to extend this natural production of beta-carotene into an additional part of the plant. In her commentary on this research in *Science*, Dartmouth biologist Mary Lou Guerinot suggests that the fears of most opponents of genetically modified foods will be allayed by the new rice (Guerinot 2000). After all, it's a far cry from transferring fish genes into plants.

** Unlike with many of the current genetically modified organisms, golden rice poses no risk of increased pest resistance to herbicides or insecticides.

** And, of course, the primary virtue of golden rice is its announced potential for solving problems of hunger and malnutrition in developing nations. Such a purpose hardly seems gratuitous or grasping. Who could possibly object?

So golden rice, as we now hear the story, looks rather like a "silver bullet" -- a one-shot, almost magical solution to a major problem. It turns out, however, that the situation is much more complex than the usual story allows.

The immediate challenge for researchers is to develop hardy strains of the transgenic rice, and then to convince Asian growers to plant the new strains. But this is barely to touch upon the conversational complexities the researchers must negotiate if they wish to enter constructively into the modern contexts of hunger and malnutrition. Here, briefly, are a few of the themes that need taking up.

If You Grow the Rice, Can You Deliver It to Those Who Need It? -----

The sobering fact is that "nearly eighty percent of all malnourished children in the developing world in the early 1990s lived in countries that boasted food surpluses" (Gardner and Halweil 2000, p. 17). The Green Revolution in Asia brought about a shift toward intensive cultivation of fewer crops like wheat and rice, which are often grown for export. Traditional diverse polycultures have yielded to large monocultures.

At the same time -- and at least in part due to the Green Revolution and other technology-driven change -- hundreds of millions of people have migrated from rural to urban areas in Asia during the past few decades. Mostly poverty-stricken, these transplants take up residence in the ever-expanding slums around cities. Their problem is that they can't buy the food they need. Golden rice will do them no good if they can't afford it -- and if they can afford it, then it is not clear what the new rice offers that would not be offered better by a more traditional and diverse diet.

Every green part of a plant contains beta-carotene. When Indian scientist and activist Vandana Shiva was asked what alternative she saw to golden rice, she cited "the 200 kinds of greens we grow on our farms". (See also Shiva 2000.) Traditional cultures never subsist on rice alone. In addition to the many different types of greens grown in India, wheat, millet, and various legumes are cultivated, not to mention the wild greens gathered from the countryside. Such polycultures develop differently in each region, but all allow, as long as there is enough food, for a balanced, life-sustaining diet.

It needs recognizing that what we in the western world embrace as export-driven economic growth has contributed to the problem of hunger in developing nations (Lappe et al. 1998). Golden rice can be seen in part as a one-dimensional attempt to "fix" a problem created by the Green Revolution -- namely the problem of diminished crop and dietary diversity. But the fix offers no direct help to those who have been displaced by the revolution and who cannot buy the food they need.

There are alternative approaches that do more justice to the complex geographical, historical, social, political, and economic issues. In 1993 the United Nations Food and Agriculture Organization, collaborating with nongovernmental organizations such as Helen Keller International, began a program to help poor people in Bangladesh grow a diverse array of plants to combat vitamin A deficiency (reported in Koechlin 2000). In areas where people have at least small plots of land, families -- usually mothers become the driving force of such projects -- were introduced to different carotene-rich varieties of fruits and vegetables and they learned cultivation methods. Landless families were shown how they could plant vines in pots on outside walls. They then planted beans and squashes that can grow up the vines.

When women noticed the positive health effects of their new diet, news spread by word of mouth, and now approximately 600,000 households (about three million people) participate in this project. This is, relatively speaking, a small number, but the project is promising because it can become part of cultural tradition. It empowers people instead of making them dependent on western aid.

Scientists evaluating the project found that the general health of the participants improved and that even small plots can provide sufficient vitamin A in the diet. Moreover, the more different kinds of fruits and vegetables people ate, the better the uptake of carotene -- an illustration of the inherent value of natural variety in the diet.

After assessing a number of such projects, John Lupien of the Food and Agriculture Organization concludes: "A single-nutrient approach toward a nutrition-related public health problem is usually, with the exception of perhaps iodine or selenium deficiencies, neither feasible nor desirable" (quoted in Koechlin 2000).

If You Deliver the Rice, Will They Eat It? -----

"We must not think", writes Jacques Ellul, "that people who are the victims of famine will eat anything. Western people might, since they no longer have any beliefs or traditions or sense of the sacred. But not others. We have thus to destroy the whole social structure, for food is one of the structures of society" (Ellul 1990, p. 53).

