Changing Nature's Course

The Ethical Challenge of Biotechnology

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Biotechnology — The New Ethical Frontier: An Introduction

Gerhold K. Becker

The twentieth century is certainly not short of important scientific discoveries, yet few have had greater impact on our lives than the unravelling of the structure of the atom and the genetic make-up of organisms. Both marked the arrival of a new age of scientific development which has successfully forged the rise of a powerful alliance between pure and applied science, between scientific theory and technological practice (and application). Besides pushing society 'into the era of high technology'[1] it has forced scientists to reconsider their social role and to accept greater responsibility for the consequences their research may hold for the rest of us. This new situation is clearly reflected in Max Born's remark:

> When I was young, it was still possible to be a pure scientist without being much concerned about the applications, the technology. Nowadays this is no longer possible, for natural science is inextricably intertwined with the social and political life (. . .) Today every scientist is a link within the technological and industrial system in which he lives. By that he has on his part also to be responsible for the reasonable use of his results.[2]

While the end of the Cold War somewhat de-dramatized our fear of atomic weapons, the potential threat from nuclear power plants continues to be the source of great anxiety. It is only rivaled by recent advances in biotechnology which have captured our imagination and propelled our expectations of the immense benefits as well as the fears of the equally immense dangers. As a report by the Office of Technology Assessment has pointed out, the arrival of the Age of Biology marks a new ‘scientific revolution that could change the lives and futures of its citizens as dramatically as did the Industrial Revolution two centuries ago and the computer revolution today.’ [3]

For its proponents, biotechnology holds the promise of generating almost limitless resources to meet the needs of a rapidly growing world population in its fight against hunger, diseases and the devastation of the natural environment through human intervention. From the development of designer foods to the creation of biodegradable pesticides, virus-resistant plants, and bacteria which consume oil spills; from gene therapy to eugenics, the impact of biotechnology can hardly be overestimated. The cover story in *Time* magazine of 17 January 1994 noted: ‘The ability to manipulate genes could eventually change everything: what we eat, what we wear, how we live, how we die and how we see ourselves in relation to our fate.’

For its critics, biotechnology is more a nightmare than the answer to our current problems. It has been argued that, instead of creating genuine opportunities for a more humane future, biotechnology will jeopardize even our past achievements and add numerous incalculable risks to our future. The human body will be commodified and objectified, becoming a source of patentable raw materials which can be combined to produce tissues and living organisms that cannot develop naturally.[4] Nature will no longer be ‘natural’ but be re-created in the image of man. It is an image, some believe, that will have more in common with Dr Frankenstein and his creatures than with Socrates, Confucius, or Mother Teresa.

Outline of a Revolutionary Technology

In spite of the singular, biotechnology is in fact a combination of several technologies which draw on a number of scientific disciplines.[5] Biotechnology as it has developed over the last 15 to 20 years is usually taken to refer to three significant technologies:

- recombinant DNA technology
- *in vitro* manipulation of cells (also called cell culture technology, or bioprocessing)
- monoclonal antibody technology

The European Federation of Biotechnology defined biotechnology accordingly as the ‘integrated use of biochemistry, microbiology and engineering sciences in order to achieve technological (industrial) application of the capabilities of micro-organisms, cultured tissue cells, and parts thereof.’[6]

Modern biotechnology is based on the discovery by James Watson and Francis Crick some forty years ago (1953) of the structure of DNA (deoxyribonucleic acid). Its famous double helix is made up of long and complex molecules which form two coiling strands of sugar-phosphate linked together like the steps of a spiralling staircase by four subunits.[7] These molecular components are called nucleotides (or nucleotide bases) and contain, apart from a sugar-phosphate combination, one of four kinds of differently shaped bases: adenine (A), guanine (G), cytosine (C), thymine (T). The genetic information which determines the whole structure and the biochemical functions of the cells of any organism is encoded in the sequence, or order of these four subunits. It has been estimated that there are about three billion base pairs which are the 'steps' of the 'staircase' containing all the genetic information of a human cell.

