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Towards a New Ethic of Science

Mae-Wan Ho
Intitute of Science in Society and Biology Department
Open University, Walton Hall, Milton Keynes, MK7 6AA, UK

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Introduction

Genetic engineering biotechnology is raising a whole range of ethical issues, and a new breed of ‘bioethicists’ have been enlisted to consider not only genetic engineered (GE) crops, but especially animal and human cloning, genetic screening for diseases, pre-natal and pre-implantation diagnosis, experiments on human embryos, xenotransplantation, and gene replacement therapy. The public have expressed deep concerns about ‘playing God’; about exploiting human beings and animals, and the re-emergence of genetic discrimination and eugenics which have blotted the history of much of the twentieth century.

There are strong moral objections to the new patents that turn life and life-necessities into commodities. Patents on genetic engineered seeds prevent farmers from saving and replanting seeds, thereby intensifying the corporate monopoly on food which has already marginalized and destroyed the livelihoods of family farmers all over the world. Plants and knowledge taken from indigenous communities are patented in flagrant acts of ‘biopiracy’. Genetically engineered animals, gene sequences, and cell lines, including those from human beings, and entire DNA database of human populations are being patented and owned by corporations, in violation of basic human rights and dignity.

One major obstacle to an open democratic debate is that the scientists developing the technology have been almost completely absorbed into the commercial sector. The public are being uncritically informed by scientists consciously or unconsciously serving commercial interest. The social ethos is increasingly hostile to the ethical practice of science itself.

Furthermore, there is a tendency in all debates on technology to leave the science untouched, to consider it separate from technology and from ethics, and to see it in isolation from society as a whole. These separations are artificial and unwarranted, and have served to obscure the most important issues. In this article, I shall put science itself in the spotlight: to examine the social control of science, the nature of the science driving the technology, and the relationship of science to society. I shall argue that there is an urgent need to reinstate independent science, and to define a new holistic ethic of science that can guide us in the safe and sustainable use of increasingly powerful technologies.

‘Science moves to centre stage’

Science is playing an increasing part in many decisions made by governments. This is hardly surprising, as science has been affecting every aspect of the daily lives of people all over the world ever since the industrial revolution. A commentary published in *Nature* [1], co-authored by UK Member of Parliament Ian Gibson, stresses the need for parliamentarians to "obtain and use unbiased information on technical matters", for "open and inclusive debates" to "deal with the wider scepticism towards science and technology that has been generated in part by commercial involvement" and "the loss of trust in institutions that manage risk on behalf of the public (for example, food safety)". It welcomes the prime minister’s statement that ‘good’ science should drive the debate on genetic engineering, but admits that after the experience of ‘good’ science in the BSE debate, when there was political suppression of data, this criterion is not enough. It also calls on scientists themselves to examine their political and public roles.

Commercialization and the demise of independent science

Western science has been instrumental in the growth of corporate capitalism since the industrial revolution. World War II ushered in a period of rapid expansion of science with generous funding from the state, and increasingly thereafter, from industry [2]. The commercialisation of science, which has been happening earlier in physics and chemistry, caught up with biology during the exponential growth of genetic engineering biotechnology in the late 1970s and early 1980s [3]. Basic molecular biology research, which until then, had been funded exclusively by the public purse, became transformed overnight into a haven for venture capital. Scientists set up companies to patent and exploit their research results. Hundreds of small biotech firms were founded, and the long established companies soon got into the act.

Under the Reagan-Thatcher regime, policies were instituted to make universities more fertile ground for corporate investors, and universities were encouraged to work more closely with industry. Tax incentives were granted to corporations, and legislation passed to provide special tax shelters and high investment income to investors in the new biotechnology. By 1987, US Federal funding for research and development in biotechnology (both basic and applied) was $2.72 billion, compared to a total funding for basic science of $6.8 billion [3]. All major universities had established links to biotech firms, and half of the active members of the US National Academy of Sciences had industrial ties. In 1998, an entire Department with 25 professors in the University of California at Berkeley was effectively sold to the Swiss biotech giant Novartis for $50 million [4]. To-day, practically all major academic and research institutions in Europe and the United States are dependent on industrial support. Yet, much of the real financing comes ultimately from the public purse.

