Morphogenetic movements and fate maps

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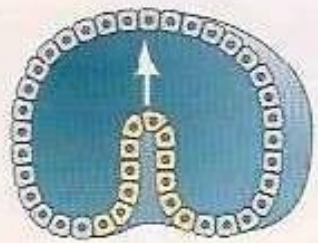
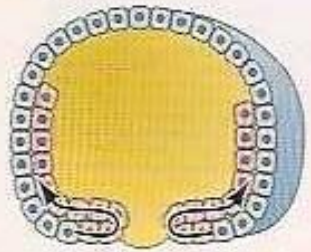
Invagination:
Infolding of cell sheet into embryo



Example:
Sea urchin endoderm

Involution:
Inturning of cell sheet over the basal surface of an outer layer



Example:
Amphibian mesoderm

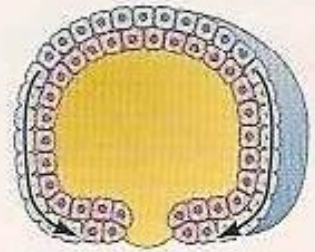
Ingression:
Migration of individual cells into the embryo

Example:
Sea urchin mesoderm, *Drosophila* neuroblasts

Delamination:
Splitting or migration of one sheet into two sheets

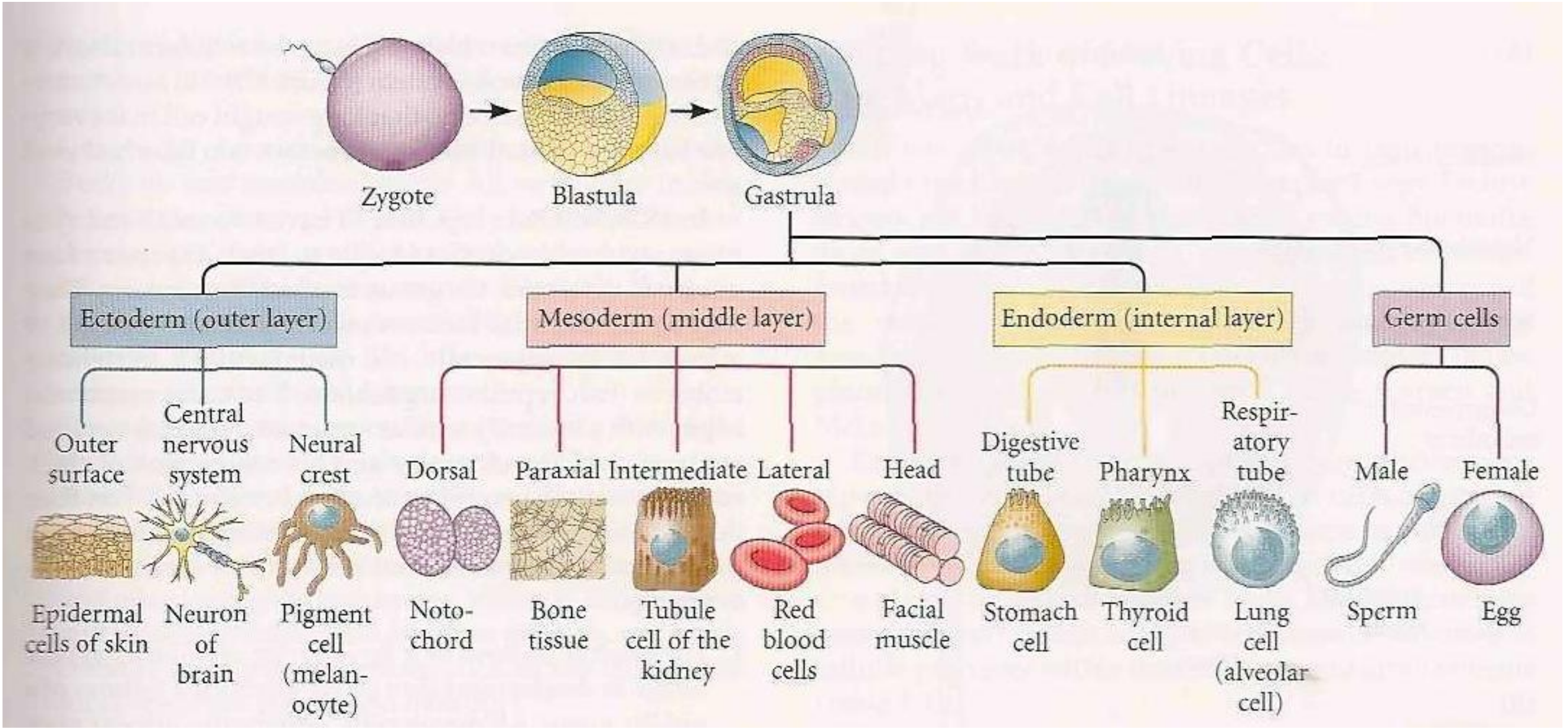
Example:
Mammalian and bird hypoblast formation

Epiboly:
The expansion of one cell sheet over other cells



Example: Ectoderm formation in amphibians, sea urchins, and tunicates

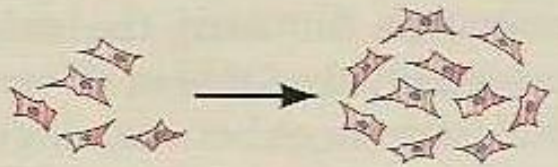
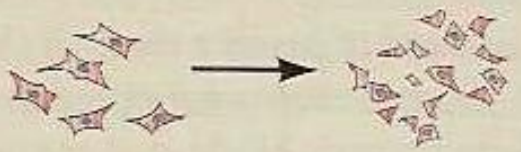
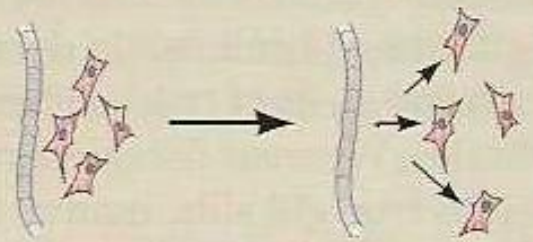
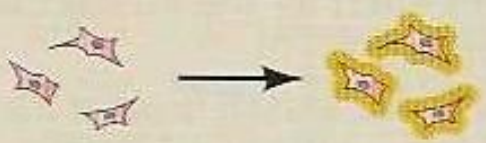
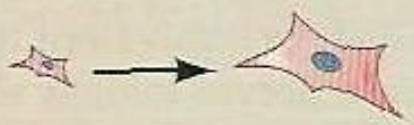
- **Invagination:** The infolding of a region of cells, much like the indenting of a soft rubber ball when it is poked.
- **Involution:** The inturning or inward movement of an expanding outer layer so that it spreads over the internal
surface of the remaining external cells.
- **Ingression:** The migration of individual cells from the surface layer into the interior of the embryo. The cells
become mesenchymal (i.e., they separate from one another) and migrate independently.
- **Delamination**: The splitting of one cellular sheet into two more or less parallel sheets. While on a cellular basis
it resembles ingression, the result is the formation of a new sheet of cells.
- **Epiboly:** The movement of epithelial sheets (usually of ectodermal cells) that spread as a unit (rather than individually) to enclose the deeper layers of the embryo. Epiboly can occur by the cells dividing, by the cells changing their shape, or by several layers of cells intercalating into fewer layers. Often, all three mechanisms are used


Zygote
Blastula
Gastrula
Ectoderm (outer layer)
Mesoderm (middle layer)
Endoderm (internal layer)
Germ cells
Outer surface
Central nervous system
Neural crest
Dorsal
Paraxial
Intermediate
Lateral
Head
Digestive tube
Pharynx
Respir-atory tube
Male
Female
Epidermal cells of skin
Neuron of brain
Pigment cell (melan-ocyte)
Noto-chord
Bone tissue
Tubule cell of the kidney
Red blood cells
Facial muscle
Stomach cell
Thyroid cell
Lung cell (alveolar cell)
Sperm
Egg

