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DATABASES
Entrez Gene: http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=gene
NIPBL | *NippedB* | *mis4*[2] | *SCC2*
OMIM: http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=OMIM
CdLS
UniProtKB: http://www.uniprot.org
Aurora B | BUB1 | BUBR1 | CDC20 | CDK1 | Eco1 | MAD2 | MEI-S332 | PICH | PLK1 | RAD21 | securin | separase | SMC1 | SMC2 | SMC3 | SMC4 | TBP | TOP1 | TOP2 | TOP3 | PP1

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SCIENCE & SOCIETY

Bio-art: the ethics behind the aesthetics

Frances Stracey

Abstract | Bio-art represents a crossover of art and the biological sciences, with living matter, such as genes, cells or animals, as its new media. Such manipulations of life require collaborations with scientists and considerable financial backing. Herein, I consider bio-art that goes 'under the skin' — in which DNA, cells or proteins are used as the media and means — to highlight the ethical implications of reducing life to art.

The use of the protocols and tools of developmental biology in bio-art represents a radical shift away from conventional art media. By using the core materials of ontogeny (the development of an organism) and phylogeny (the evolution of species) — that is, by using the processes of life — to sculpt and mould, bio-art signals a transition from the production of art objects to the creation of living entities[1,2]. Many of the mutagenic processes used to this end, such as the cloning of genes or micrografting techniques, require the help of scientists and financial assistance[3]. For example, the 2008 *SK-Interfaces* exhibition held at the Foundation for Art and Creative Technology (FACT) in Liverpool, UK, included a range of academic and corporate sponsors, such as the Goethe-Institut London, SymbioticA, The University of Western Australia, Clinical Engineering and econtis, although their roles and their financial or technological contributions were unspecified.

Given such complex, interdisciplinary partnerships, ascertaining the shared or competing agendas of the collaborators is difficult. Reading through catalogues and interviews with bio-art practitioners, their rationales and justifications for turning life into art often remain hidden behind aestheticism or scientism, or rather glib 'because I can' attitudes. In most cases, the bio-art scientists tend not to attract media attention, either because they deliberately stay in the background or because they are ignored, so their intentions remain unclear. Consequently, there is a sense of a lack of accountability on their part in the making of bio-artworks. Such quietude (whether it is witting or not) needs to be challenged. The problem with silent scientists is that they risk mirroring a limiting art-for-art's sake attitude held by some artists with a science-for-science's sake approach that is seemingly uninterested in the broader, cultural applications of collaborative developments. The process by which corporate, commercial or academic funding bodies carefully select and vet suitable bio-art projects to sponsor also remains unquestioned. To avoid the charge of naivety, if not complicity, bio-artists need to reflect on their part in the creation of economically driven new life forms[4].

This article redresses these concerns in two ways. First, it explores how controversial biotechnologies used in bio-art, such as cloning and transgenics, are either enabled or distorted by an artistic remediation and translation into a cultural discourse. It also pushes the debates around bio-art beyond their limiting aesthetic implications by focusing on their 'bioethical' ramifications (BOX 1), such as questioning who is responsible for the creation, care and disposal of a bio-engineered life form, regardless of whether it goes under the name of art, science or both.

A brief history of bio-art

Bio-art is a relatively new development in contemporary art, still at the threshold of definition, but it can be linked to two modern originators. Appropriately, one is an artist, the photographer Edward Steichen, and the other a scientist and the discoverer of penicillin, Alexander Fleming. In 1936, at the Museum of Modern Art, New York, USA, Steichen exhibited a collection of strange yet beautiful Delphinium flowers. These were the result of a chemical experiment: Steichen dosed the Delphinium seeds in a chemical bath of colchicine, a toxin that induces polyploidy, resulting in the mutated flowers. Notably, ugly, stunted, febrile rejects that also resulted from this art-orientated chemical experiment were omitted from the show, exposing the role of edited selection in bio-art. Previously, in 1933, Alexander Fleming exhibited his 'germ paintings' (images drawn by putting bacteria on paper

Box 1 | **Bioethics**

Bioethics generally refers to a branch of ethics that investigates controversies surrounding the clinical, medical or other practical applications of new biotechnologies, such as genetic engineering or embryonic stem cell research.

