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The Thickness of Tissue Engineering: Biopolitics, Biotech, and the Regenerative Body

Promoting tissue and organ development via growth factors is obviously a considerable step forward. But it pales in comparison to the ultimate goal of the tissue engineer: the creation from scratch of whole neo-organs. Science fiction's conception of prefabricated 'spare parts' is slowly taking shape in the efforts to transplant cells directly to the body that will then develop into the proper bodily component.

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Skin Jobs

In May of 1998, the FDA (U.S. Food & Drug Administration) approved a product called "Apligraf," an organic, artificially-grown skin product developed by the biotech corporation Organogenesis.[2] Apligraf is the first "off the shelf," engineered body part to have been granted FDA approval, and is now being selectively implemented in medical centers for the treatment of leg ulcers and general skin burns. Such projects are based primarily in the field of cellular biochemistry and stem-cell research–those cells which contain the capacity to turn into and differentiate into particular cell types (blood cells, nerve cells, muscle cells, bone cells, skin cells). Put simply, researchers are looking into ways in which the body's cells can be coaxed into growing and developing again as they did during the first stages of embryonic development. By harvesting cell samples, cloning those cells, and inserting them onto lattice structures immersed in growth medium, researchers can "cook" the cells which will, potentially at least, yield a new patch of skin or a new organ. Commonly known as "tissue engineering" (hereafter abbreviated "TE"), this field not only promises the ability to generate entire organs and even limbs, but, as projects framed by university, governmental, and corporate biotech organizations, also emphasizes the practical necessity of such research for transplantation, immunology, and medicine generally. Tissue engineering is not a field of speculation–it is a set of practices which is currently being applied in health care and medicine, as well as in a range of clinical trials and medical experiments.

As will be suggested in this essay, TE is not a liquidation or incorporation of the natural by the technological, if by "natural" we mean an essentialized, pre-discursive notion of "the body-itself." Similarly, TE is also not about the devaluation of the body, whether regarded as a mechanistic object different from self, or as the unpleasant conditionality of the "meat." TE is, however, very much about an engagement and re-negotiation of the "natural" as a historical and social concept with very real, material effects in its varied applications. It is in this sense that TE is involved in the medical, philosophical, and political production of what will be defined as a body by biomedical science. One of the basic issues with TE will be this re-negotiation of norms, the natural, and health, with respect to the biomedical body of the patient-subject. Another will be the implications for the traditional separation between the body and technology as separate and ontologically distinct categories: Norms, Hybrids.

TE's investment in this notion of a regenerative body is an instance of the modern investiture of power relationships in the articulation of the "biological" population, a process which Michel Foucault refers to as "biopolitics." Tissue engineering instantiates, through its applications, research, articles, rhetoric, and relations with the biotech and medical communities, a process whereby it threads itself into the very practices, techniques, and (medical-health care) contexts whereby a normativity of the body is instantiated (broadly following Pfizer's recent advertising campaign: "Making life better through technology").

Regenerative Technologies

On the technical level, TE involves an integrative, multi-disciplinary array of techniques whose primary character is that in each stage, it is the natural biochemical processes and properties of the body at the microbiological level which form the central focal point. There are three general stages of TE research and application at the time of this writing (May 1999):

First a "biopsy" or cell sample is taken, if possible from the site of damaged tissue. Once healthy, intact cells are isolated, they can be multiplied in culture to produce a batch of resource material. At this point there are several avenues of research which are being explored. Scientists working in the field of stem cell research are attempting to understand the ways in which the body's "embryonic stem cells" begin the process of cellular differentiation as the embryo develops. Such stem cells are often referred to as "pluripotent," because in their undifferentiated state they contain the potential to turn into any of the body's cell types (muscle, bone, nerve cells). The idea of stem cell research is to, through subtle manipulations of the cellular environment, control and direct the development of stem cells. so that, for example, muscle cells may be grown for the regeneration of muscle tissue. Another direction in research involves the replication of selected cells using the technique of nuclear transfer cloning developed by scientists at the Roslin Institute (who brought us Dolly the sheep). Because Roslin owns patents to this technique, this has not been a widely-explored direction. However, with the recent partnership between Roslin and Geron Corporation, a biotech firm specializing in cellular regeneration, cloning techniques may be used to multiply, for example, epithelial skin cells for the generation of skin for burn victims.[3]

Secondly, once the desired cells have been isolated and prepared, they are then implanted or "seeded" into a biomaterial frame–what researchers variously call a "matrix," a "lattice architecture," or simply a "polymer scaffold" depending on the materials used. This structure ensures that the cellular growth also has a form, so that, for example, regenerative cartilage cells will grow in the shape of an ear or a nose. Recent developments in the field of biomaterials have privileged polymer and gel structures, both of which are also biodegradable, and which simply dissolve as the regenerative cells fill their spaces.

