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Any correspondence on this subject should be addressed to :

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Center for Futures Studies

College of Education

Tamsui Campus

Tamkang University

Tamsui, Taipei, Taiwan

web site: www.ed.tku.edu.tw/develop/JFS

E-mail: future@mail.tku.edu.tw

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Biomimetic and Genetically Engineered Futures: Humanity at the Crossroads?

Alan Fricker*

Biomimicry is the modern, often high tech, equivalent of the historical practices of emulating nature. Through biotechnology, biomimicry has led into genetic engineering, where we endeavour to change nature. Biomimicry has a much wider and safer scope than genetic engineering. Biomimetic and genetically engineered futures in agriculture and health only are explored, not in terms of their technologies but in terms of their potential impacts on sustainability and the propensities of mankind. Biomimetics promises a more sustainable agricultural future than genetic engineering. Biomimetics is more limited than genetic engineering in our health futures, but both have a role. The direction of development, application and control of genetic engineering are exceedingly problematic. As a species we are, at present, too immature to apply this technology. We need to restructure our societies and redress the injustices we have inflicted on each other and the world before we develop the technology beyond the immediate need of pain and suffering.

Keywords: Genetics, biomimesis, biotechnology, health, agriculture

* Alan Fricker, Sustainable Futures Trust, 30 Akatea Rd, Petone, New Zealand, tel: 0064 4 589 1575; E-mail: frickera@actrix.gen.nz

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Introduction

Technological advances have enabled humanity, usually unconsciously, to postpone the Malthusian fate by pushing back the perceived physical limits of the planet. Those limits now seem finite for we now know that we have appropriated half the terrestrial bioproductivity of the planet for our own purposes, that biodiversity is diminishing rapidly, and that the climate change is very probably of our making. Other species merely reproduce to those limits. We, at least in the West, also consume to those limits and are now becoming besotted with extending the human life span.

The science of biomimicry emulates nature. Nature runs on sunlight; uses only the energy it needs; fits form to function; recycles everything; rewards cooperation; banks on diversity; demands local expertise; curbs excesses from within; and taps the power of limits (Benyus 1997). We have practised biomimicry for millennia, usually for utilitarian purposes and in particular agriculture. Conventional plant and animal breeding push the boundaries of biomimicry. Biotechnology began through understanding nature's processes, notably fermentation which led to vaccines and pharmaceuticals, and thus, through molecular biology, to genetic engineering, and again is pushing the boundaries. In the background however has been the scientific enquiry into how nature really works and how we might copy and assist her to our mutual benefit. This is modern day biomimicry. Biomimicry, biotechnology and genetic engineering are a continuum, rather than alternatives, where the distinction lies in who is in control - nature or man.

The pursuit of a biomimetic future has some intuitive certainty. The pursuit of a genetically engineered future presumes the planetary limits could be extended once again, but has considerable uncertainty and potentially catastrophic consequences. The phase lags of nature feedback loops may be too long to allow us to keep our options open if we are indeed close to the physical limits. It may behove us to keep well within such limits, not only in our own interests, but those of other species too whose presence not only sustains us but inspires us.

Historically we have evolved slowly, both biologically and socially, to our changing environment. Now, we have no option but to evolve culturally and quickly to the environment that we are changing. That evolution may depend on the choices we make in collaboratively adopting internal controls on our expansive tendencies. Whether that will be through mimicking nature, where nature is our guide and mentor, or

through engineering nature, where we direct and control her, or through some judicious blend is problematic.

Once our essential material needs, namely food, energy, and shelter, are satisfied, we sustain ourselves through our relationships with each other, other species, and our inner selves. Education, health and the expression of our creativity are secondary needs, for which we need materials and to develop technologies. Research in biomimicry is being conducted in most, if not all, of these material categories (Benyus 1997), whilst that in genetic engineering is, at present, effectively limited to food, health, and, to a much lesser extent, conservation biology. Yet investment in biomimicry is minuscule in comparison to genetic engineering. Agriculture and health are the main considerations here.

Life as Paradox

Rationally, we and the biosphere are not a logical, indeed a most unlikely, outcome of cosmological evolution. Yet we have sought certainty, searches that inevitably lead to more paradox. Ultimately we find we have to accept uncertainty and paradox to find meaning in our own lives, not just in life itself, and it is that uncertainty that provides purpose in life. That leads us to make choices, where deep choices are made on the basis of subjective truth rather than objective demonstrable truth.

