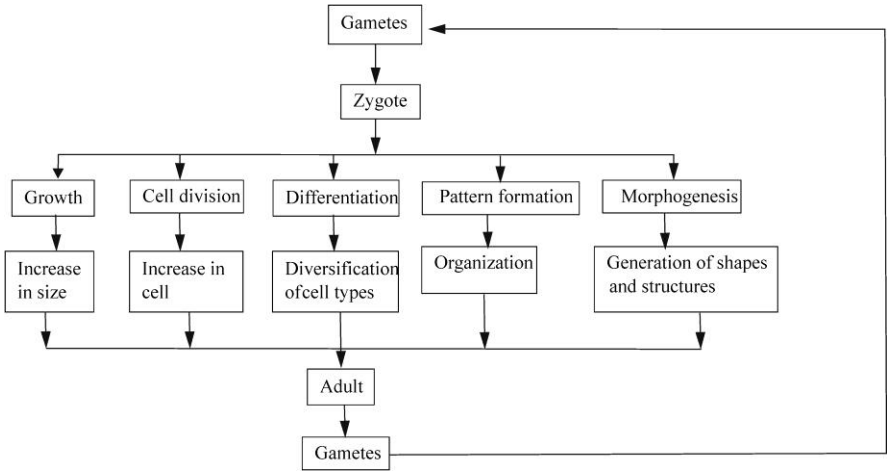
Unit 5

Developmental Biology

Unit Map

5.A Basic Concept of development

All multicellular organisms arise by a slow process of progressive change called ***development.*** Development is a process by which a multicellular organism arises, initially from a single cell. The gradual developmental strategy is known as **epigenesis**. Cell growth and cell division not only contribute to the size but to the shape and pattern as well of the developing organism.



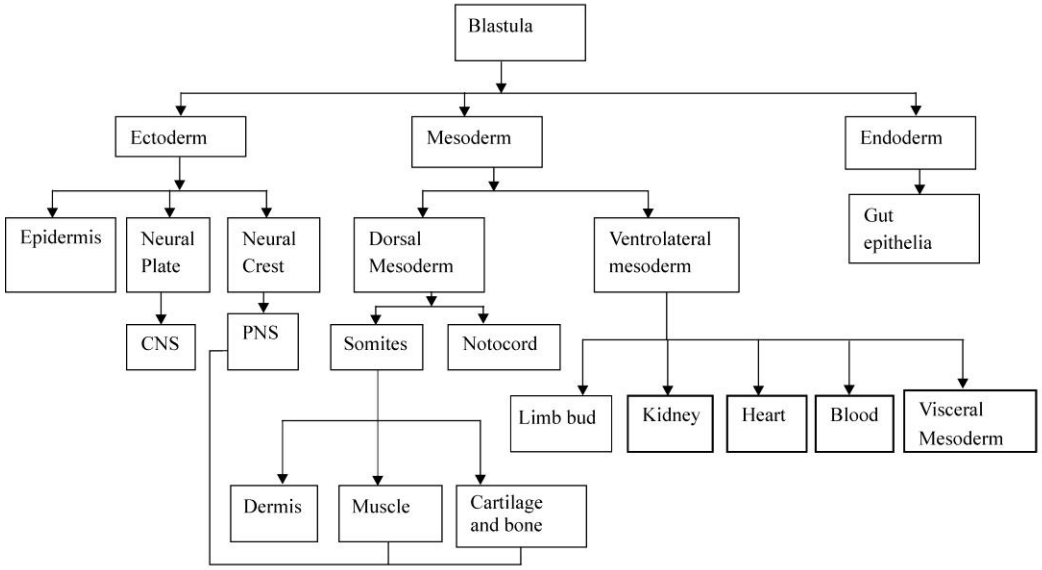
5.A.1 Potency and cell fate

Potency is the entire repertoire of the cell types a particular cell can give rise to in all possible environments. For example: A cell is pluripotent if it can give rise to all different blood cell lineages. There is a decrease in potency as cells become committed.

Fate of a cell is all the different cell types, its descendants can become during normal development.