This principle of coded information resembles that in the sequence of the letters of our alphabet, complete with stop- ('periods') and start-codes (markers for word beginnings), by which we obtain all the words of our language through the combination of just 26 letters. Similarly, the chemical substances of DNA are combined into distinct functional units — the genes — which form individual, consecutive stretches of base pairs encoding sufficient genetic information to produce simple chains of amino acids. Although the term gene preceded modern biotechnology and was first coined in 1909 to refer to Mendel's rather mysterious units of biological inheritance, its full implications emerged only when the high-tech form of biotechnology gained ascendancy. Genes vary considerably in size, and 'a typical gene might include 1,000 base-pair steps in the DNA staircase and about 100 turns in the DNA double helix.' [8] The genes represent the various words in a long text and work like commands to produce (express) all the hereditary traits in any organism. An organism's complete set of genes, comprising the totality of its genetic information, is called the organism's genome. It has been estimated that the three billion base pairs of the human genome include 50,000 to 100,000 genes. 'The rest of the genome — perhaps 95 percent of it — is nongenic sequences with unkown function, sometimes called "junk".' [9]

The chemical components of DNA are the same in all organisms and are found in the most primitive bacterium as well as in human beings. What distinguishes one organism from the other is not the overall structure of the molecules but the different sequences of the subunits within the DNAs. 'Once isolated, any DNA molecule is the same as any other, and all can be treated with the same tools and techniques in the laboratory.' [10]

The most dramatic implication of biotechnology lies in this fact of the sameness of DNA components and the possibility of re-arranging their order and substituting one gene for another. Although the technology for such an unprecedented manipulation of genetic information — recombinant DNA technology — began to become available only in 1973, it has 'undergone the most spectacular development' (Gendel). It quickly evolved into a powerful instrument which is now routinely used to alter the genetic make-up of a broad range of organisms, including microbes, plants and mammals.

The technology seems in principle rather simple although it requires highly sophisticated tools and clever methods to slice out a piece of genetic information of the host organism, manipulate it and transfer it to a cell of another organism. Recombinant DNA technology has developed rapidly and can now be used for a variety of purposes including the breaking down, manipulation and recombination of molecules. ‘The power of recombinant DNA technology is that it permits researchers specifically to reprogram an organism to produce any desirable or useful biological product.’[11]

The *in vitro* manipulation of cells is bound to revolutionize agriculture and livestock farming, and will have a strong impact on our natural environment including its fauna and flora. Although applied to the development of a variety of new bio-products both in plants and animals, the most dramatic impact of this technology lies in its capability of breaking down the species barrier by engineering transgenic plants and animals. This is based on a combination of recombinant DNA technology and cell culture technology which allows the introduction of desirable traits from various sources into the genetic make-up of an organism. ‘A transgenic organism is one that carries and expresses genetic information not normally found in that species of organism.’ Whereas ‘traditional methods can only manipulate genetic capabilities already present within the gene pool of an individual species’, ‘modern biotechnological innovations allow creation of organisms with genetic capabilities not normally found in that particular species.’ [12]

Currently, this technique is most commonly used to improve the nutritional qualities in both plants and animals and to develop natural defense mechanisms against diseases. The application in plant production includes further strengthening of their natural properties against cold or heat, and a higher tolerance to pesticides and polluted environments.

Antibodies are extremely sensitive proteins capable of recognizing a foreign molecule from among billions of others and hooking themselves to a very specific location of it. Monoclonal antibody technology then makes use of these exceptionally important properties of antibodies to produce a variety of specific indicators of other substances to which they react. It will allow the development of numerous diagnostic testing procedures of extremely high accuracy.

A New Ethical Landscape

There can be no doubt that biotechnology represents a major breakthrough in scientific research and a triumph of human ingenuity. It will be the most powerful ally in our fight against diseases and disabilities, hunger and poverty on a world scale. It will help us cope better with the devastation of nature brought about by the earlier industrial revolution and over-population in the wake of what has been described as ‘the demographic explosion’ (Paul Kennedy).

