THE IMPACT OF TISSUE ENGINEERING ON THE HIGH-TECH SOCIETY

Henry Ko[1], Oron Catts[2], Clive McFarland[1]
[1]Graduate School of Biomedical Engineering, University of New South Wales, Sydney, Australia.
[2]SymbioticA, School of Anatomy & Human biology, University of Western Australia, Perth, Australia

Abstract

Tissue engineering is an interdisciplinary field that applies the principles of engineering & the life sciences towards the development of biological substitutes that restore, maintain or improve tissue function. It is also seen as a way to develop non-medical tissue constructs for *in vitro* meat and leather production, as well as for engineering and military uses. Longer lifespan, lower health care costs, less morbidity, and overcoming ethical issues associated with treatments such as organ transplantation will be what tissue engineering promises to achieve. Tissue engineering has also pushed to public attention the role of biosciences and bioengineering in developing our high-tech society. Issues that have been raised have included (1) the ethics of stem cells and their use, (2) organ transplantation and donation, and (3) the changing identity and extent of intervention and manipulation of the human and animal body in the 21st Century. Science communication and biological art has been utilized to explore these issues. By blending techniques in bioengineering and artistic disciplines, we are developing new creative methods for tissue engineering research, and promoting public discussions on the impact of bioscience on society. This has been achieved through public installations of biological artworks, research collaborations, and public awareness initiatives.

Keywords: tissue engineering, high-tech society, art, communication.

1. Introduction: The problems of a high-tech society.

As our society develops into an increasingly technology-dependent society, to become a truly high-tech society, certain problems pertaining to a high-tech society will develop.

As can be seen in the news, and noted by many environmental scientists and nature organisations, the face of the Earth is changing. The natural jungle of rainforests and grass is being taken over by the "jungle" of concrete and skyscrapers. The loss of the natural environment is something that seems to be an unstoppable trend as we edge closer to creating a more high-tech society.

A more sinister effect is the loss of living in this artificial environment is the development of "super-bugs" – viruses and bacteria that are resistant to conventional drugs and vaccines. It has been reported that this phenomenon has been caused by a few factors such as:

1. the improper use of medicines by patients, in that the bugs survive and evolve to become stronger because of the ineffective dosage of the medicines,
2. the shielding of children from being "dirty" and from the pathogens in the natural environment, and in effect rendering the human immune system inadequately prepared for pathogens, and
3. a unique artificial environment that may actually be good breeding grounds for pathogens and may help spread the pathogens faster (e.g. legionnaires disease pathogens in air conditioning water systems, an efficient global transport system has helped make transmission of diseases faster and easier).

Convenience is a key feature of a high-tech society. Manual labour is gradually being replaced by robotics and automated systems. In stead of gathering food in fields and farms, all we need to do today is walk (or drive) to the supermarket to get food. We don't even need to cook the food as such – we now only need to heat it up for a few minutes in a microwave. To get from "A" to "B" is easy via planes, trains and automobiles. However a disturbing side-effect of this convenience is the globally growing epidemic of obesity. Two major factors combining to increase the obesity epidemic are:

1. the ease of access to, and high consumption of, high carbohydrate low nutrient foods (such as fast-foods), and
2. a reduction of physical effort needed to do activities of daily living, and an overall reduction of daily physical activity.

A final problem facing humanity in this evolving society is the changing face of morals and ethics. Humanity has opened a Pandora's Box of sorts with regards how we can manipulate the natural world (including our own biology). All this power to manipulate the physical world, even for the benefit of humanity, has continually raised the question of "should we just because we can?" But the break-neck speed at which science and technology is advancing means that the rate at which the full ethical and societal implications of our discoveries must be matched. Unfortunately this is not always the case.

2. Health issues of a high-tech society.

We are living longer. Statistically the average lifespan of humans has been increasing. This has been attributed to factors such as better standard of living, easier access to food, better understanding of health, and easier access to health care. Concurrently, there is also an increasing percentage of the population who are elderly. Table 1 illustrates the global trend of increasing life expectancies (at birth) since 1950.

Table 1. World life expectancy at birth by sex (years). Medium variant.1950-2050. World population prospects [1].