The expropriation of public finance for industrial research and development is evident within the UK. The UK Government's Technology Foresight exercise in 1996 identified "building businesses from biology and genetics" as a priority for science, engineering and technology [5]. This was adopted in the corporate plan of the major public funding body, Biotechnology and Biological Sciences Research Council (BBSRC). As a result, the BBSRC developed a strategy for integrating scientific opportunity with the needs of industry and other users. The BBSRC's chairman, Peter Doyle, is the Executive Director of UK's leading biotech company, AstraZeneca, and many members of its various committees have industrial ties [6].

John Sime, the chief executive of BioIndustry Association, whose mission is to encourage and promote the biotechnology sector of the UK economy, reported on a comprehensive series of "government initiatives to encourage the manufacturing potential of biotechnology companies", "tax incentives, technology transfer initiatives, and regional innovation strategies" all being put into action to "boost start-up activity" [7]. And this was in May, 1999, when the world market for GE crops was beginning to collapse.

It is clear that the biotech industry has been capturing large amounts of public finance in both direct and indirect subsidies for research and development, which they use to finance science that serves corporate aims. The state has, in effect, brokered the transfer of power to control science from scientists and civil society -- where it legitimately belongs -- to business corporations whose sole imperative is monetary profit.

The demise of independent science is also the demise of science itself: its intrinsic moral values of honesty, reliability and openness, its ability to inspire, to work for the public good, and in the present context, to respect the precautionary principle to prevent further damages to health and the environment, to find the means to regenerate our planet and make life sustainable for human beings and all the other inhabitants on earth. Our survival depends upon those traditional ideals of science which have been seriously eroded over the past fifty years. The consequences have become all too apparent in the current genetic engineering debate.

The genetic engineering debate

The scientific establishment is playing a key role in research and development of genetic engineering biotechnology and in actively defending the industry under the banner of 'sound science' and 'scientific progress'. Scientific advice to the government is heavily biased in favour of the industry. Lord Sainsbury, current Minister for Science, was formerly chairman of the Sainsbury family's supermarket chain, closely involved with the development of GE foods. He also owns a gene patent in agricultural biotechnology, which was transferred to his "blind trust" when he became Minister [8]. Another prominent scientist, Derek Burke, advisor to the Parliamentary Committee on Science and Technology and formerly chair of the Advisory Committee on Novel Food Products, was a key participant in the UK Government's Technology Foresight exercise, and in a follow-up group that determined the pro-biotech funding policy of the BBSRC [6]. Derek Burke is an outspoken and staunch defender of the industry. The public are being informed uncritically by scientists like Burke and others, consciously or unconsciously serving commercial interests, and legitimate concerns about safety are caricatured as irrational fear arising out of ignorance. The relationship between the general public and the scientific establishment has never been worse. In a 1990 Europe-wide survey [9], only 6% of the people questioned trusted scientists in universities to tell the truth about GE crops, well below environmental organizations (26%) and just marginally better than politicians (4%).

The credibility of science and scientists has been steadily diminishing over the years as science has become more and more absorbed into the commercial sector. Science education at every level is being subverted to corporate aims: its chief purpose is to provide skilled but uncritical workers for industry. The UK Government has even run a competition for science students on how to commercially exploit scientific research [10]. There has been no major open debate on genetic engineering within academic institutions, that has been organized by the academic staff. With very few exceptions, students are not encouraged to ask questions about the ethics or the hazards of genetic engineering on either side of the Atlantic. Instead, academic scientists have been engaged in the most comprehensive social engineering exercise on behalf of industry over the past ten years. So-called 'public perception task forces' have been set up at the taxpayers' expense, to appoint professors and build departments and courses for the 'public understanding of science', one of its main tasks being to overcome public resistance to the biotech industry [11].

Scientific evidence of actual and potential hazards, which has been steadily building up over the past ten years [12], is being ignored and dismissed. More seriously, independent scientists reporting findings damaging to the industry are gagged and victimised.

