

## The necessary “GMO” denialism and scientific consensus

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### Abstract

“Genetically Modified Organisms” are not a consistent category: it is impossible to discuss such a miscellaneous bunch of products, deriving from various biotech methods, as if they had a common denominator. Critics are too often pre-emptively suspicious of peculiar risks for health or the environment linked to this ill-assorted ensemble of microorganisms, plants or animals: yet, even before being unscientific, the expression “GMO(s)” has very poor semantic value.

Similarly, claims that recombinant DNA technology is always safe are a misjudgement: many unsatisfactory “GMOs” have been discarded, as has happened also for innumerable agri-food outcomes, obtained via more or less traditional field and lab methods.

The scientific consensus, i.e. the widespread accord among geneticists, biologists and agriculturalists, maintains that every biotech invention has to be examined case by case, evaluating the unique profile of each new organism (“GMO” or otherwise): to assess its safety, the technique(s) used to produce it are irrelevant.

Therefore, in considering “green” biotechnologies, a triple mantra should be kept in mind: 1. product, not process; 2. singular, not plural; 3. *a posteriori*, not *a priori*.

Both people’s and law-makers’ attitude to agricultural biotechnologies should be reoriented, and this is an interesting task for science communicators: they should explain how meaningless and misleading the “GMO” frame is, debunking a historical, ongoing socio-political blunder, clarifying to the public what most life scientists have been recommending for several decades.

### Keywords

Public understanding of science and technology; Representations of science and technology; Science and policy-making

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### “GMO(s)” is a pseudo-category, a semantic trap

Technologies and their outcomes, in their incessantly changing dynamics, must be constantly supervised and regulated, due to the effects they have on the environment and the frequent risks they involve for human health. Even more so for biotechnologies, whether they are “green” (agricultural), “red” (medical-pharmaceutical) or “white” (industrial).

In the agri-food area, various techniques have been used for millennia with the aim of changing and improving plants and animals. The traditional methods

— crossing, hybridization, grafting — are still used but, in recent decades, powerful new means have boosted the production of food, feed and fiber: advanced lab techniques such as tissue culture, physical/chemical mutagenesis and recombinant DNA approaches have been developed. More or less direct and targeted ways are currently used to manipulate microorganisms, cells, seeds or genomes in order to cancel undesirable characteristics (i.e. allergenicity or toxicity) or to add useful phenotypic traits (e.g. resistance to pests, herbicide tolerance, improved nutritional properties, better performance under abiotic stress such as flooding, drought, heat and climate change).

Since the mid '70s, scientists have been proposing that any evaluative and regulatory approach concerning biotechnologies (“green” or otherwise) be focused on the pros and cons of each single *product*. The peculiar characteristics of new varieties of plants or microorganisms or animals, as a matter of fact, do not derive from the *processes* used to create them [Ammann, 2014]. The calls of geneticists and biologists [Barton et al., 1997; Miller, 2010; Potrykus, 2010] and the numerous statements issued by scientific societies [APS, 2001; ASCB, 2009; ASM, 2000; ASPB, 2006; NRS, 2001]<sup>1</sup> do not urge a general hazardous deregulation of biotechnologies; instead, life scientists reasonably recommend that each new organism, obtained via any method, be examined and assessed according to its unique profile of risks and benefits — ecological, economic, and related to human and animal health.

Against this background, the expression “genetically modified organisms” is basically meaningless. It was coined as a shortcut to indicate a mixed pile of agri-food products (mostly crops and vegetables) which are created using different methods to slightly modify their genetic makeup (to “recombine” or “splice” one or a few sequences of their DNA), often adding genes taken from other species (transgenesis) or created *ex-novo* (synthetic biology).

