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Conceptual paper

Science, ideology and daily life

La ideología de la ciencia y de la vida cotidiana

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ABSTRACT

Despite years of scientific effort to develop useful and safe biotech crops, ideologies have prevailed and genetically modified (GM-)crops have still not been fully accepted by today's society. This leads one to reflect on the role of Science in society, on what makes scientists credible, and how scientists themselves understand the world we live in. While Science remains a black box for many of the uninitiated, scientists themselves are also generally less-interested in sociology or the economy, such that the coevolution of science and daily life is often frustrated by incomprehension or even disinterest on both sides.

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The title of this talk may be intriguing, but it reflects the fact that, despite 30 years of scientific efforts to develop useful and safe biotech crops, ideologies have prevailed and GM-crops have not been fully accepted by society. This leads one to think about the meaning of science, what makes people believe scientists, and how scientists understand the world. While science remains abstruse for the uninitiated, scientists are not so much interested in sociology or the economy such that the coevolution of science and daily life is often frustrated by incomprehension. A widely accepted theory of human history is that we started by hunting and gathering fruits, seeds and tubers and then progressed to understanding how to save, and select seeds of critical food crops, eventually evolving to where we are with our current agricultural practices. Indeed, food technology that utilizes the best of what science, and the life sciences in particular have to offer is an extremely recent phenomenon, and the huge population increase from the 18th century onwards would not have been sustainable without these advances in precision agriculture.

The organization Greenpeace has often warned of the precariousness of today's agriculture. In today's developed world food production is an industrial process, and I agree that such intensive agriculture can be highly disconcerting. But, with the current global

population of seven and a half billion people, and predictions that we will reach nine or ten billion within 30 years, we simply cannot turn the clock back. One may dream of a lost paradise and of the natural environment that has disappeared, but we have to face reality – there are simply so many of us on this globe that if we do not find a way to work together to develop solutions and to stop the exploitation of natural resources we will find ourselves back into slavery with its horrible injustices. Nonetheless with the advances in modern science it is clear that it is possible to make intensive agriculture sustainable.

On the acreage that has already been destroyed it is possible to double or triple the crop output by using recent scientific developments. Unfortunately, this is hindered by obstructionist ideologies.

If we look back in history, all too often we find that scientific progress and innovation has been blocked by ideologies, and yet humanity has still survived. Ideology is fantastic for motivating and bringing people together, and as individuals we sometimes need ideologies to drive the necessary changes in the society in which we live. Nevertheless, ideologies can also be dangerous when they lead to 'secondary effects'. i.e. when not based on sound reasoning or when the full meaning and consequences may be misunderstood. Indeed, things such as the joy of living, emotions, beliefs and spiritual life are part of our neurobiology and have evolved with us, emphasizing that they have been, and still are important to human social evolution. However, to understand why this is so, and how we can benefit from ideological values while avoiding collateral

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damage, requires deeper, scientific studies. This point should be kept in mind as we continue to explore the subject.

Calestous Juma, a Kenyan Professor of Sociology from Harvard University, expounds in his book, "Innovation and Its Enemies" (Juma, 2016), on an interesting issue surrounding coffee - one of the world's oldest innovations. Coffee is native to the highlands of Ethiopia and then spread to the Middle East and Western Europe. It was first cultivated in the Yemen during the 15th century but at that time Muslim opponents to its use questioned whether coffee should be allowed to stimulate our bodies, claiming that the product should be considered as potentially risky until proven safe. This shows just how old the precautionary principle concept is. Another interesting text is "Du jugement qu'on doit faire des accidents futurs", in "La logique, ou l'art de penser" (Arnauld & Nicole, 1996). This was written by scholars of the Jansenist movement centred on Port-Royal, France at the end of 17th century, when science as we know was emerging at the forefront of the Industrial Revolution. In the text, scholars were already proposing that the correct moral attitude is not to surrender to fear of potential danger but to master it by calculating the probability that unwanted consequences will arise. If something is dangerous, you apply logic to weigh up the situation and decide whether to take precautionary measures or not.