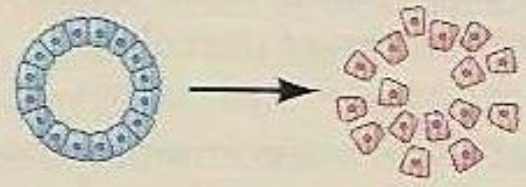
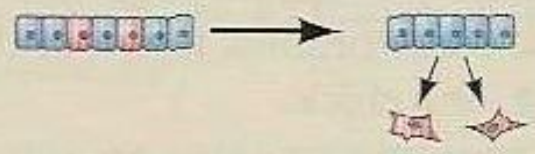
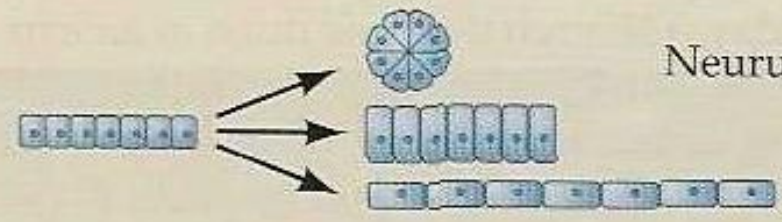
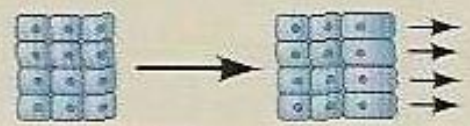
Keeping Track of Moving Cells: Fate Maps and Cell Lineages

cells do not stay still in the embryo…

TABLE 1.1 Summary of major morphogenic processes regulated by mesenchymal and epithelial cells

Process	Action	Morphology	Example
MESENCHYMAL CELLS			
Condensation	Mesenchyme becomes epithelium		Cartilage mesenchyme
Cell division	Mitosis produces more cells (hyperplasia)		Limb mesenchyme
Cell death	Cells die		Interdigital mesenchyme
Migration	Cells move at particular times and places		Heart mesenchyme
Matrix secretion and degradation	Synthesis or removal of extracellular layer		Cartilage mesenchyme
Growth	Cells get larger (hypertrophy)		Fat cells

EPITHELIAL CELLS

Dispersal	Epithelium becomes mesenchyme (entire structure)		Müllerian duct degeneration
Delamination	Epithelium becomes mesenchyme (part of structure)		Chick hypoblast
Shape change or growth	Cells remain attached as morphology is altered		Neurulation
Cell migration (intercalation)	Rows of epithelia merge to form fewer rows		Vertebrate gastrulation
Cell division	Mitosis within row or column		Vertebrate gastrulation
Matrix secretion and degradation	Synthesis or removal of extracellular matrix		Vertebrate organ formation
Migration	Formation of free edges		Chick ectoderm

Fate map

Diagrams that follow cell lineages from specific regions of the embryo in order to "map" larval or adult structures onto the region of the embryo from which they arose. The superimposition of a map of "what is to be" onto a structure that has yet to develop into these organs

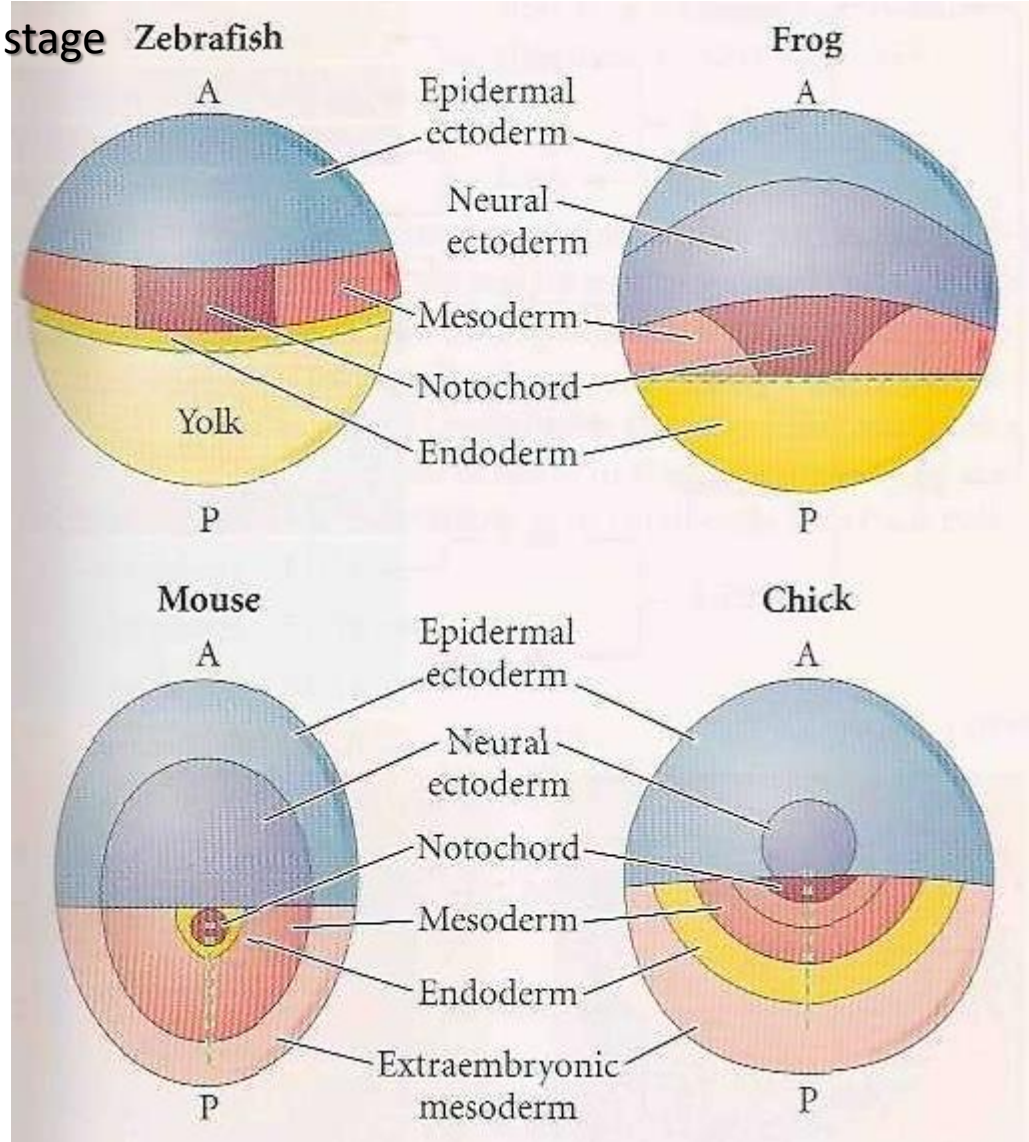
one of the most important programs of descriptive embryology became the tracing of cell lineages:

following individual cells to see what those cells become

one can label *groups of embryonic* cells to see what that area becomes in the adult organism. By bringing such studies together, one can construct a fate map

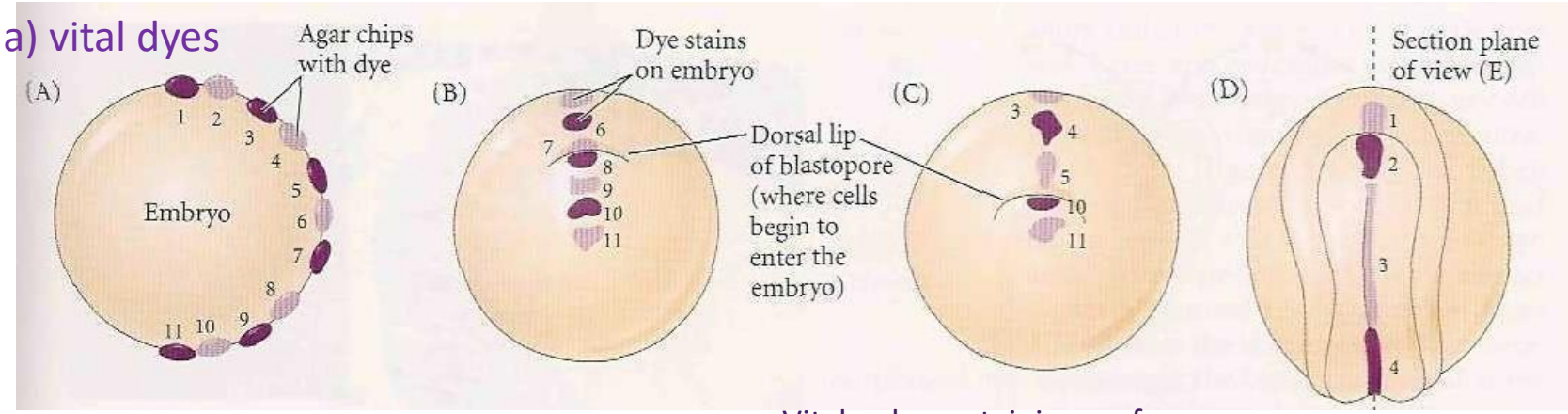
These diagrams "map" larval or adult structures onto the region of the embryo from which they arose.

