10 questions about GM foods

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1. Does genetic engineering of crops increase yields?

Genetically modified (GM) crops do not increase yield potential and sometimes decrease it. While the yields of major crops have increased over recent decades, this is due to conventional breeding, not GM.[1] High yield is a complex genetic trait resulting from many genes working together in ways that are not fully understood by scientists. It cannot be genetically engineered into crops with the existing crude techniques – or with any techniques in the development pipeline. Good farming methods, such as maintaining soil fertility, are equally or more important to maximizing yields.

A study comparing agricultural productivity in the United States and Western Europe over the last 50 years, focusing on the staple crops of maize, canola, and wheat, found that the US's mostly GM production was lowering yields and increasing pesticide use compared to Western Europe's mostly non-GM production. Contrary to claims that Europe's reluctance to embrace GM is causing it to fall behind the US, the opposite is true: the US's adoption of GM crops appears to be causing it to lag behind Europe in both productivity and sustainability.[2]

2. Do GM crops decrease pesticide use?

GM herbicide-tolerant crops are engineered to survive being sprayed with herbicide, most often glyphosate-based herbicides such as Roundup. All plant life in the field is killed except for the GM herbicide-tolerant crop. Over 80% of all GM crops grown worldwide are engineered to tolerate one or more herbicides. Around 98% of commercialized GM crops are engineered to tolerate herbicides or to express Bt toxin insecticides.[3] Herbicides and insecticides are technically pesticides.

GM herbicide-tolerant crops have led to massive increases in herbicide use.[4,5,6,7,8,9] Data collected by the US Department of Agriculture shows that GM herbicide-tolerant crops have led to a 239 million kilogram (527 million pound) increase in herbicide use in the United States between 1996 and 2011, swamping the small reduction in chemical insecticide sprays of 56 million kilograms (123 million pounds) due to GM Bt insecticidal crops. Overall pesticide use increased by an estimated 183 million kg (404 million pounds), or about 7%, compared with the amount that would have been used if the same acres had been planted with non-GM crops.[5]

GM Bt crops are not even an efficient way of decreasing insecticide use in farming. In contrast with the small reduction in chemical insecticide sprays due to GM Bt crops, by 2007 France reduced both herbicide use (to 94% of 1995 levels) and chemical insecticide use (to 24% of 1995 levels). By 2009 herbicide use was down to 82% and insecticide use was down to 12% of 1995 levels. Similar trends have occurred in Germany and Switzerland. These benefits were achieved without the use of GM crops.[2]

These progressive trends do not have to mean a severe drop in yield or farmer income. A 2011 study by French government scientists found that pesticide use could be reduced by 30% through adoption of integrated agriculture techniques, with only a small reduction in production (96.3% of the current level) and without impacting farm income.[10]

Even GM Bt crops do not reduce or eliminate insecticide use when it is considered that the plant itself becomes a pesticide. GM Bt crops generally produce more insecticide than the amount of chemical insecticide that they replace – up to 19 times the amount in the case of multiple ("stacked") trait GM Bt maize.[5]

GMO proponents claim that the Bt toxin engineered into GM Bt crops is harmless to non-target organisms and to mammals. They base this claim on the assumption that natural Bt toxin, which is derived from a common soil bacterium, has a history of safe use when used as an insecticidal spray in chemically-based and organic farming.

But the Bt toxin engineered into GM Bt crops is different from the natural Bt toxin, both in structure and mode of action.[11,12,13] Unlike natural Bt toxin, which only becomes activated in the insect pest's gut and degrades rapidly in daylight, the Bt toxin in GM Bt crops is present in preactivated form and is "switched on" constantly. GM Bt crops have been found to harm butterflies[14,15,16] and beneficial pest predator insects that are helpful to farmers, such as ladybirds[17,18] and lacewings.[18,19,20] GM Bt crops have been found to be toxic to mammals in laboratory and farm animal feeding experiments.[21,22,23,24,25,26,27,28]

3. Are GM crops a permanent and effective solution to farmers' weed problems?

The major cause of the increase in herbicide use on GM crops is the rapid spread of glyphosate-resistant superweeds.[5] Over-use of Roundup and other glyphosate-based herbicides on GM herbicide-tolerant crops[4,29] has caused selection pressure, meaning that only those weeds that are resistant to the herbicide survive spraying and pass on their resistant genes to the next generation of weeds. Farmers have to spray more herbicide, or mixtures of herbicides, to try to control the weeds.