Period	Both sexes combined	Male	Female
1950-1955	46.6	45.3	48.0
1955-1960	49.7	48.3	51.2
1960-1965	52.5	51.1	53.9
1965-1970	56.2	54.7	57.6
1970-1975	58.1	56.6	59.6
1975-1980	59.9	58.2	61.7
1980-1985	61.4	59.5	63.3
1985-1990	62.9	61.0	64.9
1990-1995	63.7	61.6	66.0
1995-2000	64.6	62.3	67.0
2000-2005	65.4	63.2	67.7
2005-2010	66.5	64.3	68.7
2010-2015	67.7	65.5	69.9
2015-2020	68.9	66.6	71.2
2020-2025	70.0	67.7	72.3
2025-2030	71.1	68.8	73.5
2030-2035	72.2	69.9	74.5
2035-2040	73.2	70.9	75.6
2040-2045	74.2	71.9	76.6
2045-2050	75.1	72.8	77.5

However, the offset of this is the phenomenon of the increasing prevalence of lifestyle diseases. As mentioned previously, convenience is not only a blessing, but also a curse. Obesity is primarily a lifestyle induced condition. Lung cancer from smoking cigarettes, skin cancer from excessive exposure to the sun, and injuries from sporting accidents are examples of lifestyle induced impairments. As estimate by the World Health Organisation, global cancer rates could increase by 50% to 15 million by 2020 [2].

High expectation of the efficacy and quality of medical treatment are inherent in the high-tech society. With advancements in the understanding of nature, the physical world, and biology, new treatments for disease and health deficiencies will be treated with the most ground-breaking and advanced methods. These methods of treating health problems may include advanced medical diagnostics, genetic therapies, and tissue engineered organs for transplantation.

3. What is tissue engineering?

Tissue engineering is an interdisciplinary field that applies the principles of engineering & the life sciences towards the development of biological substitutes that restore, maintain or improve tissue function [3]. The aims of tissue engineering range from creating whole tissues and organs for transplantation, to creating therapies that use cells to alleviate metabolic deficiencies or diseases. In biomedical applications organs that can be created include bone, cartilage, tendon, liver, skin and nerves [4, 5, 6].

As noted in Time Magazine, tissue engineering has been predicted to be the number one hottest job of the 21st Century [7].

Tissue engineering can also be applied for non-biomedical applications. These include development of non-medical tissue constructs for *in vitro* meat and leather production as shown in Figure 3 and Figure 4 respectively, as well as for engineering and military uses (such as real muscle actuators, biological computing and sensors). The use of tissue engineering in these applications may see a revolution in food production with increasing quality and processing control over the product, far more humane “animal” goods production, as well as the advent of bio-machines.

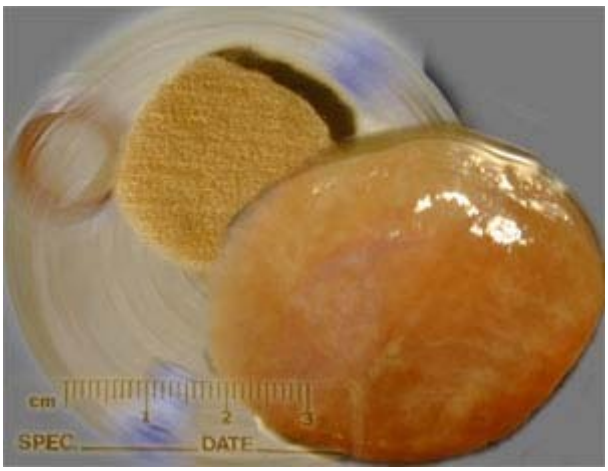

Figure 1. *In vitro* meat. Tissue Culture and Art Project. SymbioticA [8, 9].

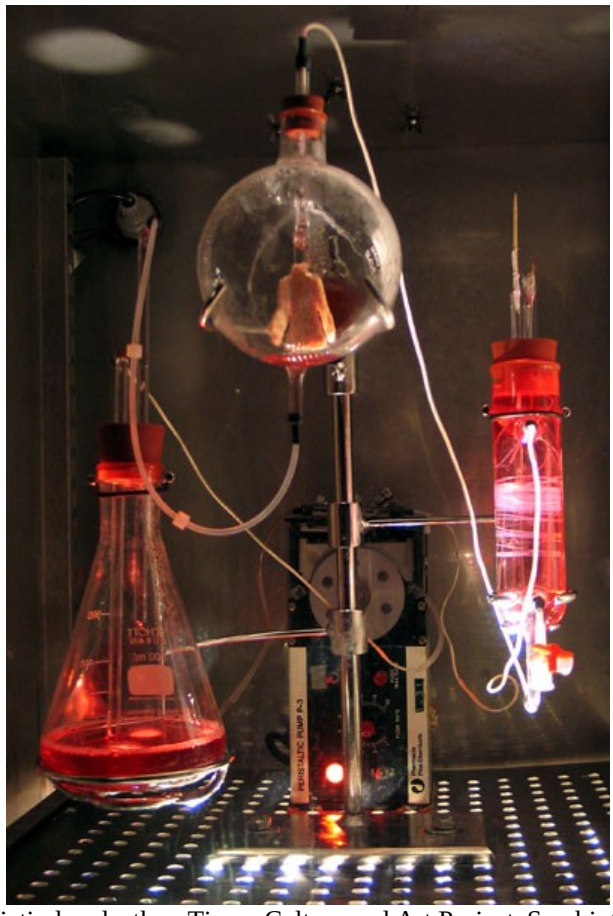
Figure 2. Victimless leather. Tissue Culture and Art Project. SymbioticA [9, 10].

