Effects on Biodiversity

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In this paper, I shall deal with Genetically Modified (GM) crops in terms of their performance in the field and their effects on the environment generally. In order to do so properly, however, it is necessary first to provide a review of the context within which GM crops and domestic animals should appropriately be viewed. In general, misunderstandings, almost exclusively, have led to widespread controversies over the safety of the GM plants and animals in principle and of the safety for consumption of products derived from them by humans and domestic animals.

In general, the lateral transport of genes is frequent in nature and not some novel aberration that human beings have introduced into agricultural systems. For example, each of us has well over a hundred transgenes that were originally derived from some other kind of organism. These transgenes have been assimilated into our basic set of some 20,000 protein-coding genes, having proven either beneficial or neutral in the functioning of our bodies. No harmful effects have ever been attributed to any one of them, and they are transmitted like all of our other genes in a regular fashion from generation to generation.

In the course of evolution of organisms generally, the lateral transport of genes between unrelated kinds of organisms has been and remains frequent. Our Academy President, Professor Werner Arber, has been an active student of such genes, and has demonstrated numerous instances of their natural occurrence. In this context, a particularly interesting example concerns the genome of *Amborella*, a plant found only in the mossy forests of New Caledonia. *Amborella* displays a greater number of archaic features than any other kind of flowering plant, resembling the common ancestor of the phylum more closely than any other living genus. In its genome are located more than thirty transgenes, which have originated from at least four other distinct phyla. Such a finding certainly makes it clear that transgenes have played an important role in the evolution of *Amborella*. It seems likely that they will eventually be discovered as part of the genomes of most, if not all, other kinds of organisms, both prokaryotes and eukaryotes. The very long molecules of DNA that make up the genome of every kind of organism are neither more nor less than the organism's instructions for transcribing enzymes and other proteins through the intermediacy of RNA. The molecules that are transcribed then direct all of the processes that lead to the particular features of individual organisms.

In general, then, altering the recipe embodied in an organism's DNA is therefore analogous to substituting a particular chord in a musical score, as a composer might do in the course of arriving at his or her final composition. If it "works", in either case, the gene or chord will be retained; and if it doesn't "work", the gene or chord will be eliminated sooner or later. In other words, if a new chord alters a musical score in a way that its composer finds pleasing, it will be retained; if not, it will be eliminated. In a similar fashion, if a new, introduced segment of DNA or gene alters the genome of the organism into which it is placed in a way that renders that organism better adapted to the environment in which that organism will attempt to survive, it will be retained, and it not, it will be eliminated. Such experimentation is clearly one of the ways in which the features of a musical score or a genome are improved, and the two processes are therefore somewhat analogous. In an organism, gene transfer may make possible more rapid adaptation to a particular habitat than would have been achieved by simple selection for particular existing alleles. In this way, gene transfer has become a relatively common feature of the process of adaption and therefore of biological evolution in general. The features of a particular organism are what lead to its improvement as a crop or its adaptation to a particular habitat, and not the particular route by which those features have evolved.

In considering the role of transgenes in domestic plants or animals, the massive genetic changes that our ancestors have wrought in them over up to 11,000 or more years of selection provide an appropriate context. Their earliest domesticated plants, which included flax, wheat, barley, lentils, vetch, and peas, have come over time to differ in varying degrees from their wild ancestors. These differences have come about as a result of thousands of generations of choosing seeds from the most productive and hardiest individual plants and sowing those particular seeds the following year. As a result, both of the original natural variation in such plants and animals and the occasional appearance of additional random mutations over the years, these plants became increasingly productive as sources of food – as did sheep, cattle, goats, chickens, and other domestic animals. Changes over the years have proceeded so far that there are no wild analogues of bread wheat, which is a hexaploid that does not occur in nature. The same is true of maize, which has come to differ so greatly from its

wild progenitors that for decades, scientists experienced a very difficult time in determining which wild grasses were in fact its ancestors. And maize has been cultivated for “only” about 5,500 years!

Starting in England in about 1800, farmers have deliberately and with mathematical tools, selected in domestic plants and animals the characteristics that they valued most highly – sustainability under varying conditions, productivity, and so forth. That process of selection was refined greatly about a hundred years later, with the rediscovery of Mendel’s laws of inheritance and their application to the process of selection. As breeders looked for even greater improvements than nature would easily allow, they began to apply strong chemicals and irradiation to the plants to break up and scramble their existing genomes into fragments that could be incorporated in various ways into other complete genomes. By doing so and growing the scrambled progeny that resulted, the breeders could sometimes produce individuals with features that were changed more fundamentally or in different directions than those that could easily be obtained by traditional breeding. Starting with such peculiar individuals, the breeders could stabilize unique new strains of crops by selecting for their new valued characteristics by further breeding and selection. Over the years, the results of these patently unnatural methods were fully accepted as a way of producing valuable new strains of crop plants, which were then adopted by farmers without reservation.

The possibilities for wide genetic transfer should not be surprising to us. Human beings share more than 99% of their genomes with chimpanzees, bonobos, and gorillas and about two-thirds of their genomes with fruit flies, maize, and bananas, just to mention a few random kinds of organisms. Most of our genomes are inert (their base sequences are not transcribed), but direct comparisons of the functional genes in different kinds of organisms have also been carried out, and those sets of genes are strikingly similar also. For example, we have compared about 4,000 of our 20,000 genes, selected randomly, with those of tomatoes, finding that only 10 of the 4,000 genes examined proved different between ourselves and tomatoes.