The area of US cropland infested with glyphosate-resistant weeds expanded to a massive 61.2 million acres in 2012, according to an industry survey. Nearly half of all US farmers interviewed reported that glyphosate-resistant weeds were present on their farm in 2012, up from 34% of farmers in 2011. The survey also showed that the rate at which glyphosate-resistant weeds are spreading is gaining momentum, increasing 25% in 2011 and 51% in 2012.[30,31]

When resistant weeds first appear, farmers often use more glyphosate herbicide to try to control them. But as time passes, no amount of glyphosate herbicide is effective.[29,32] Farmers are forced to resort to potentially even more toxic herbicides and mixtures of herbicides, including 2,4-D (an ingredient of the Vietnam War toxic defoliant Agent Orange) and dicamba.[4,33,34,35,36,37,38,39]

Some US farmers are going back to more labour-intensive methods like ploughing – and even pulling weeds by hand.[40] In Georgia in 2007, 10,000 acres of farmland were abandoned after being overrun by glyphosate-resistant pigweed.[41] One report said the resistant pigweed in the Southern United States was so tough that it broke farm machinery.[42]

4. Trillions of GMO meals have been eaten in the US. So GM crops don't have toxic or allergenic effects – right?

Feeding studies on laboratory animals and farm livestock have found that some GM crops, including those already commercialized, have toxic or allergenic effects. Effects, which may arise from the GM crop itself or from residues of the pesticides used on them, include:

- Liver and kidney toxicity[12,22,21,28]
- Enlarged liver[43]
- Disturbed liver, pancreas and testes function[44,45,46]
- Accelerated liver ageing[47]
- Disturbances in the functioning of the digestive system and cellular changes in liver and pancreas[23]
- Less efficient feed utilization and digestive disturbance[48]
- Altered gut bacteria[49,50]
- Intestinal abnormalities[24]
- Excessive growth in the lining of the gut, similar to a pre-cancerous condition[51,52]
- Altered blood biochemistry, multiple organ damage, and potential effects on male fertility[26,25]

- Immune disturbances,[27,53,54] immune responses,[53,49] and allergic reactions[55]
- Enzyme function disturbances in kidney and heart[56]
- Stomach lesions and unexplained deaths[57,58,59,60]
- Higher density of uterine lining[61]
- Severe stomach inflammation and heavier uterus[62]
- Differences in organ weights,[50] which is a common sign of toxicity or disease.

Further details of these studies can be found in GMO Myths and Truths (Myth 3.1).

In the most detailed feeding study ever carried out on a GM food, severe damage to the liver, kidney, and pituitary gland was found in rats fed a commercialized GM maize and tiny amounts of the Roundup herbicide it is grown with over a long-term period. Additional observations were increased rates of large tumours and mortality in the rats fed GM maize and/or Roundup.[63] GM maize that had not been treated with Roundup had similar toxic effects to the GM maize sprayed with Roundup and to Roundup on its own, indicating that the GM crop itself was toxic.

This study came under heavy attack by pro-GM critics and was retracted by the journal that published it, over a year after it had passed peer review and appeared in print. However, the retraction was condemned as invalid by hundreds of scientists worldwide.[64,65] A full discussion of the study and its retraction is in GMO Myths and Truths 3.2).[66]

The argument that trillions of GM meals have been eaten with no ill effects is disingenuous. No epidemiological studies have been carried out to track consumption of GM foods and to assess whether there are ill effects that correlate with consumption. What is more, such studies are not even possible on the continent where most GM meals are consumed – North America – as GM foods are not labeled there. Unless consumption caused an acute and obvious reaction that could be immediately traced back to a GM food, the link could not be made. An increase in incidence of a common, slow-developing disease like cancer, allergies, or kidney or liver damage would be difficult or impossible to link to GM foods.

5. Can GM and non-GM crops “coexist”?

GM genes cannot be controlled, contained, or recalled. Once released into the environment, they can persist and proliferate through cross-pollination and self-seeding. In addition, GM crops can be mixed with non-GM crops during harvesting, in storage, or in transport.

