Living Surfaces, Biotechnology and the Design Way

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1. Introduction

This project started as an exploration of biotechnology from the design perspective. It was set to see if the design profession, in some stage in the future, could be integrated with the development of biotechnologically generated products, which are not of a medical or agricultural nature. The initial research indicated that surface coating could be one of the first areas in which biotechnologically generated products could be used. Having a living tissue that can be sustained alive, only with the aid of an artificial structure, will avoid some of the problems concerning the release of genetically modified organisms. This paper is an introduction to the many issues that concern the emerging relationship between biotechnology and design in general, and the use of biotechnology to design and produce living surface coating in particular.

Reasons for Choosing a Biotechnologically Generated Surface Coating as a Theoretical Case Study in this Paper:

1. A surface of a product provides most of the sensual information about an object, and can be seen as the most important communicating aspect of a designed object. (Manzini, 1986)
2. The first thing that has to be considered in designing a living structure is how to protect it from contamination and from other biological and physical factors, this kind of protection is provided by the surface. Hence a living surface is the first area that needs to be explored for a successful living object.
3. Custom grown organic surface coating (CGOC) is a broad definition of a range of products that can be manufactured using different biotechnological techniques.
4. It is suggested that CGOC can be used for a wide range of products.

5. The fact that this product is perceived as a living part of a non-living object can generate a discussion on biotechnology as a means to objectifying life.
6. CGOC can be used as a starting point for discussion about the ethics of technological development (or progress) in general, and biotechnology in particular.

2. Design Issues

2.1 The Need to Exercise a Responsible Design

Design is linked to all the disciplines that concern the creation and interpretation of human generated artefacts; hence, both technological and social aspects of human existence have to be considered in the design process.

Mackenzie (1991) states that designers are the link between the manufacturers and the consumers, between technical and marketing requirements, and they are in a position to minimise the affects of the products on the environment and on society.

Manzini, (1993) observes that until recently, product designers focused on the shape of the manufactured products, now the subject of design is not the quality of products, but the redefinition of the concepts of product, production and consumption. The concept of sustainability, in which the quantity of material in products must be reduced in a significant way, and the fact that technologies already enable this reduction of quantity of material to take place, are responsible for that shift. Manzini sees the main objectives of any design object as those that are contributing to a more sustainable ecology as well as to a better society. In this paper it will be argued that Manzini's objectives could be achieved using biotechnology. Mackenzie (1991) sees designers as a force that can change the direction of technology and encourage designers to pursue knowledge which is not traditionally, it seems, related to design.

Designers are not considered experts in technology and they are not experts in social or ecological sciences; but they can, and should, aim to become legitimate experts in mediating between those different fields in order to produce tangible artefacts that will optimise the input of those different fields.

In the current state of the biotechnological debate suspicion and mistrust are distracting from a productive discussion. It seems that the level of mistrust is mutual. Scientists are questioning the political motives of those who are proposing more public input in the development of new technologies, while social movements are questioning the integrity of the scientific community.

Manzini (1992) identifies some of the reasons for the lack of trust in the scientific and technological attitudes that “everything is possible” while the public is aware of the existence of limits in areas in which techno-scientific professions are not considered expert, those areas are ecological, cultural and sociological.

The role of design is, therefore:

> To point out a path for those potential possibilities (suggested by science and technology), a path that can be completely opposed to that which technological-scientific development has followed up to now, a path whose scenarios prefigure results. (Manzini, 1992, p.19)

This paper is intended to suggest such a scenario.

2.2 Manzini's Views of the Ecology of the Artificial and Design Responsibility

According to Manzini (1992), design still lacks an ethical frame for implementing technology into culture. He sees the environmental problems as a way to generate the use of design as a tool to transform social practices.