However, the downside of biotechnology has largely to do with this unprecedented power, its use and its control. The implications and social impact of biotechnology have been compared to those of the splitting of the atom and the technological exploitation of nuclear power. As with nuclear technology, biotechnology has put enormous power in our hands. Yet, power is essentially ambiguous, it can be used for good and evil purposes. And there is growing concern that this new technology may redefine our relationship to nature by irreversibly and detrimentally changing nature's course. In altering natural evolution through human tampering with the gene pool, biotechnology would cause incalculable risks for human integrity, well-being and freedom.

This ethical concern is reflected in an increasing number of publications which cover a wide range of issues. There is also the fear that biotechnology might even have begun to change the rules of ethical decision making. In the past, ethics was based on widely (and frequently cross-culturally) shared beliefs about human nature, personhood and social responsibilities. The consequences of individual actions were never as dramatic as they are now; in addition, they were usually confined to one's own life circle. Clearly, this situation has changed, since we are now capable of literally blowing up the whole planet, destroying its ecosystem and changing humanity beyond recognition. Hans Jonas has pointed out that for the first time in history it is up to us to decide whether mankind should be at all; for the first time, the very existence of humanity is put in our hands. In the past, ethics never had to deal with such daunting questions, instead it operated on the assumption that nature was not within the reach of man[13] but ultimately inviolable. Her self-healing powers were thought to always prevail and out-do the damage man could possibly inflict on her. Certainly, this can no longer be taken for granted.

A sober reflection on the ethical implications of biotechnology as such is therefore, above all, confronted with two fundamental questions:

Firstly, does biotechnology represent a qualitatively new step in the history of science which calls for a new ethics, or is it something that can and should be understood along the lines of traditional values and within the well-established framework of moral philosophy. To put it differently: Has biotech just opened a new chapter in the long history of the scientific conquest of nature, or has it effectively closed the old volume and begun to write the first lines of an entirely different story? This text would be as much about the conquest of nature as it would be about its potential devastation, its manipulation and re-creation; in any case, it would be about changing nature's course altogether.[14]

Secondly, what impact should we allow biotechnology to have on the hidden assumptions as to how we view ourselves? Can we utilize its potential and carry on with our familiar worldviews and religious interpretations of the world, or is biotechnology in itself some sort of new ideology which challenges our traditional place in nature? Is it endowing us with the creative powers of God, or rather reducing us and the mystery of life to mere genetic components at the molecular level?

Strachan Donnelley very aptly summed up the ethical problem of biotechnology as follows: 'What should be the ethically self-imposed limits, if any, to our interventions into nature, for what reasons, in service of what moral values?'[15]

Biotechnology's Major Ethical Challenges

Apart from ethical considerations on our general relationship to high technologies, most notably biotechnology, a number of research areas have attracted particular attention. They combine most of the features of complex ethical dilemmas with a relatively well-defined research activity within the larger framework of biotechnology. The more prominent of them are represented in this book through articles on both the latest research developments and in-depth analyses of their ethical implications. These areas of biotechnological research include the following:

- human genetic engineering
- genetic screening and testing
- the engineering of transgenic plants and animals
- the patenting of life forms

The Human Genome Project and Gene Therapy

The ethical issues with regard to the Human Genome Project which will ultimately lead to a full map of the genetic information as it is encoded in the human DNA concern not so much the project itself but the potential use of the information thus acquired. Since it will be possible to produce the genetic profile of any individual, the ethical questions revolve around issues of privacy, confidentiality, ownership and autonomy: 'How should information be protected? Who should have access to the information and under what circumstances? What rights, if any, do employers, insurers, and family members have to an individual's genetic information?'[16]

Yet, the larger question looming in the background is related to human gene therapy. Although there seems widespread agreement that somatic cell gene therapy poses little ethical concern, germ-line gene therapy is highly controversial and generally rejected on ethical grounds. Whereas the former therapy could be understood along the lines of traditional medical intervention such as organ transplantation, the latter is different. It allows that changes could be made in the genetic information which would be passed on to all future generations. It raises also questions about how to understand what is normal and what is abnormal, what is deviant or deficient, and what is genuinely human.

