Living Books About Life

# Partial Life

Edited by Oron Catts & Ionat Zurr

OPEN HUMANITIES PRESS

Living Books About Life OPEN HUMANITIES PRESS JISC

# Partial Life

*edited by* Oron Catts and Ionat Zurr

# Introduction

## 'The Semi-Living' and 'Partial Life'

This Living Book is partially living – it is about the semi-living and partial lives, about tissues without a body. While the biological body cannot survive without organs and cells, the latter two can survive in a technological body, which has been removed and separated from their original biological body. They are living fragments of biological bodies, forms of lab-grown life which have been reconfigured, mixed and remixed, reappropriated, recontextualised and instrumentalised. The semi-living thus require a different epistemological and ontological understanding as well as a different consideration and, by extension, a different taxonomy of life. The liminality of this kind of technological approach to life can lead to a form of fetishism, which we call *Neolifism*. The semi-living and partial lives are a new class of objects or beings. In most cases they consist of living and non-living materials; of cells and/or tissues from a complex organism which have been grown over, or into, constructed scaffolds and subsequently kept alive with an artificial support. They are both similar and different from other human artefacts (Homo sapiens' extended phenotype), such as

constructed objects and selectively bred domestic plants and animals (both pets and husbandry). These entities are living biological systems which have been artificially designed and which, in their isolation, construction, growth and maintenance, need technological intervention.

'The semi-living' and 'partial life' can be seen as interchangeable terms. There are, however, some nuances between the two. Semi-living entities are usually shaped as forms that are not recognisable as being part of any particular body; partial life can be recognised as parts (such as an ear or tissue) of the whole of a living being. Symbolically, on the continuum of man-made life, semi-living entities are nearer to the constructed side of the scale, while objects of partial life find themselves closer to the grown side of the scale. The 'population' of what can be referred to as partial life and semi-living entities has proliferated to reach a vast amount of cells and tissues that are currently living and growing outside of the organisms from which they originated. A rough estimate would put the biomass of the living cells and tissues which are disassociated from the original bodies that once hosted them at millions of tons. In addition, there exist tons of fragments of bodies (cells, tissues, organs) that are maintained in suspended animation in cryogenic conditions. All of this biomass requires an intensive technological intervention to prevent its transformation to a non-living state. These beings are rarely referred to as subjects; their existence, supported as it is by the technoscientific project, is indicative of the transformation of life into raw material that manifests itself through utilitarian and economic value.

This edition of the Living Book attempts 'to give a voice'

to such semi-living beings by presenting their history and selected examples of their use (and existence), with the aim of highlighting the problematics they raise -- which is also a reflection of the current state of our society. This is a society which is attempting to cope with the growing gap between the rapidly increasing knowledge and the technological ability to manipulate life on the one hand, and the deeply rooted attitudes towards life which are still lurking behind on the other. It is a society that may be facing its own extinction as a result of the ecological crisis and that is in urgent need of reconsidering the Judeo-Christian view of our supposed dominion over 'nature' in favour of a more post-humanist agenda. Having control over life, its processes and the environment as a whole has always been the basis of human endeavour. Yet the attitudes towards life are now changing as a result of the accumulation of scientific knowledge and technological capabilities -- both of which are mounting up with an increasing speed and scale of manipulation. A choreographed interplay between hype and actuality is overlaid on a public which is being bombarded with information which can potentially excite and disturb, but which is also easily forgotten. As the perception of the level of control over the matter of life increases, it seems that, whereas previously biologists were applying their understanding of engineering to the life sciences, now it is the engineers who are force-fitting engineering methodologies into living systems. Life is becoming bio-matter, waiting to be engineered.

