Today, the new technologies convey a certain type of accident, one that is no longer local and precisely situated, like the sinking of the Titanic *or the derailment of a train, but* general, *an accident that immediately affects the entire world.*

—Paul Virilio

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Transgenic Accidents

Paul Virilio has commented in a number of interviews that each new technology that is embraced by a culture is accompanied by a series of possible accidents particular to the given technology. With information and communications technology (ICT) or transportation technology, the accidents have increased in scale and in their intensity of violence, due to their intimate relationship with the intensification of speed. In the case of ICT, the accident has hit a zenith in scale and intensity of violence beyond which it cannot progress. With the introduction of global, real-time technology, the possibility of an accident that could occur simultaneously on a world-wide basis haunts the margins of the spectacle of techno-utopia. As the world braced itself for the disaster of the Y2K bug, the meta-accident lived as more than a theoretical concept, and the means by which such an upheaval could occur manifested in a detailed scenario that had a tremendous material impact on every socio-economic constellation using ICT.

Resource-driven, transgenic biotechnology has a particular set of accidents that accompany it. The nature of some of the accidents is already taking shape, but there is a shortage of details. There are, however, some loose analogies. For example, when nontransgenic species alien to a given ecosystem are introduced, the results are very difficult to predict. For the most part, these introductions have been neutral or positive, but there have also been a modest number of negative outcomes. Australia is a very interesting case, as it is one of the few countries that prefers biological environmental resource management to chemical management, and has remained committed to it over the past century. And while it has had many successes, there have also been many problems. Rabbits, feral cats, European carp, and myna birds are all examples of species that have been problematic in various ecosystems in Australia. Perhaps the most well known example is the introduction of the cane toad. In 1930, sugar cane farmers in the coastal regions of Queensland, Australia, became increasingly concerned about the rising threat to their crops from the cane grub. Their grumblings about this problem spurred the government to find a method to control this pest. It was determined that the cane toad, although not indigenous to Australia, would serve as a predator that could adequately hold down the numbers of cane grubs and beetles that plagued the farmers. In 1932 a colony of cane toads was collected in Hawaii and transported to a small pond in Queensland to breed, and breed they did. Much to the chagrin of the farmers, the toads failed to curb the grub population. It became clear that the cane beetle had two incarnations, an airborne manifestation as well as an earthbound form. The beetle in its flying form was not readily available to the opportunistic toad, which preferred to eat life forms on the ground that happen to be passing by. Further, the cane toad preferred to stay where there is good ground cover, but the grubs were available during the season when ground cover in the fields was at a minimum. Consequently, the toads and the grubs did not share the same territory. Thus, the cane beetle was completely unaffected by the introduction of the toad to Queensland. To make matters worse, it was soon realized that the toad had neither natural parasites nor predators in this environment. Now the population is out of control and has had a devastating effect on the environment. Cane toads are voracious eaters, and will eat anything that will fit in their mouths. They also are rapid breeders. Hence their ever-growing numbers pose a threat to numerous small insects that are productive in the Queensland ecosystem. The cane toad has now become a superpest whose territory is ever-expanding.

In response to this problem, Australian biologists and resource managers attempted to find an organism that could control the menace. The first attempt was a study on a Venezuelan virus. Researching the potential for viruses to control cane toads involved isolating and purifying viruses from cane toads in their native habitats in Venezuela. The effects of the viruses on cane toads and native frog species were then tested in the secure biocontainment facilities at the CSIRO Australian Animal Health Laboratory. While the viruses proved effective in killing cane toad tadpoles, they also killed one species of Australian frog in the trial. This option was rejected. In a second attempt, the researchers identified two fungal pathogens that are lethal to cane toads and other amphibians. One fungus was thought to be responsible for frog fatalities in Australia and Panama, so this possibility was also dismissed. The cane toad problem is still unsolved.