Dr. Chopra, a Health Canada government employee well-known for his defence of human rights and public interest, was ordered not to appear at public meetings without the authorization of Health Canada. He has spoken out previously about Health Canada administrators who disregarded scientists' recommendations to withhold approval for drugs which endanger public safety. Chopra and other scientists wrote an internal Health Canada report about the hazards of genetically engineered bovine growth hormone, rBGH (also known as bovine somatotropin, BST), which was suppressed by the administration. The rBGH, produced by the biotech giant Monsanto for injecting into cows to boost milk yield, was formally approved in the US in 1993, but was actually marketed and used years before. A subcommittee of the Canadian Senate investigating the safety of rBGH requested a copy of the scientists' report and was refused by the administrators. The Senate subpoenaed the report in September 1998, and a court hearing eventually banned rBGH from Canada. Nevertheless, Dr. Chopra has been suspended from his job [13].

The approval of rBGH by the US FDA was itself an object lesson [14]. An 80-page report entitled, *Use of Bovine Somatotropin (BST) in the United States: Its Potential Effects*, was published by the Clinton White House in 1994, which concluded, "There is no evidence that BST poses a threat to humans or animals." Later that year, British scientists revealed that their attempts to publish evidence that rBGH may increase the cow's susceptibility to mastitis (infection of the udder) was blocked by Monsanto for three years. The scientists showed that Monsanto's submission to the FDA was based on selected data that covered up what the experiments had actually revealed - more white cells (pus) in rBGH-treated cows. Over 800 farmers using rBGH reported health problems with the cows. Side effects included death, serious mastitis, hoof and leg ailments and spontaneous abortions. Monsanto tried to bribe Health Canada officials with several million dollars to get rBGH approved. Two respected investigative journalists were fired from their jobs over a TV documentary on Monsanto's rBGH, and significant scientific findings were suppressed. For example, insulin-growth factor (IGF-1) was found to increase 10-fold in rBGH milk. Increased IGF-1 is linked to breast, colon and prostate cancers in humans. Monsanto had also withheld from the FDA data from studies on rats which showed that feeding rBGH elicited antibodies to the hormone and the males developed cysts on the thymus and abnormalities in the prostate gland. Despite all that, rBGH milk is still being sold unlabelled in the US today.

Within the UK, Dr. Arpad Pusztai, senior scientist of the publicly-funded Rowett Institute, and his collaborators were awarded a 1.6 million pound grant to carry out systematic safety testing of GE food. They found that the GE potato lines tested were toxic to young rats, and Pusztai informed the public in a brief interview which was part of a TV documentary. A few days later, he was removed from his job, denied access to his data, and forbidden to speak on the subject until an international group of twenty-four scientists spoke up for him six months later. This opened the floodgates of criticism and vilification against him and his supporters from *within* the scientific community.

Among the most vociferous critics were government scientists, like Derek Burke, who have been responsible for approving GEfoods for the market, and also the hitherto most respected and prestigious association of top scientists, The Royal Society. Fellows of the Royal Society accused Pusztai of endangering 'sound science' in making public findings which have not been peer-reviewed and published in a scientific journal. An official review was set

up by the Society to discredit Pusztai's work. There are no plans to attempt to repeat the work, nor are there serious efforts to support independent scientific research which would throw light on the hazards.

Puztai and his colleagues eventually published part of their findings amid a fresh storm of attack, and even reported threats to the Editor of the Journal publishing the paper from a prominent figure within the scientific establishment [15]. The suppression of scientific findings is nothing new; it has been happening more and more within the past decade. What is new in Pusztai's case is that it should come so blatantly from within the established scientific community.

Sir David Weatherall, regis professor of medicine, Oxford, reported on the treatment meted out to his long-standing collaborator in the University of Toronto in Canada, who was removed from her post for publishing data showing that the drug she was assessing for a Canadian company was unsafe [16]. Weatherall is critical, not only of the company trying to gag scientists, but of the lack of support for the intimidated scientists in their own academic institutions, and of the absence of open debate. These complaints may be widespread.

The Institute of Professionals, Managers and Specialists (IPMS) is a trade union recruiting largely from government research establishments and similar organizations. The February 2000 issue of their Bulletin reports that of the 500 IPMS members who responded to a questionnaire, 30% stated they have been asked to 'tailor' their results.

Since the 1970s, scientific fraud has been increasing, as has the proportion of peer-reviewed scientific papers retracted [17]. We have moved far away from the traditional ideals of science as science loses innocence and independence.