There are mainly two kinds of ethical arguments against the use of germ line gene therapy. The first one is a consequential argument that doubts the moral right of anyone to induce genetic changes whose potentially harmful consequences cannot be anticipated and whose results will affect future generations. The second argument is categorical (deontological) in nature and rules out as a matter of principle any moral right to tamper with the human gene pool and to manipulate the genetic inheritance of the human race.

Ultimately, germ line genetic therapy leads directly back to the extremely difficult questions which have been raised in conjunction with biotechnology and its impact on our fundamental beliefs about ourselves, our species and human nature as such. To what extent will biotechnology change how we view ourselves? On what ideological assumptions will scientists base their research on the human genome? Will they regard human beings as nothing more than the products of interacting genes, or will they allow for some qualitative differences between the genes and their 'product'?

It seems that the answer to questions such as these will depend on whether we will enter a new era of eugenics where we might not only aim at decreasing the number of harmful or less desirable genes (negative eugenics) but tamper with the genetic make-up of our species by introducing new or altered genes thought to 'improve' the quality of the human gene pool (positive eugenics). Unless we have arrived at an universally shared, normative conception of humanity in the comprehensive sense of the term which can ethically guide this kind of intervention, and unless we can claim solid knowledge about the long-term consequences of positive eugenics, experiments of this nature should not be allowed.[17]

Transgenic Organisms

Similar questions have been raised with regard to the development of transgenic organisms. Yet, there are also a number of more specific issues which have become the focus of ethical concern. A research project on the Ethics of Animal Biotechnology sponsored by the Hastings Center has identified three issues of particular significance:

Firstly, the concept of the species and its possible moral implications: The possibility to bridge the species barrier brings to the fore not only the very concept of the species itself but also its significance and function in the natural order of beings. It is noteworthy that in most cultures the crossing of species lines used to be the subject of taboos for humans and was exclusively reserved to superhuman beings. This indicates a strong sense for the inviolability of the natural order and its hierarchy where everything is believed to have been assigned its proper place. The attempt to change this place was tantamount to an attack on the eternal order of creation and a rebellion against its creator. It is not only in Christian inconography that the devil as the embodiment of such a rebellion is usually depicted as some sort of 'transgenic being', which has merged the properties of a number of different species (man, goat, ass, reptile, etc).

It appears then that the question as to whether species are 'real biological entities so inherent in the fabric of nature that we become morally culpable in breaking the barrier between them'[18] requires an interdisciplinary and cross-cultural approach. It would have to draw on the wisdom enshrined in the philosophical and religious traditions of mankind as well as on the discoveries of the biological sciences.[19]

Secondly, the potential pain and suffering caused to genetically engineered animals: This concern is closely related to the more general one of the treatment of animals as subjects of research and experimentation, and raises the question of the moral status and the potential (range of) rights of animals. The commercial benefits of genetically engineered livestock (greater weight, greater feed efficiency, reduction in fat) have frequently been offset by a host of painful side effects such as a high incidence of gastric ulcers, arthritis, cardiomegaly, dermatitis, and renal disease.[28]

It seems that the production of genetically engineered animals on a large scale for exclusively commercial purposes requires a strong justification of the harm done to their well-being and the pain inflicted; at present, such a justification may not be readily available. The extremes of the ethical debate are marked by conservationists and advocates of animal rights who argue against any form of human intervention in the life cycles and the natural habitats of animals, and the defenders of a more anthropocentric approach which would allow for the exploitation of animals if the benefit for mankind clearly out-weighed the harm done to them.