Another problem is the accidental release of organisms alien to a given environment. This type of accident is also pertinent to transgenics, as many of the genetically modified organisms are designed to be robust and to have competitive advantages over wild species (transgenic fish and yeast are good examples). Consequently they have to be kept in containment facilities so as not to pollute wild environments. In this case, the probability of an accident is higher compared with species that have been designed to blend in with a given environment. Before transgenics increased the risk level, there were a number of cases of environmental pollution from accidental releases that served as warnings of what could be next. One of the classic examples of accidental release in the US is the gypsy moth, *Lymantria dispar*, one of North America's most devastating forest pests. The species originally evolved in Europe and Asia and has existed there for thousands of years. In either 1868 or 1869, the gypsy moth was accidentally introduced near Boston by E. Leopold Trouvelot. About ten years after this introduction, the first ecological disruptions began in Trouvelot's neighborhood. By 1890 the gypsy moth had become such a pest that the state and federal government began attempts to eradicate it. These attempts ultimately failed, and since that time, the range of the gypsy moth has continued to spread. Every year, isolated populations are discovered beyond the known range of the gypsy moth, but these populations are either eradicated or they disappear without intervention. It seems inevitable that the gypsy moth will continue to expand its range in the future.

The gypsy moth is known to feed on the foliage of hundreds of species of plants in North America, but its most common hosts are oaks and aspen. Gypsy moth hosts are located through most of the coterminous US, but the highest concentrations of host trees are in the southern Appalachian Mountains, the Ozark Mountains, and in the northern lake states. Gypsy moth populations are typically eruptive in North America; in any given forest stand, densities may radically fluctuate. When densities reach very high levels, trees may become completely defoliated. Several successive years of defoliation, along with contributions by other biotic and abiotic stress factors, may ultimately result in tree mortality. In most northeastern forests, less than 20 percent of the trees in a forest die, but occasionally tree mortality may be very heavy. Over the last 20 years, several million acres of forest land have been aerially sprayed with pesticides in order to suppress outbreaks of gypsy moth populations. Though some areas are treated by private companies under contract with landowners, most areas are treated under joint programs between state governments and the USDA Forest Service. The USDA, state, and local governments also jointly participate in programs to locate and eradicate new gypsy moth populations in currently uninfested areas. Most of these projects focus on populations of European origin, but recently several Asian populations have been discovered and eradicated in the US and Canada.

In eastern North America, the gypsy moth is subject to a variety of naturally occurring infectious diseases caused by several kinds of bacteria, fungi, and a nucleopolyhedrosis virus (NPV), which was inadvertently introduced with the gypsy moth or its parasites. There are six species of entomopathogenic (causing disease in insects) fungi known to infect the gypsy moth. As an alternative to spraying insecticide, pest managers turned to a biological means of control. In 1984, researchers isolated an entomophthoralean fungus (*E. maimaiga*) from the Asian gypsy moth in Japan and brought isolates to the United States. Stages of this fungus now could be maintained year-round in the laboratory using several different culture media, rather than having to be perpetuated on gypsy moth larvae. Host range studies have shown that *E. maimaiga* does not infect insects other than *Lepidoptera*.

There is general consensus among scientists and pest managers that *E. maimaiga* is probably responsible for the decline of gypsy moth outbreaks and damage over the last few years. It is effective in both high- and low-density gypsy moth populations, unlike the nucleopolyhedrosis virus, which is only effective on high-density moth populations. The fungus could play a significant role in the natural control of gypsy moths, especially in years with a wet spring. Only time will tell whether increasing the area where *E. maimaiga* is established will lead to constant lower populations of the gypsy moth in North America.

Examples of such accidents and responses to the accidents could be endlessly recounted. Kudzu, killer bees, purple loosestrife, catclaw mimosa, etc., all point to the kinds of accidents that can occur when humans play mix and match with ecosystems. Transgenic organisms, however, are in a very fuzzy position in regard to alien species introduction, because they typically exist at the intersection between the alien and the localized. For example, transgenic corn tends to be introduced in corn-growing localities. It is both alien and localized at the same time. The problem here is that comparing historical cases of alien organisms' release does not get the analysis very far; it only throws up abstract cautionary flags. Does changing a single gene or a single phenotypic characteristic really change the organism so drastically that the GMO deserves the designation of alien species? Not having an answer to this question makes argument by analogy very sketchy, so the debate continues. This leaves direct research as the best and only method to try and work through the transgenic puzzle. Such research takes a tremendous amount of time, particularly because so much of the study has to be cross-temporal, ranging over generations. Such studies are necessary because biological accidents tend to be low velocity and filled with numerous latent features (bio time-bombs). Seemingly, one of the new types of accidents that transgenics can potentially deliver is the germline or perhaps even the evolutionary accident of cultural origins (perhaps the biological equivalent of Virilio's ICT real-time meta-accident). Even though such accidents could be rendered extremely unlikely given proper time and research, profit-hungry corporations continue to operate according to a "fix it as you go" policy, with the idea that a product is safe until shown to be otherwise.