The need for independent science and open debate

Independent, honest scientists are absolutely necessary in a present-day democracy, whether they are working within the government, paid by the taxpayer, or in the commercial sector. Important decisions impacting on public health and safety, the environment, as well as the social and economic benefit to civil society, all hinge on the honesty of scientists and the reliability of the scientific advice given. All the more so as technologies become increasingly powerful and uncontrollable. Wrong decisions will literally cost the earth. Industry may be tempted to prevent scientists from telling the truth for the sake of short-term financial gain. But their long-term business strategy can only benefit from scientists who are free to say what they know. More importantly, there must be open debate when scientists disagree with one another. And the debate must be conducted in terms comprehensible to the general public so that the public can participate in making decisions.

Science is an *active* knowledge system, and uncertainty is its hallmark. Judgements are invariably based on incomplete information, and that is where precaution must be the guiding principle. One might argue that had Monsanto received sound scientific advice, it might not have invested so heavily in agricultural biotechnology and might have avoided its recent debacle as the international market for GE crops has collapsed [18].

A civil lawsuit was filed in May 1998 by a coalition of scientists and religious leaders in the United States against the Food and Drug Administration (FDA) over its approval of genetic engineered foods. Secret documents have come to light indicating that the overwhelming majority of the scientists consulted by the FDA *did* give genuinely sound advice, which the agency suppressed and ignored [19]. The scientists insisted that genetic engineering is a new departure from conventional breeding and introduces new risks. They were strongly opposed to the use of antibiotic resistance genes as selectable markers, because the genes may be taken up by bacteria that cause infectious diseases, making the diseases untreatable. They warned that the process of genetic engineering is unpredictable and uncontrollable, and that unintended effects are unavoidable due to the random insertion of the artificial gene and gene-constructs into the organism's own genetic material. In the case of crops used as food, these unintended effects may include new toxins, allergens and carcinogens. The first GE crop to be commercialized, the Flavr Savr tomato engineered to prolong shelf life, actually did not pass the standard toxicological tests. The FDA approved the tomato in violation of the US Food Drug and Cosmetic Act, which requires food additives to be shown to be *safe*. Since then, no comprehensive scientific safety testing of any GE foods has been attempted, until the work of Arpad Pusztai and his collaborators.

The advice of the FDA scientists is remarkably similar to what some other scientists have been saying in public over the years: the *process* of genetic engineering itself is inherently hazardous [20].

The reason Pusztai has been so fiercely attacked, is the claim made in the paper he published with Ewen [21]: that the genetic transformation process itself or the artificial gene-construct, or both, may not be safe. If that is the case, *all* genetic engineered crops may not be safe.

What is genetic engineering? And why is it inherently hazardous?

Genetic engineering is a set of laboratory techniques for isolating, multiplying, cutting and joining genetic material from different sources, and most of all, for transferring genetic material between species that can never interbreed in nature. So human genes are transferred into cows, sheep, fish, mice and bacteria. Spider genes are transferred into the goat.

There is no limit to the exotic genes that can be introduced in any organism. Many are taken from viruses and from bacteria that cause diseases, including antibiotic resistance marker genes. There is also no limit to the new combinations of genes that can be created, which have never existed in nature. Thus, gene switches from infectious viruses are placed next to genes to make them over-express. These novel genes and gene-constructs are introduced into organisms either by physical methods such as 'gene-guns' which shoot them into cells, or the constructs are spliced into artificial gene-carriers, or vectors which smuggle them into cells. The artificial vectors themselves are made by combining bits of the most infectious viruses and other genetic parasites capable of getting into a cell and invading the cell's *genome*, the totality of its natural genetic material which is organized in precise ways. The human genetic engineer has no control over where and in what form the artificial genes and gene-constructs end up in the cell's genome, however; and this gives rise to many random, unpredictable effects. Genetic engineering animals are acts of cruelty, there are high failure rates and even the so-called successes are often monstrously deformed [22]. GE plants may well end up with

unknown toxins and allergens.

Finally, the artificial genes and gene-constructs created are unstable, and have the potential to move out of the genome to infect and invade the genomes of unrelated species in a process called ‘horizontal gene transfer’. Horizontal gene transfer involves the genetic material transferring directly from one organism to another. All cells, from bacteria to those of our own species, are now known to readily take up genetic material, which may then become incorporated into the cell’s genome. Horizontal gene transfer is generally accompanied by recombination, the creation of new and different combinations of genes.