Science, in large part, is a consequence of that search for certainty through verifiable knowledge. It has enhanced our understanding immeasurably but has driven a wedge between our appetites and our humanity, between the secular and the sacred, and between objectivity and subjectivity. Through human genetics we are wondrously poised at defining what we are and how we function in minute detail. Knowledge however that may further alienate us from ourselves for it will tell us nothing about who we are. In biomimicry we are acknowledging that we are a part of nature, where our creativity is turned towards understanding how nature functions not just in detail but in its functional interconnectedness, comforted to some extent by an intuitive certainty that nature has a proven track record. In genetic engineering we are saying we are apart from nature, perhaps even above nature, where our creativity is directed at improving on nature.

Most of the great religions and philosophies tell us that humans, at least, are all equal in the eyes of God, of the other. Yet our attitudes and

behaviours reflect deep seated beliefs that we are not all the same, that we are different, whether it be by nature, nurture, colour, intelligence, gender, sexual orientation, language, culture, and so forth. Liberal democracies at least tolerate difference and endeavour to provide equality of opportunity. Democracies therefore have a plurality of moralities, where the law, an instrument of reason rather than belief, arbitrates. Genetics is now telling us that we are indeed different. We may have 99% of our DNA in common with chimpanzees, which should speak volumes about how interconnected, how much the same even, all species are, but that 1% difference is seen as profound. Similarly we may differ by only 0.1% in our genetic make-up from other humans, and that difference too is profound. We are different. Our deep seated beliefs, our prejudices, are confirmed. Science is right after all.

The Unruly Passions of Man

The social historian, Albert Hirschman (1977), ascribed economic activity or growth as an outlet for the .. unruly and destructive passions of man. These passions may not have emerged until the advent of agriculture, a mere 5,000 years ago. Prior to that period we were conservator peoples. For millennia, most hunter-gatherer societies, even those only recently extinct or greatly modified, lived, like most animals, within the carrying capacity of their environments (Flannery 1995). Tudge (1995:154) argues that agriculture, in an evolutionary sense, was a short term tactic that became permanent. In becoming permanent it enabled our exploiter/explorer tendencies to emerge. Reaney (1995:87) argues that agriculture gradually changed our perception of time which facilitated these tendencies. Time ceased to be wholly cyclic. Time took on a linear component. Birth and death became discrete events. This gave rise to the notion that perhaps death might be final. Thus arose, in response to the fear of death, the great religions. Now with their demise, the finality seems evident, and thus there is the denial of death and denial of the future. The selfish gene has become the ego-self.

Game theory posits that an 'all-dove' society (peaceful, conservers in Tudge terminology) is the most biologically efficient state, but it is an evolutionary unstable state. The evolutionary stable state (aggressive) is one in which there are some 'hawks' (Tudge exploiters/explorers). 'Hawks' benefit at the expense of the 'doves' who are powerless to do anything about them. Nature provides a stable but not the most efficient

state. Can we assume the evolutionary stable state will remain stable as the limits are approached? Both Christ and Kant advocated an 'all-dove' society. Perhaps the transformation is the measure of man, the extent of his free will. Kant .. proclaimed that ethics begins at the point when we start to behave against our own inclinations (Tudge 1995:365). Let us not forget however that the 'hawks' may well have brought us material benefits that as 'doves' we may not have. Let us not also forget that we are, or would like to be, hawkish to some extent at different times in our lives.

Hawkishness leads to power structures and the acquisition of resources that are seen as scarce, ranging from private property to colonies. Poverty, inequality and environmental deterioration are seen as confirmation of that scarcity rather than as a consequence of consumption and private or state acquisition. Furthermore the fact that the majority poor (that is the less able since they are not rich) breed and therefore consume these scarce resources is still at the heart of modern day Malthusianism (Ross 1998). Technological advances however have enabled us to postpone the Malthusian fate (Giampietro 1994) without foregoing acquisition. The last advance, the Green Revolution, had just that effect. Now genetic engineering in agriculture is promoted as such a means.