Another example of fear, or contempt of innovation occurred in Nottingham in the 19th century with the cotton industry. New, mechanised textile businesses took over established mills which remained convinced that they were the only ones with the true knowledge and understanding of the beauty of their businesses. Such events happens every day, and now we see that opponents to biotech agriculture are destroying what the solutions proposed by plant genetic engineers, and we have to learn how to overcome this opposition. It is clear that the only way forward is for both sides to reflect, discuss, and to come to a consensus and scientists need to listen to opponents of the technology and refrain from a dismissive "I know better" attitude.

It is a pity that during their education scientists and engineers are rarely confronted with how to deal with human feelings. For thousands of years ago people have been talking about the mind and the soul, and while the mind and the body were sometimes opposed, in trying to resolve the conflict, religion has been of enormous help for many. This contrasts to the situation in science, which these themes have only recently been approached through neurobiology. For example, neurobiologists seek to examine the basis of emotional feelings such as which parts of the brain are activated during praying, its importance and meaning, and if it has a meaning, defining it. Science seeks to discover facts, but how those facts are interpreted are another matter altogether. Very often life-scientists keep to their narrow path because of the ethics of science - that research has to be carried out well and properly, and that your peers should criticize you when you do not adhere to ethical norms. However, scientists must remember that they can contribute a very limited part of the total work and that we are all in this together. Each in his specialty should look to communicate, and to be aware of what this communication is bringing. Looking into the future we should work together to understand human ecology, how the lives of humans are intimately bound together, how we live with the planet, and our relationship with all other living organisms.

There are three major points that help one to understand opposing views: science, society and economy. Science gives the facts to society, which chooses these that facilitate society's expansion, and economy provides the production. One may criticize this capitalist scheme, yet many alternatives have been tried. Currently we are left with the appalling choice of how it can be made more acceptable for society while not coming back to slavery. One can discuss how to improve the present scheme, but to destroy it would risk

the return of slavery. Possibly one can find better solutions through economy but should be solutions that do not entail violence.

Overpopulation is an important issue to be considered. The shame of poverty and hunger seems to leave many of us indifferent. I wonder if it is due to our resilience to hardship, which is sometimes necessary yet other times can mislead us? The eradication of this plague will require a fundamental shift in the way we perceive the world and our place in it. Rationality tells us that the whole of humanity should be able to share equally the economic, social and cultural benefits of our natural resources. Solutions though require the necessary political will and commitment of all nations and will require concerted actions of different segments of society including public sector science.

As has already been pointed out by other speakers, the problem of nutrition is not simply the amount of food available, but also its quality. If the nutritional quality of food is poor, then it becomes a mere staple food, without the necessary vitamins and micronutrients such as iron and zinc that we require. This can lead to developmental problems in children, such as stunted growth and reduced neurological (brain) development. In some countries up to 50% of children may be affected. It is a tragedy for our societies that many are excluded due to improper nutrition, an enormous responsibility to use science, sociology and economy to try and combat this situation. People and society must be organized such that the full amount of food and knowledge are available, and so we can live together without fighting. We must develop economy that is encompassing and acceptable to everyone, which is why growth rate is so important. If you talk to people who survived all of the horrors in Auschwitz during World War II they will tell you that they survived because they looked to things such as a tree or a sunrise, which gave them emotional and physical strength to carry on. We have a world worth saving, and it can be saved, but we must resolve to cease fighting each other and to stop destroying resources.

Two professors of philosophy at the University of Ghent, Etienne Vermeersch and Johan Braeckman, wrote a controversial book about the history of philosophy named "The River of Heraclitus" (Vermeersch & Braeckman, 2015). As most people are not versed on this subject, one is likely to be confused by the many bright minds giving conflicting views. Heraclitus wrote that you can never swim twice through a river because the water has changed in the meantime. This book is brilliant because the authors are so successful in analysing what all the different philosophers have said. They show where the philosophers were wrong but do not say where the truth is because that is not possible - there is no universal truth. Society itself is continuously changing, revolutionizing human thinking, which in turn transform society.