For these reasons, “coexistence” of GM with non-GM and organic crops inevitably results in GM contamination of the non-GM and organic crops. This removes choice from farmers and consumers, forcing everyone to produce and consume crops that are potentially GM-contaminated into the indefinite future.

GM contamination incidents have cost the food and GMO industry and the US government millions of dollars in lost markets, legal damages and compensation to producers, and product recalls. Examples include:

- In 2011 an unauthorized GM Bt pesticidal rice, Bt63, was found in baby formula and rice noodles on sale in China.[67] Contaminated rice products were also found in Germany,[68] Sweden,[69] and New Zealand, where it led to product recalls.[70] GM Bt rice has not been shown to be safe for human consumption. Bt63 contamination of rice imports into the EU was still being reported in 2012.[71]
- In 2006 an unapproved experimental GM rice, grown for only one year in experimental plots, was found to have contaminated the US rice supply and seed stocks.[72] Contaminated rice was found as far away as Africa, Europe, and Central America. In 2007 US rice exports decreased 20% from the previous year as a result of the GM contamination.[73] In 2011 the company that developed the GM rice, Bayer, agreed to pay $750 million to settle lawsuits brought by 11,000 US farmers whose rice crops were contaminated.[74] A court also ordered Bayer to pay $137 million in damages to Riceland, a rice export company, for loss of sales to the EU.[75]
- In 2009 an unauthorized GM flax called CDC Triffid contaminated Canadian flax seed supplies, resulting in the collapse of Canada's flax export market to Europe.[76,77]
- In Canada, contamination from GM oilseed rape has made it virtually impossible to cultivate organic non-GM oilseed rape.[78]
- Organic maize production in Spain has dropped as the acreage of GM maize production has increased, due to contamination by cross-pollination with GM maize.[79]
- In 2000 GM StarLink maize, produced by Aventis (now Bayer CropScience), was found to have contaminated the US maize supply. StarLink had been approved for animal feed but not for human consumption. The discovery led to recalls of StarLink-contaminated food products worldwide. Costs to the food industry are estimated to have been around $1 billion.[80] One study estimated that the StarLink incident resulted in $26 million to $288 million in lost revenue for producers in 2000–2001.[81]

Claims that farmers should have the "choice" to plant GM crops ring hollow when it is considered that the choice to plant GM crops removes the choice to eat GM-free and organic crops, a far more popular choice. Even one farmer's "choice" to plant GMOs can create tremendous financial risk for growers and food manufacturers who wish to produce organic and non-GMO products. Also, research[82] and on-the-ground experience[83] shows that once GM crops are adopted by a country, seed choice decreases as non-GM varieties are withdrawn from the market. This situation is possible because of the monopolistic control of the seed market by a few large companies, which are heavily invested in GM and their accompanying agrochemicals.[84]

6. Are GM crops needed for good nutrition?

GM proponents have long claimed that genetic engineering will deliver healthier and more nutritious "biofortified" crops. However, no such nutritionally enhanced GM foods are available in the marketplace. Some GM foods have been found to be less nutritious than their non-GM counterparts, due to unexpected effects of the genetic engineering process.[85,86]

The best-known attempt to nutritionally improve a crop by genetic engineering is beta-carotene-enriched GM "golden rice".[87,88] Beta-carotene can be converted by the human body to vitamin A. The crop is intended for use in poor countries in the Global South, where vitamin A deficiency causes blindness, illness, and death. However, despite over a decade's worth of headlines hyping golden rice as a miracle crop, it is still not available in the marketplace.

GM proponents blame excessive regulation and anti-GM activists for delaying the commercialization of golden rice.[89] But the real reasons for the delay in deploying golden rice are basic research and development problems. The first golden rice variety had insufficient beta-carotene content and would have had to be consumed in kilogram quantities per day to provide the required daily vitamin A intake.[87] As a result, a new GM rice variety had to be developed with higher beta-carotene content.[88]

Also, the process of backcrossing golden rice with varieties that perform well in farmers' fields has taken many years.[90,91] A 2008 article in the journal Science said that there was still a "long way to go" in the process of backcrossing golden rice lines into the Indica varieties favoured in Asia.[90]

