TOPIC: DIFFERENTIATION

Key Knowledge:

- Properties of stem cells that allow for differentiation, specialisation and renewal of cells and tissues, including the concepts of pluripotency and totipotency.
- The process and application of reproductive cloning technologies (U2: AoS2)

STEM CELLS

Complex multicellular organisms form when groups of individual cells function together as a collective. These cells are all genetically identical but will differentiate and specialise to complete specific functions and give rise to the development of complex multicellular systems that are capable of sustaining life.

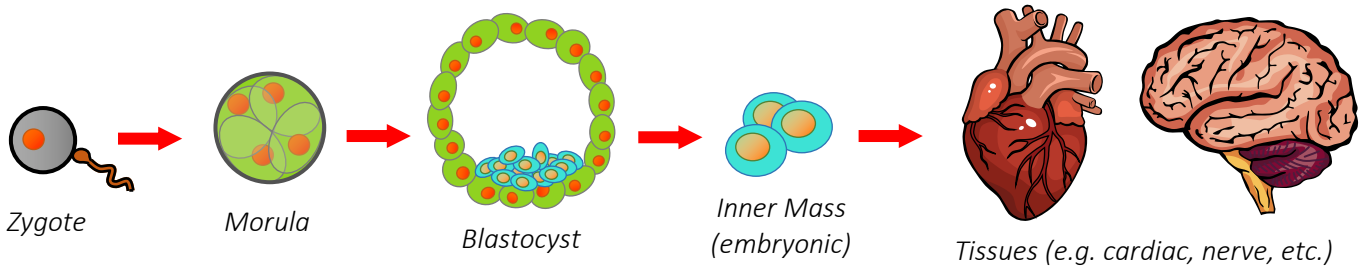
Stem cells are unspecialised cells from which all other cell types may be derived. They possess two traits:

- **Self-Renewal:** They have an unlimited capacity for growth (they can continuously divide and replicate)
- **Potency:** They retain the capacity to differentiate into specialised cell types (they are progenitor cells)

TYPES OF STEM CELLS

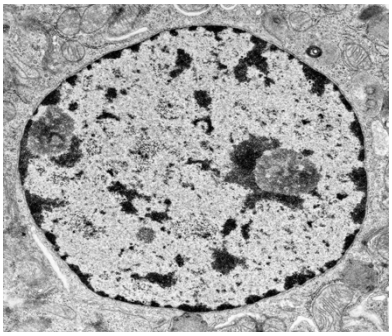
There are four main categories of stem cells that are present at various stages of organismal development:

- **Totipotent** – Can form any cell type, as well as extra-embryonic tissues like the placenta *(e.g. zygote)*
- **Pluripotent** – Can form any cell type, but cannot form autonomous life *(e.g. embryonic stem cells)*
- **Multipotent** – Can differentiate into a number of closely related cell types *(e.g. adult stem cells)*
- **Unipotent** – Cannot differentiate, but are capable of self-renewal *(e.g. precursor cells / tissues)*



DIFFERENTIATION

All cells of a multicellular organism share an **identical genome** – each cell contains the *entire set of genes* for that organism. Differentiation is the process whereby new cells become more specialised and distinct as they mature. Differentiation is caused by the activation of different genes within a given cell (triggered by chemical signals). Within the nucleus of a eukaryote, the DNA is packaged to form **chromatin**. The active genes are packaged in an expanded form *(euchromatin)*, whereas inactive genes are packaged in a condensed form *(heterochromatin)*. Specialised cells have their identical genomes packaged differently according to their function.