By analysing the artificial environment with ecological evolutionary tools, Manzini tries to create a change in perception that will lead to a change in attitudes and culture. The initial results from such analysis indicates that since the Industrial Revolution the rate of "mutations" and the creation of new kinds of products/species, and therefore competition has increased dramatically. That in turn has shortened the life span of the species/products (in some cases by built-in obsolescence), or increased sophistication and specialisation (products for specific niches) of other species/products. This blossoming of artificial species has come at the expense of the natural and physical ecology as well as the cultural ecology, it relies on the wider ecology, to provide energy and raw materials, while this transition takes place. The rate of evolutionary development of the ecology of artefacts is far exceeding the rate of evolutionary development of the cultural ecology and obviously exceeding the rate of biological evolution. The gaps between those different ecologies is the area in which designers have to operate.

In order to exist in a sustainable way, a major rethinking must be done regarding the relationship between humans and their ecology. This will require development of a new product culture; Manzini suggests a culture of "doing as reproduction" which opposes the linear perception of the current western culture of "doing as producing". "Doing as producing" can be defined generally as a narrow and linear view of production and consumption, linked together with natural resources on one end and waste products on the other end (Manzini, 1992). While "doing as reproduction" is a cyclic system that is more complex, but similar to natural systems that evolved over a long time towards a sustainable existence, Manzini recognises the fact that current culture is not ready to accept this kind of responsibility, and is not totally aware of the limits. He feels that culture lacks the ability to visualise the socio-environmental schemes that the culture of reproduction could generate (Manzini,1992, p.18).

Biotechnology, if applied correctly, can help in this process. It can help by achieving some of the objectives of the new "reproductive" culture; due to the fact that biotechnologically generated products are, in their essence, part of the natural process and can stimulate a sustainable ecosystem in a fashion very much similar to natural ecology, they can be reproduced and regenerated. Biotechnologically generated products may be more familiar to culture for the same reasons.

Manzini's suggestion for a future is one in which we will "think of objects not as instruments for our use, but as entities that are effectively linked and that need care - to think of objects as plants in our garden" (Manzini, 1992, p.20). His Utopian world is one in which the relationship with objects is much more symbiotic.

3. Biotechnology

3.1 What is Biotechnology?

Biotechnology can be defined as the practical use of biological knowledge and research for benefit in industry and technology. (Jones, 1994). The Australian Biotechnology Associationis definition of biotechnology is:

> Biotechnology involves harnessing the natural biological processes of microbes, and of plant and animal cells, for the benefit of mankind. (ABA, information page No.2, 1990)

In the context of this paper, biotechnology will be referred to as an industry that includes all of the above and in particular, genetic engineering which is also known as Recombinant DNA (abbreviated rDNA) (Watson, Gilman, Witkwski, and Zoller, 1992), and tissue engineering.

3.2 Biotechnology as a Means to Objectify Life

Development in biological research in the last fifty years has resulted in a better understanding of the way biological systems work and how their mechanics operate. Using biological processes to produce products will require rethinking of all of the process of manufacturing and consumption. From the design perspective, biotechnology can change the concept of products, from objects that have to be manufactured, to objects that can be grown. Hence growing products in accordance to natural biological processes rather than manufacturing products in superficial and mechanical ways. Another important aspect for designers is the fact that biotechnology will provide a new set of aesthetics and a new way to generate a variety of forms and objects that would never have been possible before. It may change the way ideas will be developed and concepts evolved.

Tissue engineering, will enable scientists to grow complete organs in in vitro conditions, using biomaterials and polymers as scaffolding for the tissue (Langer and Vacanti, 1995). The development in this field will determine the direction in which designers can combine living tissue and wo/man-made structures. These "half living" products will blur the perception of what is alive, and most likely will intensify the debate on the limits of human technology. Using tissue engineering and rDNA for the production of, what possibly will be called, GMT (Genetically Modified Independent Tissue), will reduce the risks to the ecology by introducing those products to the wo/man-made environment (mostly urban) and making them dependent on human intervention for their survival. These objectives will be achieved by creating a symbiotic relationship between wo/man-made structures and different kinds of tissues that have different functions, controlled by a computer or a similar wo/man-made structure. The development of such a system will produce a structure which is not alive, but parts of it are made out of living tissue.