Yet, “GMO(s)” is an inconsistent term, for many reasons. There are at least five problems with any attempted definition. 1. The incoherent expression is arbitrary insofar as it does not cover many recombinant DNA products which belong to other areas of biotechnologies, i.e. “red” (pharmaceutical: e.g. insulin from engineered bacteria) or “white” (industrial: e.g. enzymes for detergents); even “green” DNA-spliced products such as some food ingredients (e.g. chymosin for making cheese), strangely enough, are not included in the “GMO” rickety fence. 2. The bogus concept is illogical because the same traits (e.g. for crops: resistance to pests, tolerance to herbicides) can often be obtained via techniques which are not pigeon-holed under the “GMO” umbrella.<sup>2</sup> 3. The watershed between what is a “GMO” and what is not is shifting and confused, and even more so because new approaches are being developed at a fast pace:<sup>3</sup> “with the advance of technology, the distinction between genetic modification and other plant biotechnological techniques gradually blurs” [COGEM, 2006, p. 4]. For instance, transitory states

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<sup>1</sup>Many other position statements at [www.isaaa.org/search/results.asp?cx=005763828013670756947%3Ag9mmea06vvc&cof=FORID%3A10&ie=UTF-8&q=Position+Statements+on+Biotechnology&sa=Go&siteurl=www.isaaa.org%2F&ref=&ss=144j20736j2](http://www.isaaa.org/search/results.asp?cx=005763828013670756947%3Ag9mmea06vvc&cof=FORID%3A10&ie=UTF-8&q=Position+Statements+on+Biotechnology&sa=Go&siteurl=www.isaaa.org%2F&ref=&ss=144j20736j2).

<sup>2</sup>We should stick to William James’ golden maxim: “A difference that makes no difference is no difference at all”!

<sup>3</sup>The latest group of techniques, which is already proving to be revolutionary, is CRISPR: see Voytas and Gao [2014].

may occur in which a DNA insertion is purposely provisional:<sup>4</sup> it is “a GMO”, no it isn’t, maybe it is, only for a bit, just for a while — useless Procrustean terminological waste of time. . . 4. There is no common denominator to unify or at least provide a common ground for so many different products and biotechnological processes [Tagliabue, 2016]. 5. When fruits and grains from “GMO” plants are processed, the results are often indistinguishable from the same “non-GMO” products, e.g. syrup, oil, starch from maize or sugar from sugar beet do not contain DNA.

Any effort to give some coherence to such bungled semantic confusion is hopeless: there is no such thing as “GMO-ness”.

Even less scientific is the will to attribute a negative connotation to the motley bunch. Not a single peer-reviewed paper has ever been published which tries to give theoretical justifications for considering the direct DNA tinkering with agri-food plants, animals or microorganisms as *inherently* dangerous<sup>5</sup> (or indeed safe, for that matter). As for the most frequently raised concern, the alleged unknown long-term effects, those who worry about that do not offer the slightest clue (a science-based one, i.e. a possible biochemical mechanism) why a genetic time bomb should be hidden inside “GMOs” — ill-defined as they are — and not in the DNA of other biotech agricultural outcomes, deriving from other kinds of genomic manipulation: there is no epistemological indication to justify a generic and *a priori* fear of any green biotechnology process or technique while, at the same time, no such attempt can be devoid of the risk of failure.

To be clear, the confirmed safety of *each single* product coming from biotechnologies (recombinant DNA or otherwise; agricultural or otherwise) does not warrant the belief that a negative impact on the environment or health cannot appear in *other* future products, even if they are very similar. It is correct to say that the outcomes from biotech manipulations (“GMO” or otherwise) are unpredictable: yet, while this is true, it is also irrelevant. We do not need preliminary and impossible certainty about the safety of this or that green biotechnology method: accurate examination of the conclusions from each individual experiment can give us a decent guarantee that introduction into the environment, and/or into the food and feed chains, of new agri-food inventions takes place at minimal risk. Any authorized food safety operations must follow the standards established by the Codex Alimentarius, which is the international authority set up jointly by the Food and Agricultural Organization (FAO) of the United Nations and the World Health Organization: such detailed criteria dictate the necessary analyses and tests to be performed on each new food *product* once a breeder creates it (*ex-post*) and does not consider — *must not* consider — *ex-ante* the technique(s), the *process(es)* used during the experiments. Interestingly, the Codex *ad hoc* committee which was established to write the guidelines for the safety assessment of foods derived from biotechnology [Codex Alimentarius Commission, 2003–2008; and Codex Alimentarius Commission, 2008] drew up the requested documents, and then was

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<sup>4</sup>*Delitto perfetto* is the witty name (exploiting the assonance with the term *deletion*) given to one particular procedure in which, at a certain step, a few DNA sequences are inserted in the genome of a target organism and then cancelled. See Storici and Resnick [2006].