The same kinds of techniques and gene-constructs are used in every application of genetic engineering biotechnology, whether it is in agriculture, industrial production or medicine, *they involve the same potential hazards* : the spread of antibiotic resistance genes, the creation of new viruses and bacteria that cause diseases, harmful mutations due to the random insertion of the artificial genes and gene-constructs into the genome, some of which are linked to cancers [23]. The following have already been demonstrated by experiments in the laboratory: antibiotic resistance genes from genetic engineered plants were transferred to soil fungi and bacteria; genetic engineered plants containing viral genes recombined with infecting viruses to generate new viruses; and partially degraded DNA was readily taken up y bacteria that live in the human mouth and respiratory tract.

It is the burgeoning fields of gene therapy and new vaccines, however, which reveal how readily genetic material can gain access to cells and become incorporated into the cell’s genome [24]. New evidence also indicates that the constructs themselves can give acute toxic reactions, severe delayed immune reactions as well as auto-immune reactions in which the body’s immune system attacks its own cells and tissues.

There have been six deaths associated with clinical trials in gene therapy in the US within the past two years, plus more than 650 adverse reactions, all of which were concealed from the authorities, until the most recent death of a teenager triggered a comprehensive public enquiry [25].

Science and the precautionary principle

In short, there is sufficient evidence to warrant the withdrawal of all genetic engineered crops and products from environmental release until and unless they can be shown to be safe [26]. Furthermore, there is an urgent need to tighten the regulation over the release of genetic engineered microorganisms, cell cultures and their genetic material from contained laboratories and industrial use, and over all the artificial gene constructs and vectors in medical applications. This is in accordance with the precautionary principle, which can be stated as follows: when there is reasonable suspicion of serious irreversible harm, lack of scientific certainty or consensus should not be used as justification for not taking preventative measures [27].

As it is in the nature of science that scientific certainty never exists, the proper use of science and scientific findings is precisely to enable us to act with precaution. This is the most important ethic of science, which has been violated repeatedly for decades.

The attacks on Pusztai say more about the so-called ‘sound science’ his critics are defending, that lies behind current risk assessment, whether it be for radioactive discharge, industrial chemicals, toxic wastes or genetic engineered products. Pusztai does *not* regard his research as definitive proof that GE potatoes, or GE food in general is *harmful*. He has stressed the need for further research. However, the results do throw into serious doubt the claim of the biotech industry and regulatory authorities that genetic engineered food is *safe*. And herein lies the crux of the appropriate burden of proof, which, for the past 50 years, has persistently operated in favour of industry and against the protection of health and safety, biodiversity and the environment. In other words, the onus has been on regulators and civil society to demonstrate that something is definitely harmful before it can be refused approval, withdrawn or banned. This is simply a misuse and abuse of science, which has been and still is being condoned by the scientific mainstream.

In signing on to the International Biosafety Protocol in Montreal in January 2000, more than 150 governments including the UK have agreed to implement the precautionary principle. We must insist that they do so, for this will change the whole complexion of regulation to genuinely protect health and safety, biodiversity and the environment [**28**]. It is time scientists themselves insist on the precautionary approach.

The fallacy of scientific objectivity

There are deeper problems in the nature of the science itself and its relationship to society, which must also be addressed before the ethical implications are fully appreciated.

There is a general tendency for people to believe that scientific ‘progress’ is unstoppable, for better or for worse. This fatalistic faith in ‘scientific progress’ is more dangerous than the runaway technologies that the science inspires. It is why we have failed to avert the disasters time and again.

Underlying the faith in scientific progress is the assumption that science is about how nature really *is*, that the laws of nature are there waiting to be discovered by the objective scientist, one who is devoid of feelings, prejudices and misconceptions. In that ideal of ‘objectivity’ - which is seldom, if ever satisfied -- science is morally neutral. In other words, it offers no guidance as to what is good or bad, only what is right or wrong. Wolpert, Fellow of the Royal Society and a prominent member of its Committee of Public Understanding of Science, represents a fairly extreme version of this ‘absolutist’ view [**29**]. He makes a categorical distinction between science and its application, i.e., technology. Thus, the science that went into making the atomic bomb, and making the bomb were entirely separate. Science, he says, "has nothing to contribute to moral and ethical issues" although these can arise in relationship to the applications.