4. Cultural Issues

4.1 Progress

Manzini (1993), states that the new relationship with technology derives from the fact that the speed of technological progress exceeds the speed of social adaptation, and that many people are afraid that technological progress is getting out of control and may lead us to disastrous consequences. For some, the concept of progress is linked to what one perceives as a better future. Others claim that technological progress has exceeded the capability of the ecology to sustain it. (Ryan, 1993)

Progress can be seen as being linked to the economic system. The kind of technological progress that we learned to accept is definitely related to capitalism (Manzini, 1993). Those who are opposed to progress sometimes do so because of the fear of the unknown or from the fear that progress may harm their belief system. Biotechnology can be seen as one of the most problematic new technologies because it links technological progress with the core of living. However, biotechnology can assist in creating a new model of sustainable progress by the integration of human technologies with natural processes, in order to create sustainable ecology, hence, a better future.

4.1.1 Progress as an Evolutionary Process

Principals of Darwinian and post-Darwinian evolution have been applied to anything from social behaviour through economics to computer software. G. Basalla, in his book “The Evolution of Technology” (1988), analyses the development of technology through the theory of evolution. According to this book, advances in technology are not due to individuals, but are a continuation of many other factors. The author looks at diversity, necessity and technological evolution as the forces that shape technology. When this model is teamed with Stephen Jay Gould's notion that "there is no progress in evolution... Much of evolution is downward in terms of morphological complexity, rather than upward. We're not marching toward some greater thing." (Gould in Brockman, 1996, p.52). This can get us half-way between the concept of history as a linear process and history as a chaotic system. Gould's perception of evolution is that in the long run, the survival of the fittest has been replaced with the survival of the survivors, due to the random nature of events that may influence the chances of survival. In order to understand progress via evolution theories, one must remember that the forces that shape progress are not exercising any value judgment. The outcome of the introduction of biotechnology can either help our species to prosper or increase our chances to become extinct, and this has the potential to alter the course of biological evolution on this planet.

4.2 Contemporary Art as an Indicator to Cultural Shifts in the Future

Penny (1995), points out that technology and art are in some cases receptive to each other, and in some cases technology follows art. Penny sees the relationship of nature, art, and technology combined in the most intimate way in genetic engineering: "... genetic engineering presents another set of fresh mimetic possibilities by opening biological entities to human manipulation...the many subsequent transgenic innovations raise the possibility that gene splicing could become a valid artistic field, with awards for the most aesthetically pleasing transgenic forms!" (Penny, 1995, p.172).

Todd (1996) identifies a trend in contemporary art in the use of recently living organic matter, from dead animals to blood, as well as the use of the artist's body as a medium of expression.

Stelarc, an Australian based artist, can be seen as the ultimate mediator between technology and culture. He attempts to integrate men/woman ("culture/nature") and machine ("technology").

Stelarc's proposals for changing the course of development is to alienate nature even more, by changing humanity into a technology-based life form rather than a nature-based life form. In this way the need for sustaining nature as crucial to human existence is eliminated. Stelarc perceived the physical body as an object rather then a subject.

Stelarc's proposition to the future represents a continuation of the present in that technology is the driving force of development, it's what makes us human and it is unstoppable. His views, that technology has passed human development, led him to the solution of integrating technology directly with the human body in order to bridge the gap.

Integrating artificial and living organic structures can not be seen as exclusive to the human body, but it may become part of our surrounding ecology. Designers will have to be ready for this prospect, either to promote it and design artefacts that will make the transition smoother, or to discharge it and find other alternatives.

Orlan, a contemporary French artist, is raising similar issues using the modification of her own body to prove the point that technology can distance us from the body in such a way that we can modify it to suit changing values and styles. She writes:

> Religion and psychoanalysis...say...that one doesn't have to fight his body (go against what is natural); [this] is the primitive idea that we must accept ourselves [as we are]. It is a taboo to touch the body, to open the body and show the inside... but [in an age] of genetic manipulation, this is a primitive look. (Orlan in Dery, 1995, p.28)

Orlan claims that the time of this "primitive" perception of culture is over. It is time to redefine our relation with what is natural, based on the developments in technology, in particular in biotechnology.