Billions of Asians subsist on rice, which they mostly consume as white rice. To obtain white rice you must first remove the husks from rough or paddy rice, leaving the brown rice kernel. Then you must remove the embryo and bran layers by milling and polishing. These discarded, nutrient-rich layers happen to contain carotene. What is left after polishing is the shiny white endosperm -- mainly starch.

This raises the obvious question: why not solve the problem of nutritionally inadequate rice by getting people to eat brown rice, containing protein, carotene, and various micronutrients?

The issues, again, are complex. Brown rice does not keep well in the humid South Asian climates, which is the reason scientists usually cite for Asians eating white rice. But while most rice is milled and sold as white rice, the rough rice kernel -- still enveloped by its husk -- can in fact be stored for long periods. The agronomist Heinz Bruecher observed that "the small farmer in Asia proceeds differently and avoids polishing by husking only as much rice as he needs at a time. In this way he always has a nutritious grain in storage" (Bruecher 1982, p. 58). Perhaps this practice could be encouraged.

But we must also reckon with the cultural traditions related to white rice. In Asia rice is not just something that is ingested like we eat french fries. It is steeped in thousands of years of culture and tradition. Different shapes, sizes, and cooking consistencies are preferred, depending on the context: everyday rice, rice for special occasions, rice for flour, rice to accompany other specific foods, and rice for ceremonies.

The whiteness of rice also has spiritual connotations:

There is more to eating than merely ingesting nourishment to survive, more to living than merely surviving. Confucius in 500 BC knew this well as he preached the gospel of a virtuous, yet graceful life. He was a stickler for excellence and ceremony at the table and insisted on the pure whiteness of rice in sheer, elegant porcelain bowls as a background for light emerald-green vegetables picked at their succulent zenith, golden brown stir-fried morsel of duck, pork or fish, and deep red jujube dates.

"Come eat rice with me" is the most gracious greeting in Chinese hospitality. In old China, families kept two crocks of rice, a large one of gleaming, white polished rice for the family, a smaller one of coarse brown rice for seeking one more day of existence. (Gin 1975)

The sensory symbolism of "pure whiteness", or "emerald-green" shows how a religious culture judges food as a spiritual-physical reality. The diet Confucius recommends is, in more prosaic terms, nutritionally balanced. People who use white rice experience it as being lighter and easier to digest, and find that it allows the taste of other foods

to come to the fore. It is prepared in many different ways. In the context of a varied diet, white rice is an integral part of Asian cuisine.

Only the beggar receives the more nutritious brown rice -- but without anything else -- allowing him to eke out one more day. So it is that white rice can become a symbol for high social and economic status in Asian cultures. When the poor emulate the rich by consuming white rice, they are actually putting their already precarious health in greater danger. In this way social inequality accentuates nutritional problems.

It would be reasonable to encourage the use of brown rice throughout Asia, but any such program must reckon with deeply rooted cultural traditions. Certainly the new golden rice will bump up against these traditions, and it is not at all clear how the resulting conversation will play itself out. If we wish to engage in the conversation at all, the question is whether it makes more sense to push the one-dimensional "solution" offered by golden rice, or instead to cultivate the potentials of a traditional, diverse diet, possibly in conjunction with greater use of brown rice.

If They Eat the Rice, Will It Do Them Any Good? -----

If golden rice replaces white rice in the Asian diet, can we be sure this will solve the vitamin A deficiency problem? That is, leaving the social issues aside, will the silver bullet at least strike its immediate, narrow target?

Not necessarily. It is a naive understanding of nutrition -- encouraged by a habit of input-output thinking -- that says you can add a substance to food and the body will automatically use it. Beta-carotene is fat-soluble and its uptake by the intestines depends upon fat or oil in the diet (Erdman et al. 1993). White rice itself does not provide the necessary fats and oils, and poor, malnourished people usually do not have ample supplies of fat-rich or oil-rich foods. If they were to eat golden rice without fats or oils, much of the beta-carotene would pass undigested through the intestinal tract.

Moreover, fats and also enzymes (which are proteins) enable carotene and vitamin A to move from the intestines to the liver, where they are stored. Proteins are bound to the vitamin in the liver, and enzymes are again required for transport to the different body tissues where the vitamin is utilized. A person who suffers protein-related malnutrition and lacks dietary fats and oils will have a disturbed vitamin A metabolism.