After the publication of articles that once again blamed excessive regulation and anti-GM activists for the delays in deploying GM golden rice,[89,92] in February 2013 the International Rice Research Institute (IRRI), the body responsible for the rollout of GM golden rice, issued a statement contradicting the claims that golden rice was (a) already available and (b) proven effective. On the latter the IRRI said: "It has not yet been determined whether daily consumption of Golden Rice does improve the vitamin A status of people who are vitamin A deficient and could therefore reduce related conditions such as night blindness", adding that studies still had to be carried out before this could be known.[93]

At this time, the IRRI expected that it "may take another two years or more" for GM golden rice to be available to farmers.[93] But in early 2014 even this estimate was rolled back indefinitely, when field trials in the Philippines found that GM golden rice failed to produce the yields and agronomic performance necessary for farmers to adopt it. IRRI noted, "average yield [of GM golden rice] was unfortunately lower than that from comparable local varieties already preferred by farmers".[94]

Inexpensive and effective methods of combating vitamin A deficiency (VAD) have long been available and only require modest funding to roll out more widely. The World Health Organization's (WHO) long-standing VAD programme gives supplements where needed but also encourages mothers to breastfeed and teaches people how to grow carrots and leafy vegetables in home gardens – two inexpensive, effective, and widely available solutions.[95,90]

Programmes using supplementation and educational approaches have already successfully addressed the VAD problem in the Philippines, the country targeted for the introduction of GM golden rice. Only a decade ago, the Philippines was severely affected by VAD. The data for VAD in children under 5 in 1993, 1998 and 2003 were 35%, 38% and 40.1%, respectively. But the data on VAD levels in 2008 show a remarkable decline. For children aged five or younger, only 15.2% had VAD, while the figures for pregnant and lactating women were 9.5% and 6.4%, respectively. In other words, dramatic declines occurred in VAD over a five-year period, to the point where it was just above the threshold of what would be considered of public health significance.[96,97]

These data show that basic public health programmes have succeeded in saving lives, while GM golden rice, despite having swallowed millions of dollars in investment funds, is still not available. Far from people's lives being lost because of being denied GM golden rice, the truth is that lives are being lost due to money being wasted on expensive and failed GM technology instead of proven successful programmes.

Beta-carotene is one of the commonest molecules in nature, being found in abundance in green leafy plants and fruits. There is no need to engineer beta-carotene into rice. If biofortified crops are considered desirable, non-GM beta-carotene-enriched orange maize is already available.[98,99]

7. Are GM crops needed to feed the world?

The notion that GM crops are needed to feed the world's growing population is repeated everywhere. But it is difficult to see how GM can contribute to solving world hunger when GM crops do not have higher intrinsic yields (see point 1, above). Nor are there any GM crops that are better than non-GM crops at tolerating poor soils or challenging climate conditions. This is because, like high yield, tolerance to poor soils and extremes of weather are complex genetic traits involving many genes working together in ways that are not fully understood. Complex traits such as these cannot be genetically engineered into a crop.

Virtually all of the currently available GM crops are engineered for herbicide tolerance or to contain a pesticide, or both.[3] The two major GM crops, soy and maize, mostly go into animal feed for intensive livestock operations, biofuels to power cars, and processed human food – products for wealthy nations that have nothing to do with meeting the basic food needs of the poor and hungry. GM corporations are answerable to their shareholders and are interested in profitable commodity markets, not in feeding the world.

A major UN/World Bank-sponsored report on the future of agriculture compiled by 400 scientists and endorsed by 58 countries did not endorse GM crops as a solution to the challenges of poverty, hunger, and climate change, noting "variable" yields, safety concerns, and restrictive patents on seeds that could undermine food security in poorer countries. Instead the report called for a shift to "agroecological" methods of farming.[100]

Sustainable agriculture projects in the Global South and other developing regions have produced dramatic increases in yields and food security.[101,102,103,104,105,106]

A 2008 United Nations report looked at 114 farming projects in 24 African countries and found that adoption of organic or near-organic practices resulted in yield increases averaging over 100%. In East Africa, a yield increase of 128% was found. The report concluded that organic agriculture can be more conducive to food security in Africa than chemically-based production systems, and that it is more likely to be sustainable in the long term.[104]

The System of Rice Intensification (SRI) is an agroecological method of increasing the productivity of irrigated rice by changing the management of plants, soil, water and nutrients. SRI is based on the cropping principles of reducing plant population, improving soil conditions and irrigation methods for root and plant development, and improving plant establishment methods. According to the SRI International Network and Resources Center (SRI-Rice) at Cornell University, the benefits of SRI have been demonstrated in over 50 countries. They include 20%–100% or more increased yields, up to a 90% reduction in required seed, and up to 50% water savings.[107]

These results serve as a reminder that plant genetics are only one part of the answer to food security. The other part is how crops are grown. Sustainable farming methods that preserve soil and water and minimize external inputs not only ensure that there is enough food for the current population, but that the land stays productive for future generations.