This virtual cycle is also true for life sciences. The dawn of molecular biology marked by great enthusiasm with the discovery of DNA as the genetic material. Scientists were so thrilled that called the directional information flows from DNA → RNA → protein the central dogma of molecular biology. Although the directional information persists, we now know that the flow is much more complex than though at the beginning. The concept of one gene one protein is over simplistic. Pieces of DNA can jump, RNAs have regulatory functions, proteins regulate RNA editing and protein modifications are the rule. As an example, in the model plant Arabidopsis there are between twenty and twenty-five thousand genes, but they make more than a million different proteins when protein modifications are taken into account. This shows how science is complicated and that in science there is no such a thing as a central dogma. Another example is the flaw concept that the genome is a blueprint for building a body. With epigenetics, christened by Waddington in 1942, we started the understanding of pathways used in embryological development which are then switched off to prevent disturbance. Yet, under stressful situations

some of these pathways are switched on, allowing plant and animals being pushed beyond the expected bounds. This molecular base for resilience is promising in understanding phenotypic plasticity and the interplay between nature and nurture. The scientific process is iterative. We are always challenging the acquired knowledge, reviewing the scientific hypothesis and progressing.

Another fascinating novel concept is the holobiome. This states that we are not alone as individuals. We contain up to four trillion microorganisms within us, more than our number of cells. These microorganisms sometimes send RNAs which have a bearing on our health. In addition, horizontal gene transfer, where a piece of DNA that goes from one organism to another, is also a possibility leading us to ask whether genetic engineering is actually a natural process. At the very least this is true for microorganisms. It has also been proven from agrobacteria to plants (Van Montagu, 2011) and from bacteria to insects (Wybouw et al., 2014). This is important for ecology, including human ecology, since it shows how organisms are linked together. The geneticists Dawkins and Wong, in the book “The Ancestor’s Tale” (Dawkins & Wong, 2005) traced back selected organism along the tree of life, each organism telling their own story about how they acquired their different systems. This is a very interesting philosophical approach. Another interesting theorist in biochemistry is Nick Lane from University College London. In his book “The vital question” (Lane, 2015) he analyzed the changes that occurred in four and a half billion years of the existence of the planet, from inorganic to organic chemistry. He explored at life’s origin, why some membranes were in existence, how electrons and hydrogen transferred, how the cell first emerged. He goes reasoning how bacteria evolved into complex life, the role of symbiosis and sex. All these original and awe-inspiring logical thinking make us to conclude that nature is a big genetic laboratory and the living world is one large gene pool.

Our work on plant gene engineering started in the late sixties with the finding that soil bacteria like *Agrobacterium tumefaciens*, known to induce crown galls, also were able to force a plant to synthesize in these galls a high concentration of a class of odd amino acids called opines. The opines are nutrients for these infecting *Agrobacteria*. What is remarkable is that the type of opine produced was dependent of the strain of agrobacterium and independent of the host plant. This led to the conclusion that the command to synthesize the opine comes from the agrobacterium. We called the phenomenon “genetic colonization”. Next step was the unravelling of the molecular mechanism that made this possible. Surprisingly it was the transfer and integration of a bacterial DNA segment into plant genome. This DNA segment, that we called T-DNA was part of a large plasmid harboured by this very *Agrobacterium* strain. The T-DNA, contained genes for the syntheses of opines as well as genes to induce tumour formation by cell proliferation. This is how we discovered a natural event of gene engineering (Van Montagu, 2011). These findings cumulated with the demonstration, in 1983, that it was possible to turn these *Agrobacteria* strains into efficient and reliable systems for delivery and expression of foreign genes into healthy plants. Many scientific questions immediately arose that could bring about innovation and improvement to science. A series of GM-plants were developed, notably the first BT (*Bacillus Thuringiensis*) plants, that make their own insecticide; plants which are tolerant to herbicides glufosinate and glyphosate; and hybrid rapeseed with bigger grains (Van Montagu, 2011).