## The Historical Perspective on the Semi-Living

The precursors of the semi-living can be identified in whole bodies, which are sustained alive in techno-scientific 'bodies'. With the industrial revolution and

the rise of the age of the machines, coupled with the naissance of the systematic understanding of life, the late nineteenth century witnessed the birth of biology as engineering, and the union of life and technology. The introduction of industrial baby and poultry incubators coincided with the birth of tissue culturing and the appearance of the semi-living. The coming together of life and technology manifested itself in strange ways, as indicated by the example of poultry incubators and the history of Cyphers Incubator Company. The story of the development and acceptance of human incubators (whereby an incubator can be seen as a techno-scientific 'body', or 'epi-body'), and especially the way in which they were introduced to America, is fascinating. It highlights how technologically augmented life, even in human babies, needed to be articulated and negotiated before such babies became 'transformed' from objects of entertainment to subject of care. The incubator was initially 'modeled after [the] chick incubator' by Stéphane Tarnier. The 'American father' of neonatology, Dr Martin A. Couney, was a European physician who promoted the idea of mechanical incubators as an aid to prolonging and saving the lives of the newly born, who would have otherwise died. The creation of the 'need' for a device that would orchestrate the 'passage' of an infant from a fragile ambiguous zone into the realm of a person is a complex story. One impetus for developing the incubator was the desire to halt population decline. There was a need not only to save those otherwise doomed 'lives', but also to strengthen the mother-child bond (which was directly related to infant survival). The initial design of the incubators was already geared not solely for the purposes of biomedicine: the incubator was also positioned as an aesthetic device, aimed at creating

certain meanings out of the technique and the life it sustained, and at generating empathy towards the bare life on display. Incubators were promoted in Europe and the USA via public fairs, during which the enthusiastic public had to pay for admission to watch the show of the 'Infant Incubators with Living Infants'. Couney had a permanent incubator show at Luna Park on Coney Island, New York, from 1903 to 1943, and was instrumental in Cornell University's New York Hospital opening the city's first neonatal ward.

Why did a successfully working technology, which saved so many lives, take such a long time to be accepted by the medical community, while it was thriving within the realm of public entertainment? Some say that Couney never intended for the technology to become widely available as this would have ended his ability to profit from it by charging the public to come and see the living display. It may have been that the context of the Luna Park exhibition and the showmanship involved prevented the medical establishment from accepting this technology. These are interesting and valid points. However, we want to suggest that such vexed cases in which liminal beings are in transition towards not just bare life but also towards scientific and moral classification, have to be articulated initially via aesthetic rather than scientific modes of presentation. A similar story is evident in the 'cabinet of curiosities', which served as a prelude to the natural history-refined taxonomy. To a certain extent, the neonatal technology can be said to have assisted in 'classifying' premature babies as belonging in the realm of the living and the human, and therefore as persons. As a result, the context where those new lives were dependent on their epi-bodies had to be dramatically

changed -- from the realm of entertainment to that of biomedicine. Today the new cabinet of curiosities is being constructed, or grown again, in the form of new technologically-dependent and yet still to be classified lives, lives which are being created in scientific laboratories by emerging technologies. These new entities do not conform or fit with classifications propounded by natural history museums, let alone with our traditional understanding of what life is and what it means to be alive.

## The History of Tissue Culture

The idea of the cellular body dates back to Aristotle (340 BC) and Theophrastus (320 BC), who both described animals and plants as being made up of unified elements: blood and sap, flesh and fibre, nerves and veins, bone and wood. Later, scientists such as Malpighi (1675) and Grew (1682) theorised that these elements were literally 'woven' (*tissé*) into tissues of still finer elements. In 1667, Robert Hooke, using one of the earliest microscopes, observed cell structures in a thin slice of cork. He coined the word 'cell', referring to a structure that reminded him of a honeycomb. Parts of bodies have been sustained, grown and cultured for more than a hundred years now. We are not talking about the 18th century Galvani-style reanimation by external power, but rather about the continuation of life processes and of the functions of parts that have been removed from bodies -- be it organs, tissues and cells. Fluttering attempts to keep body fragments alive were performed by in 1885 Willhelm Roux, who sustained embryonic chicken tissue alive for short periods of time, and by Ross G. Harrison, who grew a frog's nerve cell outside of the body in 1907. The ongoing existence of living fragments, i.e., of the semi-living, appeared with

the more systematic and sometime occult practice of Alexis Carrel, who cultured cells, tissues and eventually organs between 1913 and the 1940s. Carrel was a well-known and respected scientist who advanced the medical field in the area of new techniques of suturing arteries as well as transplantation and tissue culturing. He won the Nobel Prize for Medicine in 1912. Carrel was a complex and controversial figure, who pushed the ontological implications of his discoveries to some rather extreme and morally dubious places -- far from their strictly biomedical or even scientific realms and into ontologically, politically and ethically questionable ones.