The Good, the Bad, and the Transgenic

While a tremendous amount of caution and study should be applied to transgenic organism release into the environment, there are strategies that reduce the level of risk. The use of *E. coli* for DNA replication in the various genome projects provides a good strategic model. In order to replicate DNA sequences in reliable mass quantities, scientists have developed a method that uses *E. coli* as a replicating machine. By placing the DNA sample desired for replication into plasmids (extra chromosomal DNA) within the organisms and then replicating them, scientists can retrieve as many samples as they want. The ecological question that follows is what if this strain of transgenic bacteria escapes from the laboratory and finds its way into the wild? To prevent any unforeseen disasters, scientists have placed safeguards into the bacteria. To be sure, this bacteria is not of great danger even without the safeguards, but this take-no-chances policy seems prudent all the same. The introduction of foreign DNA into bacteria puts it at considerable disadvantage when competing with wild bacteria. For the bacteria to replicate, it must not only replicate itself, but all the extra DNA in its system as well. This slows its reproduction process to such an extent that it would be overrun by wild bacteria, or, in other words, it would be at an extreme disadvantage in the competition for space. Scientists, however, have gone a step further in developing safety features by mutating lab-strain *E. coli* so that it is fundamentally incapable of nourishing itself outside of the lab environment. Lab bacteria is incapable of producing all the proteins that it needs without a specialized food source that they are very unlikely to find in the wild (i.e., outside the controlled conditions of the lab). Should they escape, they would again be unable to compete with wild bacteria because of this crippling feature.

This model of building in safety features has had some successful industrial applications as well. For example, the bacteria used for oil spill clean-ups is a very low risk for release because its termination has been engineered into its task. When an oil spill occurs and the bacteria are deployed, they only live as long as the food source (oil) is available. Once the oil is gone, the bacteria can no longer sustain themselves in the hostile ocean environment. The chances that they will find another food source are slim, so the ecological risk factor is quite low. Certainly, with both of these examples there is still an infinitely small amount of risk, but it is within acceptable parameters, given the benefits that these GMOs provide.

Unfortunately, this strategy of transgenic organism production and deployment is not the norm. A more common example is the socially and ecologically irresponsible corporations' production, marketing, and planting of *Bt* corn and cotton (and now potatoes and tomatoes as well). These crops are engineered using a gene from *Bacillus thuringiensis*. When this gene is mixed into the genetic structure of corn (or cotton), it allows the plant to produce a toxin that is hazardous to many of its insect predators. The promises from the corporate developers (Monsanto, Calgene, etc.) are that *Bt* crops will require less chemical management and produce higher crop yields. These positive characteristics are at least true in the short term, and hence *Bt* crops have been attractive to farmers. What is not mentioned by the corporations is the impact that this toxin could have on the environment. The primary problems are domestic and wild plant hybridization, the destruction of nontarget creatures, and unacceptable soil toxicity levels. For example, corn requires an airborne fertilization process to reproduce. The toxin produced by *Bt* corn is expressed in the pollen. Corn pollen can typically move up to 60 meters on the breeze (and even further, given less typical conditions). Like most primary domestic crops, corn has wild relatives with which it can cross-pollinate. Should the *Bt* gene be transferred to these relatives, they would have a considerable advantage in the wild. This could produce a superweed that could be very difficult to eradicate and that could overrun other species, thus affecting biodiversity. To make matters worse, many devastating weeds do not become problems immediately. Often it can take years before a weed becomes a real pest. Catclaw mimosa is good example. It took 30 years after its introduction in Australia before its powerful ability to overrun native species of plants became apparent. Currently, evidence is mounting that *Bt* corn is hybridizing not just with wild relatives but with non *Bt* corn as well (much to the dismay of organic farmers).

The destruction of nontarget species has become a second issue of contention—most notably, the destruction of monarch butterfly larvae and green lacewings. On this issue there are at least some studies; unfortunately, the data are completely unreliable. The debate stems from differing opinions on and interpretations of the level of toxicity in the pollen landing on plants eaten by the above insects, and from the oldest of all criticisms of lab studies—can a lab study really reproduce wild conditions?— ending with each side accusing the other of doing *ad hoc*, impressionistic studies.