4. How can tissue engineering revolutionize the high-tech society?

So, how can tissue engineering revolutionize the high-tech society?

With the high expectations of better healthcare solutions for our high-tech society, tissue engineering can meet the growing need to keep people healthier for longer as we age. Unfortunately we cannot regenerate our organs as well when we are older, but the amount of people getting older is increasing. Therefore tissue engineering can meet this drawback of aging by providing replacement organs for a high-tech society that still has a primitive body with a longer lifespan, and consequently, failing organs.

The cost of treating organ failure is high. There are high hospital costs involved in caring for someone who is waiting for organ transplantation. Table 2 records the various numbers of patients waiting for different organ transplants on the United States waiting lists.

Table 2. Current U.S. waiting list for transplant organs as of February 24. 2006. Compiled from OPTN [11].

Organs	Registrations
All organs	97,448
Kidney	68,983
Liver	17,650
Pancreas	1,748
Kidney/Pancreas	2,579
Heart	3,007
Lung	3,143
Heart/Lung	141
Intestine	197

Tissue engineering will see in the future the development of "off-the-shelf" organ transplantation whereby organs are readily available for vital organ transplantations, and hence reducing the burden of waiting list medical treatment costs and the human stresses associated with transplantation waiting lists and caring for patients and their families.
Associated with this point of almost immediate and completely compatible medical treatment for tissue and organ deficiencies is the reduction in patient morbidity and mortality. Tissue engineering will see the elimination of donor site, whether autograft or allograft, morbidity and damage by eliminating the need for massive donor tissue damage to treat a patient. Mortality is reduced because the failure of patients to get organ transplants is reduced drastically.
Another way in which tissue engineering will affect the lives of a high-tech society is via overcoming some of the ethical issues associated with organ transplantation treatments. Ethical issues have arisen from the use of animal organs (i.e. xenotransplantation), use of living of deceased human donors (i.e. allotransplantation), and the use of extracorporeal devices, such as dialysis machines, and implantable devices, such as cardiac pacemakers. Many, if not all, of these currently used therapies seem unnatural due to the fact that they are not derived from our own bodies and are not exact matches to our own genetic material and many do not respond in exactly the same way of the original tissues or organs. In fact many therapies have a danger of rejection by the recipient's immune system. In the past, these therapies have raised the interesting question of whether our bodies are actually all our own? But with the advent tissue engineering, we can draw upon our own body's regenerative abilities and cells to create treatments that are completely "natural", completely avoid immune system rejection, and avoid the ethical issues associated with using non-patient tissues.

5. Tissue engineering, bioethics and society

Stem cells have been a popular topic in tissue engineering and cellular therapies. The potential for stem cells to differentiate and reproduce into many different cell types has catapulted the area into the spotlight as a cure-all. With these amazing cells, the high-tech society may be able to treat virtually any tissue and organ disease and deficiency. The ethics surrounding stem cells have mainly centred on how we get the cells, for example from cord blood, adult sources, and foetal tissues. Of these sources adult stem cells seem to have the least ethical problems as long as consent is given to obtain them. Foetal sources have the most ethical controversy due to the state in which the stem cells are obtained e.g. from aborted foetuses.
However the trade-off is that adult sources are harder to obtain in larger numbers and can only differentiate into limited cell phenotypes, whereas foetal sources provide easy access to large numbers of stem cells that are totipotent, such as embryonic stem cells, which can differentiate in to virtually any cell type.
The bioethics of what sources of stem cells to use and how to use it is complex and not easily resolved.
Organ transplantation and donation is another area that this developing high-tech society needs to resolve. As tissue engineering looms as the promised solution to resolve the issue of organ rejection and lack of donor organs, another area that we must look at that currently permeates the clinical transplantation field is the black market trade in organs. Donation of an organ is usually a supreme sacrifice to another human being. However there is also a black market trade in organs, usually supplied by victims, who have not fully weighed up the consequences of their decisions, in third-world countries to supply wealthier citizens [12]. What will tissue engineering do to this trade? One scenario is that tissue engineering will eliminate the demand for this black market by making viable organs readily available in hospitals for the patients who need it.
The human body is changing. With the evolution of our surroundings, our biological body has not kept up pace. We still have a primitive body with animal instincts. However to integrate with the world the high-tech society has created we are seeing the human body change to fit in with the lifestyle of the 21st Century. On a simple level, we see personal technologies everywhere. We are so dependent on technologies that many of us would not know what to do without them. This is a simple form of how we have integrated and changed the boundaries between our own body and