- Cell potency ≥ fate
- Potency is intrinsic property
- Cell fate is equal to potency plus environment
- Cell fate becomes increasingly restricted until a cell is terminally differentiated
- Cell fate and potency are progressively restricted

➢ **Simplified developmental hierarchy in vertebrates**



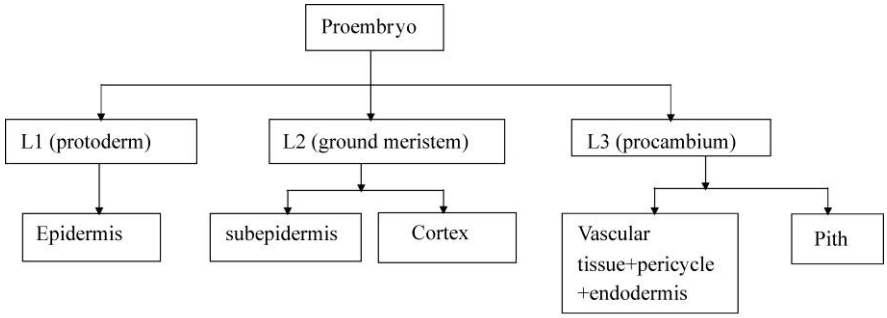
➢ **Simplified developmental hierarchy of animals**

The developmental hierarchy is the hierarchical series of decisions involving specific pre-existing cell types. Animal development is the division of embryo into the three germ layers

i. Ectoderm
ii. Mesoderm
iii. Endoderm

These developmental decisions are usually irreversible, that progressively and irreversibly restrict cell fate.

➢ **Simplified developmental hierarchy in flowering plants**



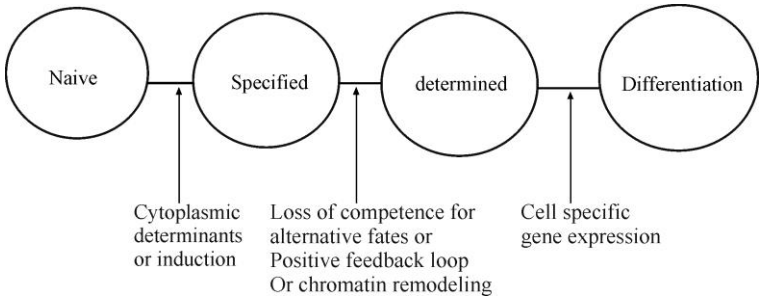
5.A.2 Commitment

Before a cell overtly differentiates, it can be said to be committed, that is, the cell has been instructed on its fate.
An intrinsic program has been activated within the cell that causes it to follow a particular pathway of development.

➢ **Levels of developmental commitment**

- As cell fate becomes restricted following each decision in the developmental hierarchy, cells become committed to a certain fate.
- An uncommitted cell can be described as naïve, meaning that it has received no instructions directing it along a particular developmental pathway.
- Fate of a cell is said to be specified if the cell is directed to follow a certain developmental pathway and does so when placed in isolation, which should provide a neutral environment. Commitment at this stage is reversible as it may be specified if placed in different environment.
- The fate of a cell is said to be determined if it cannot be changed, regardless of cell's environment. Commitment at this stage becomes irreversible.

➢ **Stages of developmental commitment**



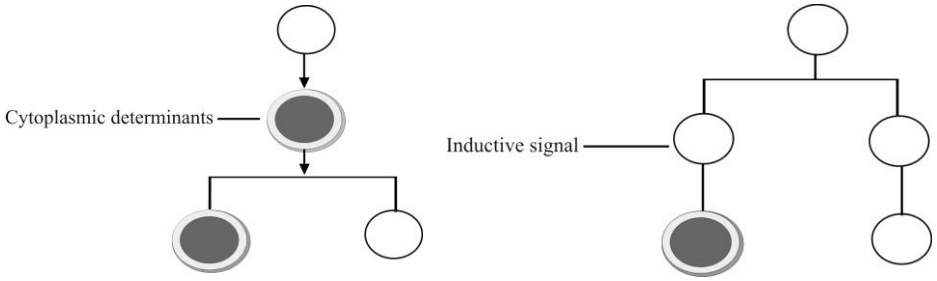
Determination to follow one developmental pathway coincides with loss of competence to follow alternative pathways.