Fate maps of vertebrates at the early gastrula stage

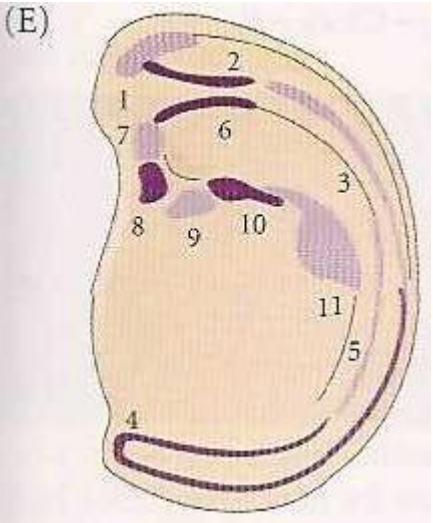


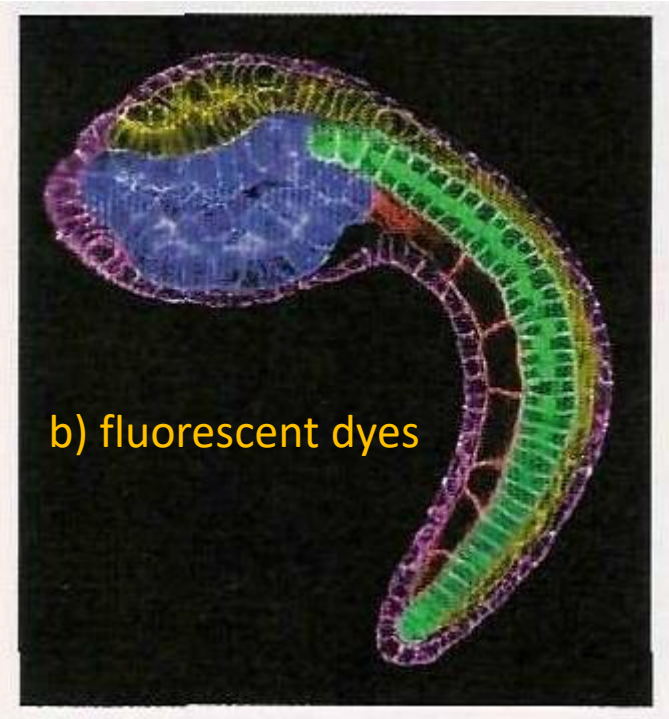
Dye marking (Vogt (1929))

a) vital dyes

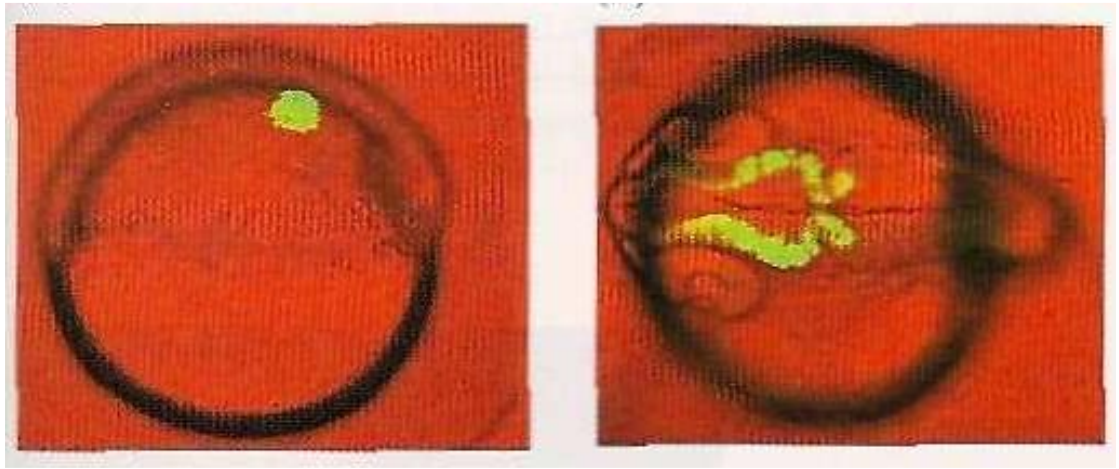


Vital dye staining of amphibian embryos. (A) Vogt's method tor marking specific cells of the embryonic surface with vital dyes. (B-D) Dorsal surface views of stain on successively later embryos. (E) Newt embryo dissected in a medial sagittal section to show the stained cells in the interior. (After Vogt 1929.)