8. Which is better at producing crops with useful traits – conventional breeding or GM?

Conventional plant breeding continues to outperform GM in producing crops with useful traits such as tolerance to extreme weather conditions and poor soils, improved nutrient utilization, complex-trait disease resistance, and enhanced nutritional value (biofortification). In some cases, marker assisted selection (MAS) is used to speed up conventional breeding by guiding the process of natural, conventional breeding, quickly bringing together in one plant genes linked to the desired important traits. MAS does not involve inserting foreign genes into the DNA of a host plant and avoids the risks and uncertainties of genetic engineering. It is widely supported by environmentalists and organic farming bodies. Any concerns focus on patent ownership of seeds developed in this way.

Conventional breeding and MAS use the many existing varieties of crops to create a diverse, flexible, and resilient crop base. GM technology offers the opposite – a narrowing of crop diversity and an inflexible technology that requires years and millions of dollars of investment for each new trait.[108,109]

The following are just a few examples of conventionally bred crops with the types of traits that GMO proponents claim can only be achieved through genetic engineering. Many are already commercially available and making a difference in farmers' fields. A more complete database is on the GMWatch website.[110]

High-yield, pest-resistant, and disease-resistant

- High-yield, multi-disease-resistant beans for farmers in Africa[111]
- High-yield, disease-resistant cassava for Africa[112]
- Australian high-yield maize varieties targeted at non-GM Asian markets[113]
- Maize that resists the parasitic weed pest Striga and tolerates drought and low soil nitrogen, for African farmers[114]
- Maize that resists the grain borer pest[115]
- "Green super-rice" bred for high yield and disease resistance[116]
- High-yield soybeans that resist the cyst nematode pest[117]
- Aphid-resistant soybeans[118,119,120,121]
- High-yield tomato with sweeter fruit[122]
- High-yield, pest-resistant chickpeas[123]
- Sweet potato resistant to nematodes, insect pests, and Fusarium wilt, a fungal disease[124]
- High-yield, high-nutrition, and pest-resistant "superwheat"[125]
- Potatoes that resist late blight and other diseases[126,127,128,129,130,131,132]
- Potato that resists root-knot nematodes[133]
- Papayas that resist ringspot virus.[134] There is also a GM virus-resistant papaya,[135] which is claimed by GMO proponents to have saved Hawaii's papaya industry.[136] However, this claim is questionable. Though the GM papaya has dominated Hawaiian papaya production since the late 1990s, Hawaii's Department of Agriculture reportedly said that the annual yield of papayas in 2009 was lower than when the ringspot virus was at its peak.[137] An article in the Hawaiian press said that GM has not saved Hawaii's papaya industry, which has been in decline since 2002. The article cites as a possible reason for the decline the market rejection that has plagued GM papayas from the beginning.[138]

Salt-tolerant

- Rice varieties that tolerate saline soils[116]
- Durum wheat that yields 25% more in saline soils than a commonly used variety[139,140]
- Indigenous crop varieties from India that tolerate saline soils, stored by the Indian seed-keeping NGO, Navdanya. Navdanya reported that it gave some of these

seeds to farmers in the wake of the 2004 tsunami, enabling them to continue farming in salt-saturated soils in spite of scientists' warnings that they would have to abandon the land temporarily.[141]