➢ **Mechanisms of developmental commitment**

There appear to be two major strategies for establishing commitment and hence initiating the series of events that result in cell differentiation.

- The inheritance of cytoplasmic determinants: Cytoplasmic determinants are the molecules in cytoplasm that can help to determine cell fate. The asymmetric distribution of cytoplasmic determinants indicates that the mechanism of

differentiation is entirely intrinsic. For example, if a mother cell contains cytoplasmic determinants that is localized to one pole as the cell under goes division, that determinant will be inherited by only one of the daughters.



- The perception of external inductive signals: The process where one cell or group of cells changes developmental fate of another is termed induction. It is extrinsic process that depends on the position of a cell in the embryo. Two identical cells can follow alternative fates if one is exposed to an external signal (often secreted by a different cell).

5.A.3 Specification

Mechanism by which the cells acquire the proper identity in space and time, and instruct genetically identical cells to express distinct sets of gene. Two general mode of development resulting in differential gene expression are

- **Mosaic development or Autonomous specification**

  If development was controlled entirely by cytoplasmic determinants, the fate of every cell would depend on its lineage, while its position in embryo would be irrelevant.

  Then embryo is made up of independent, self-differentiating parts that, if removed from embryos, would still differentiate into their normal fate.

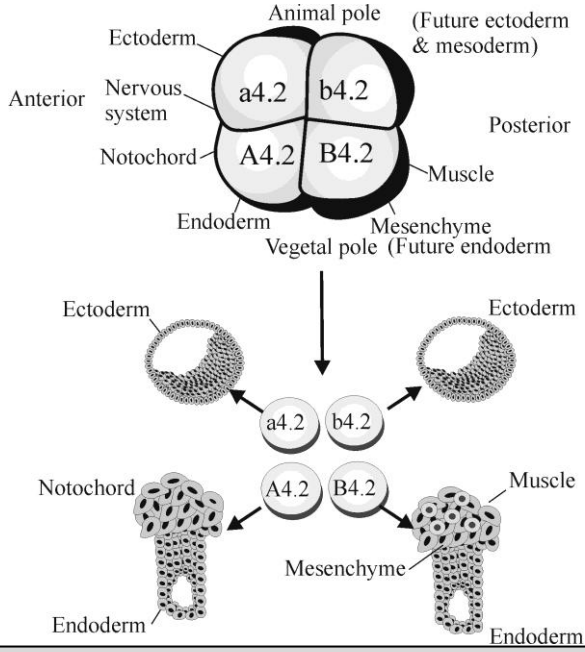


Figure 5.A.3-1
8-cell tunicate embryo: when the four blastomere i.e. a4.2, b4.2, A4.2, B4.2 are separated each form the structures, it would have formed a4.2 formed the Ectoderm and nervous system, b4.2 formed the notochord and Endoderm whereas B4.2 formed the muscle, mesenchyme and Endoderm.

Mosaic development occurs when cytoplasmic determinants (Certain proteins or mRNAs), are regionally localized within the unfertilized egg. Following fertilization, these determinants are apportioned to the different cells as embryo divides.

These cytoplasmic determinants specify cell type by regulating expression of different sets of genes.

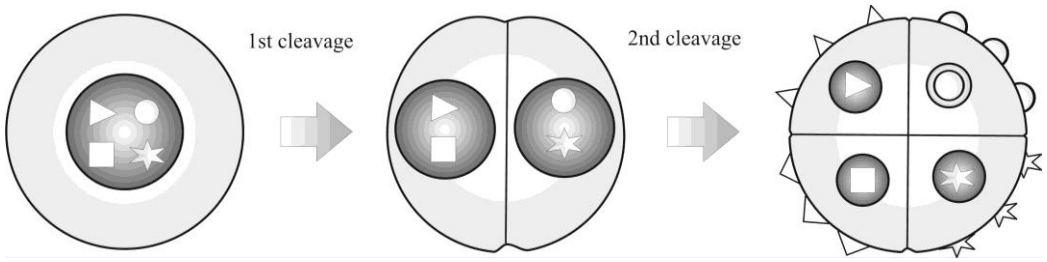


Figure 5.A.3-2
The cell contains cytoplasmic determinants known as ***Weismann's determinants***. Upon first cleavage of the cell, the cell is equally divided into two parts and so does the determinants. Upon second cleavage the cell is divided into four equal parts and Weismann's determinants are also divided equally among the four parts the cell.