This distinction between science and technology is most often made. However, it is artificial and unwarranted, even for an overwhelmingly theoretical science such as high-energy physics. Without empirical tests, the theory on paper that radioactive reactions could become critical is no more than a mathematical exercise. So making the bomb can legitimately be considered part and parcel of the science of the bomb.

For an experimental science such as molecular genetics, the separation is even more tenuous. Where would molecular genetics be without the tools that enable practitioners to recombine and manipulate genetic material from different sources? And having done that, and noted the significant, triumphant results, it is all too easy to see the world in genetic determinist terms: that genes determine destiny, and by manipulating genes including our own, we may also manipulate our destiny. It is the science, therefore, that inspires the applications or the technology, that makes it so compelling; except that the science is fundamentally flawed (see later).

In reaction to the 'absolutist' conception of science, some sociologists have claimed that the mere notions of right or wrong involve value judgements embedded in particular social and political contexts. And so, just as there is no unique cultural standard whereby one could judge all other cultures, there is no absolute scientific truth that stands above other truths. This is the 'relativist' view of science.

These opposing concepts of science give rise to different perspectives on the moral responsibility of science and scientists, but paradoxically, they converge with regard to the *relativity* of moral values. For the absolutist, science is the corpus of the 'laws of nature', and as such, stands above mere human morals. So ethics -- moral rules of conduct -- will have to be negotiated around science. The moral responsibility of science and scientists is to scientific truth, whether it is morally palatable or not is irrelevant. By contrast, the relativist puts science on a par with other kinds of human activity. The moral responsibility of scientists is no different from that of everybody else. It is a responsibility that is socially negotiated, just as morals are a matter of social consensus and judgement.

Very few scientists who have really thought about their moral responsibility will be extreme absolutists, although they would also reject the relativist position, as I do. It is all too easy to forget that there is a much wider context within which scientific knowledge is negotiated, which is nature herself. Nature is definitely not subject to our arbitrary whim and projection, but neither is she simply 'out there' waiting to be discovered. I have made the case elsewhere that the best scientific theories are works of imaginative construction -- akin to the most moving works of art. They arise out of a sensitive, intimate communion with nature [30]. Scientists, like everyone else, and in common with all living beings, exist *within* nature. *They participate in knowing nature and more than anyone else, in shaping reality by that very knowledge*. And herein lies the moral responsibility of science and scientists. Reality can be shaped for better or for worse, and it is incumbent on us to make the choice: what to do or not to do.

Participatory knowledge predates the non-participatory Cartesian framework of modern science, which sees mind distinct from matter, and hence separate from nature. Participatory knowledge has been rediscovered early in the 20 th century within the foundations of quantum theory, which shows that the 'observer' is inseparably entangled with the 'observed', and that each act of 'observation' transforms both the observer and the observed [31]. That has overturned the most cherished assumptions of the mechanistic framework of previous centuries. It also reinstates the holistic, ecological knowledge system that many indigenous cultures across the world have never lost touch with, that has enabled them to live sustainably for millennia. If we take science to be reliable knowledge of nature that enables us to live sustainably with her, then many indigenous sciences are far superior to our own,

and there is much that we can learn from them.

The most important lesson for us is the interdependence and mutual entanglement of all nature. This is the basis of a naturalistic ethic reflecting the highest moral ideals shared by traditional indigenous cultures all over the world. It is also integral to a holistic western science of the organism emerging across the disciplines [32].

I agree with veterinarian and bioethicist Michael Fox [33]: "There are moral absolutes such as the reverence for life, compassion and ahimsa (nonharmfulness) that can provide both a goal and a common ground for a reasoned and scientific approach to resolving ethical issues. These absolutes are the cornerstones of a monistic hierarchy of human values that could effectively incorporate the plurality of interests of various segments of society and of different culture." These moral absolutes arise, not from indoctrination externally imposed, but out of our most intimate experience of nature's unity.

The two-way connection between science and society

There is a two-way connection between science and society. Science is both shaped by the politics and the mores of society *and* it can reinforce them. But science can also *transcend* the *status quo* and bring about social change, if we consciously will to do so. In the wake of the quantum revolution, it is clear that we are participants in evolution and not merely subject to external forces over which we have no control.