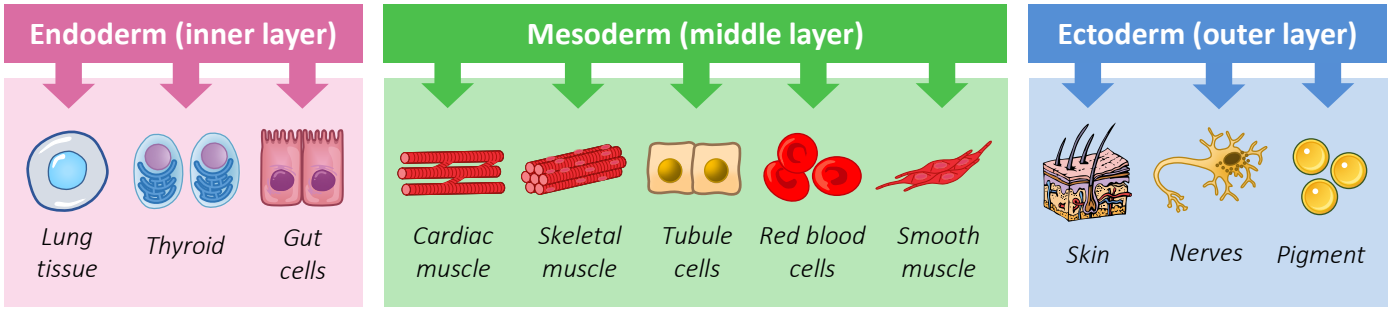


Euchromatin *Heterochromatin*

GASTRULATION

Gastrulation is an early phase of embryogenesis whereby embryonic stem cells differentiate into three **germ layers** – the ectoderm (outer layer), the mesoderm (middle layer) and the endoderm (inner layer).

- **Ectoderm:** Forms the nervous system and outer surfaces (such as skin, pigment cells and hair cells)
- **Mesoderm:** Forms the majority of body organs, including muscle, vessels, kidney, heart and skeleton
- **Endoderm:** Forms the respiratory and digestive tracts, along with associated organs (liver, pancreas)



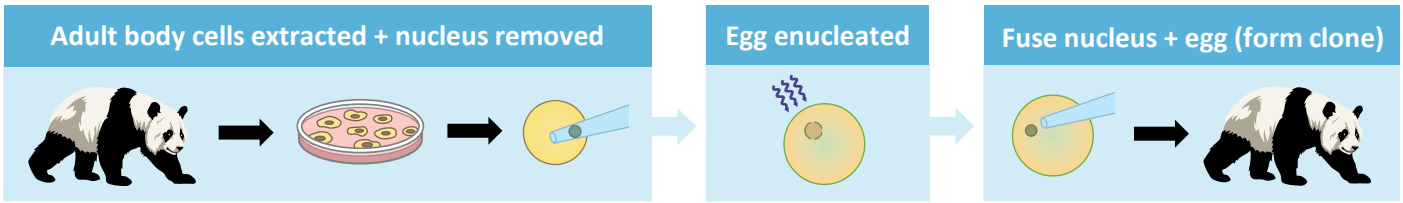
FOETAL DEVELOPMENT

An **embryo** describes an early stage of organismal development when key body structures are still being formed. Conversely, a **foetus** describes a later stage of development when all body structures are present but not fully developed. Typically, a developing human is referred to as an embryo until roughly 9 – 11 weeks after conception (at which point it is characterised as a foetus until birth).

THERAPEUTIC CLONING

Stem cells can be used to replace damaged or diseased cells with healthy, functioning ones. Adult stem cells are easy to obtain and have a low risk of graft rejection, but because they are partially differentiated (multipotent) they have a limited scope of application. Embryonic stem cells are pluripotent and hence more effective, but they are difficult to obtain (requires destruction of an embryo). One method for cloning embryonic stem cells from adult host tissue is via a technique called **somatic cell nuclear transfer** (SCNT).

- The haploid nucleus of an egg cell is removed and replaced with a diploid nucleus from an adult donor
- The diploid egg cell is stimulated to divide and will develop into an embryonic clone of the adult donor
- The embryonic cells can then be harvested to provide a pluripotent source of cells (no graft rejection)



REPRODUCTIVE CLONING

Somatic cell nuclear transfer produces a source of stem cells by creating a cloned embryo. If the embryo is implanted in a surrogate and allowed to develop, it will result in the birth of a **clone** (reproductive cloning). Reproductive cloning can be used to increase numbers of endangered species and even repopulate extinct species, however cloning of humans is currently considered to be highly unethical and is hence illegal.

Cloning of livestock is being explored as a potential way of producing meat more ethically and with a reduced carbon footprint. Cloning of plants for horticultural purposes is much more common, as adult plants retain pluripotent cells (meristem) and are capable of being cloned naturally (asexual reproduction).