To date, only a limited number of crops are genetically engineered with a limited number of traits. Nevertheless, their importance is such that they are grown on at least a hundred eighty million hectares, which is equal to ten percent of agricultural land. GM-crops cultivated in both developed and developing countries use less toxic chemicals and income benefits to farmers. They are badly needed and must be facilitated.

The highly sophisticated marketing campaigns against GM crops deployed by non-governmental organizations (NGOs) have been devastating. NGO’s preferred tool is to trigger people’s irrational fears linked to how these crops are constructed. The fact that a gene from a particular species is introduced into a completely different species is perceived as ‘unnatural’. The trendy ‘natural’ or ‘back to nature’ viewpoint is opposed to human intervention in the natural world, and therefore to the biotechnologies (Blancke, Van Breusegem, De Jaeger, Braeckman, & Van Montagu, 2015). Critics such as Greenpeace have used rats in their arguments since people hate rats. It is misleading to talk about human genes, pig genes and rat genes. In Hong Kong they had a poster of two big fishes with human genes. The Chinese are horrified of the thought of eating ancestors, so they could never eat a human gene. This is deceptive and is an issue that confronts scientists. More recently, researchers from Ghent working together with the International Potato Centre have shown that all sweet potatoes that are used in the world bear agrobacterium DNA sequences. They estimate that horizontal gene transfer probably happened six thousand years ago but was discovery only two years ago. This is due to recent technological advances that have given us the tools to study other horizontal gene transfer events that happens in nature such as bacteria gene transfer to plants and to insects.

In order GMOs to be accepted, society must appreciate their use and value. Most European farmers are banned from growing GM crops, although there are seventy-five authorisations for importation, most of which being soy for animals. We import more than 60 kg of GM soya for each of the EU’s 500 million citizens each year. These were grown in Romania and Bulgaria but the farmers were paid to desist. This was due to ideological and labour reasons as a result of negotiations with Greenpeace. After having given seventy-five approvals, it is clear that the European Union agrees that GMOs are not dangerous.

Ever since the catastrophic effects of the potato famine in Ireland, European researchers have sought to make potatoes resistant to *Phytophthora*. The potato is an hexaploid and growing it is very complex. Indeed, it took thirty-five years for breeders to create a potato variety with just one gene displaying resistance to *Phytophthora*. Unfortunately, this variety was not taken up by the market as it did not have the necessary traits to make a variety commercially successful. By comparison, using genetic engineering it was possible to insert three different resistant genes into a commercial variety. In total there are thirty-five known resistance genes that can be stacked together – imagine how long it would take by classical breeding to combine these.

There are a number of other GM-crops in the market that are not for big agribusiness corporations. An example is the Bt-brinjal. Phosphoramidate, the pesticide used to protect brinjal against insect attack was banned by the Stockholm Convention due to its high toxicity. But phosphoramidate is very popular and Bangladesh finally allowed it, followed by India. The cultivation Bt-brinjal in Bangladesh reduced the number of insecticide application by a massive 70–90% and improved marketable yield by at least 30%.

Another example, after golden rice, is folate rice. In some countries women have a shortage of folate in their diets and have to take folate pills in order to avoid spina bifida. With genetic engineering we can make folate-rich rice along with a long list of new plants ready to tend to needs such as these. There is a whole generation of GM crops that are good for health.

Other crops have been developed to increase consumption and/or reduce food waste. As an example, apples have been developed that do not turn brown leading people to keep them longer and not throw out with the waste. Things like these are accepted in the United States and they help the economy. The ethics of this can be discussed, but this is how the economy currently works.