Biotechnology will blur the borders between animate and inanimate, between what is natural and what is artificial. Designers will have to operate in this zone, designing objects which are both, yet "non". Stelarc speaks about a new evolutionary energy that the synthesis between technology and nature will generate. The role of design will be to guide this evolution to some extent. The synthesis between nature and technology does not have to be as alienating as Stelarc's views, nor does it have to be superficial as Orlan's, neither can it remain as it is, for it will not be sustained for long. Broadbent (1995) identified "Guided Evolution" as an important area in which design has to play a major role in the next few decades.

4.3 The Need for a More Natural Urban Environment

Reality in the 1990s, is that a person can live most of their life without coming into physical contact with a living surface beside human skin. Papanek (1995) states that living in the highly artificial environment deprived from our sensory experience may result in damaging "the performance of our senses and brain-body systems." (Papanek, 1995, p.77).

The prospect of growing living surfaces is derived from the sensory need for a more naturalistic environment. This is a textural need for touching living surface.

In a survey that was done as part of this research 93.75% of the participants stated that touching something that is alive is important for their well being, 76% of the participants that had pets reported that being in contact with their pet makes them more relaxed. This information highlights the human need for natural sensation (in particular the tactile).

5. Ethics

Ethics are codes of behaviour and are concerned more with the action and what has brought it about than the result (Bullock, Stallybrass, Trombley, eds.,1988). Ethics are alien to evolution, but very related to our perception of ourselves as human. Every group has its own code of ethics that may seem immoral to other groups. Biotechnological practice has engaged many groups that oppose it. Some of the arguments have already been discussed in this paper. Others will be discussed later. However, some arguments such as theological ones are practicing sets of logic which are not computable with the logic of this discussion and will not be covered here.

5.1 Bioethics

Bioethics tries to supply scholarly solutions for ethical problems regarding the use of the knowledge of biological science. The modification of organisms by humans began with agriculture and the breeding of plants and animals. There is no apparent moral debate regarding breeding garden plants or farm animals and pets; that seems ‘natural’. The debate has to be about the kind of uses for living objects and the extent of the risk-evaluating process that has to take place. The ethical issues that arise from these kinds of products, such as the extent of human intervention with nature and the right of humans to control and manipulate other living organisms, can be regarded as the harm that those kinds of products may inflict on the delicate ecology. It seems that a long term successful implementation of these kind of products will have to be linked to the concept of ecological sustainability. Biotechnology will introduce a new kind of human ecology, which will operate, more than any other technology, according to natural processes.

6. Ecological Issues

Those who are opposed to biotechnology, predict a grim future if biotechnology is not restricted or regulated. They claim that biotechnology has the potential to have devastating effects on the ecological balance, and there is the possibility of an accidental or deliberate release of deadly biological agents which may kill most of the world's population (McKibben, 1990).

The need for renewable resources is one of the most important issues facing our generation; most environmental groups embrace the principle of minimum intervention and minimum effects of human acts towards nature. Most of the major environmental groups, such as Friends of the Earth and Greenpeace are opposing biotechnology, mainly because of the potential irreversible harm that irresponsible and economically driven biotechnology practice may cause.

The constant search for the optimum environmentally friendly product is usually perceived as a way in which a product in all of its life cycle (manufacturing, delivery, consumption, use and disposal) has the least harmful impact on the environment. Biotechnology can reduce some of the harmful effects of industrial manufacturing while increasing the risks of harming the ecology in ways that are unique to this industry. Most of the biotechnologically generated products are produced in an organic way, hence they generate less poisonous pollution. On the other hand, an irresponsible release of GMOs can cause unpredictable harm to the ecology. GMTs are intended to bypass this problem by eliminating the risks of surviving outside of a controlled environment, and effecting the natural environment.

