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**Fatal attraction: The intuitive appeal of GMO opposition**

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1 **Public opposition to genetically modified organisms (GMOs) remains strong. By contrast,**  
2 **studies demonstrate again and again that GM crops make a valuable contribution to the**  
3 **development of a sustainable type of agriculture. The discrepancy between public opinion**  
4 **and the scientific evidence requires an explanation. We argue that intuitive expectations**  
5 **about the world render the human mind vulnerable to particular misrepresentations of**  
6 **GMOs. We explain how the involvement of particular intuitions accounts for the**  
7 **popularity, persistence and typical features of GM opposition and tackle possible**  
8 **objections to our approach. To conclude, we discuss the implications in science education,**  
9 **science communication and the environmental movement.**

10

## 11 **Explaining public opposition to GMOs**

12 Concerns about health, environmental and socio-economic hazards have resulted in a strong  
13 public opposition to genetically modified organisms (GMOs) [1-3]. These worries tend to have a  
14 large impact on national and international policies. For instance, in India, the government  
15 suspended the culture of *Bacillus thuringiensis*-engineered *Solanum melongena* (*Bt* brinjal),  
16 despite the initial approval for commercialization [4]. In Europe, the lack of public support for  
17 GMOs has led to a *de facto* moratorium within the European Union on new GM crops from 1999  
18 to 2004 and has steered the development of an extremely strict and expensive regulatory  
19 framework concerning the import and cultivation of GM crops [5]. In Africa and Asia, the  
20 resistance to GMOs has had tragic consequences, costing thousands of lives [6, 7].

21         However, research shows that cultivation of GM crops does not pose any specific health  
22 or environmental risks, but instead can bring benefits to local farmers [8-11]. The reason for the  
23 discrepancy between public opinion and scientific evidence needs clarification. Some people  
24 suggest that post-Christian beliefs or romantic notions of nature are responsible, whereas others  
25 blame the lack of direct benefits for Western consumers [6, 12, 13]. These accounts are definitely  
26 on the right track. Nonetheless, they fail to explain why opposition also occurs in non-Christian  
27 cultures, why people do not reject every technology that brings no immediate benefits or why  
28 people prefer romantic views in the first place.

29         Here, we suggest a cognitive approach to account for the opposition to GMOs. In other  
30 words, we use ideas from the cognitive sciences, evolutionary psychology and cultural attraction  
31 to rationalize the popularity and typical features of this phenomenon. We argue that intuitions  
32 and emotions make the mind highly susceptible to particular negative representations of GMOs.

33 We suggest ways to rectify the current situation and improve science education and  
34 communication.

35

### 36 **An intuitive understanding of GMOs**

37

38 Although generally we feel as if we control willfully what we think and do, much of our thinking  
39 depends on intuitions, of which the working largely stays below the radar of conscious  
40 awareness [14]. Among other things, these intuitions, which evolved in response to particular  
41 adaptive situations, automatically shape expectations about the world or induce reflexive risk  
42 assessments [15]. Under ecologically relevant conditions, these intuitions tend to generate  
43 rational responses [16], but, when confronted with abstract and complex situations, these  
44 intuitions tend to break down [17]. For instance, people are more easily scared by spiders than by  
45 cars, although in modern society the number of mortal car accidents is much higher [18]. As to  
46 our understanding of the world, cognitive predispositions can result in deeply engrained biases  
47 that, if not dealt with by education, lead to persistent resistance to contra-intuitive scientific  
48 theories in adulthood. Dualist intuitions, for instance, make it difficult to accept that mental  
49 states result from physical processes [19]. Nevertheless, our thinking relies on at least two types  
50 of reasoning processes. Besides the fast and automatic intuitions described above, humans can  
51 resort to an effortful and reflective type of reasoning that allows them to consciously evaluate  
52 and relate different information types [14, 20, 21]. By exercising this reflective capability and  
53 thanks to the development and use of social and epistemic methods, tools and practices, scientists  
54 have been able to tweak and build on their intuitions and, thus, to gain a more objective and  
55 scientific understanding of the world [22-24].