Thirdly, the possible ecological impact: The engineering of transgenic plants has been particularly successful and resulted in a number of new products; their commercialization is about to begin.[21] In the last five years, the UK Ministry of Agriculture, Fisheries and Food has approved the marketing of nine different types of genetically engineered food. In Britain alone, seven genetically altered organisms are scheduled for release in the fields in the second half of 1995.[22]

Researchers usually point out the many benefits this kind of genetic intervention will bring to mankind and tend to minimize the risks the intentional or accidental release of genetically altered plants could have on the environment. Although our understanding of the potential role and impact of transgenic organisms on the environment is still in its infancy and has so far brought only scanty results, this is no reason for complacency. We should, however, equally avoid falling into the opposite trap of painting risks in too gloomy colours, since this will only foster in many of us a sense of helpless despair in the face of what seems to be the inevitable course history will take. The anticipated dangers may involve: health hazards for humans and animals alike; economic losses especially in developing countries caused by a combination of unaffordable prices for patented crop seeds and changed patterns of soil cultivation (monocultures, cattle breeding); species imbalances or depletion which could lead to a host of subsequent perils ranging from soil erosion and deforestation to climatic changes.

Risk Assessment and Regulatory Policies

It is a matter of great urgency to develop adequate methodologies of risk assessment for all areas of high-technology, particularly biotechnology. In pondering the socio-cultural consequences of these advanced technologies and their ethical implications, researchers in biotechnology need to draw on the results of the emerging discipline of risk assessment and utilize its methodology. One major difficulty, however, lies in the fact that ecological and evolutionary risks can only be simulated to a very limited extent in computer models. Their full-scale assessment relies heavily on hypotheses which could be tested only when the events had been realized. This amounts to a rather paradoxical situation: one would have to await the outcome of certain artificially induced evolutionary developments in order to decide whether they should have been prevented from occurring! This perplexing and dilemmatic scenario has led to opposing views as to how one should proceed with regard to the release of transgenic organisms. Whereas some have argued for a moratorium, others have favoured an even accelerated release. They envisage greater overall dangers in the mistaken belief that we could ever be able to design and manage flawless experiments. Unless we decide to give up science altogether, there will always be surprises and unexpected results in the outcome of experiments. Yet, even failed experiments appear to be better than no experiments whatsoever. Since, according to this view, the knowledge thus provided is of greater significance for the well-being of mankind and makes it much more likely that we will be able to cope with undesirable side effects, it is better to promote research than to abstain from it. [23]

Despite these complex problems, the development of assessment strategies and the study of short- and long-term ecological effects of transgenic organisms remains a high priority. Yet, in the case of decisions where the stakes are as high as in biotechnology, one can never rely exclusively on scientific methods to determine how one should act. Unless risk assessment strategies are comprehensive enough to incorporate also the fundamental beliefs on which our society rests, they can at best provide the information which is vitally needed for responsible action but not serve as its substitution. The desirability of biotechnology as such cannot be exclusively determined on the basis of scientific data and knowledge. The evaluation of the implications biotechnology is likely to have for our life, for our society and our culture reaches beyond the expertise of the scientist qua scientist and calls for a comprehensive discourse in which the various moral, social and cultural interests will find the attention they deserve. It is for our society as a whole to decide on the way we want to live.

It is therefore not surprising to see the conviction gaining ground that research in biotechnology in general and in transgenic organisms in particular needs to be carried out with extreme caution and a high degree of (individual and public) responsibility. This has prompted many countries to develop regulatory policies and to legislate against uncontrolled research.[24]

It is obvious that, in spite of its undoubted significance, such legislation must be balanced against another social good which deserves protection: the liberty of science and research. Any regulatory policy has to tread a fine line and aim at safeguarding the overall interests and the well-being of society without stifling science and research.

Finally, the impression must be avoided that any kind of legislation could ever release the indvidual researcher from his moral responsibility for the consequences of his research.[25] This is particularly necessary since there will always remain a certain gap between the stipulations of the law and their practical implementation and enforcement.

Paradigm-shift

This introduction would be incomplete without the attempt to map biotechnology onto the canvass of the philosophical tradition in the West, since this can help to clarify the extent to which biotechnology has begun to redefine our traditional relationship to nature. Although the following remarks can only give a rough outline of this relationship and its ideological implications, they will lend support to the claim expressed above that biotechnology represents a decisive turn away from a tradition which for centuries provided our moral perspective with inspiration and direction. Following a Nietzschean line of thought, it will be argued that biotechnology is the culmination of a larger development and the clearest indication to date of the paradigm-shift it stands for.