The fact that biotechnologically generated products will be manufactured according to the basic biological principles, joined with a better understanding of ecology, can make the monitoring of their impact on the environment more coherent and understandable.

7. Surfaces

7.1 An Exploration of Artificial Surfaces from a Design Point of View

A surface of an object can be defined as the location of the points where an object's material ends and the surrounding ambient begins. The surface has to experience all sorts of stresses and mechanical, physical, chemical and biological factors. (Manzini,1986).

This last layer, the surface, is one of the most important parts of an object from a design point of view. Most of the information about an object is obtained from the surface of the object; the shape of an object is the only non-surface element that adds sensory information (Manzini, 1986). Surfaces provide information about the material the object is either made of, or what the designer wants us to think the object is made of. The initial perception of an object derives from the sensory feedback we get from the object.

7.1.1 Modified Surfaces

This concept of applying different materials which are in a solid state to the outer layer of an object, can generally be seen as ways to transform an appearance of an object whilst keeping the inherent qualities of the inner material, as well as protecting it. The evolution of artificial outer layers towards more complex and multi task surfaces resembles the beginning of the evolution of organic outer layers.

Manzini comes to a conclusion which is different from what will be argued in this paper. He predicts more attempts to imitate the successful natural outer surface, whereas this investigation will try to establish the potential to harness these successful natural solutions to be applied directly on artificial objects. Instead of looking at ways to resemble natural phenomena we should look at ways to integrate them for our use.

7.2 Nature's Surfaces

CGOC can be seen as generally as we want it to be. It can be vines growing on an old house and keeping it insulated from the elements, it can be moss growing on a concrete pavement and giving it a touch of vivid colour. It can be a high-tech skin graft or a replacement for car paint. It can be a cutting board that grows back. It can be a leather jacket without stitches. Millions of years of evolution have developed natural solutions for many problems that humans try to solve in artificial ways. Among those problems, that have been solved in many different and amazing ways by nature, are those which are concerned with the surface.

7.2.1 Arthropods outer surface

Arthropods (animal with jointed legs) are a biological group of organisms, where their surface is also their skeleton, which provides protection and support for the soft body organs. The rigid outer part of these animals is called a cuticle. The problem with the cuticle is that once it has hardened it cannot expand or change its shape and once it breaks, it is hard to patch (Foy,1982). An arthropod's cuticle is an extremely versatile compound material that can be utilised for different surface applications and as a biological replacement to some plastics. In the context of CGOC it can not be considered a living surface. However, by using biotechnological techniques, such as genetically modified bacteria, to produce the cuticle's different components, in particular sclerotin, it can be used for many other purposes.

7.2.2 Vertebrates Skin

Skin is the largest organ of the (vertebrate's) body. The skin is made out of two layers: the epidermis as the most outer part and the dermis which is the inner layer. Some include the layer of fatty cells which is connected to the dermis as a third layer of the skin. Each layer has different kinds of cells and functions that form a multi-functional and complex organ that is the skin (The Skin, www.SKINCARE.com, 1995).

7.2.3 Skin's Qualities

The primary function of the skin is to "contain and protect the living cells that constitute the animal." (Foy, 1982, p.76). The skin is a very important sensory organ; it mediates between the organism and the outside, alerting the animal of the proximity of other objects. The skin is also used as a barrier preventing foreign objects and organisms from entering the body. If the skin is damaged it must repair itself as quickly and neatly as possible in order to retain its function as a barrier and prevent contamination. The skin can grow thicker or thinner according to local needs, and in some cases can change its shape upon an order from the brain (Foy, 1982).

7.2.4 Reptilian Skin

Reptilian skin can represent a possible source for CGOC. Besides its obvious visual and tactile characteristics, it may be easier to be sustained alive and will require a less sophisticated bio-reactor. This is due to the fact that reptilian body temperature does not have to stay constant all the time.