<sup>5</sup>Of course, the situation is different if we consider “black” biotechnologies (dealing with pathogens for military purposes) or even some objects of “red” biotechnologies (e.g. dangerous viruses or bacteria that must be kept under strict control).

disbanded. Of course, those instructions are a repetition of those to be followed for *any* food, according to different profiles of risk, because there is no reason to think that “GMOs” should be treated differently.

Thus, if this or that new vegetal variety, or micro-organism, or animal, proves to be unsatisfactory, we will simply discard it: that is exactly what we have done in the past in various cases, getting rid of ill-fated “GMO” varieties of barley, canola, maize, potato, rice, wheat, etc. and traditional ones, of squash, celery and potato [Haslberger, 2003, pp. 739–740; Kuiper et al., 2001, p. 516].<sup>6</sup> Here, the meaninglessness of any imaginary gap between recombinant DNA cultivars and other similar products is fully evident, as it is replaced by a meaningful divide between healthy foods/feeds and problematic or invalid ones — which end up in the waste bin.

The oft-cited acronym “GMOs” is therefore void of semantic and scientific reference: it does not indicate a group of products with even a minimal degree of homogeneity. Thus, the disordered lot cannot be subject to any all-encompassing evaluation with regard to the supposed safety, or lack of safety, of “GMOs” as a whole. The same consideration applies to the important issue of the environmental impact of any new cultivar or animal; again, the necessary assessment must be done case by case: “genetically engineered organisms should be evaluated and regulated according to their biological properties (phenotypes), rather than the genetic techniques used to produce them.” [Tiedje et al., 1989].

Therefore, a supposed watershed between rDNA products and the rest of the agri-food world is unscientific, as factually and theoretically inexistent: that tangled mix of techniques and products which has been contortedly framed as “GMO(s)” is incoherent on epistemological grounds and counterproductive in the real world.

Yet, generic fears regarding this bogeyman are widespread: prudence is often invoked — and frequently stated by law — with regard to recombinant DNA organisms and not all the others. To understand why, we need to examine better what I would call the “GMO” *solid nothing*.

**“Illicit pluralization” as a logical fallacy**

The inevitable confusion on what “GMOs” are supposed to be (the first error we explained) is therefore massive. However this is not the most relevant point, because the second common mistake to be fought is much worse: “some GMO crops, when fed to animals, have exhibited harmful effects” [Krimsky, 2015, p. 884]. Why does the author feel the need to underline that a number of cultivars, which are allegedly noxious, are “GMOs”? Is this or that recombinant DNA technique (don’t forget there are many, and not easily placed before or after the blurry “GMO” border) at the origin of the alleged problems? As already pointed out, we have lists of negative outcomes from more or less traditional biotech methods: a statement such as “some *hybridized* crops have exhibited harmful effects”, as is perfectly true, does not reasonably suggest that we should be pre-emptively wary of any attempt at crossbreeding. Again, “GMO-ness” — some *process(es)* — is given as a source of concern, without any credible justification; it is taken for granted, without any explanation: most probably, no such rationale exists.

<sup>6</sup>See also other examples of “Discontinued Transgenic Products”, in a list which is not recent but valid: <http://cls.casa.colostate.edu/transgeniccrops/defunct.html>.

To better understand this crucial and very common misunderstanding, let's examine a class of agri-food products which are obtained through two well-defined methods, i.e. physical and chemical mutagenesis; here the distinction — as far as the description of the interventions is concerned — is clear: such vegetal varieties, which number some thousands,<sup>7</sup> derive from fortuitous results obtained by systematically exposing great quantities of cells or seeds or seedlings, of many crops or vegetables or ornamental varieties, to sources of mutagenesis, i.e. radiation or certain chemical elements. Yet, this clear definition of a group of biotechnologies cannot give us any hint at all of the possible outcomes from single experiments: technicians place several lines of different crops at increasing distances from a radiation source in a field [Dick and Jones, 2012, with images of "atomic gardens"] and provide various levels of irradiation,<sup>8</sup> following specified timetables; or they manage cells and seeds in a lab, exposing them to various sources of radiation or to carefully assessed quantities of mutagenic chemicals. Then the outcomes are checked: in almost all cases, the genomes are scrambled in ways that the organisms die or are irretrievably warped; sometimes — alas, not so frequently! — one or a few survivors are able not only to stay alive, but even to show interesting new phenotypic traits, e.g. resistance to certain pests or tolerance to herbicides (note that to obtain such results we often do not need to create "GMOs"). Such "happy" results, whose genomes have randomly and successfully reorganized themselves, are carefully treated like precious living nuggets, then cloned and multiplied in billions of plants of commercial value. Now, let's suppose that a few of such new cultivars with interesting added features, when properly tested, prove to be allergenic or toxic: the phrase "some mutagenized crops have exhibited harmful effects", while empirically correct, would not cast any doubt on the technology *per se*; those ill-starred results would be ditched, full stop.