Carrel's 1935 publication, *Man, the Unknown*, combined with his religious, or even mystical declarations, led him to speculate on the great problems of human destiny. Carrel theorised that mankind could reach perfection through selective reproduction and the leadership of an intellectual aristocracy. Through scientific enlightenment humanity would be free from disease, and achieve longevity and spiritual advancement. He proposed gas chambers as the way to eradicate unwanted elements in society. 'Eugenics', Carrel wrote in the last chapter of *Man, the Unknown*, 'is indispensable for the perpetuation of the strong. A great race must propagate its best elements'. The book, a worldwide best-seller translated into nineteen languages, brought Carrel international fame. Was it the realisation that life was much more complex than previously thought that led Carrel to mysticism? This may have been the case, but what was it that led him to eugenics? One can argue that the experience of developing partial life forms, which contradicted the Christian-humanist perception of the whole body, drove

him to engage with the occult. In short, the ontological questions thrown up by Carrel's scientific experiments ironically seem to have led to his mystic and eugenic tendencies.

However, rather than looking at tissue culture or partial life as a metaphor for the pure and perfected life, we would like to explore partial life (or semi-life) as a hybrid, dependent and imperfect entity. In the 'The Tissue Culture King', written in 1926, Julian Huxley reflects and articulates some of the anxieties surrounding early experiments in this field. 'The Tissue Culture King' is a story about a Western scientist, Hascombe, who is captured by an African tribe. In order to save his life, he employs his skills in the service of an African king. He decides to merge scientific principles and techniques with the religious tendencies of the tribe. Hascombe then employs tissue culture techniques to create 'The Factory of Kingship or Majesty, and the Wellspring of Ancestral Immortality'. The idea is to culture parts of the king's (or other ancestors') bodies and, through that, increase the biomass of the king, thus enabling the people of the community to own parts of the king, and to physically nurture, care and worship them. Furthermore, this technique promises to 'increase the safety, if not of the king as an individual, at least the life which was in him, and I presumed that this would be equally satisfactory from a theological point of view.' Hence, the fragment stands for the whole in this story. Huxley considers the wide implications of the discipline of tissue culture and the associated epistemological revelations by looking at the option of mass production. He also considers the economic and spiritual potential of the use and abuse of scientific knowledge and of applied technologies and social

sensitivities (see also Wilson, 2005).

## Plasticity: Cell Lines, Tissue Engineering and The Technoscientific Body

It was not until 1948 that a continuous line of cells, originating from one organism, was established: it was the strain-L mouse cell line, still widely used in laboratories. The strain-L was followed three years later by the first continuous human cell line -- HeLa cells. HeLa cells constitute an immortal cell line that was derived from cervical cancer cells taken from a black American woman, Henrietta Lacks, who died of cancer in 1951. The cells were propagated without Lacks' knowledge or permission. The case reveals many social and political paradoxes resulting from developments in biotechnology -- such as that a person (just like any other animal) cannot, according to the law, own her own tissues; the commercial rights of one's own tissues; and issues of race, class and gender, which are especially heightened when profit is at stake. The realization that cells from complex organisms can not only be sustained alive outside of the body, but also grow, divide and function emerged in the 1910s, when Dr. Alexis Carrel began his experiments in a technique he termed 'tissue culture'. However, it took more than eighty years to realize that cells could be grown in three dimensions to form a functional tissue that had the potential to replace missing or failing body parts. This development came from the collaborative work of a surgeon, Dr. Joseph Vacanti, and a material scientist, Dr. Robert Langer. They developed a system that uses specially designed degradable polymers that act as a scaffold for the developing tissue.