Reptilesí scales are not separate structures, but a localised thickening of the skin tissue (Spellerberg, 1982). Lillywhite and Maderson (1982) describe reptilian scales as areas in which the epidermal (and sometimes the dermal) folds. In the case of CGOC, on a non-moving object, cell and structure differentiation can be suppressed in order to achieve one continuous "scale". In some reptiles the epidermal scales are supported internally by bony plates and thickened structures that derive from the dermis (Spellerberg, 1982).

One of the most interesting characteristics of some reptiles' skin is its ability to change colour. The colour of the skin is controlled by pigment cells (chromatophores) which are located in the outer parts of the dermis (Spellerberg, 1982). Colour combinations therefore are achieved by different concentration of pigments in different pigment cells (Harris, 1963). In chameleons this process is being controlled by an autonomic nervous system, while in other groups, there is both a hormonal and neural control for colour change (Spellerberg, 1982). If this colour changing process could be utilised in the production of CGOCs, this will result in exciting design possibilities.

8. Uses

CGOC could be applied as a surface coating for to a variety of objects. It will provide protection and sensorially (visual, tactile, and olfactory) pleasing messages about the object. If CGOC is damaged it will restore itself. Used in conjunction with other GMTs, it will be able to form a part of an almost closed ecology; such as a domestic ecology or an ecology of an office building. Using biotechnology we will be able to produce urban nature, all artificial but ecologically sound, alive and natural. The following are examples of similar concepts that are already implemented.

8.1 Lichen

Victor Papanek (1984) describes the use of lichen as a replacement of paint on walls of art galleries in Europe. “Lichen pigment is an excellent wall covering for art galleries. Walls that would normally need to be constantly repainted to hide nailholes now become ‘self-healing’.” It is being used by galleries in West Berlin, Amsterdam, Yugoslavia, and elsewhere. (Papanek, 1984 p. 205).

8.2 The Breathing Wall - A Natural Symbiotic System

Kellan (CNN, 1996), describes the use of a “Living machine” that cleans office air. This system is described as “a mini-ecosystem comprised of plants, small fish, insects and water.” The “breathing wall” where plants, fish and insects live, surrounded by running water, is designed to supply the fresh air from an indoor source. “The plants exhale needed oxygen into the room while inhaling carbon dioxide, the biggest problem gas in sealed office buildings. Water plays a key role, too, acting as a magnet to pull everything out of the air...A fan behind the wall creates a vacuum to pull room air through the 'breathing wall'. The air goes back into the room through the ceiling. Tests show the air in the board room is clean or cleaner than air in well-ventilated offices." (Kellan, CNN, 1996)

9. Manufacturing Techniques

There are many ways in which CGOC could be produced, depending on the origin of the structure. Two of these techniques will be further discussed in this chapter.

9.1 Botanical Origin

Plant derived CGOC can come in two forms; the first is a genetically modified whole plant (GMO) and the second is part of a GMT structure. Here are just some of the points that indicate that it may be feasible to use genetically modified plants as CGOC.

Flavell (1995) states that plant biotechnology "provides the means to translate an understanding of, and ability to modify, the fundamental processes of plant growth and reproduction into new products." (Flavell, 1995, p.313). Researchers have managed to isolate many genes that are responsible for growth. And the knowledge of controlling the expression of these genes to desirable results is growing. (Newbin, Smyth and Clarke, 1995).

The genetically modified plants that will be used for CGOC will still retain the system of delivering nutrients (living roots and a trunk). Photosynthesis is already built-in (filtering the air and improving the $CO2/O2$ balance). They will be relatively easily kept alive, and will be prolific; with familiar textures, and colours.

9.2 Tissue Engineering

The Pittsburgh Tissue Engineering Initiative (PTEI) defines tissue engineering as the ëmanipulation of artificial implants, laboratory-grown tissues, cells or molecules to replace or support the function of defective or injured body parts.í (PTEI, www, What is Tissue Engineering,1996). Currently the research into tissue engineering is focused on the replacement or repair of human tissues, by controlling cellular growth and development. Tissues that have been already grown successfully in in vitro conditions are human skin, cartilage, ligament, bone, cornea, muscle, liver and other tissues.