Therefore, there is no point at all in stressing that certain "losers" are "GMOs". A few studies supposedly show that this or that "GMO" is noxious: while we must not forget that those alleged results have been heavily criticized by many scientists as invalid, let's take them at face value. Pusztai's reportedly poisonous potatoes and Séralini's supposedly cancer-inducing maize should be banned, without wanting to involve all "GMOs" in the anathema: "Even if it were demonstrated that Pusztai's conclusions were correct, namely, that GM potatoes containing the gene for lectin have detrimental effects on the immune system, metabolism and organ development of rats, this would not justify a general conclusion that all GM foods are dangerous to human health." [Krebs, 2000]. A micro-lesson in elementary logic; a simple way of reasoning which is sorely absent in the blanket "anti-GMO" propaganda.

Consequently, any attempt to assess the safety of "GMOs" — or of any other more or less botched pseudo-category of agricultural products *as a whole* — is simply nonsensical, unless someone shows that bad outcomes are inherently linked to the fact that such reportedly negative outcomes are DNA-spliced: the very connection which is missing.

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<sup>7</sup>The complete data base is available at <http://mvgs.iaea.org>.

<sup>8</sup>The irradiation aimed at mutagenizing crops, to create "prototypes" of new cultivars ([https://en.wikipedia.org/wiki/Mutation\\_breeding](https://en.wikipedia.org/wiki/Mutation_breeding)), must not be confused with the irradiation of certain foods ([https://en.wikipedia.org/wiki/Food\\_irradiation](https://en.wikipedia.org/wiki/Food_irradiation)), a routine treatment, variously disciplined in different countries, to destroy possible pathogens or to delay the shelf life.

One last example should ultimately expose the misunderstanding. Are mushrooms safe? Anybody can see that there is no rational content in such a question. If we reject a mushroom species as poisonous, the ban would not apply to all mushrooms. Please note that “mushrooms” is a category with some taxonomic value; “GMOs”, instead, is nothing more than a semantic trap.

Thus, again, each new rDNA organism (or any other, for that matter) must be assessed on its own; any “illicit pluralization” should be erased from our minds. There is no such thing as “GMO-ity” or “GMO-ness”: in this sense, we *must* all be “GMO” deniers!

While being “anti-GMO” is meaningless, the situation is a little different for those who declare they are “pro-GMO”: this is basically an unfortunate shortcut to mean that one is “pro-biotechnologies”; it should not be used, as it reinforces the perception of significance of a bogus and misleading kind. Unfortunately, the expression is frequently adopted by the media, when a necessarily nuanced position, which is typical of the scientific attitude, is brutally reduced to a rough-hewn label, in an attempt to over-simplify contending opinions.

A recurrent mistake of “pro-GMOers” is to maintain that the results of recombinant DNA manipulations are “more predictable”: this is true in a statistical sense, if we compare the time and resources necessary to create a transgenic cultivar and, say, a mutagenized or hybridized one; but we should not engage in useless never-ending discussions on a general forecast for what may be the more probable outcomes of different methods. Biotechnologists, while carefully taking advantage of previous experiences and accumulated knowledge, just try and see — as breeders have done since the beginning of domestication of plants and animals. Moreover, also claiming that DNA-splicing is “more precise” — which is true — is no guarantee of safe results: we should not forget that massive phenotypic consequences — frequently undesirable — can derive from even the slightest change in an organism’s genotype. We will name this clever remark “Schubert’s warning”, from the name of the biologist who called attention to it [Schubert, 2002]. Sadly, this scientist did not clarify a crucial corollary of his correct statement: that such risk of failures from even little tweaks to a genome applies to each and any intervention, not only to “GMOs”.