There is plenty of room for improvement but that will come with hard work. Rich Roberts pointed out in his speech that it is scandalous that in Africa we have so many solutions waiting to be implemented but regulations are preventing them from being used. Bananas are a good example. Black Sigatoka is the most threatening banana disease with yield losses of up to 50% worldwide. Transgenic lines expressing antifungal peptides isolated from *Dahlia merckii* are currently waiting for field trials approvals by the biosafety committees in different countries.

Poor farmers in Africa stand to particularly benefit from agricultural biotechnology focused on nutrition improvements or environmental stresses and biotic factors that affect yield and post-harvest quality. Key staple crops in many African countries such as sorghum, millet, groundnut, cowpea, common bean, chickpea, pigeon pea, cassava, yam and sweet potato are grown in niche geographical areas by poor farmers. Because they are not extensively traded, these crops, as well as many fruits and vegetables, have been completely ignored by Ag-biotech. These are the crops that we to improve if we want a world free of hunger and poverty.

To achieve global food security both intensive and subsistence agriculture are necessary. By 2050, food production must increase by 70% and at the same time halve its environmental footprint. It is only possible with sustainable intensification of agriculture. The use of GM technologies, new breeding techniques (NBTs, CRISPR-Cas), and various uses of molecular biology to enhance plant breeding potential are without doubt some of our most important tools for achieving sustainable intensification. The position of Greenpeace, which clearly states they do not want GMOs, is erroneous as there is nothing dangerous about them. There is no danger to humans and no danger to the environment.

In this discussion it is important to ask whether there is an agribusiness monopoly or not. If so, we should try to determine how to solve the problem, discussing the impact on the economy and society. Greenpeace rightly says that just because you can do something does not mean you should. That is elementary logic. Faced with uncertainties one must make decisions. But our choice must be guided by rationality and one can evaluate science decisions in the same manner as an accounting firm. One can make statistical predictions about accidents that can have a negative effect, then make decisions accordingly.

In neurobiology we learn that human beings do not concentrate well enough to think wisely and have only limited capacity for rational thought. We tend to use emotions more than rational thoughts. It is this emotional thinking that blocks scientific progress. We would be better off by convincing students and our community to do better thinking. It is not rationalism that is wrong; it is the failure to use rationalism that is wrong, and that is a point that we have to address.

We have discussed that DNA determinism is deceptive. Genetic essentialism is biased. The genome is not a blueprint for building a

body. Faulty emotional logic might say that if fish genes were to be put into tomatoes, the tomatoes will have the smell of a fish. There are also conflicts of this type with theological thinking, such as in the protestant view that the world is based on intelligent design and as such we cannot meddle with it, leading to an anti-GMOs standpoint. Throughout history we have seen emotions bringing about negative consequences, such as with racism, homophobia, and indoctrination in France and Germany in the 1930s. But these things have turned around, the same way that our thinking against GMOs can turn around. Currently we hear the thinking that children in Africa should starve rather than allow GMOs to be available.

There exists social and emotional learning. One can make decisions on ethical standards and talk about safety and social norms. But we must contemplate responsible decision making taking into account not only logic, but all aspects of society in living together as a community. Without this forethought, we could end up with something like the Spanish Civil War. Science needs to be used to our greatest advantage for agriculture while leaving faulty emotional thinking aside. The farmer may pray for good weather and rain, but it is not the best way for either the farmer or society. With our current knowledge we have to use the best of science so that the farmer may have more tools at his disposal.

Leonardo Da Vinci made marvellous inventions in engineering more than five hundred years ago, but at the end of his life he said that he believed that he had offended God and mankind by doing so little with his life. This was just one man. We should contemplate what we can achieve if we all work together exploiting all the strengths of our society. In our dialogue with society we have to learn how to listen to diverse views. There will always be a viewpoint we have not yet considered, and yet may lead us to either change our own views or give us more motivation to pursue the dialogue.

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