The old eugenics was a response to the pressure on resources, so as to enable those in authority - the privileged, well-born, able, intelligent - to continue to acquire a disproportionate share. Socially that view of the poor, the minorities, the disabled, the 'perverted' is no longer overtly acceptable within democracies today. Our deep seated beliefs and prejudices that we are different however remain and have been validated by genetics. Thus eugenics is still alive and we must be on our guard as to the real motivations, conscious and subconscious, and unforeseen consequences of human genetics. The challenge will be to separate genuine compassion from socially ingrained, even inculcated, injustice and prejudice.

Agriculture

Modern industrial agriculture is championed on the basis of the overall threefold increase in useful biomass brought about by the Green Revolution. Plant breeding has been at some cost to the plants themselves, for less energy of metabolism is available to protect and reproduce themselves. Hence their lack of robustness, almost total loss of self-

propagation, dependence on artificial fertilisers and the need for chemical protection. Similarly with animals.

The revolution was promoted with the best of intentions - to feed the world's hungry. Instead it (together with safe water supply and disposal, and medicine) furthered human consumption and expansion and numerically increased the hungry. Along the way it was subverted by commercial interests, where agricultural development in the developing world was seen as producing cash crops for export to the developed world in order to earn overseas revenue. In the process not only were their own subsistence crops not grown, they have been unable to afford staple foods produced elsewhere, and many have become displaced from the land, their livelihoods disrupted with consequent social decline and outward migration.

The impact of the revolution on the developed world has been as traumatic in a different way. The greater global production and higher yields have created surpluses which have driven prices down. Many labour intensive traditional on-farm operations have been replaced by externally manufactured (and subsidised) inputs, such as fertilisers, to reduce costs. The proportion of household income in the developed world spent on food and beverages has decreased from 71% to 11% over the last century (Senauer et al 1991:131).

Modern industrial agriculture has made traditional and subsistence farming uneconomic, but not obsolete as many of the practices were sustainable. In the process it has become unsustainable for it degrades and depletes the soil (Fricker 2000). Between 3,000 and 12,000 years are required to form sufficient soil for productive agricultural use. Soil erosion rates of up to 10 mm/yr and declining soil quality are common. The Prairie soils in the USA have been eroded up to 1m as agriculture intensified over the past century. Soil erosion on conventional farms can be 100 times faster than the formation rate. For the US as a whole erosion is proceeding at a rate 17 times faster than formation. At least 25%, perhaps 80%, of the world agricultural land has been moderately to severely eroded. About 30% of the agricultural soils in the USA have been abandoned because of erosion (Pimental 1995).

Biomimetic Agricultural Futures

Alternative agriculture is a response to conventional agriculture. It embraces organic, biodynamic, biological, and integrated pest manage-

ment practices. Most of these are unsustainable too, relative to the soil, but are an order of magnitude better than conventional agriculture. Many traditional agricultural practices, at least in Europe until the end of the 19th century, maintained (and often improved) the soil and its fertility. Alternative agriculture is still in transition, either in re-learning the old ways or in learning the new. They all reflect a common desire - to use local and natural materials; for minimal artificial fertilisers and pesticides; for diversity; and to work with rather than against nature.

Concern about the unsustainability of conventional agriculture led to the establishment of the independent Land Institute in Kansas in the 1970s. The prime intent was to reverse the declining fertility and erosion of Prairie soils. The objectives are to develop perennial grains through plant breeding techniques (preferably using indigenous grains), to avoid tilling and the use of artificial fertilisers, and to develop polycultures of crops to avoid (or at least minimise) the use of pesticides. After less than one human generation they are on the verge of success. Sustainable agriculture is imminent, when considered in terms of material and energy balances and soil sustainability, unlike monocultures of annual grains (Benyus 1997).

Genetically Engineered Agricultural Futures

Based on the premise that agricultural sustainability is founded on soil sustainability, genetically engineered developments must be assessed in terms of whether they enhance, or at least do not diminish, soil sustainability. Soil is not just a substrate. A healthy soil is a living world of its own (Suzuki and Dressel 1999:23). This is the realm of viruses, bacteria, fungi, algae, protozoa where horizontal gene transfer, the principal concern of molecular biologists in more complex species, is most frequent and rapid. As so little is known about soil ecology the impact of genetic engineering can only be speculation. Already it is known that the accumulation in the soil of the natural insecticide *Bacillus thuringiensis*, as a consequence of genetically engineered resistance in selected plants, is adversely affecting soil microbial activity (Creechio and Stotzky 1998). It is also known, but only fortuitously, that a genetically modified soil bacteria *Klebsiella planticola*, which showed much promise under sterile laboratory conditions in accelerating the rotting of crop wastes, killed off all the fungi, and thereby all the plants, in a real living soil (Suzuki and Dressel 1999:120).