The modern field of bioethics, especially in terms of a code of practice, emerged in the 1950s and 1960s, in part as a response to the biological experiments of the Nazi party, which were exposed during the Nuremberg trials. The term 'bioethics', however, was first used in the early 1970s by the biologist Van Rensselaer Potter. Potter initially used it to refer to a new field devoted to human survival and an improved quality of life, before it gradually came to refer more broadly to moral problems that arise from the life sciences and their expansion into non-medical terrains. By the late 1970s, bioethics was a studied discipline in universities. Its range and scope has continued to expand, such that today bioethics features in the curricula of diverse disciplines, from forensic anthropology to philosophy and, with the growth of bio-art, in art history and visual culture programmes.

A consequence of this expansion is the re-examination of the meaning of bioethics, with cultural historians posing new questions about life and the similarities and differences between humans and other animals. Some academics, such as Dominique Lestel and Cary Wolfe, challenge what they see as a limited, judicious and human-centric model of bioethics that actively discriminates against non-human animals, which are presumed to have no cognition, consciousness, culture or communication. These criticisms have contributed to attempts to establish bioethical rights for and responsibilities towards all living, and even semi-living, organisms.

that was pre-soaked in a culture medium and then incubated), albeit in a hospital rather than an art gallery. In both of these early cases of bio-art, the mutational experiments were reductively judged in terms of their aesthetic criteria — that is, 'beauty'[5,6].

Responses to more recent and controversial forms of bio-art, such as the creation of transgenic mammals, have gone beyond judgements of beauty in favour of more sublime and apocalyptic assessments. These range from accusations of promoting a new 'artful' eugenic movement, to cries of aesthetic indulgence in "carnivalesque sadism", to condemnation of the artists as naive or unwitting pawns in a market-driven public relations game on behalf of bio-tech industries, using the allure of culture to sell controversial science to a wider audience. That is, 'scary' bio-art paves the way for a new social order that includes scary scientific manipulations of life — such as the chimeric geep[7] (a cross between a goat and a sheep) or ear mouse[8] (an ear-shaped construct grown on the back of a mouse). These 'mutants' garnered some hostile publicity, with the scientists accused of having a Frankenstein complex in their guise as self-appointed artists and "creator gods" of a "second-genesis"[9]; no longer inspired by divine guidance or the forces of evolution, but by human imagination or madness[10].

This article, by contrast, suggests that bio-art deserves a more reflective reception. I develop this idea by considering the contribution bio-artists have had in mediating new biotechnologies to a broader public; not as naive pawns, but as a thoughtful, crucial interventionists, although not without some uncertainties and ambivalences.

Bio-art: samples

Herein, I have selected examples of bio-art that operate 'under the skin' — in which DNA, cells or proteins are used as the media and the means — to probe and provoke questions about manipulating life as art[11,12]. To give a sense of the diversity of media, processes and practices that are involved, examples are divided into four categories: DNA portraits, which explore the role of genes in identity formation; life sculpting, which involves the physical manipulation or sculpting of organisms; transgenic collages, which explore inter-species hybrids; and semi-living entities that straddle the border between the living and the dead.

DNA portraits. In 2001, the British artist Marc Quinn exhibited his *Genomic Portrait: Sir John Sulston* at the National Portrait Gallery in London, UK (FIG. 1). Despite its abstract appearance, Quinn described it as the ultimate 'realistic' portrait, unveiling the hidden genetic blueprint not only of Sulston (who led the British effort to decode the human genome), but also of "his parents and every ancestor he ever had back to the beginning of life in the Universe"[13]. This implies that not only is a single self or identity discernable from genes alone, but so too is all of human history. This model aims to revolutionize the concept of the portrait: it is no longer about capturing a facial resemblance (a mere surface appearance) but about unveiling genetic essences.

This portrait raises a controversial issue: some critics interpret this reduction of complex life to a sort of genetic processing system as enabling the rise of a 'genocracy'[14] — the idea that genes alone determine matters of life and death[15]. Using DNA to replace skin, hair colour and other broader cultural signals as the repository of markers of identity may be a welcome move away from crude, appearance-based prejudices, but it risks leading to new gene-based forms of discrimination. For example, life insurance companies might demand gene testing for indicators of a propensity to a certain disease. Quinn's model and rhetoric that the self or identity can be fully represented as biologically (or genetically) determined presents a one-sided view of what constitutes a portrait. This is because it excises or represses acknowledgement of other, external factors, such as environmental conditions or socio-cultural customs, that