The mechanistic paradigm of western science grew under the legacy of the Judaeo-Christian tradition beginning in sixteenth century Europe. It inspired the search for eternal laws, ordained by God, which could make the universe move in predictable, mechanical ways. Through Copernicus, Galileo and Descartes, this strand of thought eventually culminated in Isaac Newton's mathematical laws of mechanics. So successful was the mechanistic framework that every event in nature came to be seen in this perspective.

Another strand in the legacy of the Judaeo-Christian tradition is that human beings are considered to be created in the image of God and have immortal souls, while animals and the rest of nature are there to be used by human beings. Descartes established the dualistic separation of human beings from nature, of mind from body and matter from spirit. And that has plagued western philosophy ever since. He maintained that only human beings can reason, that animals are unfeeling machines; and condoned cruel experiments on dogs and cats. Francis Bacon, similarly, urged that we "vex Nature of her secrets" that it was our right to extend our power and dominion over the universe. In *The Island of Dr. Moreau*, he described animal parks used for public viewing and for "dissection and trials, that thereby we may take light what may be wrought upon the body of man..." [34].

Thomas Hobbes went further. He maintained that nothing exists except body, matter and motion, that not only the universe but man himself can be explained mechanically. He argued that humans are determined purely by their appetites and aversions, and without the rule of a powerful king to restrain and channel those animalistic impulses, our lives would be "poor, nasty, brutish and short". In other words, absolute government is necessary to prevent the war of each against all to which natural selfishness inevitably leads [35]. Hobbes was

writing when mercantilism reached its high point in Europe, and brought great power to those princes and merchants who successfully accumulated vast quantities of gold and other precious metals.

Hobbes' influence has passed down to us via Charles Darwin in an age that saw the birth of capitalism and the expansion of the 'free' market under the military might of the British Empire. Nature became ultimately reduced to isolated atoms jostling and competing in the struggle for survival of the fittest. In its present-day form, neo-Darwinian sociobiology has changed very little from social Darwinism. It is based on denying and explaining away every good there is -- such as love, moral feelings and altruisim -- as different forms of disguised selfishness [36]. Neo-liberal economic theory is in many ways much more pernicious than Adam Smith's *laissez-faire* economics, which is based on competition tempered by moral restraint [37]. And so, through the self-fulfilling prophecy, mechanistic science has created a dysfunctional social *milieu* and a globalized economy which is destroying our planet and failing to serve the physical and spiritual needs of the vast majority of humanity [38]. *That* was the main reason fifty thousand people took to the streets at the World Trade Organization conference in Seattle in December, 1999.

It is clear that the mechanistic paradigm has spectacularly failed the reality test in life. What is not generally recognized is that *it has also failed within science itself* . It has been thoroughly discredited by scientific findings. But the discredited paradigm is still perpetrated by the mainstream academic institutions, if only because it serves so well to promote the engineering of life itself.

'Frankenstein science'

Mechanistic biology has reached its logical, nightmarish conclusion, when organisms including human beings are to be genetically manipulated and cloned. The first 'human' clone has already been created, by injecting the genetic material of a human being into a cow's egg [39]. It is all too reminiscent of Mary Shelley's prophetic parable of *Frankenstein*. Dr. Frankenstein is the scientist obsessed with mastery over nature; so much so that he attempts to create the perfect human being, only to realise too late that he has created a monster. Mary Shelley's classic is as much a parable of the mechanistic science that inspires the deed as it is of the scientist 'playing God'.

All species of animals are being genetically manipulated. Millions of genetically engineered mice are created to serve as dubious models of human diseases, and an increasing number have to be sacrificed to make room for more. Livestock are 'humanized' to provide spare organs for transplanting into human beings, or engineered and cloned as 'bioreactors' to produce pharmaceuticals and industrial chemicals in their milk, blood, urine and semen [40], and with tens of thousands of failures and abnormalities.

Apart from the potential hazards of creating new viruses that cross species barriers, the excessive suffering inflicted on the animals violates the most basic moral code of our society. Michael Fox strongly questions the right of human beings to interfere so profoundly with the inherent nature or *telos* of other species [41]. Indeed, each species has its own intrinsic value, its own purpose in the scheme of nature, which we violate at our own peril.

This is also the most abiding ecological wisdom which western science has lost touch with, and is only now rediscovering.

