Embryology

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Year 2

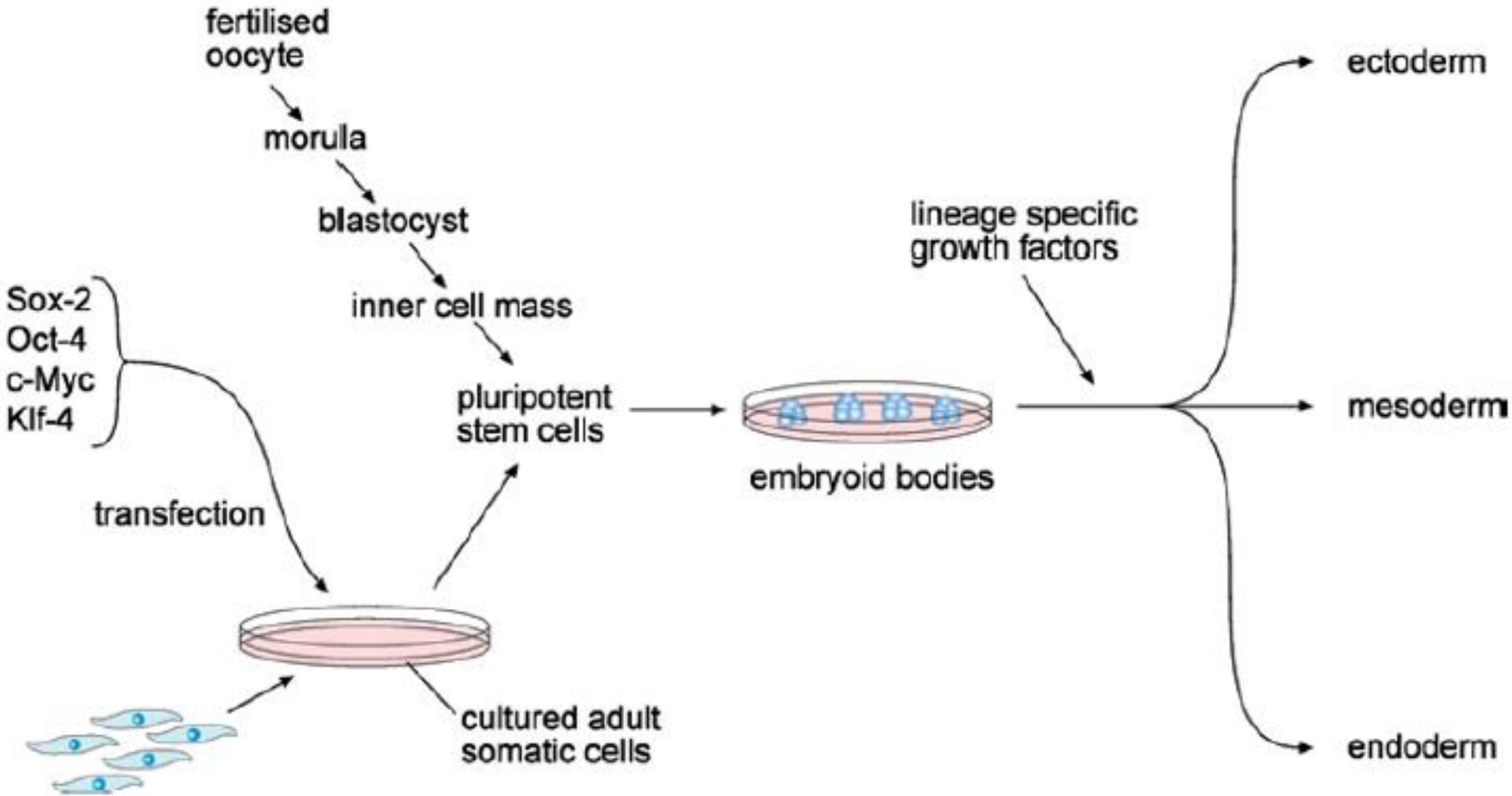
Stem Cell

Stem cells: are specialized cells capable of self-renewal. They produce daughter cells which retain the same characteristics as the stem cells from which they derive.