Maintaining and growing living fragments, the semi-livings, involves the creation of a surrogate technoscientific body (or epi-body). This technoscientific body provides conditions that allow the cells to grow and proliferate. In the most basic terms, this includes providing the right temperature, nutrients and other substances and, in some cases, substrates that promote cell growth. The cultivated fragments are unquestionably alive, in that they are metabolising, growing and multiplying. They experience at least some of the processes and functions that are needed for something to be 'alive'. In the last couple of decades, and only in some cases, the technoscientific body and the semi-living have begun to form a cyborgian entity, whereby function and feedback make such an entity a responsive and effective unit. The growth of three-dimensional 'functional' tissues is no longer confined to the biomedical world. As other aspects of regenerative medicine such as stem cell, therapeutic cloning and cell engineering are increasingly taking dominance over the field, technologies that where originally developed for the purpose of tissue engineering in the 1990s are now being used for non-clinical ends. Tissues and cells from complex organisms are being grown in large quantities for the production of biological substances; liver cells are being grown as toxicity sensors; different cells from different sources (bodies and organs) are being cultivated together in micro-fluidic chambers to make 'animals' on chips as an alternative to animal and human drug testing; in vitro meat is being seriously considered as an alternative to traditional meat production; and an increasing number of artists, designers and architects are working with living tissue as part of their practice.

With regard to the current research into the production of in vitro meat, the editors of this Living Book actually began exploring the possibility of growing meat without the need to slaughter animals already in 2000, as part of their residency at the Tissue Engineering & Organ Fabrication Laboratory at Harvard Medical School in 2000. The first steak was grown from pre-natal sheep cells (skeletal muscle), harvested as part of the research into tissue engineering techniques in utero. The steak was grown from an animal that had not yet been born. However, one major complication arising from such a 'victimless meat endeavour' as a manifestation of the techno-scientific project is that it may create an illusion of victimless existence. First, in order to grow in vitro meat, there is still the need for a serum, which is created by using animals' blood plasma. Although research to find alternatives for this ingredient is being developed, there is no solution in the near sight and animals (mainly calves or foetal bovines) are sacrificed for that ingredient. Second, we need to consider the total cost involved in running a laboratory, i.e., the fossil fuels burned, the green house gases produced, the water and trees consumed, the miles travelled and the waste created. Third, what we are witnessing here is a shift from 'the red in tooth and claw' nature to a mediated nature. In this process, victims are pushed farther away; they still exist, but are now much more implicit and inconspicuous.

Different cells from different bodies (regardless of sex, race, age or animal species) can be co-cultured. Furthermore in some cases, cells fuse. Cell fusion is 'the nondestructive merging of the contents of two cells by artificial means, resulting in a heterokaryon that will reproduce genetically alike, multinucleated progeny for

a few generations'.1 When an undifferentiated stem cell fuses with a mature differentiated cell, the resultant cell retains the mature cell phenotype.2 Cell fusion among different species and different families along the evolutionary tree has been carried out successfully since the 1970s. One example, the fusion of Xenopus and carrot cells, was discussed in 1978: Cultured Xenopus cells have been induced to fuse with carrot suspension cell protoplasts using PEG at high pH in the presence of high Ca2+. Ultrastructural observations confirm unambiguously that the fusion bodies seen by light microscopy are animal/plant cell heterokaryons. The cytoplasmic events occurring in these Xenopus/carrot fusion products during the first 48 hours of culture provide evidence for their viability (see Davey *et al.*, 1978). The phenomenon of cell fusion, besides its practical applications such as a method for passing on specific genes to specific chromosomes, compelled Oxford University Professor Henry Harris to write about his experience as a pioneer in cell fusion techniques (see Harris, 2005). Harris' 2005 article opens with a somewhat romantic quote:

> There is a tendency for living things to join up, establish linkages, live inside each other, return to earlier arrangements, get along, whenever possible. This is the way of the world. The new phenomenon of cell fusion, a laboratory trick on which much of today's science of molecular genetics relies for its data, is the simplest and most spectacular symbol of the tendency. In a way, it is the most unbiologic of all phenomena, violating the most fundamental myths of the last century, for it denies the importance of specificity, integrity, and separateness in living things. Any cell – man, animal, fish, fowl, or insect – given the chance and under the right conditions, brought into contact with any other cell, however foreign, will fuse with it.