Even shakier is the statement “The recombinant DNA technology is safe”: the aforementioned lists of discarded “GMOs” show that the opposite is sometimes true. Again, no biotechnology — traditional or otherwise — gives a guarantee of success. But we should not be so preoccupied: in agri-food biotechnologies we are not dealing with infective microbes or pathogenic viruses, where an incorrect manipulation can have dire consequences; once a positive result (in transgenesis a lucky outcome is called an “event”) has been thoroughly checked out, the “prototypes” of new cultivars can be propagated and commercialized with a reasonable certainty that they are safe.

Ironically, a real danger is inherent in the use of the already mentioned double technology nobody is worried about: in experiments of physical/chemical mutagenesis, operators must follow strict safety procedures while using radiation and nasty chemical substances — a peril that does not exist with green recombinant DNA practices. To be sure, once the reactors have been stopped and the poisonous

chemicals have been stored, the outcomes show no trace of their origin: although one of the crown jewels of mutagenesis is the Italian variety of wheat named Creso [Bozzini and Bagnara, 1974], we are not eating radioactive spaghetti!

**Scientific  
consensus: a  
concept not to be  
misused**

An important collateral issue which is frequently linked to the “GMO” debate is the “scientific consensus” concept.

To start, we should simply stick to the meaning of the word: “consensus” is defined as “a generally accepted opinion or decision among a group of people”.<sup>9</sup> Therefore, it must not be confused with “unanimity” — which is a condition very rarely achieved in any human activity, let alone in scientific debates. Such an inappropriate semantic shift is often performed by “GMO” sceptics. For instance, the American Association for the Advancement of Science released a statement against the mandatory labelling of “GM” foods, arguing that such an obligation “can only serve to mislead and falsely alarm consumers.” [AAAS, 2012] Twenty-one scientists took a contrary position.<sup>10</sup> Commenting that “[t]his episode underlined the lack of consensus among scientists about GMO safety” [ENSSER, 2013, p. 4] is utterly wrong, because the word “consensus” is definitely misused. While the dissenters have every right to clarify their position, the factual truth is that the overwhelming majority of their colleagues (the AAAS numbers 125,000 members) think differently. This is what “consensus” is all about — in plain English and in any other language.

Are the quasi-totality of scientists wrong, while the very few opponents are unheeded prophets? It is possible: maybe time will tell. What we are pointing out here is simply the correct use of the word “consensus”.

Similarly, the safety of *currently commercialized* “GMO” crops (not of “GMOs” *per se*) is affirmed by most scientists, therefore talking of a consensus on such an issue is clearly correct. As we have already argued, this point is not very significant because the “GMO” safety issue should evaporate as nonsensical in favour of what actually matters, i.e. the safety and environmental sustainability of each and any agri-food product. Instead, it is claimed again that there is “no scientific consensus on GMO safety”, because “the scarcity and contradictory nature of the scientific evidence published to date prevents conclusive claims of safety, or of lack of safety, of GMOs” [Hilbeck et al., 2015]. Here, both the misuse of the meaning of “consensus” (after all, a venial sin) and the illusory reality of the inexistent “GMO” category (the real deadly sin!) are fully evident.

Two remarks are mandatory.

One. Talking about the “scarcity” of consensus to be found in papers regarding the safety of *presently traded* “GMOs” is not correct: just compare the number of studies listed in the wider review of the scientific publications on the subject, which amounts to 1,783 records over a decade (“the scientific research conducted so far has not detected any significant hazard directly connected with the use of GM crops.” [Nicolia et al., 2014, p. 85]), generally confirming such safety, with the 26 opposing articles which have been collected [Krimsky, 2015, pp. 894–897].

<sup>9</sup><http://dictionary.cambridge.org/dictionary/english/consensus>.

<sup>10</sup>[www.environmentalhealthnews.org/ehs/news/2012/yes-labels-on-gm-foods](http://www.environmentalhealthnews.org/ehs/news/2012/yes-labels-on-gm-foods).

A brief consideration regarding the alleged deficiency of tests of recombinant DNA organisms must be added. There are no assortments of products that are checked and controlled as agri-food “GMO” products are, ill-defined as they may be. Those who call for a never-ending health and environment assessment of this supposed ensemble of cultivars should demand thorough testing of many “natural” foods, which are *certainly* allergenic to a significant percentage of us (kiwis, peanuts, eggs, etc.). Instead, only recombinant DNA products are subject to suspicion. Yet, the European Union invested a large amount of public money, over a quarter of a century, to commission a goodly number of studies that reached an unequivocal result: “The main conclusion to be drawn from the efforts of more than 130 research projects, covering a period of more than 25 years of research, and involving more than 500 independent research groups, is that biotechnology, and in particular GMOs, are not *per se* more risky than e.g. conventional plant breeding technologies.” [European Commission, 2010, p. 16] This is another example of the actual scientific consensus.