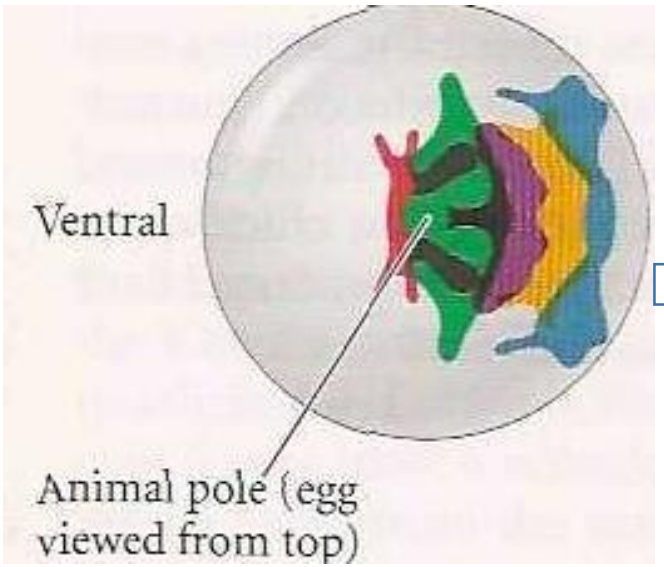


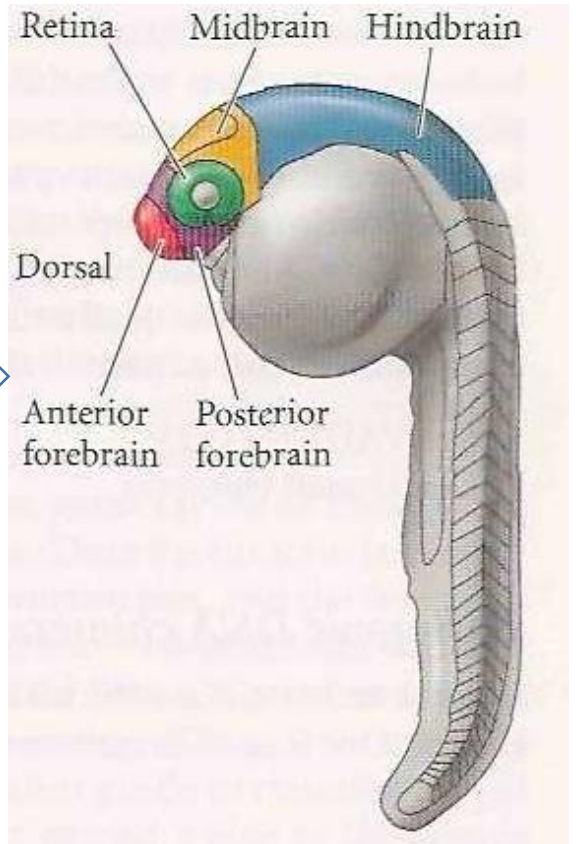


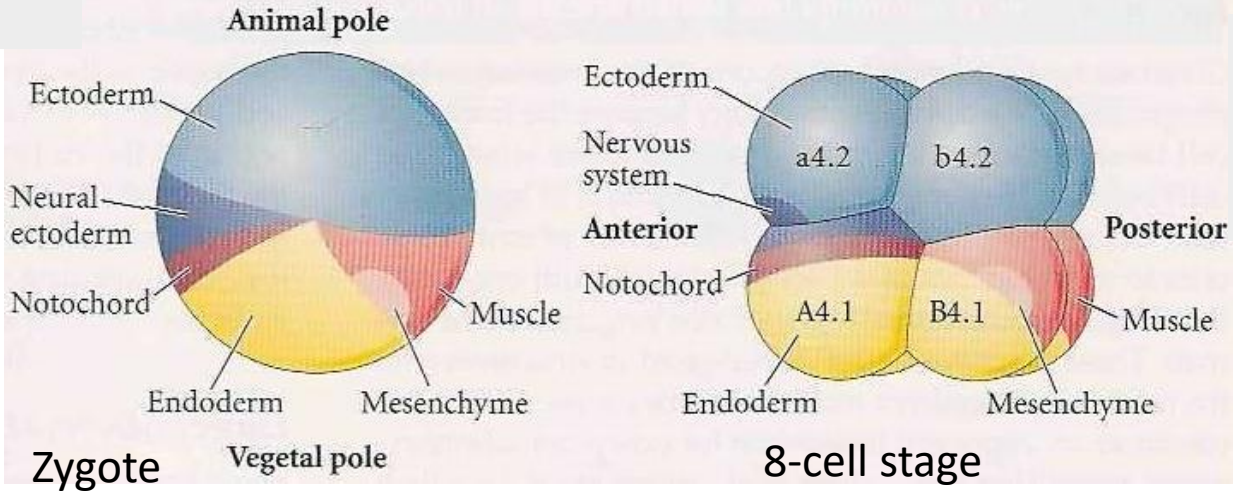
Fate map of the tunicate embryo: Confocal section through a larva of the tunicate *Ciona savignyi*. *The notochord* cells are stained green; the cell boundaries are stained white. The endoderm is blue, the muscles red, the neural tube yellow, and the epidermis magenta.



Zebra fish


Ventral
Animal pole (egg viewed from top)