> Cytoplasm will flow easily from one to the other, the nuclei will combine, and it will become, for a time anyway, a single cell with two complete, alien genomes, ready to dance, ready to multiply. It is a Chimera, a Griffon, a Sphinx, a Ganesha, a Peruvian God, a Ch'i-lin, an omen of good fortune, a wish for the world. (Thomas Lewis, cited in Harris, 2005)

## Semi-Living Art and Neolife

One of the roles that art can play is that of offering scenarios for 'worlds under construction' and of subverting technologies for the purpose of creating contestable objects (see Dixon, 2009). This role of art makes the emergence of the semi-livings as evocative art 'objects' and the multi-level exploration of their use so relevant and important. The Tissue Culture & Art Project (TC&A), was set up by us (Oron Catts and Ionat Zurr) in 1996 to explore, develop and critique the use of tissue technologies for artistic ends. From the beginning, TC&A has been interested on a practical level in investigating human relationships with the different gradients of life through the construction and growth of a new class of objects/beings -- that of the semi-living. The semi-living form parts of complex organisms which are sustained alive outside of the body, and which are coerced to grow in predetermined shapes. These evocative objects are a tangible example that brings into question our deep-rooted perceptions of life, identity and selfhood, and the position of the human with regard to other living beings and the environment. We are interested in the new discourses and the new ethics, epistemology and ontology opened up by issues of partial life and by the contestable future scenarios these partial life forms are offering us. With this, we have relied on and developed some new ways of

growing tissue by using and subverting scientific tools and techniques from almost a hundred years ago to the present.

As discussed briefly earlier, one of the more interesting interpretations, and definitely the most post-anthropocentric perspective on the existence of the HeLa cell line, comes from a scientist, Leigh Van Valen. Van Valen controversially suggested to his peers that the HeLa cell line was an embodiment of a new taxonomical branch -- that it was a new species of its kind. Due to its ability to replicate indefinitely, and its non-human chromosome number, Leigh Van Valen described HeLa as an example of the contemporary creation of a new species, *Helacyton gartleri*. It was named after Stanley M. Gartler, whom Van Valen credits with discovering 'the remarkable success of this species'. His argument for speciation depends on three points: • The chromosomal incompatibility of HeLa cells with humans, which makes them non-human. • Their ecological niche, which may be technologically dependent, but we can assert that many species, including humans to a large extent, are by now technologically dependent. • Their ability to persist and expand well beyond the intentions and imaginations of human cultivators.

Scientific knowledge leads to shifts in the perception of life: life is becoming a raw material, while biology is turning into engineering. Whenever life and technology mix, odd things happen. Where does lab-grown and engineered life fit in the human taxonomy? In tissue banks that provide cell lines, one starts to find all sorts of oddities: cells that have three different organisms as its origins, or fused cells of human and mouse origin. These cells are only classified by catalogue numbers or

by very unusual names. This is what we can describe as neolife. More and more museums have started to collect fragments of life; frozen cells that represent the whole. Here, the technology of collection is converging with the technology of making strange. The old ways of privileging form (staffed idealised forms of animals) are been replaced with information and fragments on display. New life forms are entering collections, but the collection is not complete -- the 'odd neolife' is not part of our natural history collections, as the lab-grown, lab-modified life forms are still absent from it. Our *Odd Neolifism* is an updated cabinet of curiosities. Museums have their own conventions with regard to displaying preserved life forms. In the *Odd Neolifism* display, ideas about a progressive complexity of species are questioned. At the far end of the display we have included the only living element -- cell tissue within a bioreactor (a surrogate, technological body). These life forms are so abstracted from their source and yet they are growing. Perhaps it is time to realise that we need to find a place in our ecology for neolife.

A pattern, even if somewhat blurry and ever changing, may be observed among the different examples of the semi-living. It is manifest in the desire to sense as well as make sense of a situation that is post-anthropocentric and in the attempt to articulate the relation and interdependency of all living parts along the continuum of life and technology, through the intriguing and perplexing example of the in-between – the semi-living. This opens up new discourses about the different relationships we might form with these neolife forms, allowing us to shed new light on our perception of life. Such entities might eventually become fetishised, or even become our 'natural-ish' companions, thus invading and replacing our constructed and

manufactured environments with growing, moving, soft, moist, and care-needing things.

**Notes**

1 http://medical-dictionary.thefreedictionary.com/cell+fusion

2 http://www.medterms.com/script/main/art.asp?articlekey=32440

**References**

Davey, M. R., Clothier, R. H., Balls, M. & Cocking, E. E. (1978) 'An ultrastructural study of the fusion of cultured amphibian cells with higher plant protoplasts', *Protoplasma*, 96:1-2, 157-172.