The arguments for genetic engineering in agriculture, increased yields to feed the global hungry, reducing the applications of pesticides, environmental protection, enhanced consumer acceptance have yet to be unequivocally demonstrated. Despite the claims of increased yields, a definitive comparative study of thousands of varieties of conventional and herbicide resistant soya beans over eight States in the US found that the resistant yields were from 4 to 6% less than the conventional yields (Oplinger 1999). Humanitarian and environmental concerns become subsumed in technological challenge and commercial opportunity. The vitamin A enriched 'miracle' rice dilemma has its roots in the intensification of agriculture and the elimination of edible companion plants which provided the necessary vitamin.

The risks to other plants, human health, and the environment have a better chance of being known in advance than they do to the soil. This is not to say that there are indeed serious risks. We just do not know. We must therefore adopt the precautionary principle. There are no grounds, as yet, for believing soil sustainability will be enhanced and strong grounds for believing genetic engineering in agriculture is in effect an extension of unsustainable modern intensive agriculture.

Nevertheless the developing world has a great need for food. If genetic engineering can increase output without comprising the true sustainability of agriculture - the soil - then it should be in the hands of the developing world themselves, with assistance if required from the developed world.

Health

By and large, our bodies are self-regulating systems provided we take care of them by eating appropriately, live in healthy, supportive environments and are not over-stressed. The advent of clean and safe water reticulation services and better nutrition has made a much greater contribution to health and longevity than has medicine. Medical advances, other than the treatment of infectious diseases, benefit individual health rather than public health. Over the past 50 years, only about four months have been added to the expected life span of a person who is already 60 (Appleyard 1999:124). Concurrent with these advances has been decreasing health due to deteriorating environmental factors, notably from chemical pollutants. A century ago, cancer was a rare disease now it is common and cannot be attributed to people living longer. Environmen-

tal and social factors account for 80% of cancers (Hubbard 1993:83). Furthermore, the lower socio-economic groups have poorer health and die earlier.

The health of the British public during World War 2 under the strict but fair rationing regime was much better than it is today. The developed world tends to over-eat and inappropriately, whilst many in the developing world have insufficient food. The Worldwatch Institute in a recent report claims there as many overweight people in the world today, 1.1 billion, as underfed. The developed world is using medicine and surgery to remedy conditions largely of our own making. Often they are not cures, merely alleviation, a shift from acute to chronic states. Major heart surgery extends life expectancy on average only a few years, but among them are individuals who enjoy many years. Health has been reduced to statistics and probabilities, which is of no comfort to the individual affected or with a propensity to affliction.

Nevertheless, our bodies are not always totally reliable. Genetic mutations and natural selection have given rise to our generally healthy selves. A few mutations go awry and become inherited, but most conditions are recessive rather than dominant. A recessive gene needs both parents to be carriers before it may be expressed. A dominant gene does not. Carriers of a recessive gene are in no sense ill. Some recessive genes have imparted evolutionary benefits to carriers, eg. a greater resistance to malaria from the sickle cell gene that is relatively common among African and Mediterranean peoples. An expressed mutation should not necessarily be considered as disease or disability. Persons with Down syndrome do not consider themselves disabled in any way; different and disadvantaged yes. Neither do many thalidomide 'babies'. Our perception of normalcy has been challenged.

Biomimetic Health Futures

Animals, including our forebears, found out what could be eaten and how much by trial and error, developing their senses of taste, smell, and sight which reduced the amount of trial and error. In the process we, and other animals, also found that some plants had medicinal value.

As biodiversity diminishes bioprospecting by drug companies is intensifying. This scatter-gun approach to ethnobotany is being joined by zoopharmacognosy. Here scientists observe the behaviour of mainly primates when they are ill - mostly in their native habitats but also in

'foreign' habitats (Benyus 1997). There are stories of how sick primates seek out specific plants and specific parts of those plants to heal themselves, even travelling long distances to places they have never been. Some Navajo teachings and medicines are based on observations of the self-medication of bears. Traditional and alternative medical practices are biomimetic, many aspects of which are receiving endorsement from conventional medicine.