In sum, carotene uptake, vitamin A synthesis, and the distribution and utilization of vitamin A in the body all depend on what else a person eats, together with his physiological state. You can't just give people more carotene and expect results. There is no substitute for a healthily diverse diet.

Who Will Grow the Golden Rice? -----

Of the many thousands of rice varieties grown in Asia, most are local land races. Despite the introduction of high-yielding varieties in the Green Revolution, Indian farmers still use traditional varieties in over 58 percent of the rice acreage (Kshirsagar and Pandey 1997). These varieties serve their desire for different types of rice, while also providing the diversity needed within local ecological settings. The number of varieties a farmer grows tends to increase with the variability of conditions on the farm.

For example, when they don't irrigate, farmers in Cambodia plant varieties with regard to early, medium, and late flowering and harvesting dates; eating qualities (such as aroma, softness, expansion, and shape); potential yield; and cultural practices (Jackson 1995). In India a farmer might have high, medium, and low terraces for planting. The low terraces are wetter and prone to flooding; they are planted with local, long-growing varieties. In contrast, the upper terraces dry out more rapidly after the rains, so farmers plant them with drought-resistant, rapidly maturing varieties. Altogether a farmer may plant up to ten different rice varieties -- a picture of diversity and dynamic relations within a local setting (Kshirsagar and Pandey 1997).

This multiformity has evolved locally and regionally over long periods. Since the Green Revolution, more and more farmers plant, in addition to land races, high-yielding varieties. The price they pay for this progress is dependence on irrigation, fertilizers, and herbicides. The use of insecticides has become widespread, although they have been shown to be ineffective (Pingali et al. 1997, chapter 11). (Sometimes the highest, if also most mindless,

recommendation for western, industrial-style agricultural practices in the third world is that they're "modern".) The locally evolved land varieties, in contrast, tend to be more drought- and pest-resistant.

Imagine transgenic golden rice in this context. Currently this rice exists only in a laboratory variety. The next step is to make transgenic varieties that can do well under field conditions. Then large-scale seed production could begin and also interbreeding with other varieties. If bred into high-yielding varieties, golden rice would be grown primarily on large, export-oriented farms. In this case the rice would do little to alleviate Asia's food problems -- and, who knows, it might even end up being exported to America and Europe.

If, on the other hand, the golden rice DNA is introduced into varieties that small farmers use, then these new, transgenic varieties will be subject to local practices and conditions. What started out as an isolated laboratory variety would gradually intermix and change, probably looking very different in different places. Whether the genetic alteration would prove stable in the midst of this flux is a real question. Although no one can say what will happen, one **can** say: things will change. It is unrealistic to think you can simply introduce a new plant and that it will then produce carotene on demand. Genetically engineered plants are not immune to context.

What Will Rice Make of Its Golden Genes? -----

The fundamental problem with genetic engineering from the very beginning has been the absence of anything like an ecological approach. Genes are not the unilateral "controllers" of the cell's "mechanisms". Rather, genes enter into a vast and as yet scarcely monitored conversation with each other and with all the other parts of the cell. Who it is that speaks through the whole of this conversation -- what unity expresses itself through the entire organism -- is a question the genetic engineers have not yet even raised, let alone begun to answer.

But without an awareness of the organism as a whole, we can hardly guess the consequences of the most "innocent" genetic modification. The analogy with ecological studies is a close one. Change one element of the complex balance -- in an ecological setting or within an organism -- and you change **everything**. It is a notorious truth that our initial expectations of an altered ecological setting often prove horribly off-target. And the possibility of improving our discernment depends directly upon our intimate familiarity with the setting as a whole in all its minutia and unity.

Certain herbicides kill plants by bleaching them -- that is, by disrupting carotene metabolism and blocking photosynthesis. When scientists genetically altered tobacco plants to give them herbicide resistance, some of the plants indeed proved resistant to an array of herbicides (Misawa et al. 1994). Unexpectedly, however, leaves of the transgenic plants produced greater amounts of one group of carotenes and smaller amounts of another group, while the **overall** carotene production remained about normal. In some unknown way the genetic manipulation affected the balance of carotene metabolism, but the plant as a whole asserted its integrity by keeping the overall production of carotene constant.

Such unexpected effects are typical, expressing the active, adaptive nature of organisms. An organism is not a passive container we can fill up with biotech contrivances. Even when scientists try to change the narrowest trait of an organism, the organism itself responds and adapts as a whole.

