

Chapter 21

The Genetic Basis of Development

From Single Cell to Multicellular Organism:

Ideal model organism:

Readily observable embryos

Short generation times

Small genomes with well-studied genes

The model organisms: *Drosophila*,
Caenorhabditis elegans, mouse, zebrafish,
Arabidopsis

Drosophila

- Small
- Easily grown in the laboratory
- Short generation time (2 weeks)
- Produces many offspring
- Develop outside the mother's body

Caenorhabditis elegans

- Small (1mm)
- Transparent body with a few types of cells
- Short generation time (3 and half days)
- Most are hermaphrodites
- Easy to detect recessive mutations

Mouse (*Mus musculus*)

- Has a long history of being used as a model
- Transgenic mice have been created by knocking out particular genes by mutation

Disadvantages:

complex animals with large genome

observation of embryo is difficult

Zebrafish (*Danio rerio*)

- Small (2-4 cm long)
- Easily raised in large numbers
- Embryos develop outside the mother's body
- Early embryonic development proceeds quickly

Generation time is long (2-4 months)

Embryos are difficult to manipulate

Wall cress (*Arabidopsis thaliana*)

- Can grow in test tube
- Produce thousand of progeny (8-10 weeks)
- Small genome (100 million base pairs)
- Genes can be easily manipulated

Embryonic development

- Cell division
- Cell differentiation
- Morphogenesis

Morphogenesis: physical processes that give shape to the organism and its various parts.

Differences between animals and plants in morphogenesis:

Animals

1. Movements of cells during development.
2. Morphogenesis and growth do not occur throughout the entire life.

Plants

1. No
2. They occur throughout the entire life.

- All cells in an organism have **genomic equivalence** (same genes).
- **Totipotency**: the ability to develop into different types of cells.

Nuclear Transplantation in Animals

In 1950s, Robert Briggs and Thomas King removed the nucleus from the frog egg, and transplanted the egg with the nucleus from embryo or tadpole cell. They found out the ability of the transplanted nuclei to support normal development is **inversely related** to the age of the donor embryos.

- Cells in an organism contain the same genes. Cells differ in structure and function.
- Demethylation is the removal of methyl group ($-\text{CH}_3$) of DNA to turn on the genes.

Reproductive Cloning of Mammals

In 1977, Scottish researcher Ian Wilmut and his colleagues successfully cloned an adult sheep.

The Cloning of “Dolly” the Sheep

A mammary cell is taken from a Finn Dorset donor ewe

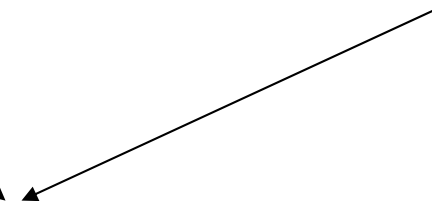
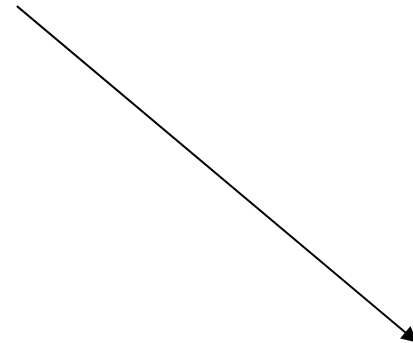


The cell is placed in a nutrient-poor medium for 3 days

An egg cell is taken from a Poll Dorset ewe



The nucleus is removed (enucleated egg)



Cells are mixed in a Petri dish





Subjected to mild electrical shock to facilitate cell fusion



Cell is allowed to undergo several cell divisions to form a cluster of cells (embryo)



The embryo is implanted in a Scottish Blackface ewe (as a surrogate mother)



After 5 months, a lamb (“Dolly”) is born

Problems Associated with Animal Cloning

1. Only a small percentage of cloned embryos develop normally to birth
2. Development of defects such as obesity, pneumonia, liver failure and premature death

The abnormalities may due to the repression of the genes by acetylation of histones or methylation of DNA. **Acetylation** is the addition of $-\text{COCH}_3$ group to histones which change shape, allowing transcription factor to access to the genes so transcription can occur. **Methylation** of DNA will turn off the genes.

Stem Cells

- **Embryonic stem cells** are **totipotent** (able to give rise to various specialized cells, including sperm and egg cells).
- **Adult stem cells** are **pluripotent** (able to give rise to multiple nonreproducing specialized cell types but not sperm and eggs).

- **Cytoplasmic determinants** (messenger RNA, proteins) are maternal substances that influence the course of early development. They regulate the expression of genes that affect the developmental fate of cells.

Apoptosis

Apoptosis is the programmed cell death.

Cell survives:

A master gene called *ced-9* gene produces *ced-9* protein, which inhibits *ced-4* gene to produce *ced-4* protein. Without *ced-4* protein *ced-3* gene will not be activated to produce *ced-3* protein. With no *ced-3* protein, proteases and nucleases will not be activated. So, the cell survives.

Cell dies:

A death signal molecule attaches to the receptor of the cell. The information is conveyed to the genome. The *ced-9* gene is turned off. So, it cannot produce *ced-9* protein. Without *ced-9* protein, *ced-4* gene is not inhibited. It produces *ced-4* protein. *Ced-4* protein activates *ced-3* gene, which produces *ced-3* protein. The *ced-3* protein then activates proteases and nucleases. **Proteases** digest proteins and **nucleases** digest nucleic acids of the cell. So, the cell dies.