technology. Mobile phones are examples of devices that are virtually extension of our bodies nowadays. More extreme examples include devices ranging from hip prosthesis, cardiac pacemakers, and hearing aids.
Tissue engineering is changing the way we define our bodies. Tissue engineering may provide us with a method to treat diseased organs with new viable natural organs from our own cells, but is this implanted organ or tissue our really natural and our own? Some may say it is a natural part of our bodies because it is made form our own cells, but some may argue that it is unnatural because it was not made by processes within our own bodies.
More analysis and discussion is needed to define the human body in this high-tech society.

6. Tissue engineering and the strategic impact on a high-tech society

Creative cross-disciplinary research collaborations have been forming in the field of tissue engineering. On the technical biomedical technology side we see the combining of various areas in biology, engineering, medicine and computing combining to advance the area in leaps and bounds. Figure 3 illustrates some of the areas needed in tissue engineering.

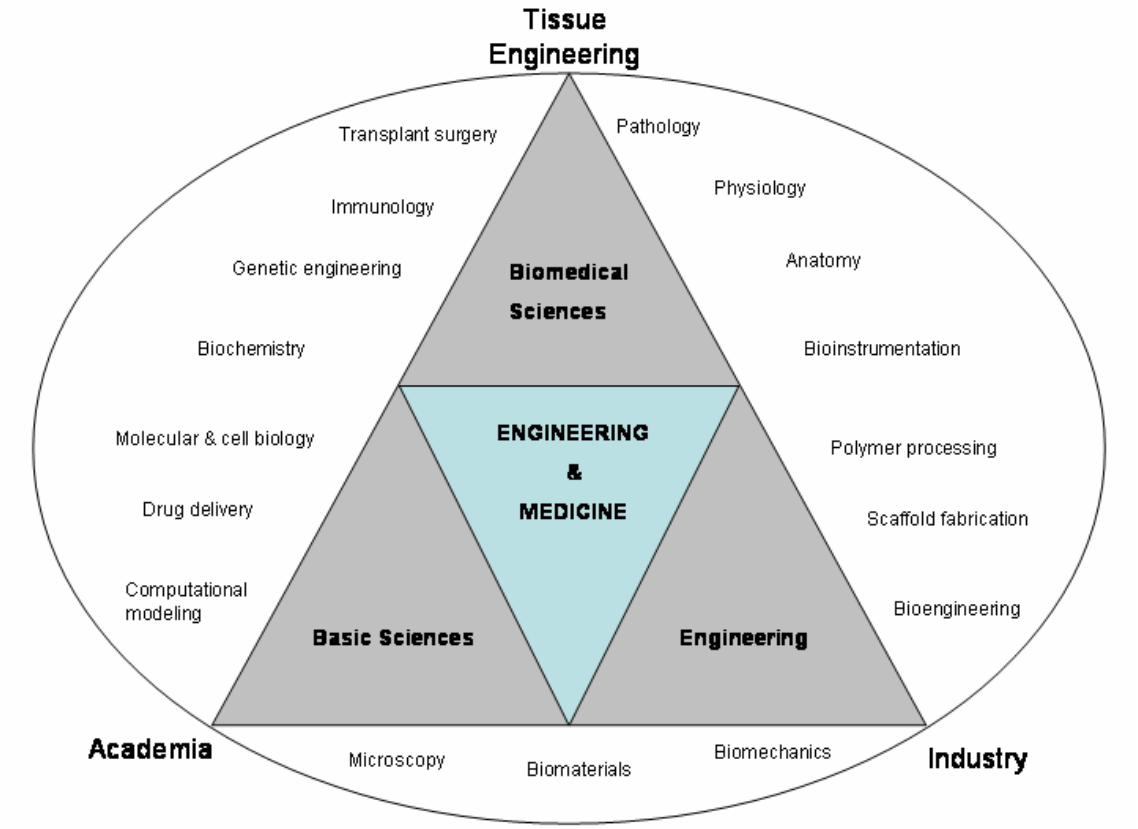

Figure 3. The various disciplines needed for tissue engineering.