- Stem cells can be described as ‘totipotent’, ‘pluripotent’, ‘multipotent’ or ‘unipotent’ according to their degree of differentiation.
- Both induced pluripotent stem cells (iPSCs) and embryonic stem cells can give rise to entire embryos in a number of species.
- While stem cells have great therapeutic potential in the treatment of degenerative diseases, technical problems relating to the reprogramming of somatic cells require further investigation before such procedures can be used therapeutically in human medicine.
- Although iPSCs have been obtained in a range of domestic ungulates, including pigs, sheep, cattle and horses, progress on their applications has been slower than that in humans and mice

- Cells which derive from the inner cell mass, referred to as embryonic stem cells, form the basis of the structures and body systems necessary for the formation of a defined pattern of growth during embryological and fetal stages of development.
- The characteristics of stem cells which set them apart from other cells in the adult mammalian body include their ability to retain an undifferentiated state and also to undergo self-renewal, producing identical daughter cells which retain these same characteristics.
- The zygote is totipotent and has the ability to develop into an embryo including its fetal membranes.
- In the early embryo, totipotent cells differentiate, eventually producing cells with increasingly specialized functions.
- The term ‘differentiation’ describes a progressive process whereby cells and tissues develop specific structural and functional roles characterized by their specialized physiological or biochemical activities.

Stem cell type	Origin / Characteristics	Competence	Comments
Totipotent stem cells	Inner cell mass in developing embryo	Have the ability to form every cell type present in the embryo including trophoblastic placental cells	The totipotency of embryonic stem cells is retained by cells of the inner cell mass for a limited number of cell divisions
Pluripotent stem cells	Embryonic cells	Have the ability to form all embryonic cell types except trophoblastic placental cells	Pluripotent stem cells have the ability to produce viable embryos
Induced pluripotent stem cells	Somatic cells reprogrammed by: introduction of transcription factors which induce nuclear reprogramming in fully differentiated cells from an adult mammal; somatic cell nuclear transfer into an enucleated oocyte. Additional methods for induction of pluripotent stem cells include *in vitro* culture of primordial germ cells and culture of spermatogonial stem cells	These induced pluripotent stem cells have similar characteristics to naturally formed pluripotent stem cells	These induced cells can give rise to viable embryos
Multipotent stem cells	These embryonic cells have the ability to generate a limited range of subsets of cell types	Multipotent stem cells are restricted in their lineage capabilities	Subsets of cells produced are limited to defined cell types such as epithelial cells or white blood cells
Committed stem cells	These cells are more differentiated than multipotent stem cells	Committed stem cells have limited lineage capabilities	Cells produced are confined to a narrower range of cell types than those produced by multipotent stem cells
Progenitor cells	Although grouped with stem cells, these particular cells have limited self-renewal capabilities	Because they are more differentiated than stem cells, their self-renewal capability is limited	These cells give rise to a limited range of cell types
Unipotent stem cells	Unlike progenitor cells, these cells are restricted in their ability to divide	Unipotent stem cells are destined to become definitive cell types after a limited number of divisions	Because these cell are more differentiated than other types of stem cells, they become definitive cell types after limited differentiation



Outline of the growth and differentiation of pluripotent stem cells derived from the fertilized oocyte or alternatively by transfection of adult somatic cells.