The organic revolution and the new ethic of science

Genetic determinism has ruled biology and the popular culture at large before genetic engineering really got underway 25 years ago. It offers a simplistic, reductionist description which is a travesty of the interdependence and complexity of organic reality. It has no concept of the organism as a whole, nor of societies or ecosystems. Instead, it sees only selfish individuals, each competing against all and all against nature. The organism, similarly, is regarded as nothing more than a collection of 'traits', each mechanically tied to specific genes. The genes are supposed to pass on unchanged to the next generation, except for very rare random mutations. If all that were true, genetic engineering would be as precise and effective as is claimed: identify the gene that determines the desired trait, isolate it, and transfer it to another organism, and you transfer the desired trait, once and for all.

Unfortunately, scientific findings over the past 25 years reveal an immense amount of cross-talk between genes, which function in complex, entangled networks. Genes are nothing if not sensitive, dynamic and responsive, to other genes, to the cell or organism in which they find themselves and to the external environment. Genes are active, or not, depending on the environment. Not only that, they can mutate, multiply, rearrange and jump around. Genes may even jump out of one organism to infect another in horizontal gene transfer. The genetic material is so flexible and dynamic that geneticists have coined the phrase, "the fluid genome", to describe the situation back in the 1980s.

Genetics has changed out of all recognition. Genes have to be seen as having a very complicated ecology, and that for genes and genomes to remain constant, we need a *balanced* ecology. The new genetics is radically ecological, organic and holistic, it is diametrically opposed to the mechanical conception of nature that has dominated the west for hundreds, if not thousands of years. The transition between classical genetics and the new genetics is analogous of the transition between classical and quantum physics [42]. That is the reason why genetic engineering, at least in its current form, can never work. It is based on misconceptions that organisms are machines, and on a denial of the complexity and flexibility of the organic whole.

Biologist Tasios Melis and his colleagues in the University of California in Berkeley have just discovered how to 'grow' hydrogen, the cleanest, most environmentally friendly fuel that generates pure water when it burns. They simply change the medium in which the microscopic alga *Chlamydomonas reinhardtii* lives [43]. The alga makes its living normally by photosynthesis, a process in which the energy of sunlight is captured to make carbohydrates and other macromolecules. However, when starved of sulphur and deprived of oxygen, the organism switches over to another metabolic state in sunlight, to recycle sulphur by breaking down its proteins and release hydrogen at the same time. The hydrogen is made by recombining electrons in the electron-transport chain with the protons, both normally generated by photosynthesis, with the help of an enzyme, hydrogenase. Hydrogen is produced at an average hourly rate of 2 milliter per litre of culture. The scientists believe they could increase the yield 10-fold. No genetic engineering has achieved that, and none

was required.

This brings us to a problem in the ethics of science which has never been seriously addressed: the kind of science appropriate to society, which can transcend the existing dominant ethos, to support the necessary transition to sustainable ways of life, and to connect with the organic uprising that is coming from the grassroots all over the world.

Many remarkable individuals and local communities are indeed changing their own lives and the world around them for the better. They all do so by learning from nature and recognizing that it is the *symbiotic*, *mutualistic* relationships which sustain ecosystems and make all life prosper, including the human beings who are active, sensitive participants in the ecosystem as a whole [44].

The same organic revolution has been happening in western science over the past thirty years. Jim Lovelock's Gaia theory, for example, invites us to see the earth as one super-organism [45]. Even more remarkable is the message from quantum theory: that we are inseparably entangled with one another and with all nature, which we participate in co-creating [46]. It is this holistic, organic perspective that can enable us to negotiate our path out of the moral maze of genetic engineering biotechnology. It provides the basis of a new ethic of science that can reshape society and transform the very texture and meaning of our lives. Seattle has shown us that things can be different. Society does not have to be ruled by the dominant culture. Science can transcend the dominant *status quo* to reshape society for the public good, which is also the private good. We begin to appreciate how the purpose of each organism and species is entangled with that of every other. Our humanity is a function of this entangled whole, and we cannot do arbitrary violence to one another, nor to the nature of other species without violating our own. The ethic of science is no different from that of being human.

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The Institute of Science in Society
PO Box 32097, London NW1 OXR
Tel: 44 -020-7380 0908