When tomatoes were engineered for increased carotene production, some plants did make more carotene, but often in places where they wouldn't normally produce much of the substance -- for instance, in the seeds, the seed leaves, and the area where the tomato breaks off the stem (Fray et al. 1995). In addition, the plants produced more and different kinds of carotene than expected. More surprisingly still, the plants were dwarfed. The more carotene a plant produced, the smaller it was. Because a substance that normally stimulates growth in plants (giberillin A) was reduced thirty-fold, the scientists assume that the carotene increase interfered with giberillin production.

This is not an isolated example of how genetic manipulations can affect the vitality of a plant. In the first successful alterations of rice to produce precursors of vitamin A, half the transgenic plants were infertile (Burkhardt et al. 1997). Of course, infertile or markedly dwarfed plants are left by the wayside, while the researchers select the most desirable specimens for their breeding stock. But unexpected effects are not always as apparent as dwarfed tomato plants.

The transgenic golden rice plants were reported to be "phenotypically normal" (Ye et al. 2000). This statement needs to be read: "no visible modifications were noted". The researchers evidently didn't undertake a biochemical analysis of the kernels to see how their overall content might have changed. What *doesn't* a golden rice kernel produce as a result of the plant's breaking down excessive amounts of carotene? What new substances does it produce? And what are the changed balances among substances normally present? The more one learns about the flexible and dynamic nature of organisms -- demonstrated so clearly by genetic engineering experiments themselves -- the more one comes to expect the unexpected and to realize that we cannot know what subtle effects a manipulation may have.

How many genetic engineers have pondered the remarkable fact that rice, despite the myriad varieties that have arisen over thousands of years, never produces carotene in the endosperm of the kernel? The rest of the above-ground plant makes carotene, and the endosperm should (according to prevailing conceptions) have the genes that would allow it to produce carotene. But it never does so. Certainly that should give us pause to consider what we're doing. Might the excess carotene in the seed affect in some way the nourishment and growth of a germinating rice plant? What does it mean to force upon the plant a characteristic it consistently avoids? Can we claim to be acting responsibly when we overpower the plant, coercing a performance from it before we understand the reasons for its natural reticence?

Organisms are not mechanisms that can be altered in a clear-cut, determinate manner. The fact is that we simply don't know what we're doing when we manipulate them as if they were such mechanisms. The golden kernels of rice almost certainly herald much more than a novel supply of beta-carotene.

A Disproportionate Interest in Silver Bullets -----

We often hear that biotechnology is merely doing what high-yield breeding, industrial agriculture, and nutritional science have done all along -- but now much more efficiently. In one sense that's exactly right and also exactly the problem: we don't need more of the same. What we need is to overcome an epidemic of abstract, technological thought that conceives solutions in the absence of organic contexts. We need a refined ability to enhance life's variety rather than destroy it. And we need to realize that the problems of life and society are not malfunctions to be fixed; they are conversations to be entered into more or less deeply. The more deeply we participate in the conversation, the more thickly textured and revelatory it becomes, reacting upon all the meanings we brought to the exchange.

The engineering mindset that tries to insert individual traits into rice by manipulating particular genes is closely allied to the long-standing agricultural mindset that tries to improve crop yields in a purely quantitative sense by injecting the right amounts of NPK (nitrogen, phosphate, and potash) into the soil. On this view the soil offers little more than a structural support for the roots. At the same time, it is a kind of hydroponic medium into which we place the various "inputs" that we can identify as requirements for plant growth.

What this approach overlooks is ... well, just about everything. Fixated upon inputs, outputs, and uptake mechanisms, it loses sight of the unsurveyed, nearly infinite complexity of life in a healthy, compost-enriched soil. The truth of the matter is that whatever we can do to enhance the diverse, living processes of the soil will likely improve the quality of the crop, and yet an input-output mentality proceeds to destroy the life of the soil through simple-minded chemical applications. Our silver bullets, much too narrowly targeted, rip through the fabric of the life-sustaining context.

Sponsors of the green and genetic revolutions are not inclined to ask what is lost when input-intensive, high-yield monocultures replace the kind of local diversity that results in thousands of local rice varieties throughout Asia. We have never heard a biotechnologist venture the thought that local varieties may actually -- through their long history of co-evolution with the people who bred them -- be uniquely adapted to the nutritional needs and dietary complexities of the local population.

The adaptation is not hard to imagine when you consider beta-carotene. Plants make many different types of carotene; beta-carotene is only one member of a large family of substances. Each species of green, squash, or brown rice produces its own unique array of carotenes, with different types and amounts arising in different tissues depending on changing conditions. Numerous species-specific carotenes have scarcely been investigated.