Much conventional medicine is biomimetic too, as many pharmaceuticals are based on natural products. Some are sourced from animals, perhaps with the assistance of genetic engineering for technical or economic reasons. But do biomimetic health futures lead on smoothly to genetically engineered futures?

Genetically Engineered Health Futures

Molecular biology is enabling the prevention, alleviation or cure of several genetic disorders, such as Tay Sachs, Huntington chorea, sickle cell anaemia, multiple sclerosis, cystic fibrosis. Furthermore there is the promise of extending the life span through genetically engineered human growth hormone. The prospects are wondrous but they are equally as frightening for how will we use this ability and how will that impact on the capacity of the world to sustain us? A raft of ethical and ontological questions are raised to which we must quickly find answers, for the technological juggernaut has enormous momentum.

Before molecular biology came of age, the biologist Marshall Nirenberg in 1968 wrote: When man becomes capable of instructing his own cells he must refrain from doing so until he has sufficient wisdom to use this knowledge for the benefit of mankind. (Appleyard 1999: 31). Whilst there can be no doubt we must endeavour to do our best to alleviate pain and suffering, the potential consequential, and even sinister, effects of unbridled development are alarming.

Germ line therapy is directed at future people, who might inherit an undesirable condition. Furthermore, the effect will be permanent for it will persist in their progeny. The gene pool will be altered. This is the perverse logic of denying a future person the right to exist as they would have been. The responsibility however for the potential unknown risks to the yet unborn will be carried by persons long deceased. How necessary is it that the person should be conceived or born? Genetic screening can indicate alternative options, avoidance of conception, embryo

selection, and adoption. Screening itself is not without risks, both medical and social. Screening for Tay Sachs, where avoidance rather than treatment is the only option at present, has had beneficial outcomes, whilst screening for sickle-cell anaemia had very unfortunate social outcomes wherein our innate assumptions and prejudices about racial differences were quasi-officially confirmed (Appleyard 1999:78). Although medical ethical committees from all around the world have already rejected the notion of engineering human germ lines, the notion lives on and is certainly researched with other animals.

Somatic gene therapy is directed at living people, including foetuses. Stem cells, the basic building blocks such as blood and marrow, are preferred as on-going therapy is then much less frequent. The thalassemias, of which sickle-cell anaemia is one, cystic fibrosis, and muscular dystrophy are among the most common disorders. Clearly we should use medical technology to do our utmost for such people within the constraints of competing demands.

But is it always therapy that is advanced? Therapy is usually thought of as treatment of a genuinely disabling condition. Much of the gene therapy being advanced includes the elimination of an undesirable trait or the enhancement of a desirable trait, or propensity towards. Not all the potential applications are directed at reducing pain and suffering. Many are directed at - our preferences, making spare parts for ourselves, our pockets, our fears, even our prejudices, and animals as factories. We may wish our child to be male, or to have blue eyes. We may wish, and society may encourage us, to avoid the embarrassment and cost of a Down offspring. We may soon be able to select genes that influence intelligence or sexual orientation, or that supposedly govern behaviour, such as laziness or criminality, notwithstanding that behaviour is more nurture than nature. Research concentrates on clinical rather than social and environmental causes of undesirable behaviour because it has become easier to study genes than it is to remedy the underlying causes. So who is receiving therapy - the patient or ourselves?

We are all flawed in someone else eyes, so who will determine what is flawed? In liberal democracies the choices are falling on the individual. That choice becomes socially mediated, even for yourself. Society has a preference for physical uniformity, for normalcy - the avoidance of difference. To be short, it seems, is not a desirable characteristic. In selecting to avoid shortness we gradually change the natural distribution of height. Eventually what was once not considered short could become short. The distribution may not necessarily shift but become narrower,

even more uniform. A society which values the dollar more than it values people may have a preference for non-physical attributes that it considers valuable, such as computer modelling, or entrepreneurial flair. Undirected counselling is therefore perhaps impossible, no matter how skillful. The driver of most societies today is the economy rather than compassion. The compassion is there but it must be within a framework where commercial advantage and technological challenge are satisfied if not paramount. The promises feed on our prejudices and our fears - even our fear of death, through, for example, genetically engineered human growth hormone to extend our life span.