Results of the collaborations have included improved techniques for biomedical research, new insights into the processes of the human body, and increasingly better performance in bio-analytical computing.

Biological art has been seen as a new way to engage with the public to inform, educate and promote public debate on the impact of biotechnologies on society. Unique techniques and methods to engage the public have been developed with varying success and feedback. SymbioticA's The Tissue Culture and Art Project has been very successful in engaging the public to think about issues regarding biotechnologies and tissue engineering [8].

Public awareness and science communication is an important tool in educating the public about tissue engineering and its potential impact on the lives of people in the high-tech society. Through sources such as media (print, television, radio), and via public seminars, displays and other public events, the aura of mystery surrounding tissue engineering and biotechnologies can be eliminated. With unbiased and informative presentation of the issues, adoption and acceptance of tissue engineering and technology will be made easier by the public. Setbacks and public criticisms may occur to certain tricky issues, but as long as science communicators try to expose all information to the public and keep the debate open, society as a whole will benefit.
A way to reach the future leaders of tomorrow has been to target youth, and to educate them about tissue engineering and biomedical technologies. This has been accomplished by groups such as AusBiotech's Australian Biotechnology Students Association, and their focus on facilitating researchers and scientists to interacting with youth and the public [13].

There is also a shift in the receptiveness and openness to technology, with a generation that has grown up with rapid technological advancement now gradually assuming positions of societal responsibility. Access to information now makes more and more people knowledgeable about issues. Whether the information is correct or incorrect is up to the scientists and science communicators to monitor.

7. Conclusions

An openness to question and probe the full implications of technologies is paramount to ensuring that our high-tech society develops and maintains an informed perspective on these new technologies and their impact on our lives. Tissue engineering will play a very important part in our high-tech society by way of revolutionizing medical treatment. It will also be able to contribute to non-biomedical aspects of our lives as well, as exemplified by SymbioticA's exhibits of "meat" production, and humane "leather".

A more pressing matter for science communicators, researchers and artists is not only in collaborating to develop new innovative and creative research, but also to communicate to the public the various ethical and societal issues that the discoveries will have on everyone. To be able to have informed and intelligent public debate and discussion on tissue engineering and its various issues, and eventually facilitating public understanding and acceptance, is a powerful element in advancing our high-tech society.

8. References

(1) United Nations Population Division, "Table 1: World life expectancy at birth by sex (years). Medium variant.1950-2050. World population prospects. The 2004 revision population database", http://esa.un.org/unpp/p2k0data.asp, 2004, Accessed 8/3/2006.

(2) World Health Organisation, "Global cancer rates could increase by 50% to 15 million by 2020", http://www.who.int/mediacentre/news/releases/2003/pr27/en/, 2003, Accessed 9/3/2006.

(3) National Science Foundation, USA, 1988, http://128.150.4.107/pubs/2004/nsf0450/role.htm

(4) Tissue Engineering Pages, What is tissue engineering?, http://www.tissue-engineering.net/index.php?seite=whatiste&PHPSESSID=70a3f91f878eb5f9163b5bee4547440a

(5) M.J. Lysaght & J. Reyes, The growth of tissue engineering, Tissue Engineering, Vol. 7: 485-493, 2001

(6) Fuchs, J.R., Nasseri, B.A., & Vacanti, J.P., 2001, Tissue engineering: a 21st century solution to surgical reconstruction, Annals of Thoracic Surgery, Vol. 72, pp577-591

(7) Rawe, J., What will be the 10 hottest jobs, Time Magazine (Europe), May 29, Vol. 155, No. 21, 2000, http://www.time.com/time/europe/magazine/2000/0529/v21jobs.html

(8) SymbioticA, The Tissue Culture and Art Project, "Disembodied cuisine", http://www.tca.uwa.edu.au/disembodied/dis.html, Accessed: 7/3/2006.

(9) SymbioticA, http://www.symbiotica.uwa.edu.au/, 2006, Accessed: 7/3/2006

(10) SymbioticA, The Tissue Culture and Art Project, "Victimless leather", http://www.tca.uwa.edu.au/vl/vl.html, Accessed: 7/3/2006.

(11) The Organ Procurement and Transplantation Network, "Current U.S. waiting list for transplant organs as of February 24. 2006", http://www.optn.org/latestData/, 2006, Accessed: 8/3/2006.

(12) CBS News, 48 Hours, "Your money or your life", http://www.cbsnews.com/stories/2002/02/11/48hours/main328992.shtml, 2002, Accessed: 9/3/2006.

(13) AusBiotech Australian Biotechnology Students Association, http://www.ausbiotech.org.