And finally, once the scaffold or matrix structure has been seeded with cells, the complex is set in a "bioreactor" which gives the cells an initial jump start towards regeneration. Often engineered proteins and/or growth factors are added to aid this process of regeneration. When the cells are stable and set within the scaffold or matrix structure, the complex is then surgically implanted (back) into the damaged target site in the patient's body, where, ideally, the cells will continue to grow, meshing themselves with cells in the surrounding environment, and vascularizing the new tissues as well (growing the necessary network of tubular structures–capillaries, vessels, veins, arteries).

An important point here is that at no point in this process are mechanical or non-biological, non-organic artificial materials or components incorporated as part of the core process of cellular and tissue-related regeneration. All "natural" biochemical processes are maintained in their normal functioning, and (according to TE researchers) it is only the extracellular, environmental context which has shifted. The regenerated tissue ultimately derives from the patient-body's own biological resources.

This reconfigured notion of the body as a (universally, naturally) regenerative body also involves several implications with respect to how this biomedical body is spatially reconfigured. As the series of techniques involved in TE above suggests, the regenerative

body will not simply be the familiar, anthropomorphic body as seen by modern anatomical science. It will be, through its techniques, externalized (but not disconnected), partitioned (but still functional), and circuitous (and yet different from itself).

Originally, TE is a medical response to the problems of tissue and organ failure and the shortage of organ donors, where previous and current alternatives were mostly reduced to organ transplantation. By engineering and growing the needed biomaterials in the lab, TE researches refer to the field as "regenerative medicine." An economy of body parts (transplantation, xenotransplantation) is thus replaced by an economy of auto-generation (the generation of tissues from one's own cells) that is circular and proliferative.

This is in contrast to the homeostatic and therapeutic logic of modern medicine, which is based on a fundamental state of normativity and/or health to which one returns. In TE the biomedical body only returns to itself in a spiral which simultaneously moves upwards (an infinitely reproducible body) and downwards (an expendable body). That is, while one notion of medicine in the West has traditionally been regarded as a therapeutic, supplementary science (medicine as a practice restoring the health of the individual, medicine as a regulatory surveillance of an individual's health status), tissue engineering represents part of a new concept of medicine. With tissue engineering, the body is not treated by medicine, is not improved or repaired by medicine; rather, tissue engineering is part of a new type of medicine which instead facilitates the generation of the body's own materials. The difference here is between a range of technologies intended to supplement or repair the body (from drugs to surgical repair to prosthetics in modern, therapeutic medicine), and a biotechnology whose aim is to be able to literally synthesize or materialize the body (from the engineering of genes to the growing of organs).

Each and Every

In his later work, Foucault began to refine his theories of the relationships between power, knowledge, and their manifold points of contact with the body of the subject. Increasingly Foucault reserved the term "biopolitics" for a particular strategy of power relations, exemplified by the "art of government" in the modern State, in which what was of primary concern was a collective body, or the population.[4] Biopolitics is thus a management and regulation of the population, but at the biological level, or at the "species" level. With the emergence of political economy, modern subjects were not only situated within a range of disciplinary and often institutional contexts, but they were also collective biological bodies with their own dynamics which could be articulated and organized as sources of knowledge. Biopolitics was thus "the endeavor, begun in the eighteenth century, to rationalize the problems presented to governmental practice by the phenomena characteristic of a group of living human beings constituted as a population: health, sanitation, birthrate, longevity, race…"[5]

One of the key strategies of biopolitical power identified by Foucault is its ability to simultaneously universalize and individualize through its biological-species perspective. A population could be a source of knowledge-production as a collective biological species, but this could only be possible if the parameters of individualized biological subjects were also taken into account. The universal category which enables a conceptualization of the species-population to take place is the notion of the continuity and universality of the individual human body itself. In this sense biopolitics makes the individualized biological body the foundation for a quantifiable and flexible system of knowledge-production (e.g., health statistics, governmental health policy, health records, hospital management).