Western philosophy derives much of its strength from the intuition that in spite of its various tumultuous events the world is no chaos but a 'cosmos': a beautifully and intelligibly arranged system of order. This order not only permeates everything from the lowest to the highest scale of beings but defines also to each its proper (metaphysical) place. It is this assumption of intelligibility and order which provided the fundament for Plato's philosophy and set the philosophical agenda for centuries to come.

Plato's metaphysics entailed what Lovejoy has called the principle of plenitude. This principle required 'the realization of conceptual possibility in actuality'.[26] The universe then is composed of 'an infinite number of links ranging in hierarchical order from the meagerest kind of existents, which barely escape non-existence, through 'every possible' grade up to the *ens perfectissimum.*'[27] In allusion to Homer's *catena aurea*, this order of nature was called the Great Chain of Being which, on Lovejoy's account, held sway from the Platonic beginnings of Western philosohy up to the nineteenth century. Alexander Pope's *Essay on Man* (1733/34) bears witness to the prominence of this 'vast chain of being' extending from God through the whole range of creatures all the way down to mere 'nothing'.

Man's place in the order of beings was precariously set in the middle. Drawing on both Greek metaphysics and Christian theology, Thomas Aquinas called man the 'horizon and border' which connects as well as separates the material and the spiritual (intellectual) world. This view is still valid in the seventeenth and eighteenth centuries when Pascal sees in man 'a middle point between all and nothing' [28] and when Pope has him 'placed on this isthmus of a middle state'[29].

About a hundred years ago Nietzsche stated that this order no longer existed and that its underlying metaphysical worldview had definitively come to its end. With the chain 'broken', man lost his metaphysical place in the hierarchy of beings. His 'essence' is no longer set from eternity by the divine order of things but malleable as clay in the hands of a potter. Man is emphatically the 'animal which is not yet fixed'.

Consequently, Nietzsche's Zarathustra declared the end of man which derived essence and identity from his preordained place in nature. Man is now 'something that must be overcome', is merely 'a bridge and not a goal',[30] a 'passage' to something greater than what he used to think of himself. 'Man is a rope, fastened between animal and superman'[31] who ultimately will replace him, and whose arrival was already announced.

Nietzsche's philosophy of the superman draws as much on the traditional worldview as he rejects it. Whereas previous ages saw man encouraged to improve on himself within the limits set to him by the divine laws of nature, Nietzsche's philosophy advocates a qualitative step which leads beyond the boundaries of nature, metaphysics and religion.

Nietzsche was convinced that his philosophy marked the turning point in Western intellectual history and that he anticipated things to come on a much larger scale. His intuition is based on two 'events' in the intellectual history of humankind which in his view are deeply intertwined: the 'death of God' and the ascent of modern science.

Nietzsche's 'madman' proclaims that there 'has never been a greater deed' than the death of God from the hands of man since it makes man become part of 'a higher history than all history hitherto'. In Nietzsche's reading, the rejection of theistic metaphysics is a structural condition of modern science which puts it squarely on the basis of what has been called methodological atheism. Yet, with God the whole metaphysical structure has been lost which once defined man's nature and his place in the universe. Since this 'entire horizon' was wiped away with our sponge, we lost orientation and are now 'plunging continually', — 'backward, sideward, forward, in all directions'.[32]

Whereas the 'death of God' implies the demise of the metaphysical frame of reference (worldview) for man's theoretical as well as practical orientation, modern science compensated man for this loss by cutting his imagination loose from past constraints and inviting him to define for himself who he wants to be.