56           The intuitive mind is not well equipped to address intricate questions, such as “What is  
57 biotechnology?”, “How does it work?” and, most importantly, “Is it dangerous?” The ability to  
58 understand such issues and, hence, to have a subsequent objective and rational judgment requires  
59 an important effort and, even then, the mind is still liable to relapse into biased thinking. Lay  
60 people are often unable or are simply not interested in investing large amounts of time and  
61 energy to acquire a profound grasp of complex technologies. Therefore, when lay people are  
62 confronted with and have to evaluate information about GMOs and the risks involved, they will  
63 predominantly rely on their intuitive mind. As a result, lay people tend to prefer GMO  
64 representations that are most in line with their intuitive expectations, because these are easier to  
65 understand and remember. Anti-GMO groups have successfully tapped into people’s intuitions to  
66 promote their cause, thus making their campaign highly attractive to the human mind [Box 1].

67           Below, we explore which intuitions make people vulnerable to GMO antagonism and  
68 show how our approach explains the popularity, persistence and typical features of the GMO  
69 hostility and also briefly counter some objections that might be raised. Finally, the implications  
70 for science education, communication and the environmentalist movement are discussed.

71

## 72 **The intuitive appeal of anti-GMO representations**

### 73 *Folk biology*

74           The human mind intuitively understands how the biological world functions. One constituent of  
75 this folk biology is psychological essentialism [25] that amounts to the belief that organisms hold  
76 an unobservable, immutable core determining their identity and, thus, their development and  
77 behavior. Psychological essentialism makes sense evolutionarily, because it allows individuals to  
78 categorize automatically the biological world. As such, valuable information becomes

79 immediately available, enabling apt responses to living entities in the environment. For instance,  
80 when one is confronted with a tiger, the immediate realization that one is coping with a specimen  
81 of the category “tiger” and, thus, that with its mighty claws and sharp fangs it might catch and  
82 eat its prey, is a more adaptive reaction than to reassess each and every encountered stripy feline  
83 [26]. Nevertheless, in spite of the obvious adaptive rationality of this cognitive predisposition,  
84 psychological essentialism regularly interferes with a scientifically informed biological  
85 understanding [27]. Notoriously, it impedes people’s understanding of basic aspects of  
86 evolutionary theory, but it also affects people’s comprehension of GMOs, primarily because they  
87 interpret DNA as the essence of organisms [28]. In a United States survey, more than half of the  
88 respondents did not reject the idea that tomatoes whose genome had been modified to insert the  
89 DNA of cat fish would taste like fish [29]. Apparently, people assumed that the fish’s essence  
90 had been introduced into these tomatoes, including a fishy taste. That people systematically  
91 prefer cisgenic over transgenic organisms provides another indication of an essentialist bias [3].  
92 In their campaigns, opponents of GMOs explicitly appeal to these essentialist intuitions by  
93 distributing edited images of tomatoes with fish tails or by claiming that biotech companies  
94 insert scorpion DNA elements into corn (*Zea mays*) to produce crispy corn flakes. The notion  
95 that growing GM crops with herbicide tolerance will promote so-called superweeds falls back to  
96 the same misconception that a weed can be characterized by a single gene. On the contrary,  
97 typical weed characteristics, such as withstanding harsh environments, competing for light, water  
98 and minerals and fast reproduction are the result of the interplay of numerous genes.

99

100 *Teleological and intentional intuitions*

101 Another aspect of the intuitive mind that affects people's preferences for particular GMO  
102 representations and the perception of the risks involved are teleological and intentional  
103 intuitions. These intuitions tend to translate in religious beliefs, but they can also contribute to a  
104 quasi-religious view on nature [30, 31]. Indeed, large parts of Europe, where the resistance  
105 against GM food is strong, are highly secular. In the cognitive science of religion, religion is  
106 commonly assumed to be a byproduct, generated by the peculiarities of our mental make-up that  
107 includes essentialist thinking, but that is also highly receptive to the feeling that the world has  
108 been designed for a particular purpose [32-35]. This design illusion has effectively been  
109 debunked by evolutionary theory, but the mix of essentialist, teleological and intentional biases  
110 continues to allure a lot of people in believing that a certain order exists in nature that should not  
111 be meddled with. Indeed, genetic engineering is considered the opposite of "natural" [3, 36].  
112 GMO opponents accuse scientists who produce transgenic plants of "playing god" and condemn  
113 their acts as "against nature". Biotech food is often referred to as 'Frankenfood', suggesting that,  
114 just as with Mary Shelley's artificial creature, the technology will escape the control of the  
115 haughty scientists and result in horrific environmental doom scenarios.

