Aspects regarding cell specialization

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Abstract

The aim of this paper is to suggest a theoretical model for cell specialization.

We postulated that the specialization is acquired through two fundamental mechanisms:

- Differentiation (which shapes the structure of the cell);
- Activation (which determines the cell to start functioning).

A special kind of activation process is the "Brain Activation" process, as the function of the brain is not solely generating electrical impulses, but also mental processes.

Specialization of a cell

When studying a cell it is crucial to describe both its structure and function. These two components (that from this point are going to be called "structural component" and "functional component" respectively) have a high influence on each other. This is why when we see a specific structure we can deduce what functions it might have and also can imagine a structure that is specific for a certain function.

The purpose of this paper is to describe a theoretical model for the process of cell specialization. The structural and functional components of a cell are the result of the cell specialization. The specialization of a cell is the result of two mechanisms: differentiation processes and activation processes. The structural component is shaped by the differentiation processes. The functional component is the result of the action of activation processes.

The structure of the cell is very stable after differentiation. An exception is represented by the gametes (the only cells in the human body that naturally undergo a reprogramming). The zygote is a totipotent stem cell (Dănăilă, 2016) created by the

reprogramming of the gametes. This process is the one that allows a new organism to be formed and is fundamental to life itself.

One of the breakthroughs in stem cell research is the work of Professor Shinya Yamanaka. He was able to artificially reprogram somatic cells in order to make them become pluripotent stem cells (also named "embryonic stem cells"). He called this kind of cells "induced pluripotent stem cells" (iPS cells).

However, the pluripotent stem cells (and iPS cells) are different from the totipotent stem cells (also named omnipotent) (Dănăilă, 2016). A totipotent stem cell (e.g. the zygote) is a cell that has the capacity of specializing into becoming any kind of cell and can also grow into a whole organism. A pluripotent stem cell (e.g. the cells of the blastocyst) has the capacity of becoming almost any kind of cell, but will not be able to grow into a whole organism.

If we study the development of the zygote we will observe that the cells which are derived from this totipotent stem cell are totipotent stem cells themselves up to the morula stage. The term "morula" (Latin of mulberry) designates an embryo with a dozen or more cells present, but no blastocystic cavity (Muller and O'Rahilly, 1997).

During days 3-4 of development, as the cleaving embryo makes its way into the uterine cavity, fluid enters its centre, forming the "blastocystic cavity" (Dănăilă, 2016). After the appearance of the cavity of the blastocyst the cells of the embryo lose their omnipotent character and become pluripotent stem cells (Hertig et al., 1954; Augustine, 2008) (Dănăilă, 2016). The fact that the cells become pluripotent stem cells after the appearance of the blastocyst cavity leads to the conclusion that there is a mechanism that underpins this transformation.

As both the totipotent stem cells (TS cells) and pluripotent stem cells (PS cells) have the capacity of developing into multiple types of cells their structure is not yet well-defined. We can say that the cell has a well-defined structure after the anatomical component is definitively formed (the respective cell cannot become another type of cell by natural means).

As postulated before, the anatomical component is shaped by differentiation processes. The change from a TS cell to a PS cell helps narrow the developmental possibilities for a

cell, so it also helps shaping the anatomical component. The process that transforms a TS cell into a PS cell is thus a differentiation process and has been called "primitive differentiation".