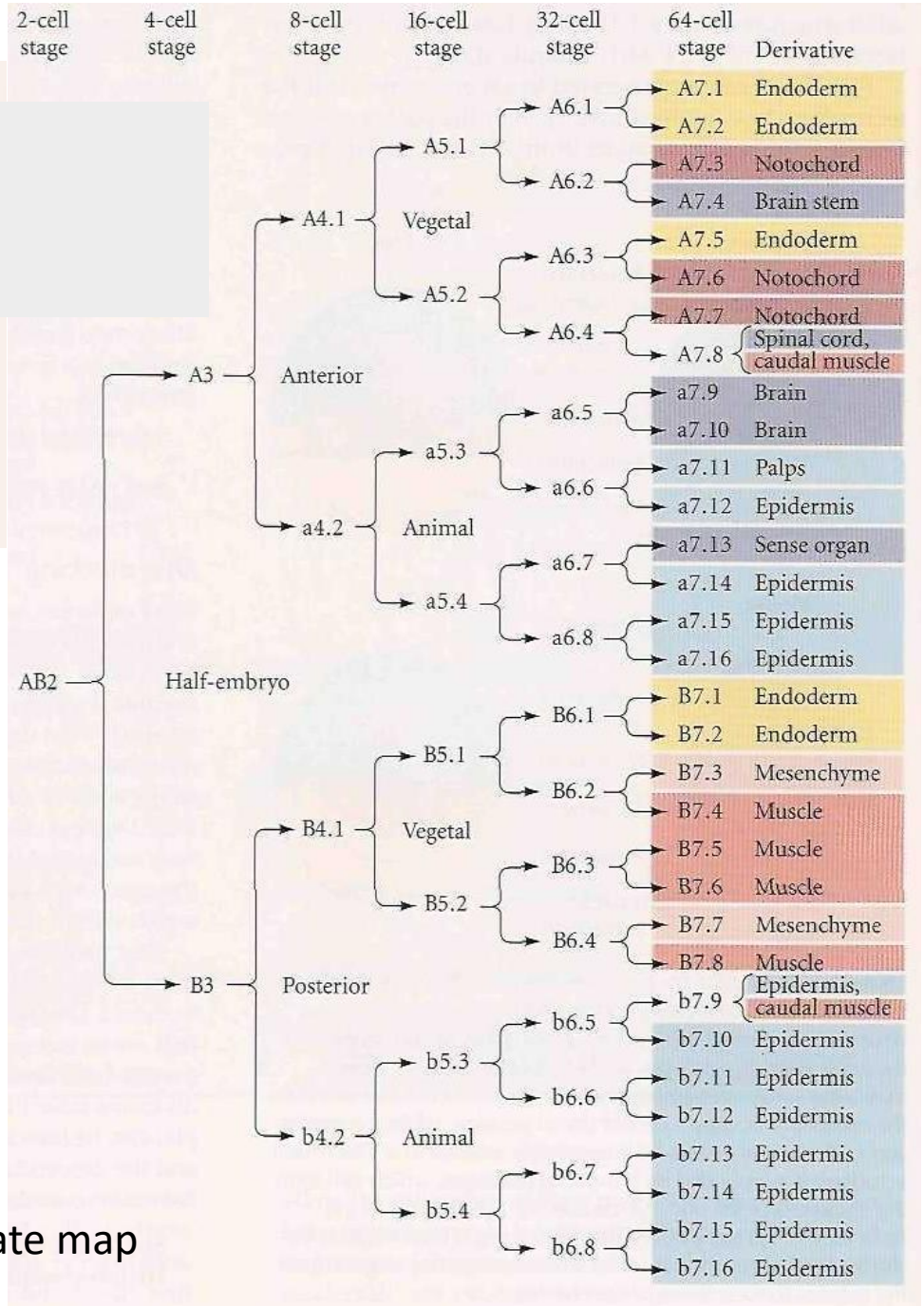

Retina
Midbrain
Hindbrain
Dorsal
Anterior forebrain
Posterior forebrain



Zygote

8-cell stage

Styela partita



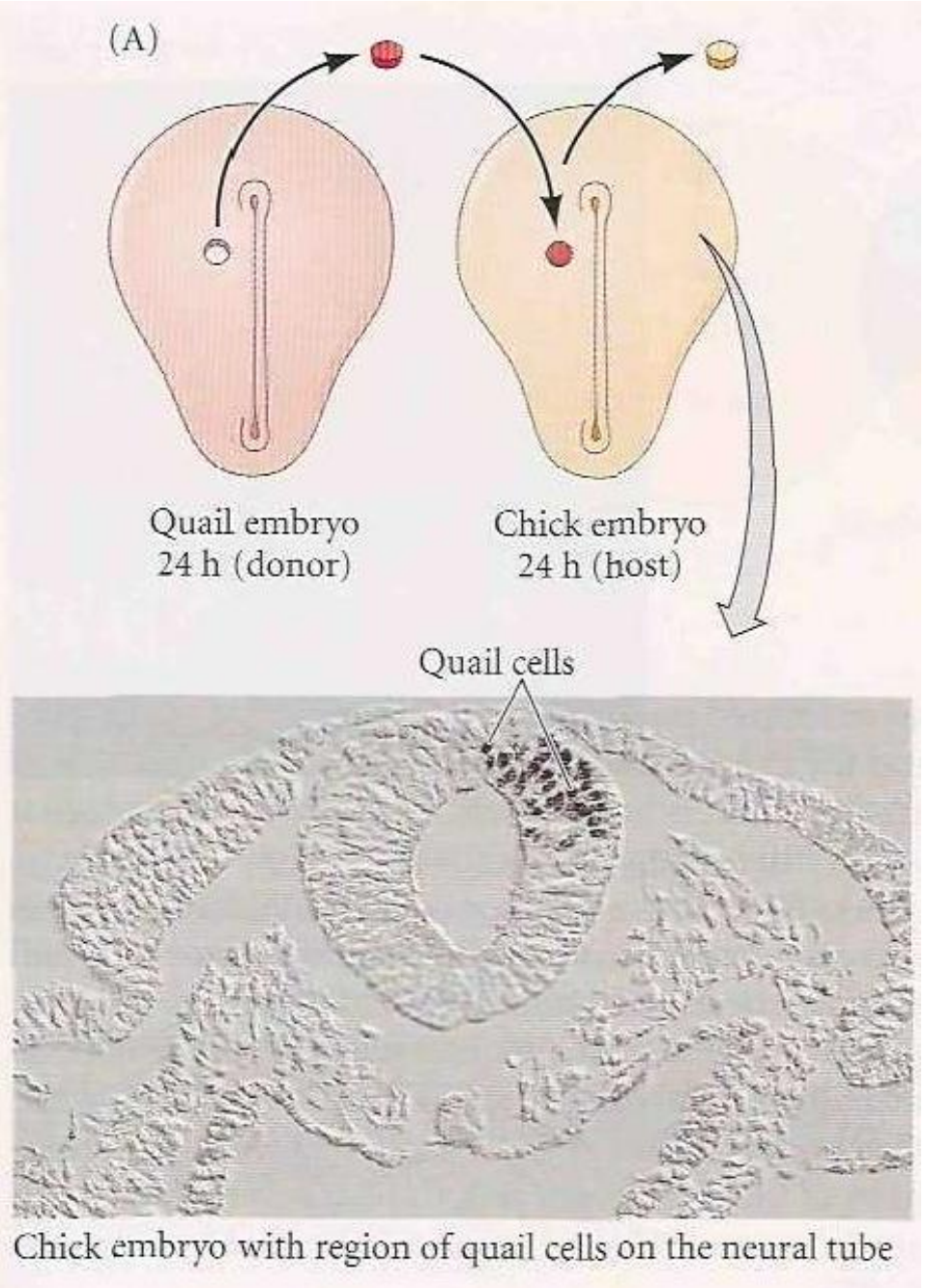
Linear fate map

Chimera

Quail cells differ from chick cells in two important ways.

First, the quail nucleus has condensed DNA *(heterochromatin)* concentrated around the nucleoli, making quail nuclei easily distinguishable from chick nuclei.

Second, cell-specific antigens that are quail-specific can be used to find individual quail cells, even if they are "hidden" within a large population of chick cells.

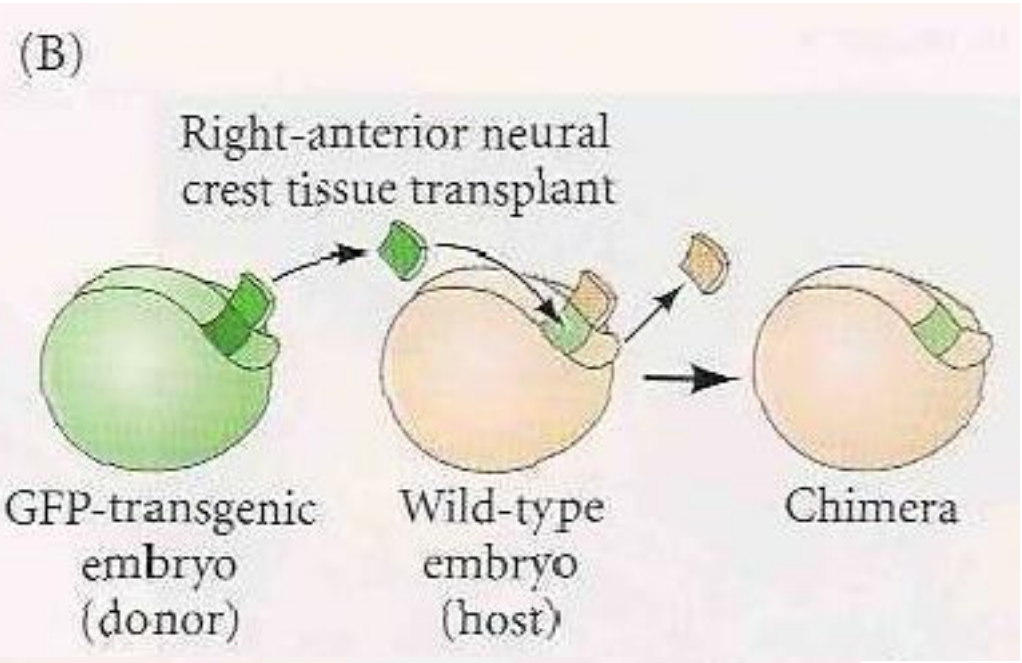


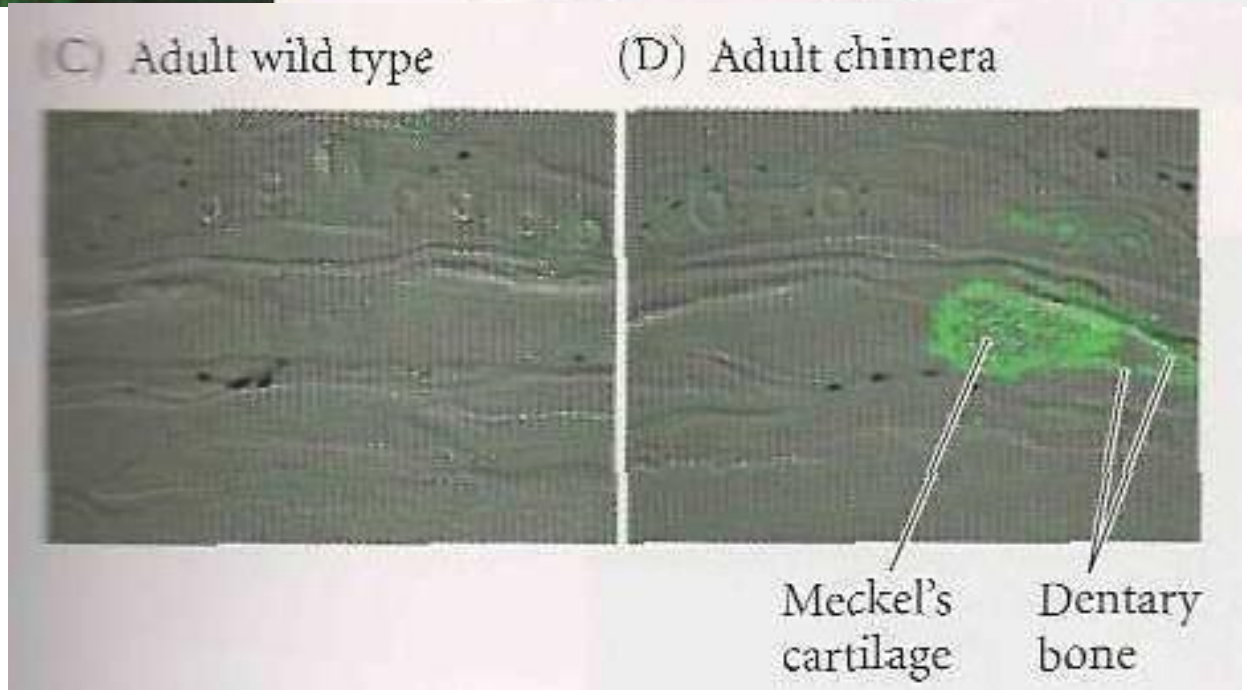
Chick embryo with region of quail cells on the neural tube

Chick resulting from transplantation of a trunk neural crest region from an embryo of a pigmented strain of chickens into the same region of an embryo of an unpigmented strain. The neural crest cells that gave rise to the pigment migrated into the wing epidermis and feathers.