Figure 1 | **Marc Quinn, *A Genomic Portrait: Sir John Sulston* (2001).** This portrait was created using standard methods of DNA cloning. DNA was extracted from a sample of Sulston's sperm and replicated in an agar culture, resulting in transparent colonies of bacteria, each grown from a single cell containing part of the full genome of John Sulston. The final image (approximately the size of an A4 piece of paper) consisted of a piece of polycarbonate agar jelly, bacteria colonies (from cloned human DNA) and a gel cell all enclosed in a refrigerated, stainless steel frame, making it suggestive of a sterile, 'scientific' environment. The genetic reductionism of Quinn's model of identity is matched at its pictorial level. Without informative labels, this abstract image would not be readable as a portrait. Expert advice is required because the viewer is deprived of recognizing the image of the person through conventional modes of figurative representation. Figure is reproduced, with permission, from Marc Quinn © (2001).

affect how the genetic substructure of life is expressed, adapted or realized and so contribute to the construction of an identity.

Life-sculpting. Nature has long been a source for art. In bio-art, however, nature is used not as a model to copy, but as a living, malleable material to sculpt and mould. The following two examples show how genetic modification is not the only way to alter the appearances of an organism — external interference (changing the level of proteins or how cells communicate) can result in a new, non-inheritable phenotype (because germline information remains unaltered).

In the case of the Portuguese artist Marta de Menezes, her organism of choice is the butterfly, or specifically the caterpillar metamorphosing into a butterfly pupae. In *nature?* (2000) (FIG. 2), with help from biologist Paul Brakefield, she explored the boundaries, similarities and differences between the artificial (or human designed) and the natural by modifying the patterns and eyespots of one wing but not the other. This somatic interference may reveal a resilience and plasticity in the regenerative and alternative pathways available to an organism during its major metamorphosing transition, but this was supplementary to Menezes' prime intention to create a unique and temporary artwork[16,17]. This also raises awkward (and unaddressed) ethical questions: what are the rights of a living creature that has been reduced to art? What happens when, or if, it is released into the wild? And who benefits from this life-sculpting process[18]?

In 2002, the New York-based artist Brandon Ballengée, with the help of scientist Stanley Sessions, created the *Malformed Amphibian Project* in an ecological, interventionist exhibition called *Ecovention*. Using a tool (as opposed to a toxin), Ballengée physically interrupted the development of amphibian limb buds by disrupting the embryonic prelimbs, resulting in a frog with supernumerary limbs. This malformed artwork, according to the biodiversity ethic of the artist, was not meant to shock or disgust the audience, but rather to help inform them about the complex growth processes of living organisms and how these can be damaged through parasitic infestations or pollutants. Moreover, he raised the question of what can be done to prevent such mutations. Yet, various ambiguities and inconsistencies persist. For example, it is not clear how a physically induced malformation relates to abnormalities caused by parasites or pollutants. Furthermore, to highlight the damage done to frogs in the wild, Ballangée replicates, and so partakes in, the mutational processes he wants to prevent. Again, responsibility and concern over what happens to these artificially malformed frogs remain neglected issues.

Figure 2 | **Marta de Menezes, *nature?* (2000).** For both *Bicyclus anynana* (top) and *Heliconius melpomene* (bottom) butterflies, one wing has a 'natural' design, whereas the patterns on the other has been artificially modified. The insert shows a magnification of the areas of intervention. This work was produced in collaboration with the biologist Paul Brakefield, who specializes in the evolutionary development of butterfly wing patterning. Unspecified types of 'modifications' were applied to the caterpillar during its transition to butterfly pupae. Tools used include microsurgical needles, red-hot cauterizing needles and tools for micrografting. The micromanipulation of the wing imaginal disk results in new, non-intuitive patterns that affect the colour and design elements, such as new eyespots. The wounds are small and heal seamlessly and painlessly because the pre-wing disks do not have nerves. Playing with scarified colour patterns has the potential to reveal evolutionary insights, thus producing good scientific practice as well as controversial art. The presumption that these humanly modified butterflies carry out a 'normal' life remains untested. Figure is reproduced, with permission, from Marta de Menezes © (2000).

Transgenic collages. The creation of transgenic life forms has proven to be the most controversial type of bio-art. A transgenic organism is one that has had foreign DNA (from another animal, bacteria, fungus or virus) inserted into its genome. Therefore, the alterations of these interspecies 'collages' are permanent and inheritable.