Thus transgenes, like any other group of genes, are neither “good” nor “bad” as a class. Traditional breeding methods are capable of returning tomatoes or eggplants to their original poisonous nature in relatively few generations, but we don’t choose to carry out that experiment in cultivated fields. In thinking about transgenes, or any other genes, the key point is *how do the characteristics they produce function in a living plant or animal – how do they modify its characteristics?* Among these undesirable characteristics would obviously be weediness. Considering that any new kind of plant or animal that is bred will be tested extensively before there is any thought of putting it on the market, we can see that there is clearly a degree of safety built into the system. If a particular crop already has weedy strains, as do sunflowers and sugar beets, then they might acquire immunity to pests or pesticides by cross breeding with the crop varieties; but such problems are both rare and obvious, so that steps are taken to avoid them. And in nature, if the wild strains become resistant to pests or parasites, or to chemicals, would that be a bad thing?

Are the products derived from GM plants and animals safe for consumption by humans and domestic animals grown to produce food for us? To help illuminate this subject, it can be pointed out that virtually all of the cheese, beer, and bread consumed anywhere in the world, as well as a large percentage of our medicines, including prominently all of our insulin, are produced using GM organisms. In the US and a number of other countries, our food is almost all produced from GM organisms too, and this has been true, with the proportion increasing, over a period of approximately 25 years. It is highly significant that during all of that time, not a single case of any problem or illness has been found among the hundreds of millions of people consuming these products every day or, for that matter, among the billions of farm animals consuming similar diets. The farmers who produced these products didn’t make their choices to grow GM plants for no reason, or simply because someone told them to do so; they made these choices because their fields became more sustainable and productive when the GM strains were grown than otherwise. As a result, nearly all the maize and soybeans cultivation in the United States is now based on GM plants. For similar reasons, farmers in India have adopted GM cotton almost exclusively. When they are not legally prohibited for fanciful reasons, GM strains are very often more successful and productive that the others available in the same markets. Similar stories are developing throughout the world as people everywhere become familiar with the features of the GM plants that are increasingly available to them.

When we view these facts and relationships against a background of a hostile Europe making it difficult or impossible for starving people in Africa to be able to preserve their lives and improve their health by growing better strains of crops, when Europe has no problem feeding itself, then such denial seems to amount either to immorality or to ignorance. The problem is not only with food. Thus millions of people worldwide are denied access to adequate quantities of the micronutrients they need to preserve their lives and health, when there is no scientific evidence of harm from the sources for such micronutrients that are available if not legally prohibited. For example, over some 20 years, the use of Golden Rice, fortified with Vitamin A precursors, has been controversial for no scientific reason whatever. While this controversy has continued, millions of children have lost their sight and hundreds of thousands of have died because of their receiving insufficient amount of Vitamin

A in their diets. In my opinion, such an outcome can only be termed disgusting, even obscene; it amounts to the rich making the poor abide by their arbitrary standards for no good reason except, perhaps, power. In the US itself, the organic food industry, currently US$50 billion, succeeded, against all rational considerations, in getting “GM” foods added to their criteria for “non-organic” produce, this designation functioning mainly as a selling point. When organizations that depend on public campaigns for their income continue to act in ways contrary to the known and established facts of a given situation, we may reasonably conclude that such organizations are acting primarily in their own financial self-interest. As such, their continued actions should be condemned and understood in the same light as we understand the tobacco industry, which has fought and continues to fight public understanding of the demonstrated harm that smoking does to the health of smokers.

What about the overall effects of growing GM plants on neighboring ecosystems? With some 40% or more of the Earth’s surface already being cultivated or grazed to feed a rapidly growing population of 7.5 billion people, the effects of agriculture on biodiversity can only be described as catastrophic. The only way to limit further damage is to make agriculture as productive as possible in the areas that we already have under cultivation, so as not to destroy more of the natural landscape in the course of increasing our total yield. Obviously, fields that are intensively cultivated do not harbour a great deal of biodiversity, but agriculture that is not as productive as it can possible be destroys a large proportion of the existing biodiversity over what is intrinsically a much larger area. Should large-scale, “industrial” agriculture be practiced everywhere? Obviously not: small-scale agriculture works better in some regions, perennial plants are more sustainably productive than annual ones under some conditions, and agroforestry works best in others. Clearly, we need much research to determine what agricultural practices are best suited for the many different conditions in which we produce food. If we allow ourselves to remain confused about the factors that we need to take into account, as in assuming that GM plants or animals are harmful as a class, then we certainly will be limiting our ability to find the best answers for this problem. We certainly have no logical reason to assume that the particular genetic methods by which we derived the most productive plants should have any logical importance in making those decisions about agriculture.

In conclusion, transgenic technology is a modern development that fits into a very long succession of improvements in the methods used for plant breeding. Today, the importance of GM technology is being partly replaced by the more recently developed CRISPR technology, which offers even more precise methods and simpler methods of altering genes selectively. But the key point with which I want to leave you is that every allele of every gene is different; the characteristics that they produce in the particular organism are of ultimate significance, and not the methods by which they were produced. The is no disagreement about this point, or concerning the categorical safety of foods or other products derived from GM plants or animals, among all the academies of science or similar bodies anywhere in the world. The contrary articles that have appeared from time to time in the press, scientific or popular, have either been demonstrably incorrect or ultimately proved to be so. In fact, most such articles have been removed from the journals in which they have been published where there has been time to examine them in detail. Is it reasonable then, let alone ethical, to let hundreds of millions of people starve and others suffer the ravages of malnutrition because we have chosen an irrational course, and not taken the time to consider the facts in a deliberative, rational way? I think not, and hope that you will agree with me.