Transgenic DNA chimera

Fate mapping with transgenic DNA shows that the neural crest is critical in making the bones of the frog jaw.





SPECIFICATION

Introducing Cell Commitment and Early Embryonic Development

“the greatest of all wonders of the material universe: the existence, in a simple, unorganized egg, of a power to produce a definite adult animal.”

-William Keith Brooks, 1883

Differentiation The process by which an unspecialized cell becomes specialized into one of the many cell types that make up the body.

Commitment Describes a state in which a cell's developmental fate has become restricted even though it is not yet displaying overt changes in cellular biochemistry and function.

Simply…

The generation of specialized cell types is called *differentiation*

and the process is

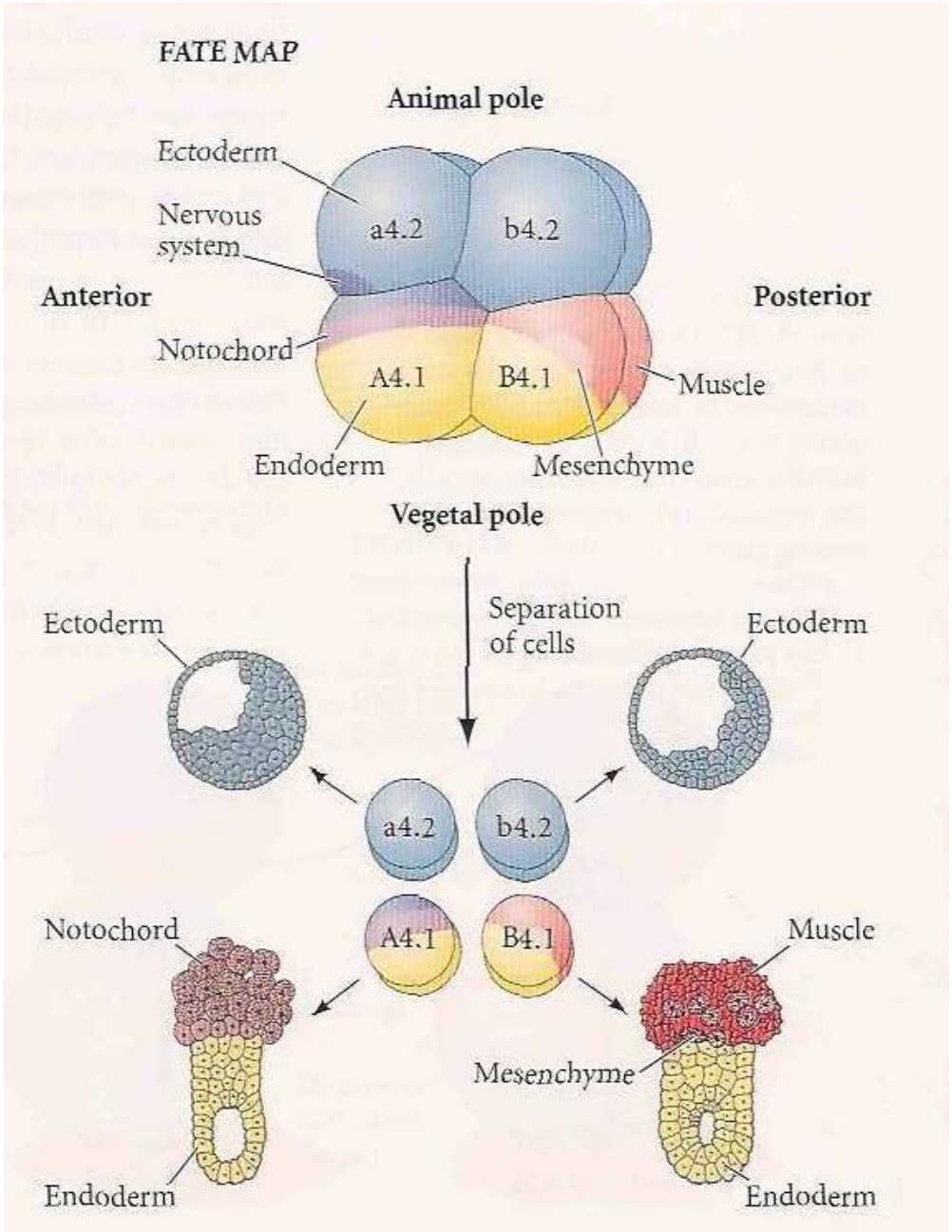
commitment

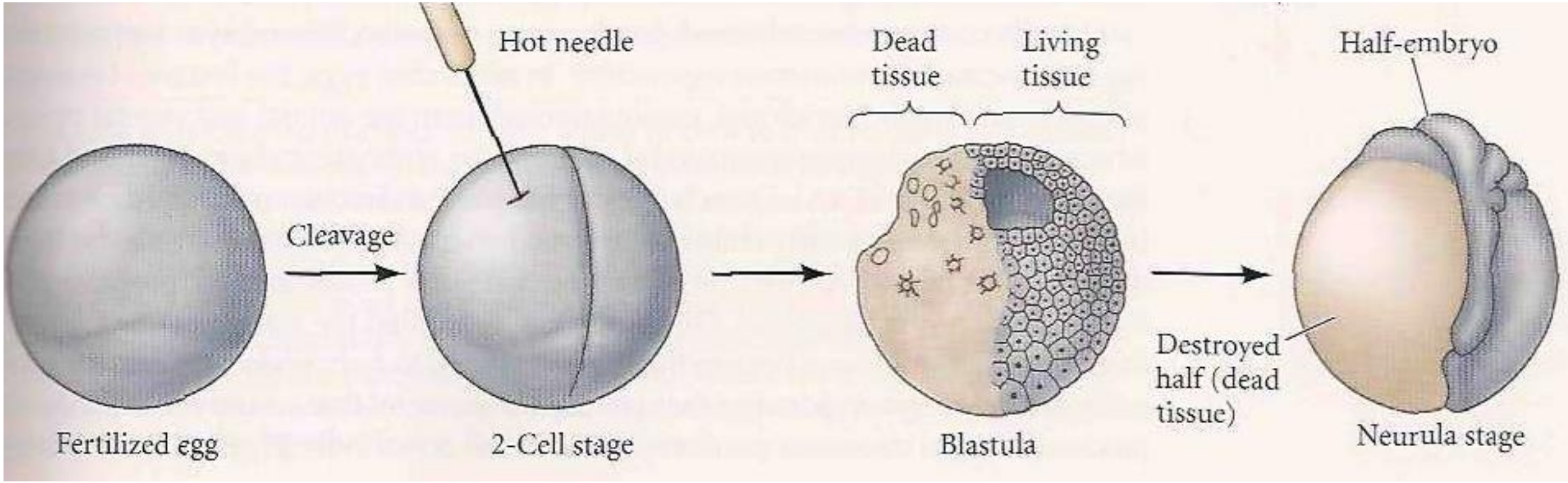
Commitment have two stages…

1)Specification_the labile one

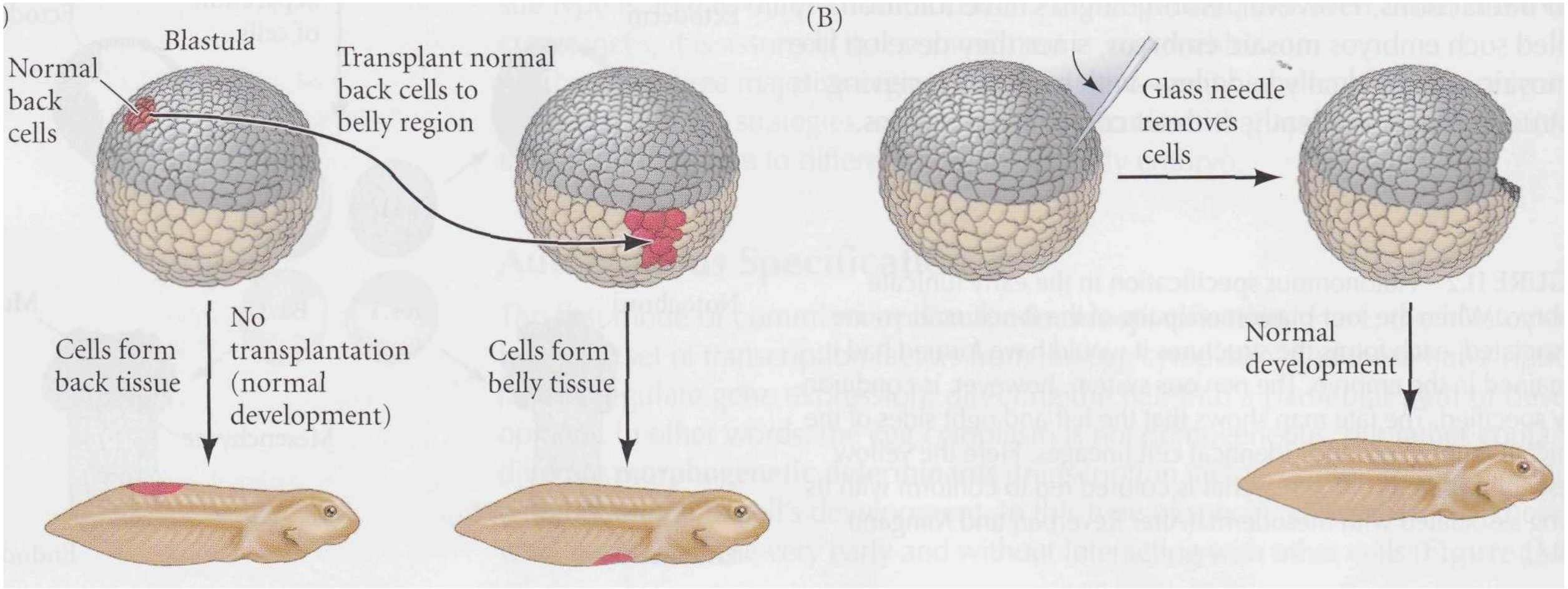
2)Determination_the irreversible one

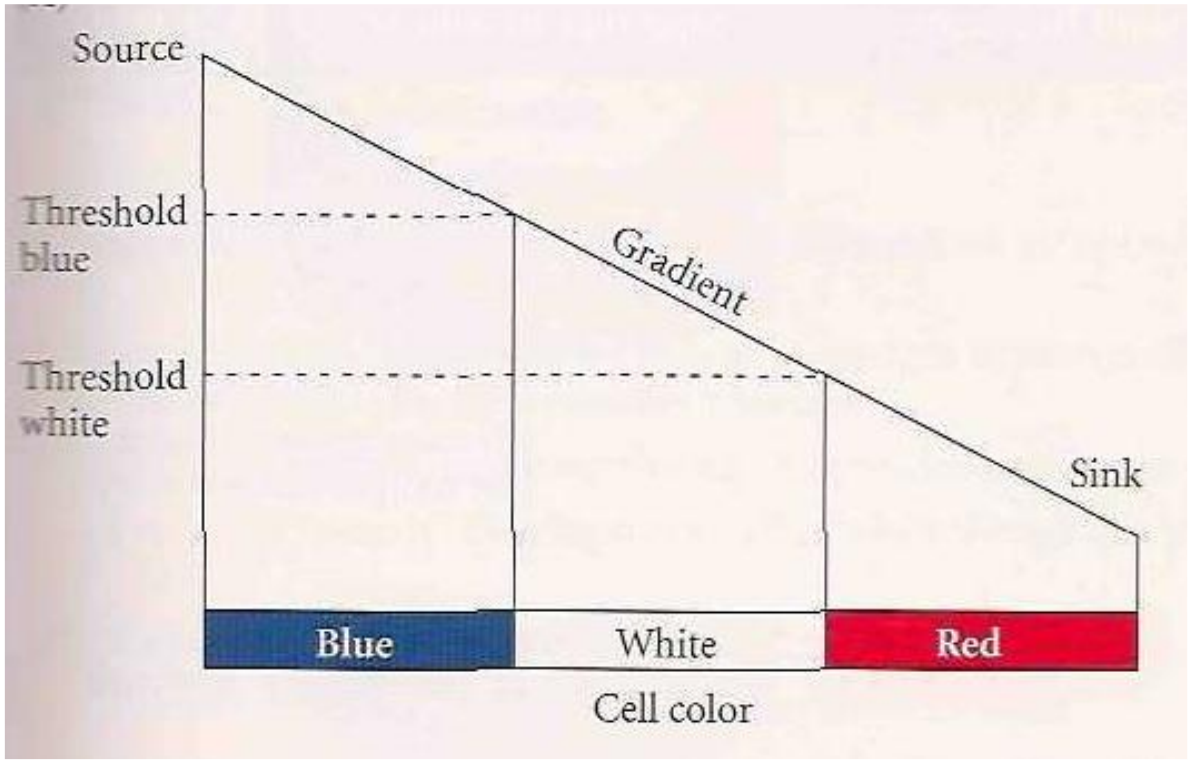