Dixon, D. P. (2009) 'Creating the semi-living: on politics, aesthetics and the more-than-human', *Transactions of the Institute of British Geographers*, Volume 34, Issue 4.

Harris, H. (2005) 'Roots: Cell Fusion', *BioEssays*, 2:4, 176-179. Wilson, D. (2005) 'Early Tissue Culture in Britain: the Interwar Years', *Social History of Medicine* (August) 18 (2), 225-243.

# Articles

## The Historical Perspective on the Semi-Living

### Precursors of the Semi-Living

Standard of the World Cyphers Incubator Company, Buffalo N.Y., U.S.A. Annual catalogue, published 1896
Poultry Growers' Guide for 1912, published by Buffalo, Cyphers Incubator Co.

Dr Lawrence M. Gartner and Dr Carol B. Gartner
The Care of Premature Infants: Historical Perspective

### The History of Tissue Culture

Alexis Carrel
On the Permanent Life of Tissues Outside of the Organism

Alexis Carrel and Montrose T. Burrows
Cultivation of Tissues In Vitro and Its Technique

Alexis Carrel and Montrose T. Burrows
An Addition to the Technique of the Cultivation of Tissues In Vitro

Alexis Carrel
Contributions to the Study of the Mechanism of the Growth of Connective Tissue

J. A. Witkowski
Alexis Carrel and the Mysticism of Tissue Culture

Alexis Carrel
*Men, the Unknown*

Julian Huxley
The Tissue Culture King

**The Plasticity of Cell Lines**

About the ATCC-LGC Standards Partnership, which facilitates the distribution of ATCC cultures and bioproducts to life science researchers throughout Europe and India

Stephen J. O'Brien
Cell Culture Forensics

Brendan P. Lucey, Walter A. Nelson-Rees and Grover M. Hutchins
Henrietta Lacks, HeLa Cells, and Cell Culture Contamination

## The Technoscientific Body

Mark J. Powers *et al.*
A Microfabricated Array Bioreactor for Perfused 3D Liver Culture

Jianzhong Xi, Jacob J. Schmidt and Carlo D. Montemagno
Self-Assembled Microdevices Driven by Muscle

Thomas Boland *et al.*
Cell and Organ Printing 2: Fusion of Cell Aggregates in Three-Dimensional Gels

I. Datar and M. Betti
Possibilities for an In Vitro Meat Production System

P. D. Edelman *et al.*
In Vitro Cultured Meat Production

**Cell Fusion**

Cell Fusion

## Regenerative Medicine and Stem Cells

Jeremy P. Brockes and Anoop Kumar
Appendage Regeneration in Adult Vertebrates and Implications for Regenerative Medicine

Farhan Chowdhury *et al.*
Soft Substrates Promote Homogeneous Self Renewal of Embryonic Stem Cells via Downregulating Cell-Matrix Tractions

Hannah Landecker
Living Differently in Time: Plasticity, Temporality, and Cellular Biotechnologies

## Semi-Living Art

Oron Catts and Ionat Zurr
Towards a New Class of Being –The Extended Body

Oron Catts and Ionat Zurr
Big Pigs, Small Wings: On Genohype and Artistic Autonomy

Oron Catts, ed.
The Aesthetics of Care

## Neolife

The Tissue Culture and Art Project

The Frozen Ark Project

# Attributions

Standard of the World Cyphers Incubator Company Buffalo N.Y. U.S.A. Annual Catalogue published 1896. Link: http://www.slpowermuseum.com/equipment/cypher/cyphersManual.pdf.
Licence: In public domain. Made available via a link to the website of St. Lawrence Power and Equipment Museum.

Poultry growers guide for 1912, published by Buffalo, Cyphers Incubator Co. Link: http://www.archive.org/details/poultrygrowersgu00cyph
Licence: In public domain. Made available via a link to the Internet Archive.

Dr Lawrence M. Gartner and Dr Carol B. Gartner, 'The Care of Premature Infants: Historical Perspective in Neonatal Intensive Care', NEONATAL INTENSIVE CARE - A HISTORY OF EXCELLENCE, A Symposium Commemorating Child Health Day Sponsored by the National Institute of Child Health and Human Development. Originally presented October 7, 1985, National Institutes of Health Bethesda, Maryland NIH Publication No. 92-2786, October 1992. P.4. Link: http://www.neonatology.org/classics/nic.nih1985.pdf.
Licence: U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES. Public Health Service, National Institutes of Health NIH Publication, made available via a link to http://www.neonatology.org.