The collapse of the metaphysical basis, however, is quite ambiguous. It opens the door for the existentialist reading of man's freedom which is as much a condemnation as it is a blessing. In the ontological phraseology of Sartre, this means that 'existence comes before its essence'. Consequently, 'there is no human nature' and 'man is nothing else but that which he makes of himself'.[33] Yet, already Nietzsche knew of the anguish which comes with this new and radical freedom. If freedom lacks a grandiose vision of the future of man, the ensuing disorientation is bound to lead to suppression and degradation at the hands of petty and selfish individuals, 'the last men'. These have no qualms to violate nature 'with the aid of machines and the heedless inventiveness of our technicians', and 'to experiment with ourselves in a way we would never permit ourselves to experiment with animals.'[34] The vision which makes the difference is that of superman. It sets out a new, higher goal for humankind and at the same time prevents human scientific endeavours from going astray.

Nietzsche accepted that the time for his bold vision had not come yet. He took comfort in the fact that 'some are being borne posthumously', and that he was merely the prophet of a new age that would arrive anyway.

That age may finally have come. Biotech, so it seems, represents both the pinnacle of modern science and its eclipse, the power and the inability of reason. It vindicates admirably the Baconian formula that knowledge is power while illustrating at the same time the loss of moral orientation. The enormous advances we have made in science and technology are quite obviously not matched by a similar progress in our moral awareness that would enable us to put our scientific knowledge in the service of a shared vision of 'the good life'. It needs the combined efforts of all concerned, including scientists, policy makers, social planners and philosophers to take up the challenge which has begun to change nature's course and to impact our lives more than anything before in the history of mankind. Nietzsche's sketch of the ideological implications of modern science has been etched out with crude tools (he called this proudly 'to philosophize with a hammer'); it can, however, serve as a vivid reminder of what is at stake.

Notes

1. Lawrence Busch, William B. Lacy, Jeffrey Burkhardt, and Laura R. Lacy, *Plants Power and Profit. Social, Economic, and Ethical Consequences of the New Biotechnologies* (Cambridge, Ma and Oxford: Blackwell, 1992) 3. See also W. B. Lacy and L. Busch, 'Changing Division of Labor Between the University and Industry: The Case of Agricultural Biotechnology'. In J. Molnar and H. Kinnucan, eds., *Biotechnology and the New Agricultural Revolution* (Boulder: Westview Press, 1989) 21–50.
2. Max Born, *Physik und Politik* (Göttingen: Vandenhoeck & Ruprecht, 1960) 45 (my translation).
3. Office of Technology Assessment, *New Developments in Biotechnology: Public Perceptions of Biotechnology* (Washington, DC: US Government Printing Office, 1987) 9.
4. Andrew Kimbrell, *The Human Body Shop. The Engineering and Marketing of Life* (San Francisco: Harper San Francisco, 1993) 188f.; 268f.
5. Stephen M. Gendel, 'Foreword'. In William F. Woodman, Mack C. Shelley II, and Brian J. Reichel, *Biotechnology and the Research Enterprise* (Ames: Iowa State University Press, 1989) VII-XII, VIII.
6. M. Chiara Mantegazzini, *The Environmental Risks from Biotechnology* (London: Frances Pinter, 1986) 136. A somewhat biased definition is found in Pat Spallone, *Generation Games. Genetic Engineering and the Future of Our Lives* (Philadelphia: Temple University Press, 1992) 4: 'Biotechnology is the exploitation of living things, and of substances from living thing, to create products and processes for many different purposes.'
7. David Suzuki and Peter Knudtson, *Genethics. The Ethics of Engineering Life* (London: Unwin Paperbacks, 1988) 30–51; here and in the following I refer particularly to pages 32–34 of their acclaimed explanation of a rather complicated matter.
8. Ibid., 34.
9. Sharon J. Durfry and Amy E. Grotevant, 'The Human Genome Project', *Kennedy Institute of Ethics Journal* (December 1991) 1 (Scope Note 17): 347–362, 347.