TE also universalizes the biomedical body in this way, but it subtly shifts the applications of the universal categories of the human biological body. As previously mentioned, TE emerges as a response to problems in transplantation, which more or less are problems of immune system rejection of foreign tissue. Thus, while medical science could posit the universality of the biological body (implicit in the very idea of organ transplantation), the problems of immuno-compatibility frustrated such categories (that bodies, though the same, could nevertheless identify each other as foreign). TE, by contrast, also posits the universality of the biological body, but does not apply this universality between specific, individual bodies. Instead it applies a posited general category to individual cases (which are, from the start, enframed as universal instances–one technique will work for all bodies).

Thus biomedical bodies are, in terms of their biological processes occurring within themselves, universal instances valid across a population. The biopolitics of TE works through a highly compartmentalized universality of closed, self-regenerating biological processes, which are nevertheless consistent across a population. The practical models of health care relating to this field–cell banks, off-the-shelf organs, donations of discarded embryos from fertility clinics–these models form bio-economies of body parts which illustrate the apparatus by which TE is able to produce a vision of the regenerative body, a body always potentially in excess of itself.

The Fantasy of Technique

From this biopolitical perspective, I want to suggest that TE, as a branch of biotech, offers two "fantasies" with respect to its novel approach to the human biological body.

(a) The first is what we might simply call the fantasy of transparent technology, and it goes back to the etymological usages of the term "biotechnology" in agriculture and the breeding of livestock. This fantasy is to conceive of a technology which is indirect, invisible, and transparent to the natural and biological orders–the technology simply helps things along, making minor adjustments here and there. In agriculture and breeding this meant first gaining a knowledge of natural processes and then utilizing them as processes geared towards slightly different ends (greater crop diversity or production). In other words, this fantasy of biotech betrays a deep-running anxiety over the maintenance, at all costs, of the technology/nature divide, while at the same time conceiving of nature as something that is manipulable, but still nature itself. For TE, and biotech generally, this dual maintenance project is crucial because the notion of a pre-discursive, natural body forms the foundation of modern biological science and medicine and its rhetoric of privileging, above all, the naturalization of health technologies. If biotech were to suggest that these bio-technologies are in an important way constitutive of the biological body, that fundamental referent would be lost, as would the basic assumptions and claims of modern biological science.

(b) This combination of a body that is natural, and which remains natural through the applications of biotechnologies, leads to a second fantasy, more concentrated on the body itself. That is, biotech attempts to practically and technically conceive of the normative, biological body as something that is simultaneously material/biological/natural as well as malleable/technical/engineered. Because TE researchers claim that in the future entire organs and limbs will be regenerated, this in no way implies that the body has disappeared beneath language and discourse. TE is an urgent endeavor precisely because it is always based in the materiality of the biological body (as defined by the biological sciences). The links which researchers have made to embryogenesis and developmental biology is instructive here, because this dual property of being material and

malleable points to the possible future ways in which the biomedical body will morphogenetically emerge.

Norms, Hybrids

This analysis of TE has tried to show how it produces a range of different qualities: the biomedical body of TE is both externalized and forms within a closed biotechnological loop; it is an example of a bio-technology presented as transparent and still natural, and it is an example of a vision of the biomedical body as simultaneously natural/material and technological/malleable; finally, following Foucault's work, TE instantiates a biomedical, embodied subject that is both individuated and universalized.

Continuing this line of inquiry, I want to suggest that what all these different qualities move towards is, specifically, a vision of what the normative, biomedical body can become, and more generally what this vision may mean for the ways in which subjects are produced within the bio-sciences and medicine.

Norms: TE is establishing–through its research, clinical trials, and product development–a unique biomedical norm, which is encapsulated by the phrase "regenerative medicine." To posit a regenerative body is antithetical to postmodernist claims for the body's disappearance, for TE is deeply committed to the materiality of the body, to its notion of the flesh itself. On the other hand, it would not exactly be accurate to say that TE simply assumes a natural, pre-discursive notion of the body as something pre-given by nature. The researchers and knowledge systems informing biotech are not so naive as to be blind to their own technologies and applications. So then, what is this regenerative body? I want to suggest, to begin with, that the regenerative body is doubly marked by a movement of production and by a movement of excess–the model here is not incorporation or recuperation, but production and (re)generation. To posit a regenerative body implies that we are presented with bodies which are, theoretically speaking, infinitely reproducible. Furthermore, this notion of a body that can be regenerated is done so along the anatomical logic of body parts (cells, tissues, organs). Thus it is not the whole body which is regenerative, but rather the body parts or those sections articulated through anatomical and physiological science, as well as molecular genetics, which operate within the body according to certain variants (e.g., the organ of the heart operating according to the mechanics of the circulatory system).