Carrell, A. (1912) 'On the permanent life of tissues outside of the organism', *Journal of Experimental Medicine*, vol. 15 no. 5 (May 1), The Rockefeller University Press, 516-528. Link:

http://jem.rupress.org/content/15/5/516.full.pdf. Licence: Ownership of copyright remains with Rockefeller University Press authors. Third parties may reuse our content for noncommercial purposes without specific permission as long as they provide proper attribution.

Carrel, A. & Burrow, M. T. (1911) 'Cultivation of tissues in vitro and its technique', *Journal of Experimental Medicine*, 13 (3) (March 1): 387-396. Link http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2125263/pdf/387.pdf.
Licence: Ownership of copyright remains with Rockefeller University Press authors. Third parties may reuse our content for noncommercial purposes without specific permission as long as they provide proper attribution. Available in PubMed Central c/o Rockefeller University Press. PMCID: PMC2125263.

Carrel, A. & Burrow, M. T. (1911) 'An addition to the technique of the cultivation of tissues in vitro', *Journal of Experimental Medicine*, 14 (3) (September 1): 244-247. Link: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2124775/pdf/244.pdf. Licence: Ownership of copyright remains with Rockefeller University Press authors. Third parties may reuse our content for noncommercial purposes without specific permission as long as they provide proper attribution. Available in PubMed Central c/o Rockefeller University Press. PMCID: PMC2124775.

Carrel, A. (1913) 'Contributions to the study of the mechanism of the growth of connective tissue', *Journal of Experimental Medicine*, 18 (3) (September 1): 287-298. Link:

http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2125069/pdf/287.pdf.
Licence: Ownership of copyright remains with Rockefeller University Press authors. Third parties may reuse our content for noncommercial purposes without specific permission as long as they provide proper attribution. Available in PubMed Central c/o Rockefeller University Press. PMCID: PMC2125069.

Witkowski, J. A. (1979) 'Alexis Carrel and the mysticism of tissue culture', *Medical History*, 23:279-296. Link: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1082475/pdf/medhist00098-0025.pdf. Licence: Available via a link to PubMed Central, PMCID: PMC1082475. Articles from Medical History are provided there courtesy of The Wellcome Trust Centre for the History of Medicine at UCL.

Carrel, A. (1935/1939) *Men, the Unknown*, HARPER & BROTHERS. Link: http://quantumfieldtheory.org/ALEXIS%20CARREL%20Man%20the%20Unknown%201935.pdf.
Licence: In public domain. Available here via a link to The Quantum Field Theory blog.

Huxley, J. (1946) 'The Tissue Culture King', in Great Science Fictions by Scientists, Groff Conklin Ed., Collier Books NY pp.147-170 1946. Link: http://www.revolutionsf.com/fiction/tissue/index.html.
Licence: In public domain. Available here via a link to Revolution SF.

About the ATCC-LGC Standards Partnership. Website link.

O'Brien, S. J. (2001) 'Cell culture forensics', *Proceedings of the National Academy of Sciences of the United States of America*, vol. 98, no. 14 (July 3), 7656–7658. Link: http://www.pnas.org/content/98/14/7656.full.pdf
Licence: Available here via a link to PNAS Online. PNAS Online launched in January 1997 and now receives over 21 million hits per month. The site contains the full text, figures, tables, equations, and references of all articles in PNAS dating back to 1990.

Lucey, B. P., Nelson-Rees, W. A., & Hutchins, G. M. (2009) 'Henrietta Lacks, HeLa Cells, and Cell Culture Contamination', *Archives of Pathology & Laboratory Medicine*: September , Vol. 133, No. 9, 1463-1467. Link: http://www.archivesofpathology.org/doi/full/10.1043/1543-2165-133.9.1463. Licence: Copyright © 2011 College of American Pathologists. Available here via a link to the *Archives of Pathology & Laboratory Medicine* website, where this article is free to read.