The issue of soil toxicity is in the same fuzzy position. There is agreement that the *Bt* toxin is expressed and secreted in the root structure of the plant, but beyond that, no consensus has been reached. Some studies argue that the *Bt* toxin can bind with soil particles, giving the toxin a much longer lifespan (up to 230 days) for its insecticidal properties, and that it can increase in concentration over time. Consequently, damage to the decomposition and nutrient cycles of the soil could occur, primarily due to the toxin's effect on the many organisms that inhabit the soil and function as catalysts for these cycles. As to be expected, there are just as many counter-studies.

Given the degree of scientific conflict over the use of *Bt* corn, it would seem prudent to err on the side of caution, but that is simply not happening. Biotech companies are taking the position that until there is conclusive evidence of a problem, no precautions need to be taken. Conclusive evidence takes a very long time to produce, if it can be done at all. By analogy, cigarette companies still do not believe that there is "conclusive proof" that smoking is a health hazard. Also, the funding for tests on such matters is lacking. This situation gives Monsanto the time it needs to sell as much *Bt* corn (and other *Bt* crops) as possible, until it is too late to stop the process without it having a devastating effect on the farming industry. (As of 1998, *Bt* corn already constituted one-fifth of the corn acreage in the US, and it is continuing to grow.) If history is any indicator, Monsanto is taking an almost sure bet that if this crop is fully interwoven into the market, economic demand will outweigh ecological responsibility.

Unfortunately, the *Bt* conflict does not stop at the ecological level. From the perspective of developing nations, a much different primary issue arises. In India, for example, there is not nearly as much concern over ecological or health risks from transgenic crops as there is in North America and Europe.[1] These are luxury issues generally reserved for industrialized nations. The promise of higher crop yields is very significant in countries where an adequate food supply is always a concern, and this potential must be balanced against the primary negative issue—neo-colonization. Monsanto is quite open about its goal to consolidate the food supply. In agrarian nations like India, where 700 million people are directly dependent on farming, the fastest way to control a country is to control the food chain. (Monsanto is also expanding its operations into water supplies as well.) If biotech companies in general are able to make the agricultural classes of developing nations dependent on corporate research, products, and knowledge, any possibility of food security for these nations will be out of the question. Moreover, the corporate method of focusing on product and production as a way to solve supply problems in locations like India is practiced at the expense of human capital. The strategy is to dumb-down the population by stripping them of traditional agrarian knowledge and to push farmers further into a serious debt so they will never achieve independent ownership of the means of production.

One of the countermodels to GM farming that offers a tremendous amount of hope in India is provided by the Deccan Development Society. This organization works with the poorest Indian women to reclaim land thought to be unusable. By investing in education to teach the women about seed banks, composting, inter-cropping, manuring, and soil fertility, they have produced self-reliant farmers and returned degraded land back to fruitfulness. There are two key points of great significance here: First, an obvious alternative to agricultural improvement through product is land redistribution and ownership! Ownership of *personal* property can have the effect of increasing production every bit as much (or more than) using high-tech seeds. The other point is the value of investment in human capital in this type of situation. A key part of this capital is the reclamation and maintenance of traditional knowledge. Take for example the use of the traditional farming method of planting a variety of crops. If one fails there are plenty more to sustain the farmer for the year. The biotech corporations have been insisting on the planting of single crops (mostly *Bt* cotton—not even a food). If the crop fails, it is a life-and-death situation for the farmers, which has led to situations like the mass suicide in Warangal, where over 500 farmers committed suicide by hanging or drinking their insecticide because they could not pay local loan sharks (the local agrarian product distributors who also loan money). While even the radical left of India does not totally reject GM farming, most insist that a hybrid between these new methods and traditional farming will serve India best; however, policy must be constructed around the farmers' needs rather than the corporations'. Only through such positioning can the colonial nightmare of the molecular invasion be averted.

Risk Assessment

If techno-accidents are taken as a given, and if transgenic products are accepted or rejected on a case-by-case basis, the questions must be asked, how should research be conducted regarding transgenic products and processes, and what constitutes acceptable risk? No one can say for sure what the fallout of any new technological direction may be, but some hypotheses are significantly more educated than others, and useful theories exist about what constitutes rigorous scientific study and statistical analysis in the various specializations in biology.

Currently, research standards for product safety regarding transgenic products that produce toxins in the US are unquestionably unacceptable for a number of reasons. The most obvious reason is that corporations do their own studies, which are used to apply for product and mass cultivation approval from the Environmental Protection Agency (EPA) and the United States Department of Agriculture (USDA). The conflict of interest is rather obvious. Allowing corporations to partially police themselves when the possibility of a potential accident is so high does not seem to be in the public interest. When a corporation wants a product approved, it does test studies and submits the results to regulating agencies. The agencies *review* the data (as opposed to replicating the study), and decide whether or not approval should be awarded. Testing from independent sources is not required, but it should be. The tests should not be left to the corporations, nor should they be left to even a single independent agency.