But along with this infinitely reproducible body, regeneration also implies a region of excess as that which is displaced by regeneration. Thus, along with the infinitely reproducible body, there is also the expendable body, the "spare parts" which researchers speak of replacing. Taken together, we have a kind of bio-economy of TE, where the biological body is conceived of as a partitioned, self-regulating, auto-generative system with the capacity to not only regulate but to improve itself, through the minimal intervention of technology. The more indirect and invisible the technology becomes, the more the body of TE becomes this autonomous, enclosed, proliferative bio-system. The more the discourse of the natural body is asserted within TE and medicine, the more this vision of a regenerative body is instituted as a normative constraint defining the normal, healthy, biomedical body. The result is that the body of medicine once again is objectified, but in a particular way, such that the body can be seen, in the right conditions, as a self-regenerating, self-curing "black box."

In addition, the body–as a regenerative bio-object, as a black box–becomes a highly valued zone. This needs some explaining, because, given this vision of the body as expendable, one would expect that the body–as an object–would be the source of a devaluation ("I can always

grow it back. again"). However, while this is certainly a point, it is one which would need to posit an essentialist notion of the body, which, I am arguing, TE does not exactly do. What it does do, to the contrary, is to deeply invest the flesh and materiality (as defined by bioscience) with a force which attempts to break out of the constraints of the flesh, materiality, and corporeality. With telomerase research (the source of natural chromosome degradation), the biological body becomes immortal on the cellular level; with stem cell research, the cells of the body become "pluripotent," capable of transforming themselves into any of the body's cell types (muscle, nervous, epithelial); with nuclear transfer cloning, the genetic body can be replicated infinitely; with the genetic engineering of growth factors and plasmids, the cells of the body can be made to produce any desired protein, the "building blocks of life"; and with TE generally, the body very gradually arises out of a torture garden of mortality and very quickly heads towards what is essentially a body without death.

The view of the body which results from this is that of an autonomous biological "black box" which regulates itself–with minimal technological intervention–according to its own "biochemical wisdom." The long-range implications here are that a normal, healthy biomedical body is less defined by the contingencies of the mutability and mortality of the flesh, and increasingly defined according to the body's capacity to biologically re-produce itself, under certain (technological) conditions.

Hybrids: On the one hand, TE appears to be a very literal example of the constructionist argument (the flesh is actually synthesized or produced in the universalized context of the lab), but on the other the technologies it uses do not simply form fusions with the biological body, or quantified human/technology hybrids.

TE forms a unique configuration between the body (specifically, the biomedical body) and technology (specifically, biotechnology and molecular genetics), such that the technological is fundamental, implicit, and constitutive of the biological. Such a relationship depends, nevertheless, on an absolute, originary division between biology and technology. From there a complex interaction emerges. Technology is, in TE, not opposed to the body, and neither is technology external to the body. The technology of TE as outlined above is instead internal to the very biological processes of the body, but it does not simply supplant or displace those processes. Whereas related biomedical applications, from prosthetics (non-organic technology externally designed and incorporated), to surgical procedure (the medical intervention of technique into the body's interior), to gene therapy (the introduction of a range of synthetic and engineered biomolecules), contemporary biomedicine continues a logic of medical practice as both interventionist and external to the patient-body.

Beginning from the modernist assumption concerning humans and nonhumans, bodies and machines, nature and technology, TE, through its practices, research, and techniques, forms a particular type of hybrid biotech body.[6] Without denying the obvious medical benefits of TE, especially in cases of organ and tissue failure, what is also currently at stake is the medical, philosophical, and political effects TE may have in contributing to a notion of what the normative, healthy body may become in the so-called "biotech century."[7] The point here is not to relativise the very notion of "norms," but rather to ask what kinds of contingencies and constraints are intrinsic to TE. Another way of stating this is to simply ask what is not taken into account in the body of TE? As stated above, if TE begins from an assumption concerning the absolute division between body and technology, and then proceeds, through its practices, to construct a notion of a natural, biological body that is defined by its regenerative capacity, then it seems that TE is centrally concerned with a twofold movement: to simultaneously preserve the referent of the natural, pre-discursive, body-in-itself while also re-defining the

qualities of that body through the use of biotechnologies which minimally (that is, transparently) intervene in this process of redefinition. The body of TE never strays from its codification by modern science as a natural-biological entity, and even the notion of regeneration is presented in almost totally biological, biochemical, and organic terms. However this natural-biological body is only made possible through a particular, indirect, and facilitative use of bio-technologies. These technological practices and techniques are the non-visible interstices of the body of TE. They are the media of transparency which form the network of connective tissue which constitutes this vision of the regenerative body.

