Tissue engineering

The first time tissue engineering was introduced it gave the promise to repair or replace damaged organs, the field has dramatically evolved from its origins in the late 1980s.

Tissue engineering is a field that is rapidly growing and becoming extremely important within biomedical engineering, it mainly links the rapid developments in cellular and molecular biology together with chemical and mechanical engineering.

The graph below shows the amount of money the US federal government is spending on different areas of stem cell research.

The National institute of health in the United States defined tissue engineering, in other words regenerative medicine as being:

“ An emerging multidisciplinary field involving biology, medicine, and engineering that is likely to revolutionise the ways we improve the health and quality of life for millions of people worldwide by restoring, maintaining, or enhancing tissue and organ function.” (1)

Tissue engineering is in fact the application of certain scientific principles brought together to enhance the design, modification, construction, growth, and the maintenance of living tissue.

Tissue engineering is divided into two main categories. The first being Vitro, this involves the construction of bioartificial tissues from cells isolated by enzymatic dissociation of a specific donor tissue.

Bioartificial tissues are ones which are used as an alternative to organ transplantation, these tissues are composed of natural and synthetic substances.

The second category of tissue engineering is Vivo, this involves the alteration and variation of cell growth and function.

Examples of applications of tissue engineering include, bone and cartilage implants, formation of bioartificial skin and nerve regeneration.

Perhaps the most important concept in tissue engineering is stem cell biology. This is the concept which brought back the idea of using cell based approaches for treating diseases such as heart diseases. Research made on stem cells aims to get knowledge on how an organism develops from a single cell and how healthy cells replace damaged cells in adult organisms.

Stem cells can be defined as ‘ a small subpopulation of the proliferating compartment, consisting of relatively undifferentiated proliferative cells that maintain their population size when they divide while at the same time producing progeny that enter a dividing transit population within which further rounds of cell division occur, together with differentiation events, resulting in the production of the various differentiated functional cells required of the tissue.’ (6)

Stem cells are different to other kinds of cells in the human body. All stem cells have three general properties which contribute to their scientific importance. (1)

The first is that they are capable of dividing and renewing themselves for long periods. Other kinds of cells including muscle cells or nerve cells do not normally replicate themselves. Stem cells may replicate many times or proliferate. A population of stem cells that proliferates for many months in laboratory can yield millions of cells.

The second property of stem cells is that they are unspecialised, the ability of the cells resulting from proliferation to continue being unspecialised like the parent stem cells makes them capable of long term self renewal.

In fact stem cells do not have any tissue specific structures that allow them to perform specialised functions.

A stem cell does not have the ability to perform the functions a heart muscle cell or a red blood cell would do. In other words, a stem cell cannot work to pump blood through the body like a heart muscle cell, and it cannot carry oxygen in blood like a red blood cell does.

The third property of stem cells is that they have got the potential to differentiate into various cell types in the body, this process happens during early life.

When a stem cell divides, new cells formed could either remain as stem cells or become another type of cells with a more specialised function. Unspecialised stem cells develop into specialised cells, including heart muscle cells, nerve cells and others.

In research two kinds of stem cells have been used, these are embryonic stem cells and non embryonic stem cells, also called somatic or adult stem cells.

Embryonic stem cells are ‘ undifferentiated cells derived from a 5 days pre-implantation embryo that are capable of dividing without differentiating for a prolonged period in culture.’ (1)

Embryonic stem cells are mainly derived from embryos that result from eggs that have been fertilised in vitro.

Scientists have discovered a method to obtain stem cells from human embryos and then growing them in vitro, these cells are called human embryonic stem cells.

Human embryonic stem cells are derived from the blastocyst. These are embryos that are around five days old, the time required for blastocyst formation to start after fertilisation in humans.

A non embryonic (Somatic or adult) stem cell is ‘ an undifferentiated cell found in many organs and differentiated tissues with a limited capacity for both self renewal (in vitro) and differentiation.’ (1)

Non embryonic cells are undifferentiated cells found in a tissue or an organ that can renew themselves and can differentiate and develop specialised cell types of the specific tissue or organ. This type of stem cells is found in many organs and tissues. Adult stem cells are present in the stem cell niche, this is a specific region of each tissue.

The main roles of adult non embryonic stem cells in humans are to maintain and repair the tissue in which they reside. The cells remain inactivated and do not divide for long periods of time until a certain disease or an injury in the tissue in which they reside activates them, and they will then start dividing as more cells are required to maintain the specific tissue.

Recently researchers came up with new conditions that would allow specialised adult cells to be genetically programmed in order to be able to differentiate into any type of cell. This type of stem cells is called induced pluripotent stem cells.

Pluripotent stem cells have unique special characteristics that make them very useful in a wide range of applications.

They have the ability to replace damaged cells and provide a new potential for treating disease. They are used in the treatment of extensive burns, and to restore the blood system in patients with diseases such as Leukaemia and other blood disorders.

Stem cells can be used to study the development of humans from a fertilised egg and all the processes involved, scientists could Identify the mechanisms that determine whether a stem cell chooses to replicate itself or to differentiate into a specific cell type, and if that is the case what cell type would it be, these information would allow scientists to find out and understand what controls normal human development.

In practice a more complete understanding of the genetic and molecular control of these processes may provide scientists with helpful information

about how certain diseases arise. This allows scientists to suggest new ways of treating those diseases.

The exceptional property of human embryonic and induced pluripotent stem cells that they can renew themselves while maintaining the ability to differentiate into useful cell types. For example, they have been used as a source of human cardiomyocytes. This allowed scientists to go further in research by using those cardiomyocytes in cell based cardiac therapies, cardiomyocytes have also been used in modeling human heart development and in testing drugs. (4)

Also stem cells have the ability to provide a source of insulin producing cells, or repair the damaged the pancreatic tissues. This provides another potential to treat diabetes. (5)

New medications could be tested for safety on specific cells that perform special functions. A large number of the specific type of cells on which the medications are to be tested is generated from stem cells.

Stem cells have the ability to replace cells lost due to other devastating diseases for which no cures have been found yet.

Today donated tissues and organs are often used to replace the specific damaged tissues or organs.

The problem with that is the fact that, the need for transplantable tissues and organs is a lot more than the supply available. Stem cells, with the ability to differentiate into specific cell types could offer the possibility of

providing a renewable source of replacement cells and tissues to treat diseases and replace the damaged tissues and organs.

However significant technical barriers concerning stem cells remain, but they are to be overcome by research which is increasing in both importance and scope due to the huge benefits that could be obtained.

References:

1- www. stemcells. nih. gov

2- Tissue engineering, Bernhard O. Palsson and Sangeeta N. Bhatia.

3- Principles of tissue engineering / edited by Robert P. Lanza, Robert Langer, Joseph Vacanti, 2nd edition.

4- Cardiac applications for human pluripotent stem cells. Shiba Y, Hauch KD, Laflamme MA. www. Pubmed. gov

5- Adipose tissue derived stem cells for regeneration and differentiation into insulin-producing cells. Kim SC, Han DJ, Lee JY. www. pubmed. gov

6- Essentials of stem cell biology [electronic resource] / editors, Robert Lanza ... [et al.]. Pages 11-13