The problem appears worse when the nature of the studies themselves is examined. Problems arise both in sampling procedures and in study replications. The conflict among scientists over the danger level of *Bt* products stems from these very problems. The *Bt* studies (whether positive or negative results were obtained) were small in scope, and did not have the "statistical power" to yield convincing results. Moreover, the replications of the studies for purposes of comparison were typically very few in number. For example, Calgene's *Bt* cotton studies that were used to obtain product approval for commercial scale cultivation consisted of four replications, which is hardly enough to produce a basis for measurement and reliable data by any standard of scientific rigor. The EPA has recognized the problems of statistical power and study replication, and is at least working on guidelines to measure the impact of a product on nontarget organisms, but this alone will not be enough. The complexity of the systems under study cannot be successfully examined under general guidelines. Each product study will require its own unique set of guidelines. Even the scientific advisory panel appointed by the EPA believes this to be true. Neither the government nor the corporations want such guidelines, due primarily to cost.

The final problem is that these studies give only immediate data rather than cross-temporal data. To return to the Calgene example, its study of the effects of soil toxicity on earthworms was carried out over only 14 days. An earthworm lives for years. This study could not measure long-term effects, nor could it reveal what the toxin levels might do to subsequent generations. A proper study must at least last for the duration of an organism's lifespan, if not longer. If the studies have proper cross-temporal observation, sampling procedures, replications, and reliability studies, and find no negative results, the product could be construed as reasonably safe for mass cultivation. Will such cautionary measures be introduced? It is very unlikely.

The problem, of course, is that neither the government nor the corporations will cooperate with such safety standards. The biotech companies complain that they are being unfairly targeted by demands for impossible procedures that are placed as a burden upon them solely as a means to calm public hysteria. Further, they complain that other products are not put through such rigorous testing, and that to do so would raise the cost of bringing a product to market to unacceptable levels. However, most products do not appear to have the accident potential that certain transgenic products do. To compare a toxin-producing transgenic plant to even another insecticide is a false analogy. While they may both have the potential for ecological disturbance, an insecticide does not have the same potential for long-term disruptive genomic and reproductive consequences.

Given the financial power that biotech corporations have, their profound lobbying capabilities, and the grip that they have already gotten on the worldwide food supply, it seems unlikely that the public interest will play much of a role in policy construction, unless focused, informed resistance forces the issue. However, democracy, as useless as it usually is, is worth a try in this rare case. It would be possible to mount a popular front (from radicals to moderates) that could focus pressure on the EPA and USDA about testing procedures.[2] More stringent research would have the effect of slowing the spread of GMOs. But for the public to unite in this manner a great deal of consciousness raising has to occur. The corporate complaint that the public is "hysterical" is not totally without merit. This is where cultural production will play a major role. It has the pedagogical power to present information in a compelling way that can reveal the exploitive capitalist subtexts of GM production, teach the science at amateur levels, replace either/or, categorical judgments ("Are you for transgenics or against it?") with tactical analysis, and redirect fears into informed resistance. Of course, using resistant cultural production in the hopes of building a democratic popular front is more or less a utopian strategy. Other methods of direct resistance by small collectives and resistant cells have to be developed as well if inertia is to be introduced into the systems of GMO distribution.

Notes

1. Of all the arguments against rapid deployment of GM products, the health issue is the least convincing. Currently, the two main worries are the production of allergens and carcinogens in food. However, this concern is not grounds for an argument against the use of GM food in particular or GM technologies in general. The argument that can be reasonably made is for proper product labeling (another thing that food-producing biotech companies tend to resist). What the body can mingle with, carcinogen or not, should be a matter of individual choice, and not legislated. At the same time, the public should have the maximum amount of information available on a substance in order to make the decision that is best for each individual. Having such matters legislated just gives the security state more power in an area (body control) where it has far too much to begin with.

2. CAE cannot emphasize enough the need for focused pressure: Find the weak points and concentrate efforts there. Bioresistance will be most successful when the weakest link in the product chain is identified and popular political capital is focused upon it. These links tend to be at points where the corporations have the least amount of direct control.