Connective Tissue

Tissue engineering presents a version of the body in which all capacities for regeneration, replacement, and supplement come from within the same body of the subject/population itself, through a range of techniques, technologies, and engineered biomolecules. What the biotech industry values in the body of tissue engineering is not supplementary objects which relate to the body from the outside (organ harvesting, artificial organs, prosthetics), but the value of the biotech body to reproduce its own materiality internal to its purportedly originary, natural conditions. Again, tissue engineering, in implying the potential physical and biological manipulability of the human body, is not suggesting that the body is somehow "less real." It does not accept and in fact rigorously denies that the body is a simulacra or a product of a techno-culture's hyperreality.[8] There is no body-anxiety with tissue engineering; it is, rather, an explicit (and medical-political economical) investment in the very value of the body as a potentially infinite natural resource.

Without a consideration of the dynamics whereby scientific practices such as TE are always already situated by discourses, knowledge-systems, and technologies, it becomes all-too-easy for modern biological and medical science to habitually desire, at any cost, the fantasy of a body transcending itself, and yet still a body.

As one TE researcher states, "ten millennia ago the development of agriculture freed humanity from a reliance on whatever sustenance nature was kind enough to provide. The development of tissue engineering should provide an analogous freedom from the limitations of the human body."[9] In utilizing bio-technologies in ways in which they are not manifest–and thus appear only at the interstices–TE seems to be gearing itself towards a standard of the biomedical body which strategically eliminates one entire sector of the biological body's contingencies (chromosome degradation, tissue aging and decay, and the markers of the body's mortality). Again, while this may be done with the best intentions, what needs to be asked is whether this fantasy is more valuable for what it excludes than for what it promises. What is needed is a consideration of the body of TE as an ontologically-distinct entity which is not simply the natural body, and which is significantly different from the body of biomedicine to date. The range of techniques and technologies which connect up and constitute this regenerative body need to be taken into account, not only in the potential philosophical-political implications with regards to embodied subjecthood, but also in the very questions which may be posed by research and medical application. If we consider contemporary biotechnologies and biomedical practices such as TE as biopolitical endeavors, then we are encouraged to consider those very interstices which enable such a governmentality to reconfigure the body as both universal and individuated, as natural but transparently mediated.

Notes

[1] Mooney, David; Antonios Mikos, Growing New Organs. *Scientific American 280,* April 1999, pp. 60—67. For more on tissue engineering see this issue of Scientific American.

[2] Ibid.; and Arnst, Catherine; John Carey, Biotech Bodies. *Business Week,* 27 July 1998, pp. 56—63.

[3] For these and other techniques see Patrick, Charles, et al., *Frontiers in Tissue Engineering,* Pergamon Press, 1998. For the Geron-Roslin partnership, see Wade, Nicholas. Researchers Join in Effort on Cloning Repair Tissue, *New York Times Online,* 5 May 1999, <http://www.nytimes.com>

[4] For example, see Omnes et Singulatim: Towards a Criticism of 'Political Reason,' *The Tanner Lectures* (ed. Sterling McMurrin), Cambridge UP, Cambridge 1981; and Governmentality, in *The Foucault Effect* (ed. Graham Burchell et al.), University of Chicago Press, Chicago 1991.

[5] The Birth of Biopolitics, *Ethics: Subjectivity and Truth* (ed. Paul Rabinow), The New Press, New York, 1994, p. 73.

[6] On networks and mediation in modernity see Bruno Latour, *We Have Never Been Modern,* Harvard UP, Cambridge 1993.

[7] Rikfin, Jeremy, *The Biotech Century,* Jeremey P. Tarcher/Putnam, New York 1998.

[8] See, for example, Jean Baudrillard's *The Ecstacy of Communication,* Semiotext(e), New York 1987, and *Forget Foucault,* Semiotext(e), New York 1987, as well as Paul Virilio, *The Aesthetics of Disappearance,* Semiotext(e), New York, 1991.

[9] Mooney & Mikos, ibid., 65.