- **Cytoplasmic determinants** For example the ability of isolated B4.1 blastomeres to develop into muscle, even when removed from the embryo, correlates with the presence of "yellow crescent" cytoplasm (tunicates are unique in having colored cytoplasm): When B4.1 blastomere is removed no muscles develop. When yellow crescent cytoplasm is transferred to a B4.2 (ectoderm forming) blastomere, ectoderm and muscle are generated.

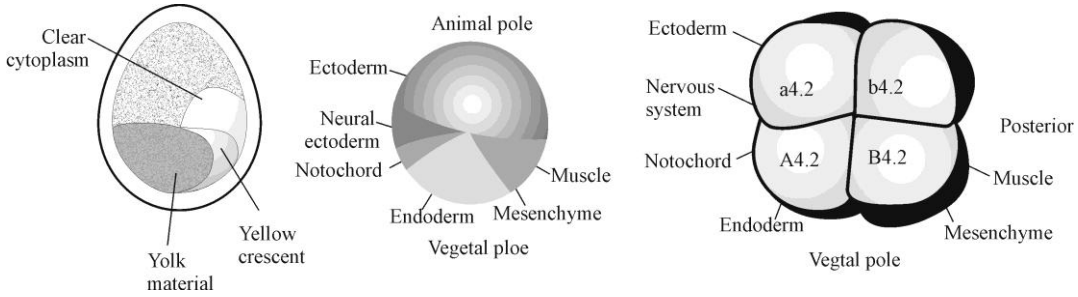
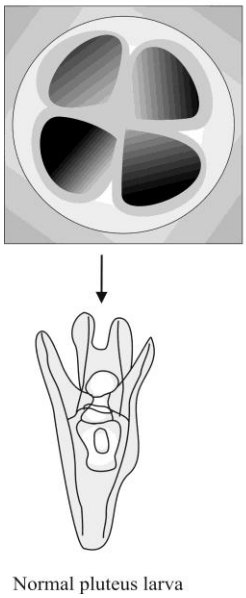


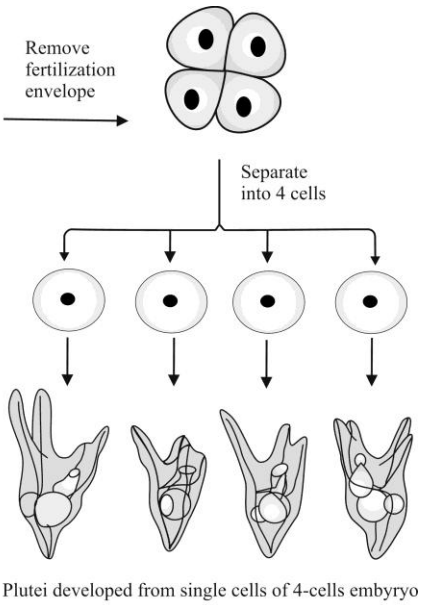
Figure 5.A.3-3
b4.2 blastomers contain "Yellow crescent" cytoplasm, because of this it remain its ability to develop muscle when yellow crescent is removed from b4.2 no muscle development occur in b4.2, but when it was transferred to B4.2, it showed muscle development.

➢ **Regulative development or Conditional specification**

If development was controlled entirely by inductive interactions, the fate of every cell would depend on its position in the embryo and its lineage would be irrelevant.



Normal pluteus larva



Plutei developed from single cells of 4-cells embyryo

Figure 5.A.3-4
The four cell sea urchin embryo: give rise to normal pluteus larva under normal condition but when the fertilization envelops is removed it is separated into four individual cells. These cells give rise to four plutei embryo; mean each cell gave rise to plutei embryo even after separation.