Nutritionally fortified and health-promoting

- Soybeans containing high levels of oleic acid, reducing the need for hydrogenation, a process that leads to the formation of unhealthy trans fats[142]
- Beta-carotene-enriched orange maize, aimed at people suffering from vitamin A deficiency[98,99]
- Millet rich in iron, wheat abundant in zinc, and beta-carotene-enriched cassava[143]
- Purple potatoes containing high levels of the cancer-fighting antioxidants, anthocyanins[144,145]
- A tomato containing high levels of the antioxidant lycopene, which has been found in studies to have the potential to combat heart attacks, stroke, and cancer[146]
- A purple tomato containing high levels of anthocyanins and vitamin C[147] (this story attracted only a fraction of the publicity gained by the John Innes Centre's GM purple "cancer-fighting" tomato[148,149,150])
- Low-allergy peanuts.[151]

9. Is GM crop technology precise enough to ensure that it will not result in unpleasant surprises?

GM proponents claim that GM is a precise technique that allows genes coding for the desired trait to be inserted into the host plant with predictable outcomes and no unexpected effects. But the genetic engineering process is crude, imprecise and highly mutagenic (see GMO Myths and Truths, Myth 1.2).[66] It causes unpredictable changes in the DNA, proteins, and biochemical composition of the resulting GM crop,[152] which can result in unexpected toxic or allergenic effects (see point 4 above) and nutritional disturbances (see point 6 above),[153] as well as crop failure in the field and unpredictable effects on the environment (see point 2 above).[154]

Claims that new genetic engineering techniques are making GM technology more precise and predictable are not supported by evidence. For example, with regard to zinc finger nuclease (ZFN) technology, two studies found that ZFNs caused unintended off-target effects in human cell lines,[155,156] potentially causing a range of harmful side-effects. Another new technology, Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR-Cas9), was found to cause unintended mutations in many regions of the genome of human cells.[157]

Cisgenesis (sometimes called intragenesis) is a type of genetic engineering involving artificially transferring genes between organisms from the same species or between closely related organisms that could otherwise be conventionally bred. Cisgenesis is presented as safer and more publicly acceptable than transgenic genetic engineering, in which GM gene cassettes containing genes from unrelated organisms are introduced into the host organism's genome. However, in cisgenesis, the GM gene cassette will still contain DNA elements from other unrelated organisms like bacteria and viruses.

Cisgenesis is as mutagenic as transgenesis, and cisgenes can have the same disruptive effects as transgenes on the genome, gene expression, and a range of processes operating at the level of cells, tissues and the whole organism. Studies show that a cisgene can introduce important unanticipated changes into a plant.[158,159,160]

10. Why are crops being genetically engineered?

While non-GM seeds are also increasingly being patented, GM seeds are far easier to patent because the "inventive step" necessary to satisfy patent offices is clearer. From the beginning, the introduction of GM seeds was strongly connected with the idea of consolidation and patented ownership of the food supply.[161] For example, a 1992 OECD publication[162] stated that within the seeds sector, the main company focus should be on the reorganisation of the seed market, leading to a greater integration and dependency with the agrochemicals sector. According to the expert group ETC, just ten companies control two thirds of global seed sales.

Genetic engineering and patents served as a major tool in this context. The patent granted on a GM gene sequence introduced into plant material extends to seeds, plants and any plants that are bred or otherwise derived (for example, by propagation) from those GM plants, all along the chain of farm and food production up to markets such as food and biofuels.[161]

Thus patents became an important driving factor in the consolidation process. They made it possible to hamper or even block access of other breeders to the biological material. In comparison, the traditional plant variety protection (PVP) system that has long applied to non-GM seeds allows free access to commercially traded seed for the purpose of further breeding ("breeders' exemption"). Thus PVP works as an open source system for other breeders.[161]

Patents do not only block access to genetic material of a certain variety. The monopoly rights of patents apply as long as the patented genetic sequences can be found in any progeny. Thus even after plants are cross-bred, the patented gene sequences can accumulate in the subsequent generations. So contrary to the principle of breeders' exemption in the PVP system, no other breeder can use patented seeds for further development of new varieties if the patent holder does not issue a licence. The main objective of these patents is the monopolisation of resources rather than the protection of inventions.[161]

Within this context, the fact that GM fails to increase crop yields, reduce pesticide use, or deliver useful traits does not matter in the least to the companies that own the patents. As a report by the expert organization ETC Group said, "The new technologies don't need to be socially useful or technically superior (i.e., they don't have to work) in order to be profitable. All they have to do is chase away the competition and coerce governments into surrendering control. Once the market is monopolized, how the technology performs is irrelevant."[163]

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