116

### 117 *Emotions*

118 A category of mental features that particularly interferes with people's risk assessment of GMOs  
119 are emotions. Disgust is especially important in this context. Particularly, revulsion may  
120 influence the reactions to GMOs because people object more to GM food than to GMOs  
121 developed for other applications [37]. Disgust evolved probably in response to adaptive  
122 problems related to pathogen and poison avoidance [38-40]. The evolutionary rationale explains  
123 why the emotion is on a hair trigger: To forego a nutritious meal because it is erroneously

124 considered toxic or contaminated is potentially far less harming than to consume spoiled food  
125 under the misguided assumption that it is perfectly edible [40]. Hence, distaste can be elicited by  
126 food that is completely innocuous. Indeed, food taboos offer clear examples of disgust regulated  
127 by cultural conventions, often involving meat derived from animals that are fit for human  
128 consumption, but considered vile and dirty. In experiments, scientists induce revulsion by  
129 presenting orange juice stirred with a sterilized cockroach or dog feces-like shaped caramelized  
130 biscuit spread [41]. In the case of GM food, feelings of disgust possibly arise because of  
131 psychological essentialism by which people intuitively interpret gene modification as an  
132 unwarranted and contaminating intervention into the organism's essence, rendering the organism  
133 impure and, therefore, no longer consumable. The effect will probably be enhanced when the  
134 introduced DNA comes from a different species, or a species that is considered dirty. Anti-GMO  
135 activists bombard the public with edited images that imply that GM foods cannot be trusted, such  
136 as tomatoes with syringes or suspiciously blue biotech strawberries amid fresh red ones. *Bt* crops  
137 are described as poisonous and instigate the fear that biotech crops will "contaminate" the  
138 surrounding environment. Moreover, disgust also affects our moral judgment [38, 40, 42].  
139 Hence, the emotion incites people to condemn not only the GM food itself, but also the  
140 producers and developers of GM products as immoral. Linking socio-economic abuses to GM  
141 products has become today's major focus of the anti GMO critique. To trigger moral disgust,  
142 stories are brought up of big multinationals that chain farmers to ruthless contracts and patents or  
143 even push resource-poor farmers into debt and suicide after they have been "seduced" to buy the  
144 'killer' seeds. Plant biotech research institutes are pictured as a scientific community that burns  
145 tax money while becoming totally dependent on research contracts with the big industry. The  
146 current socio-economic implantation of GM technology into agriculture merits further analysis,



147 because this issue raises important questions about the place and role of science in our complex  
148 society. For instance, how should science relate to industry? Nevertheless, the current situation is  
149 certainly not as black-and-white as activists pertain, and it is plainly wrong to call a single  
150 breeding technology the cause of these complex issues.

151

### 152 **How the opposition to GMO takes (and does not take) shape**

153

154 Some representations are more popular than others. The popularity of a representation is  
155 determined by the relevance of the information it purveys. Whether information is relevant  
156 depends on its ability to capture attention and the ease by which the mind can process it. The  
157 more information is in line with our intuitive expectations, the easier it is apprehended,  
158 remembered and, thus, communicated. As intuitions are universally shared, appropriate  
159 representations stand a greater chance of becoming widely distributed and culturally stable. At  
160 the population level, an outline emerges in which representations converge into and stabilize  
161 around hypothetical points, called cultural attractors [43, 44]. This pattern of attraction also  
162 occurs in the case of the GMO opposition. The negative representations produced by anti-GMO  
163 activists happen to reflect essentialist and intentional understandings of nature and suggest  
164 contamination, hence, becoming highly salient to the corresponding intuitions (Figure 1). Due to  
165 their aggregated relevance, these depictions will tend to outcompete the demonstrations of  
166 scientists and other experts that require an enhanced cognitive effort. As such, the anti GMO  
167 campaign has been extremely successful, not only to the surprise of scientists, but also of the  
168 instigators themselves [45].