Two. The main misjudgement is demanding “conclusive claims of safety, or of lack of safety, of GMOs”, or even imagining that such conclusions could theoretically and practically be assessed. We invite the reader to undertake a very simple experiment. Please read the following phrase carefully and fill in the blank space with whatever heterogeneous category of agri-foods you can imagine: “We hereby demand scientists to produce conclusive claims of safety, or of lack of safety, of \_\_\_\_”. Did you choose to write “cross-bred cultivars”? “Grafted plants”? “Natural fruits gathered in the wild”? It should be easy to see that the statement cannot make sense anyway because any such class, in general and pre-emptively, cannot *by definition* be assessed to be safe or unsafe *as a whole*.

The statement containing the wrong question, as of 20 January 2015, had been signed by 313 people (quite a few of them are medical doctors — hardly agricultural biotechnology experts): the aggregate number of members of the many life sciences academies around the world, which have officially endorsed a “product, not process” and “case by case” approach to the evaluation of agri-food biotechniques,<sup>11</sup> amount to hundreds of thousands. We may roughly compare the two figures and conclude what the current prevailing opinion is, at least among specialized scientists.

Therefore, it is very important to understand that the actual scientific mainstream view is related to the need for a logical unlinking of the single results of biotechnological experiments (each *product*) from whatever method that may be used, or a combination of them (the *processes*): thereby looking for promising outcomes, whose pros and cons can be ascertained only after each attempt, and of course prior to the launch of new agri-food inventions onto the market.

**An engaging  
undertaking for  
science  
communicators**

An interesting task for science communicators is to explain how absurd and counterproductive the “GMO” imbroglio is. While this is not the place to discuss the reasons of the tireless and successful action of many anti-biotech organizations, it should be clear that the “GMO” meme has distracted the public perception of agricultural biotechnologies for too long. People’s attitude should be reoriented,

<sup>11</sup>See note 2 above and the related text.

deflating any misplaced fears and encouraging the comprehension that the reasonable concerns over new varieties of plants, animals and microorganisms must focus on the risks and benefits of each agricultural *product*, without any pointless reference to the *processes* used to create them.

This message should be sent also to lawmakers, since the existing agricultural biotechnology regulations are almost always biased, showing a strong and unjustified “anti-GMO” approach. Yet, a rational and science-based technical-legal framework is already available: the Stanford University Project on Regulation of Agricultural Introductions [Barton et al., 1997; the Model has been updated: see Conko et al., 2016] is the result of the participatory work of a number of scientists from several countries. The guidelines for careful well-calibrated risk assessment of new cultivars are explained; to ascertain the pros and cons of each new plant, the different biotech methods are considered irrelevant: the “GMO” blunder is not even mentioned. As for field tests, sensible questions are provided regarding the ecological impact (to what extent is the plant potentially invasive?) and the health issues (what exams need to be performed to evaluate possible allergenicity or toxicity?). As the vast majority of scientists recommend, the norms at all geographical levels should be rewritten, thus uprooting the bizarre “anti-GMO” fence, re-harmonizing the due analysis and careful supervision, applying the rules — with the necessary strict criteria — impartially on each and every product (“GMO” or otherwise), once created, irrespective of the biotechnological techniques used: “A future regulatory framework should be product rather than process based so that it is consistent and applies to the novelty of the characteristics of new plant varieties” [EASAC, 2013, p. 32].

It is clear that life scientists have not been adroit in teaching the triple mantra that must be applied to agri-food biotechnologies (“GMO” or otherwise): 1. product, not process; 2. singular, not plural (or: case by case); 3. afterwards, not beforehand (for those who appreciate a little Latin: *a posteriori*, not *a priori*). Science communicators should fill the gap and heal the cognitive wound: they should accept the important challenge of explaining a huge semantic and scientific mistake, revamping the public understanding of green biotechnologies, for the benefit of societies at large.

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