10. Gendel, loc. cit. IX.
11. *The International Biotechnology Handbook* (London: Euromonitor Publications, 1988) 28–33, 33.
12. Rivers Singleton, et al., 'Transgenic Organisms, Science, and Society', *Hastings Center Report* (1994) 24, 1. *Special Supplement*: S4-S14, S4.
13. Here and in the following, 'man' is always used as a gender-neutral term.
14. Whereas the proponents of biotechnology tend to emphasize its continuity with past technologies and processes of natural selection and cultivation, the skeptics and 'opponents of rapid development stress discontinuities and the harms that can come from bold departures.' Vivian Weil concludes: 'Whether or not there is a radical break with the past, it has to be conceded that living organisms are less predictable than mechanical systems.' Vivian Weil, 'Ethics and Biotechnology — Identifying Issues in the Face of Uncertainties'. In Matthias Kaiser, and Stellan Welin, eds., *Ethical Aspects of Modern Biotechnology* (Goeteborg: Centre for Research Ethics, 1995) 7–24, 8.
15. Strachan Donnelley, 'Exploring Ethical Landscapes', *Hastings Center Report* (1994) 24, 1. *Special Supplement.* S1-S4, S3.
16. Sharon J. Durfry, and Amy E. Grotevant, ibid. 350.
17. For a more positive assessment of germ line therapy see: John Harris, *Wonderwoman and Superman: The Ethics of Human Biotechnology* (Oxford: Oxford University Press, 1992). See also: Matti Häyry, 'Categorical Objections to Genetic Engineering — A Critique'. In Anthony Dyson, and John Harris, eds., *Ethics and Biotechnology* (London/New York: Routledge, 1994) 202–215.
18. Rivers Singleton, et al., loc. cit. S5.
19. The groundwork for this research has already been laid in the work of Ernst Mayr who distinguished between three different conceptualizations: essentialist, nominalist and modern. See Ernst Mayr, *The Growth of Biological Thought* (Cambridge, Mass.: Belknap Press, 1982) esp. chapter 6: 'Microtaxonomy, the Science of Species'. See also: Marc Ereshefsky, *The Units of Evolution. Essays on the Nature of Species* (Cambridge, Mass: MIT Press, 1992).
20. Daniel Koshland, 'The Engineering of Species', *Science* (1989) 244: 1233.
21. The first genetically modified agricultural product was Calgene's Flavr Savr tomato which has now reached the marketplace in the Unites States.
22. *Gen Ethics News* 7(1995): 4, 12.
23. A. Wildavsky, *Searching for Safety* (New Brunswick: Transaction, 1988).
24. As regards Hong Kong, it seems that there are presently no rules governing the growth of any kind of transgenic plants. This lack of regulations could prove very attractive to biotechnology firms interested in potentially dangerous experiments which are prohibited in their own countries of origin.
25. Vivian Weil has argued that since the increased complexity of modern research and the various factors which drive it still leave some latitude to the individual scientist for defining the research even in large, hierarchical organization, researchers have to 'accept responsibility for contributing to foreseeable outcomes beyond the laboratory and the company'. Loc. cit., 19.
26. Arthur O. Lovejoy, *The Great Chain of Being. A Study of the History of an Idea* (Cambridge, Mass.: Harvard University Press, 1978) 52.
27. Ibid., 59.
28. Blaise Pascal, *Pensées* (1670), Léon Brunschvicg, ed. (Paris: Librairie Générale Française, 1972) fr. 199.
29. Alexander Pope, *Essay on Man*, II, 3.

30. See: Friedrich Nietzsche, *Thus Spoke Zarathustra. A Book for Everyone and No One.* Tr. by R. J. Hollingdale (Harmondsworth: Penguin Books, 1972) 215–216.
31. Ibid., Prologue, 4.
32. Friedrich Nietzsche, *The Gay Science*. Tr. by W. Kaufmann (New York: Vintage Books, 1974) 181 (§ 125).
33. Jean-Paul Sartre, *Existentialism and Humanism*. Tr. by Philip Mairet (Brooklyn: Haskell House Publ., 1977) 28.
34. Friedrich Nietzsche, *On the Genealogy of Morals*. Tr. by W. Kaufmann (New York: Vintage Books, 1989) 113 (III, 9).

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