Autonomous specification



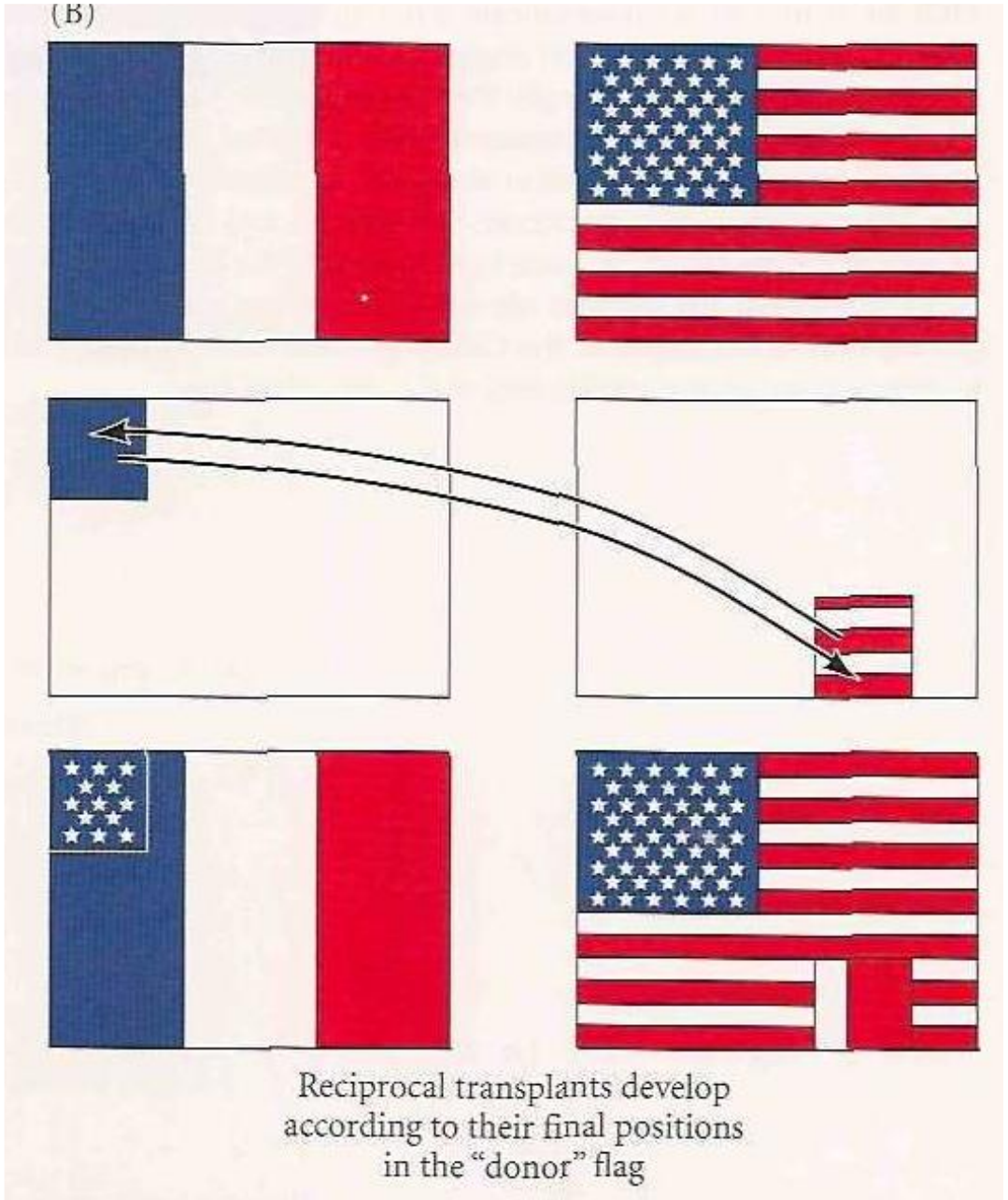

Hot needle
Dead tissue
Living tissue
Half-embryo
Cleavage
Destroyed half (dead tissue)
Fertilized egg
2-Cell stage
Blastula
Neurula stage

Conditional specification



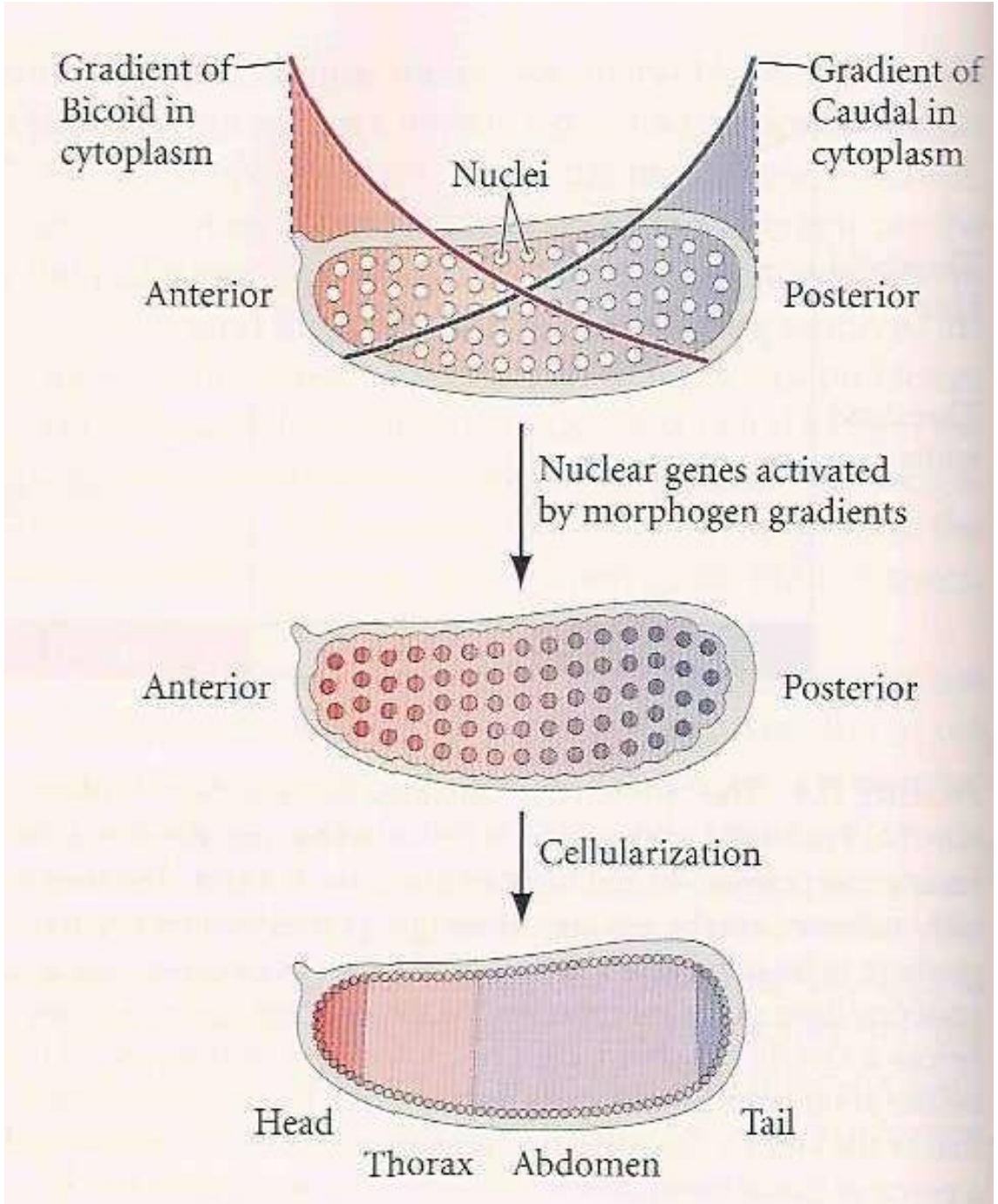


French flag analogy of conditional specification

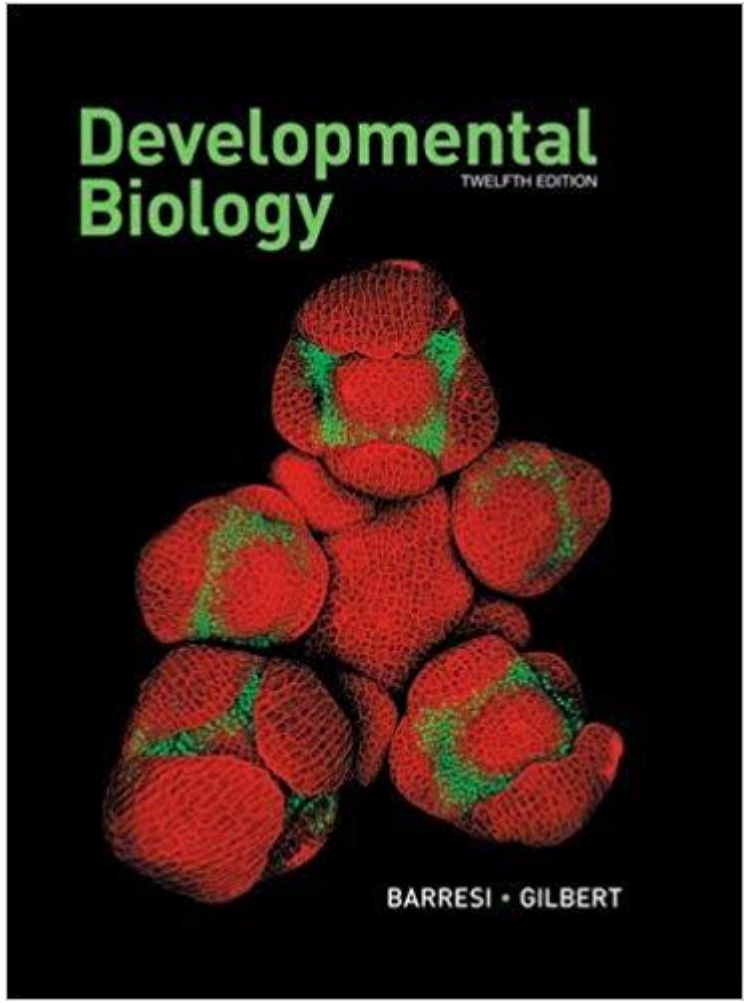


Reciprocal transplants develop according to their final positions in the "donor" flag

Syncytial specification



References:



That’s all…