Similarly, human beings need different kinds of carotenes, and, as long as a reasonable diversity of crops is available, each individual will draw out of his food what he needs. But what if, in the name of this or that specific "input" abstracted from the complex, nutritional matrix of life, we proceed to destroy the matrix? The disproportionate hope placed in golden rice, together with its salesmen's casual disregard of biological and social context, suggests the likelihood of precisely such destructive consequences.

There are no silver bullets in any profound conversation. There is only a progressive deepening of meaning. Or, if we prefer the satisfaction of unambiguous bits of information, then -- whether we conceive those bits as genes or NPK or the dietary inputs of Asian children -- we abandon the wholeness and coherence of the conversation altogether. We can, in this case, certainly proceed with our narrow programs of manipulation and control, which are what we have left when we give up on conversation. But the results will be no more satisfying than a diet of rice alone.

(Craig Holdrege, the primary author of this paper, is director and Steve Talbott is senior researcher at The Nature Institute in Ghent, New York. The Nature Institute is dedicated to pursuing a science of nature rather than of mechanisms assumed to lie behind nature. This is a qualitative science, contextual and holistic in spirit, and ethically informed in immediate practice rather than in afterthought. The Nature Institute also promotes humane uses of technology rather than mechanical uses of humans. Email: nature@taconic.net.)

Related articles:

** "The Tyranny of the Gene" by Craig Holdrege in NF #80.
http://www.oreilly.com/~stevet/netfuture/1998/Nov2498_80.html#3

** "Is Genetic Engineering `Natural'?" in NF #75.
http://www.oreilly.com/~stevet/netfuture/1998/Jul3098_75.html#2b

** "The Trouble with Genetic Engineering" in NF #31, a review of Craig Holdrege's *Genetics and the Manipulation of Life: The Forgotten Factor of Context*.
http://www.oreilly.com/~stevet/netfuture/1996/Nov0596_31.html#2

** "Finding Wholeness in a Pile of Manure" in NF #79.
http://www.oreilly.com/~stevet/netfuture/1998/Oct2798_79.html#2c

References -----

Bruecher, H. 1982. *Die Sieben Saeulen der Welternaehrung*. Frankfurt am Main: Waldemar Kramer.

Burkhardt, P. et al. (1997). Transgenic Rice (*Oryza sativa*) Endosperm Expressing *The Plant Journal* 11:1071-1078.

Ellul J. (1990). *The Technological Bluff*, translated by Geoffrey W. Bromiley. Grand Rapids, Mich.: Eerdmans.

Erdman, J. et al. (1993). Absorption and Transport of Carotenoids, in *Carotenoids in Human Health*, edited by L. Canfield et al. New York: New York Academy of Sciences.

Fray, R. et al. (1995). Constitutive Expression of a Fruit Phytoene Synthase Gene *The Plant Journal* 8:693-701.

Gardner, G. and B. Halweil (2000). *Underfed and Overfed: The Global Epidemic of Malnutrition*. World Watch Paper 150. Washington, D.C.: The Worldwatch Institute.

Gin, M. (1975). *Ricecraft*. San Francisco: Yerba Buena Press.

Guerinot, M. (2000). The Green Revolution Strikes Gold. *Science* 287:241-243.

Jackson, M. (1995). Protecting the Heritage of Rice Biodiversity. **GeoJournal** 35:267-274.

Koechlin, F. (2000). 'Golden Rice' -- A Big Illusion? (www.blauen-institut.ch.html; click "Hintergruende", then click "Vitamin A Documents").

Kshirsagar, K.G. and S. Pandey (1997). Diversity of Rice Cultivars in a Rainfed Village in the Orissa State of India. **International Development Research Centre**. Ottawa, Canada. (www.idrc.ca/books/focus/9/833/kshirsag.html)

Lappe, F. et al. (1998). **Hunger: Twelve Myths**. New York: Grove Press.

Misawa, N. (1994). Expression of an **Erwinia** Phytoene Desaturase Gene **The Plant Journal** 6:481-489.

Pingali, P. et al. (1997). **Asian Rice Bowls: The Returning Crisis?**. New York: CAB International.

Shiva, V. (2000). Genetically Engineered Vitamin A Rice: A Blind Approach to Blindness Control. (www.gene.ch:80/genet/2000/Feb/msg00064.html)

Ye, X. et al. (2000). Engineering the Provitamin A (Beta-Carotene) Biosynthetic Pathway into (Carotenoid-Free) Rice Endosperm. **Science** 287:303-305.