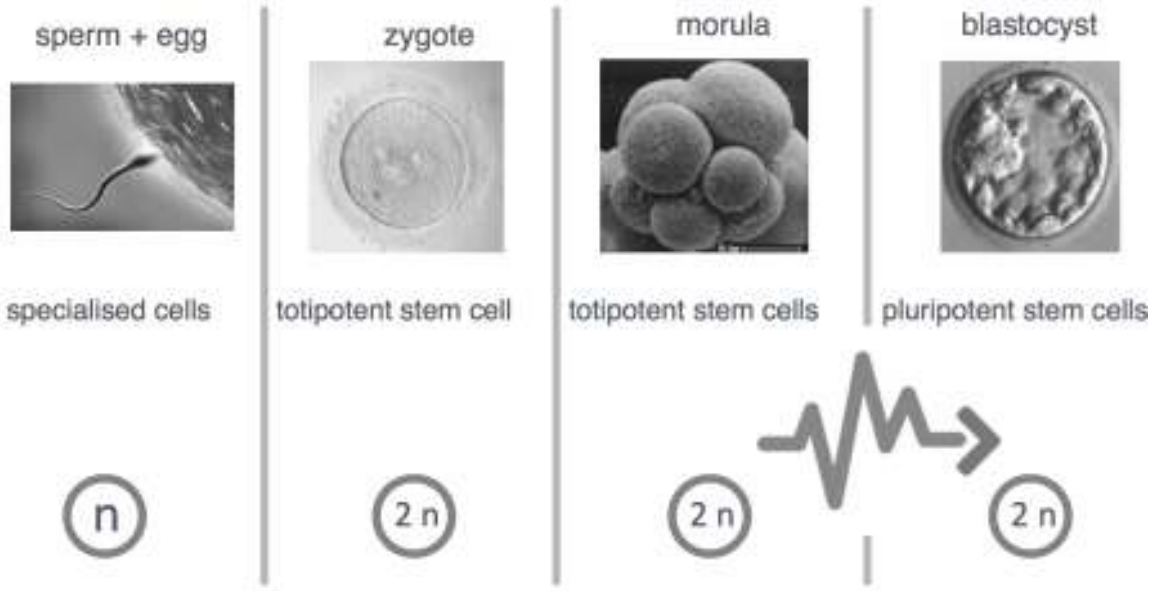

Fig. 1. Two haploid specialized cells (sperm and egg) give birth to the zygote (a diploid totipotent stem cell). From the morula stage to the stage of blastocyst the primitive differentiation determines the totipotent stem cells to become pluripotent.

Given the fact that when reprogramming a somatic cell in the laboratory the result is an iPS cell (that is more like the cells of the blastocyst and not of the zygote or morula), we can conclude that the primitive differentiation is practically an irreversible process (using the methods known today).

Differentiation processes

Cells that form from the zygote develop different anatomical components by differentiation processes which occur respecting the following fundamental principles:

I. Appearance of transcription factors.

It is thought to occur during the primitive differentiation (O'Connor & Adams 2010).

II. Asymmetric distribution of determinants. The influence of neighbouring cells.

Asymmetric distribution of determinants in the egg gives rise to an asymmetric distribution of cells in the embryo (Gurdon, 2015).

III. The influence of signalling molecules (growth factors).

It is known that different signalling molecules (also called the growth factors) help form different kinds of cells. Signalling between cells causes further differentiation to give the ectoderm, mesoderm and endoderm (Gurdon, 2015). All the cells arise from these three layers of the embryo (Dănăilă, 2012). Different signalling molecules (also named growth factors) form different types of cells.

A growth factor can determine the formation of more than one type of cell by exposing the undifferentiated cell to different concentrations. To better illustrate this, we will use the example of neural induction:

- The molecule Sonic Hedgehog (SHH) is secreted by the cells of the mesoderm. Cells of the ectoderm that are in the proximity of the mesoderm receive a high amount of SHH and will become glial cells. Cells that are farther away and are exposed to lower concentrations of SHH become motor neurons. An even lower concentration promotes the formation of interneurons (*Brain Facts*, 2012). Cells of the ectoderm which have not received the signalling molecules diffusing from the mesoderm become skin (*Brain Facts*, 2012).

Activation processes

A cell that has a well-defined anatomical component, but upon which no activation process has acted (has not been activated) shall be called a "non-functional cell". An

activated cell is a “functional cell”. All activation processes occur by means of the following principle:

- There are certain genes that become active and determine the synthesis of proteins (the central dogma of genetics: DNA-->RNA-->proteins). These proteins determine the activation process by biochemical and biophysical means.

Activation processes are specific to every kind of tissue.

Case study: The Brain Activation process

The most complex activation process (and the only one which has two distinct stages) is the Brain Activation process.

In the first stage there are certain genes (HOXA2, HOXB1, HOXB2, LIM1, OTX2, FOXG1, FGF8, NKX2,1) that determine the synthesis of specific proteins by the means described earlier (Sadler, 2007). After this stage the brain is a functional brain.

A non-functional brain is an encephalon (or a developing encephalon) that has a well-defined anatomical component, but where no nerve impulses are present. A functional brain is an encephalon (or a developing encephalon) that has a well-defined anatomical component and in which at least one nerve impulse (electrical impulse) can be identified at any moment of time.

The first stage of Brain Activation transforms a non-functional brain into a functional brain (Arimia, 2016). Given the cognitive and psychological components of the cortex, there must be a second stage of the brain activation process (this second stage can be called “cortical activation”). It occurs only in the neurons of the cerebral cortex and leads to a “fully functional brain” (a brain that presents superior nervous activity like abstract thinking and reasoning). After an activation process has acted upon a cell that cell is a specialized cell.

Prospects

Using the definition of the non-functional brain, we can say that the brain of a person that is in cerebral death is indeed a non-functional brain. By artificially inducing the first stage of the Brain Activation the cerebral death might be reversed (Arimia, 2016).

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