169           The preferential adoption of negative GMO representations takes place reflexively,  
170 instantaneously, and largely under the radar of conscious awareness. However, the resulting  
171 negative affect is consciously registered and, consequently, prompts people to justify their  
172 feelings. A form of motivated reasoning emerges, in which arguments become highly prominent  
173 that are applicable equally to other technologies, but are suddenly ignored. The alleged  
174 unnaturalness of genetic engineering or the involvement of multinationals can just as easily be  
175 applied against medical biotech applications, but only seem relevant in the case of GMOs. Other  
176 arguments make sense because they are attuned to particular components of the mind's intuitive  
177 appraisal. To a mind that is primed with feelings of disgust, it seems evident that GMOs can  
178 provoke sickness or contaminate the environment. [Box 2]

179           Nevertheless, intuitions interact with other sensitivities and with the cultural  
180 environment. For instance, people who may reap direct and considerable benefits from the  
181 development and commercialization of GM products will become apt to adopt more positive  
182 viewpoints. Moreover, they may trust information sources, such as scientific reports that  
183 demonstrate that GMOs are safe and even beneficial. As such, the human mind is not  
184 predetermined to think that GMOs are poisonous, disgusting or unnatural. However, once these  
185 negative representations become culturally available, for instance, because of intense  
186 campaigning by environmental groups or lack of any strong cultural counterforces, the human  
187 mind will be highly susceptible to them. Furthermore, because cultural attraction addresses  
188 statistical effects, we can expect intra-group varieties in the adoption of negative representations  
189 of GMOs. In a culture that predominantly opposes GMOs, members will also be present that are  
190 pro, and vice versa. Indeed, the opposition to GMOs is not everywhere as strong as it is in  
191 Europe, although it is more common than people tend to think.

192

**193 Concluding remarks and implications**

194 The human mind comprises evolved intuitions that shape and constrain cultural preferences. In  
195 the case of GMOs, folk biology, religious intuitions, and emotions, such as disgust, leave the  
196 mind readily seduced by representations of GMOs as abnormal or toxic. By pointing out how  
197 public aversion to GMOs thrives on such preferences, it is understandable why people continue  
198 to resort systematically to concerns about GMOs that are scientifically unsubstantiated. With  
199 such a perspective that is not intended to characterize public worries in general as irrational, we  
200 hope that a cognitive understanding can contribute to a better insight into and perhaps a more  
201 lenient attitude toward the public's anxieties. Additionally, we expect to open up the eyes of  
202 those who reject GMOs as a whole and wish to let them realize that their concerns arise from  
203 sources that cannot be trusted *prima facie* and that the risks and benefits can only be assessed on  
204 a case-by-case basis, depending on the result and not the process [46].

205 Education can, at least to a certain extent, abate the intuitive appeal of negative GMO  
206 representations. Instruction of young people about biotechnology and its implications will  
207 require educational strategies that specifically target and tweak intuitive modes of thinking.  
208 However, this method of immunizing minds is certainly not foolproof. Intuitive thinking remains  
209 a trap, even to the minds of experts. At the same time, scientists and institutions, companies and  
210 governments that communicate about GMOs and their potential risks can also appeal to the  
211 intuitive mind. Although GMOs are at a disadvantage because they are commonly associated  
212 with unnaturalness and trigger disgust, emphasis on the benefits would effectively induce  
213 sympathy [37, 47]. Even though individual people may not always experience a personal  
214 advantage by purchasing and/or consuming GMOs, it will certainly help to inform the public

215 that, *e.g.*, (i) *Bt* corn contains less mycotoxins and is thus healthier than conventional maize [48],  
216 (ii) herbicide-resistant crops require less tilling and, thus, improve the soil quality, (iii) *Bt* crops  
217 enhance the insect biodiversity [49], (iv) biotech crops help reduce poverty in India [50], and so  
218 on.

219 Finally, our approach suggests that people who are genuinely concerned about the  
220 environment may intuitively adopt strategies that have the opposite impact on what they set out  
221 to achieve. GMOs can be a formidable tool in the realization of a sustainable form of agriculture.  
222 By leading people to choose the wrong adversaries and to urge policy makers to take counter-  
223 effective measures, negative GMO representations may indeed exert a fatal attraction.