In 2000, the Brazilian–American artist Eduardo Kac collaborated with the artist Louis Bec and two scientists, Louis-Marie Houdebine[19] and Patrick Prunet (who work at the Institut National de la Recherche Agronomique in France) to create a cross-species rabbit called Alba, as part of *GFP Bunny* (where GFP is green fluorescent protein) (FIG. 3). By experimenting with a rabbit, a typical family pet as well as laboratory animal, Kac deliberately sought a provocative dialogue both about the use of animals in science and about the selective

Figure 3 | **Eduardo Kac, *GFP Bunny* (2000).** *GFP Bunny* (where GFP is green fluorescent protein) was a three-stage project carried out by the artist Eduardo Kac and scientists at the Institut National de la Recherche Agronomique (INRA), France. The first phase of this artwork comprised genetic modification, such that an albino rabbit, named Alba, expressed enhanced GFP. When illuminated with blue light, Alba glows a bright green. The second phase of this project concerned the lively social, cultural and ethical debates provoked by this 'man-made' mutation. The third phase involved taking Alba back to Kac's home in Chicago, Illinois, USA, to live as part of his family. However, this phase was never completed, as the INRA laboratory refused to release the transgenic rabbit for undisclosed reasons. Figure is reproduced, with permission, from Eduardo Kac © (2000).

breeding of domestic pets[20]. Indeed, Kac is clear that the creation of Alba was just one part of the artwork, with another based on the public debate raised by 'her' existence[21]. For the final phase of this project, Kac originally planned to take Alba back to his home in Chicago, Illinois, USA, but for undisclosed reasons the laboratory refused to release her, sparking further controversy, legal battles and an offshoot campaign called 'Free Alba'. This was all played out in newspapers, on television and on the radio[22,23]. It has been argued that this work emphasizes our ethical responsibility towards "other humans, part-humans, posthumans and non-humans with whom we cohabit and … seek to perfect and control"[24]. What Kac and his supporters fail to discuss, however, is that GFP and other fluorescent molecules used in imaging can cause cell damage[25,26]. The fluorescent proteins in Alba (and in Kac's other organisms[27]) might be toxic, if not fatal.

Instead of creating new transgenic animals, the artist Kathy High works with existing ones that are produced for scientific research. In *Embracing Animal* (2005), which was part of the exhibition *Becoming Animal* (curated by Nato Thompson) for the Massachusetts Museum of Contemporary Art in May 2005 (see the Embracing Animal website), High exhibited three retired breeding rats named Tara, Star and Matilda Barbie. These are transgenic rats that stably express HLA-B27, a human class I major histocompatibility complex molecule. This rat line is routinely used as a disease model for diagnostic research on Crohn's disease and related autoimmune disorders. These rats suffer the same pain and metabolic disarray that comes with such disorders, from which the artist herself suffers. High's empathetic artwork consists in giving these retired 'Barbies' a new home, care and attention, and even some of her homeopathic remedies. These bald, stumbling rats expose the less pretty side of transgenic life, but also its possible improvement: in their new surroundings, the fur of these rats grows back, they playfully interact with one another and exhibit signs of different personalities. High does not challenge the rights to produce and use transgenic animals, but she at least forces us to consider the ethical issue of how we should care for a bioengineered life[28].

Semi-living entities. In 2004, the art collective The Tissue Culture and Art (TC&A) project (formed by the artists Oron Catts and Ionat Zurr) created *Victimless Leather — a Prototype of a Stitch-less Jacket Grown in a Technoscientific 'Body'* (FIG. 4). This prototype organic jacket (an alternative to traditional forms of leather making) comprised living tissue that was grown over a three-dimensional armature and kept alive in a bioreactor. By this process, TC&A claim to have created a new, artificially designed category of the 'semi-living' located at the border between the living and the non-living, objects and subjects, the grown and constructed, and the born and manufactured[29]. Yet, these synthetic skins or entities are not 'victimless': fetal calves were destroyed to provide the serum that sustains their existence[30,31]. The testing of this 'victimless' claim was, however, an explicit part of the artwork: the 'feeding' rituals addressed the nutritional requirements for the semi-living's survival, whereas dismantling the bioreactor at the end of the exhibition reflected on the temporal nature of the living art, the demise or 'killing' of which becomes the responsibility of its human creators[32].