In general, tissue engineering usually begins with a scaffolding made out of bio-degradable polymers, which form the shape of the desirable organ or tissue. As the cells grow, they replace the polymers scaffolding and produce a fully organic tissue.

Skin is the first engineered tissue available as a medical device to treat a large market of patients due to the relatively simple structure of the organ. The research that has been done concerning skin can be used as a starting point for producing CGOC. According to Wood (1996), the cost of growing ten cell layers thick skin to the size of 100 square centimetres, is about $100 Australian. As the research continues there is a good chance that reductions in manufacturing costs will occur. The fact that CGOC is not designed for implants, but as a stand-alone product, can simplify the growing processes and reduce costs even more.

9.2.1 How Tissue Engineering Could be Used to Grow CGOC?

The prospect of using tissue engineering for producing CGOC depends on the willingness to accept engineered tissue as a product which is not part of an organism. Using computer-aided design and manufacturing, researchers produced a three-dimensional scaffolding out of ultrafine, biodegradable plastics or polymers. Those scaffoldings are made in the shape of the desirable tissue and then ìseededî with the appropriate cells (Langer and Vacanti, 1995). A mechanical bio-reactor system will have to be designed in order to provide nutrients, exchange gases, remove waste and modulate temperature (Langer and Vacanti, 1995). In order to minimise the chances of contamination by bacteria and other biological agents, the CGOC will have to engulf the object completely, with the epidermis layer most outward. Another way to achieve the objective of reducing the risks of contamination is by having a structure in which the epidermis is on both sides. Using the elasticity of this tissue, CGOC can then be mounted on any object with any shape.

10. Conclusions

As demonstrated, design can and should become an important part in reconciling science and culture, technology and nature, for a more ecologically sustainable future. This role, besides the considerations of the sensory qualities of new designed objects, may be to act as a mediator between the techno-scientific realm and the social and cultural realm; to help direct the products of technology towards cultural and ecological needs and to help society to accept scientific and technological developments. Biotechnology can supply a platform from which this can be achieved. The case study of CGOC has helped ease some ecological concerns due to the fact that it is not going to be a genetically modified organism, but rather it enhances tissue that will help transform the wo/men-made environment.

This transformation will be towards a world in which our environment will behave and feel natural. However, at the same time it will be an artificial world designed to fulfil our needs as modern humans (or even post humans). This will require new kinds of relationships with our world of objects and may enhance our awareness of ways in which closed, sustainable eco-systems operate.

It is clear that the practical implementation of CGOC is still some time away. The need for much more practical research is obvious. Design has a role to play in further developments. Design can redirect some of the techniques of biotechnology towards producing a new realm of objects. These objects, although not alive, will have some living parts in them and in the case of CGOC will communicate liveliness due to the fact that its surface will be alive. A surface, according to Manzini (1986), supplies almost all of our sensory information and stimulations regarding the nature of the object. These objects will need care, as coined by

Manzini (1992) in a metaphor of a garden. In a cultural shift away from consumption and towards a more 'natural' way of living, the care for these products can be an economically valid substitute for the production of goods.

It seems that any investigation into new directions in technology, and in particular in biotechnology, generates many questions and problems that have to be answered. In this stage of the investigation this is desirable, in order to generate a discussion that will require rethinking of cultural values and beliefs, as well as progress and technological development. This investigation generates more questions than it answers, which are the first steps in responsible design - creating new perceptions that will require people to rethink their relationships with nature, artificial objects and different parts of society. The area of GMTs (Genetically Modified independent Tissues) has the best potential to generate such a discussion in a much more benign state, than the modification of whole organisms.

Hopefully, this investigation has gathered enough theoretical background to be able to begin more practical and technological research into GMTs (Genetically Modified independent Tissues) in general and CGOC (Custom Grown Organic surface Coating) in particular. It is my intention to continue towards practical research into this exciting area.