224

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226

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- 348
- 349

350 Box 1 – The role of intuitions in cultural domains

351 The opposition to GMOs is not the only complex of beliefs that piggybacks upon folk intuitions.  
352 For instance, religious beliefs are typically explained in terms of the appeal they exert on  
353 ordinary human cognition that includes essentialist reasoning, a hyperactive agency detection  
354 system and an intuitive theory of mind [32-34]. Also pseudoscience taps into these and other  
355 intuitions, a trait that can persist in the face of scientific discovery. Creationism is anchored in  
356 essentialist, teleological and intentional intuitions and creationists even explicitly call upon these  
357 intuitions to bolster their case [51]. Pattern recognition leads us to over-detect correlations and  
358 causation, leaving the mind susceptible to all kinds of superstition, such as fear of black cats or  
359 walking under ladders. Furthermore, medical pseudoscience owes its success largely to placebo  
360 thinking by which people who are ill get better merely by thinking that they will [52]. In fact,  
361 intuitions affect a wide range of social and cultural domains, such as social institutions and the  
362 development of science [52-54]. The cases of GMO opposition and pseudoscience demonstrate  
363 that intuitions can even favour the distribution of beliefs that are flatly contradicted by evidence.

364

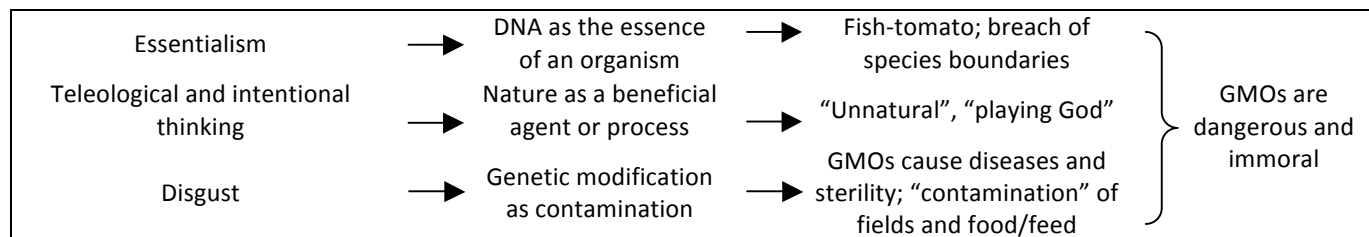
365 Box 2 - Reasonable doubt?

366 The influence of intuitions highly accounts for the typical features and popularity of the  
367 opposition to GMOs. Moreover, many of the arguments levelled against GMOs articulate  
368 concerns that clearly arise from intuitions and emotions. Other arguments only become relevant  
369 in the context of GMOs because people seek ways to rationalize their intuitively felt resistance.  
370 In turn, some of these arguments tap into and exploit moral concerns about fairness (such as  
371 multinationals exploit small farmers) and environment (such as GMOs kill butterflies) that can  
372 consequently become amplified with intuitively appealing allegations about sickness and  
373 unnaturalness. Arguments against GMOs sound even more convincing when they come from an  
374 allegedly trustworthy source, such as an environmentalist organization or a friend, or when they  
375 are popular among the social group one wants to be part of. Hence, people oppose GMOs for  
376 reasons other than mere intuitive appeal, such as trust and conformity. Are there any reasonable  
377 scientific worries to account for the opposition against GMOs? Some reports and studies have  
378 claimed that GMOs *per se* badly affect health, environment, and small farmers in developing  
379 countries. These studies, however, turned out to be unsubstantiated. Anti-GMO activists continue  
380 to refer to these studies. As such, they cloak their arguments under a scientific veil, thus  
381 exploiting the cultural authority of science. In this regard, the opposition to GMOs resembles  
382 pseudosciences, such as “scientific” creationism and homeopathy that mimic science in an  
383 attempt to gain respectability [52]. At the same time, anti-GMO activists also adopt  
384 pseudoscientific tactics to undermine the authority and autonomy of the science that contradicts  
385 their claims, for instance by overstating the impact of industry on plant sciences. As a result,  
386 people may wrongly assume that there are good scientific reasons to oppose GMOs.

387 For sure, our cognitive analysis does not render every public concern unfounded *a priori*. Some  
388 of these apprehensions can be legitimate. For instance, herbicide resistance in weeds has indeed  
389 become a problem in areas, such as the United States and Argentina where farmers have over-  
390 relied on a single herbicide-resistant crop that was tolerant to glyphosate. However, these  
391 concerns are typically unrelated to the technology of genetic modification, but result from  
392 unsound agricultural practices and policy that also can cause problems in the case of  
393 “conventional” crops. Moreover, whether a particular GM application has unwanted effects  
394 needs to be tested on a case-to-case basis, thereby focusing not on the technology, but on the  
395 resulting product.

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399 Figure 1. Unsubstantiated negative representations of GMOs tapping into intuitive preferences