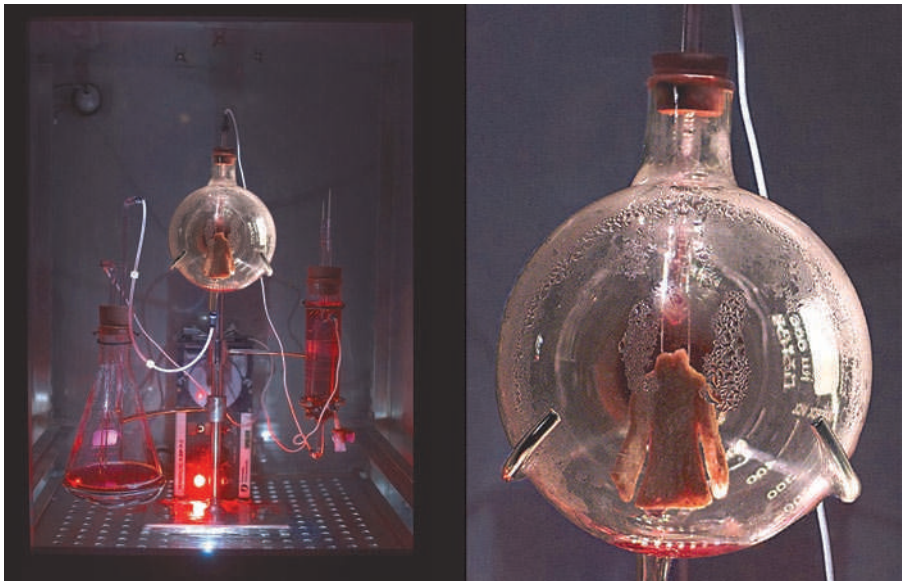

Figure 4 | **Tissue Culture and Art Project, *Victimless Leather – a Prototype of a Stitch-less Jacket Grown in a Technoscientific 'Body'* (2008).** This semi-living miniature 'skin' jacket was grown from immortalized 3T3 fibroblast (mouse) and HaCat keratinocyte (human) cell lines. This interspecies material, which was created using tissue and stem cell technologies, consists of living tissue grown over a three-dimensional armature or coat-like scaffold (made of artificial biodegradable and bio-absorbable polymers), all kept in a sterile and temperature-regulated environment that emulates suitable living conditions. These semi-living entities are kept alive and their growth is assisted using fetal bovine serum, which supplies the appropriate growth hormones. Because the growth process is essential to this artwork, the 'jacket' was displayed in an incubator that allowed it to grow throughout the two month exhibition period. Figure is reproduced, with permission, from Oron Catts and Ionat Zurr © (2008).

Conclusion

Beyond a shared use of 'biomedia' or living matter, the artists and scientists involved in bio-art may have divergent or even conflicting intellectual, ethical or aesthetic aims and interests. Such conflicts need clarification if we are to negotiate the role that bio-art has in disseminating often controversial science to a non-expert audience. The placement of mutagenic creations in the public space of a gallery does enable wider access to complex, cultural debates about how and who is responsible for the shaping of our biotechnological future, thereby opening up a space for critical dialogue beyond or in-between the specialist discourses of both art and science.

Bio-art is least successful, and most contentious, when the science is reduced to mere aesthetic spectacle, and no account is taken of the specific or paradigmatic differences that affect how one discipline is mediated through another. On the one hand, the artists who are involved must be candid about how and why they appropriate and make an artwork out of a particular science, and how this is transformed through its remediation as 'art'. On the other hand, scientists need to voice their explanations about how or why the realm of culture is suitable for disseminating and making accessible their practice, and at what and whose cost or benefit.

At its self-reflective and critical best, however, bio-art can show that life is more than brute matter and more than the sum of cells, proteins or genes; it can emphasize the social constituents or social situation of production. In Critical Art Ensemble's *Immolation* (2008), for example, which was exhibited at the *SK-Interfaces* exhibition, artists Steve Kurtz and Lucia Sommer used tissue culture and microimaging to stage and reproduce the effects of incendiary weapons on civilian skin cells contained in Petri dishes. By pairing this microscopic imagery of disintegrating human skin cells with large screen projections of footage of past and present wars, the fraught and complex interrelationship or dialectic (of the microscopic and macroscopic worlds) is made emphatic. And Natalie Jeremijenko's cloned *OneTree* (1999), for example, consists of 1,000 trees, all clones, micropropagated in culture. Despite being biologically identical, these clones, planted in different areas with different soil and climate conditions, will "render the social and environmental differences to which they are exposed" during the years of their growth[33]. These examples form a branch of bio-art that emphatically exposes and tests the determinations and mutations of life by entwining the microscopic (or molecular) and the macroscopic (external conditions). Bio-art can thus be a provocative reminder that how life is modelled and represented matters to how it is valued, used and disposed of.

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DATABASES
OMIM: http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=OMIM
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The Tissue Culture and Art (TC&A) project: http://www.tca.uwa.edu.au