Powers, M. *et al.* (2002) A microfabricated array bioreactor for perfused 3D liver culture, *Biotechnology and Bioengineering*, volume 78, issue 3, 237-353. Link: http://www.ocf.berkeley.edu/~mctbl/BiotechBioeng2002_LiverChip.pdf<pdf> Licence:

Xi, J., Schmidt, J. J., & Montemagno, C. D. (2005) 'Self-assembled microdevices driven by muscle', 1, in *Nature Materials* 4, 180 - 184.'
Link:
http://www.nature.com/nmat/journal/v4/n2/full/nmat1308.html.
Licence: Copyright: Nature Publishing Group. Made freely available on the Nature website and offered here via a link.

Boland, T. *et al.* (2003), 'Cell and Organ Printing 2: Fusion of Cell Aggregates in Three-Dimensional Gels', *The Anatomical Record Part A: Discoveries in Molecular, Cellular, and Evolutionary Biology*, Volume 272A, Issue 2, Link: http://onlinelibrary.wiley.com/doi/10.1002/ar.a.10059/pdf.
Licence: © 2003 WILEY-LISS, INC. Made freely available on the Wiley Online website and offered here via a link.

Datar, I. & Betti, M. (2010) 'Possibilities for an in vitro meat production system', *Innovative Food Science and Emerging Technologies*, 11, 13–22. Link: http://www.new-harvest.org/img/files/datar_and_betti.pdf.
Licence: © 2009 Elsevier Ltd. Made available here via a link to the New Harvest website.

Edelman, P. D., McFarland, D. C., Mironov, V. A., & Matheny, J. G. (2005) 'In vitro cultured meat production', *Tissue Engineering*, May/June, 11(5-6): 659-662.
Link: http://www.new-harvest.org/img/files/Invitro.pdf.
Licence: Author's manuscript. Made available here via a link to the New Harvest website.

Cell Fusion definition, link to The Free Dictionary by Farlex. Link: http://medical-dictionary.thefreedictionary.com/cell+fusion

Brockes, J. P. & Kumar, A. (2005) 'Appendage Regeneration in Adult Vertebrates and Implications for Regenerative Medicine', *Science* 23 December, Vol. 310 no. 5756, 1919-1923. Link: http://www.sciencemag.org/content/310/5756/1919.full

Licence: DOI: 10.1126/science.1115200. Freely available on the *Science* website and offered here via a link.

Chowdhury, F. et al. (2010) 'Soft Substrates Promote Homogeneous Self Renewal of Embryonic Stem Cells via Downregulating Cell-Matrix Tractions', PLoS One, 5(12): e15655. doi:10.1371/journal.pone.0015655. Link: http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0015655.
Licence: © 2010 Chowdhury et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Landecker, H. (2005) 'Living Differently in Time: Plasticity, Temporality, and Cellular Biotechnologies', *Culture Machine*, Vol 7. Link: http://www.culturemachine.net/index.php/cm/article/viewArticle/26/33%3E.
Licence: © Landecker. Culture Machine is an open-access journal.

Catts, O. & Zurr, I. (2006) 'Towards a new class of being –The Extended Body', Artnodes, Issue 6, November. Link: http://www.uoc.edu/artnodes/6/dt/eng/catts_zurr.pdf Licence: This work is subject to a Creative Commons Attribution-Noncommercial-NoDerivativeWorks 2.5 licence. They may be copied, distributed and broadcast provided that the author and the journal that publishes it (Artnodes) are cited. Commercial use and derivative works are not permitted. The full licence can be consulted on http://creativecommons.org/licenses/by-nc-nd/2.5/es/deed.en.

Catts, O. & Zurr, I. (2005), 'Big Pigs, Small Wings: On Genohype and Artistic Autonomy', *Culture Machine*, Vol 7. Link: http://www.culturemachine.net/index.php/cm/article/view/30/37.
Licence: © Catts & Zurr. Culture Machine is an open-access journal.

Catts, O. 'Aesthetics of Care', Ed. ISBN: 1 74052 080 7. Link: http://www.tca.uwa.edu.au/publication/THE_AESTHETICS_OF_CARE.pdf.
Licence: © Catts. The Aesthetics of Care is published by SymbioticA, School of Anatomy and Human Biology, University of Western Australia, 35 Crawley Avenue, Nedlands 6009. Western Australia. August 2002. www.symbiotica.uwa.edu.au