The humanitarian priorities are the more common disorders, even though the rare disorders are as deserving. The technological priorities are those that combine challenge and funding. Here, we need to recognise the conflict between the private minds of the scientists and the public propaganda of science (Appleyard 1999:165). The commercial priorities are those with the maximum opportunity, the largest market, even if it has to be created. This lies in broadbrush genetic screening for conditions or propensities which may never manifest themselves, where knowledge of them may be more distressing than the potentiality, and which could be discriminately used, in insurance or employment for example. Furthermore, our fancies, fears and prejudices could be fuelled. These are the new eugenics. Our nobler and baser tendencies would be in juxtaposition. The prevailing worldview, based on a utilitarian attitude to life, would most likely swamp our nobler instincts. Genetic engineering would become yet another technology whereby we endeavour to postpone the Malthusian fate.

Implications

Ecology and biomimetics are telling us that humans are a mature species behaving as a pioneering, opportunistic species. Organisms in a mature ecosystem - use waste as a resource; diversify and cooperate; gather and use energy efficiently; optimise rather than maximise; use materials sparingly; don't foul their nests; don't draw down resources; remain in balance with the biosphere; run on information; and shop locally (Benyus (1997:297). Benyus offers four steps towards a biomimetic future, that of - quieting (immersing ourselves in nature); listening (interviewing the flora and fauna); echoing (taking nature as model and measure); and stewarding (preserving life diversity and genius). Learning from them (nature

lessons) will require only stillness on our part, a quieting of the voices of our own cleverness.

Genetic engineering on the other hand continues the opportunistic course. Its role in agriculture seems unnecessary as the global food problem is not production, but distribution and access to money and land. Furthermore, it may further undermine the sustainability of agriculture, namely soil sustainability. The potential for severe and permanent ecological consequences mean we should proceed with great caution. Clearly genetic engineering has a role in alleviating human pain and suffering. Beyond that its role serves some well meant but misguided purposes that could even have sinister outcomes. Even though society, rather than the commercial and scientific communities, should determine the direction and applications of those developments (Fricker 1997), society still does not have the wisdom that Marshall Nirenberg wrote of over 30 years ago.

Man, and scientists in particular, like and need a challenge, to channel their unruly passions. Biomimicry offers as great, if not a greater, scientific and technological challenge, but in other theatres, than genetic engineering. There is commercial opportunity too, for although a mature ecosystem implies a static state, that is far from the case. There is considerable activity and recycling in a mature system, and the greater the diversity the greater the activity. The challenge is to promote and exploit technologies that have ecological advantage whilst observing the canons of nature. They lie in biomimetic energy (photosynthesis), manufacturing (composite materials), and information technology (carbon computing) among others (Benyus 1997). Biomimicry even suggests opportunities in governance that are similar to the ideas put forward by the industrial trainer, Peter Block (1993). Biomimicry is therefore a doveish technology, whereas genetic engineering tends to be hawkish. We need to become a conserver people again, where we gather the knowledge of how nature works in all her complexity and hunt for opportunities to emulate her.

The role for genetic engineering may be forever problematic, for it takes us to the edge of hubris and blasphemy, to where we respectively challenge and offend the gods. We may be forever anxious, as we always have been. Man, being free and bound, both limited and limitless, is anxious. Anxiety is the inevitable concomitant of the paradox of freedom and finiteness. Man is anxious because he does not know the limits of his possibilities. It is not possible to make a simple separation between the creative and destructive elements of anxiety. (Niebuhr 1941:194-6).

We have every justification to be anxious about the dysfunction and unsustainability of the prevailing worldview. The sacred and the secular need to be reintegrated, as science is under no obligation to produce morally acceptable outcomes. Even science is acknowledging that objective truth is only partial truth and sometimes illusory, that scientific insight begins in subjective truth, and that there are many ways of knowing (Wildman and Inayatullah 1996). There are also processes for us to critique our worldview and develop alternative worldviews whereby we find new stories of how we now understand the world and our place within it, such as causal layered analysis (Inayatullah 1998). The choices we make in endeavouring to attain just and sustainable futures relate less to the technologies themselves but to the wisdom behind those choices.

Science is wonderful and the new technologies are astonishing, .. Only when we are straight in our own heads, and have structured societies that are able to override their own innate tendency to be overtaken by hawks and hawkishness can we hope to create the kind of world that can be sustained,.. (Tudge 1995:373).

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