Stem cells in the embryo

- During embryonic development, stem cells of numerous lineages play a central role in the formation of body structures.
- The cells which arise from the blastocyst progressively differentiate into the three germ layers, endoderm, ectoderm and mesoderm, an initial step toward specialization from which the tissues and organs of the body are formed

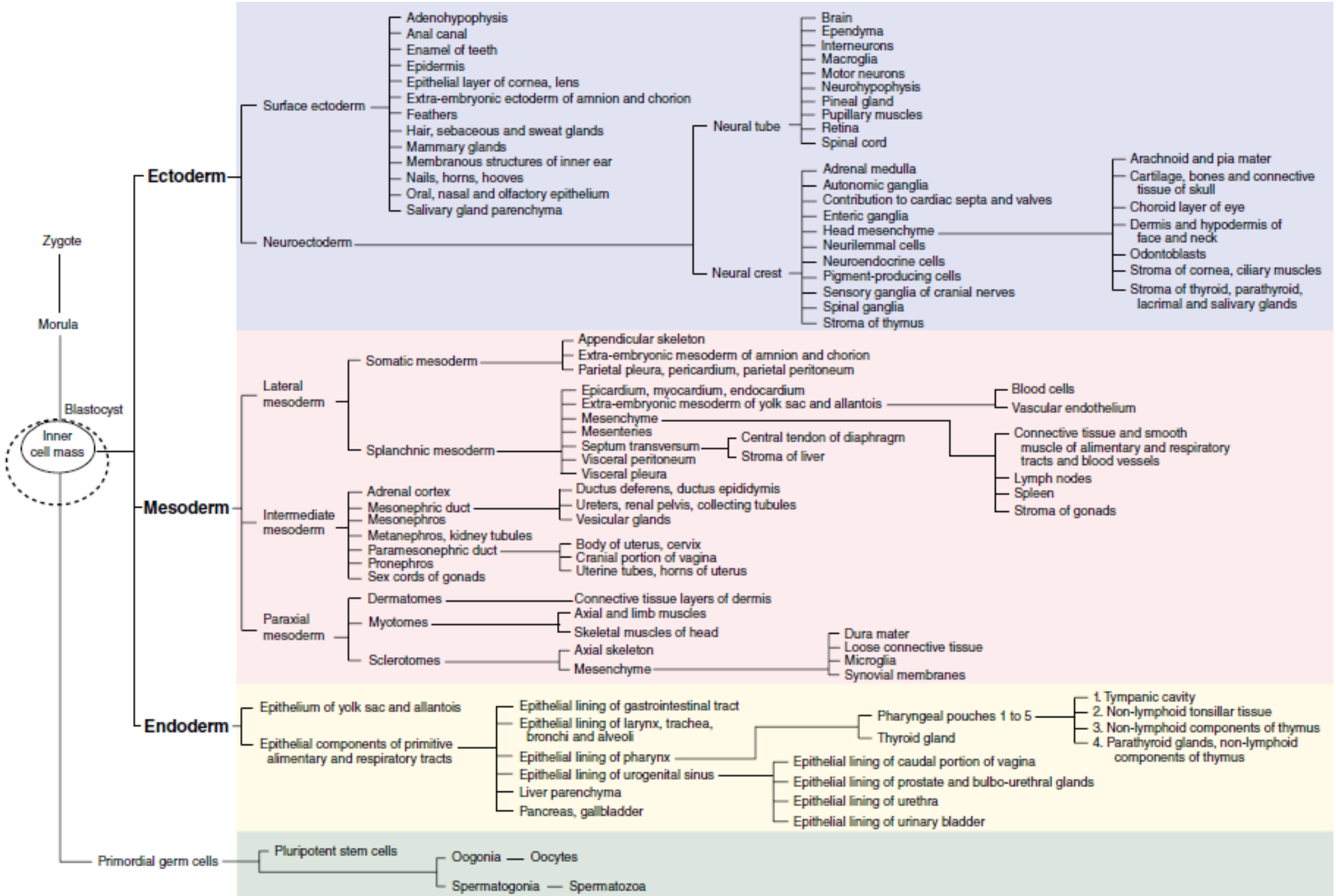
Stem cells in adult mammals

- In adult mammals, many organs and tissues contain stem cells, enabling their self-renewal and repair. Stem cells ensure the orderly replacement of cells with defined life spans such as red blood cells and epithelial cells and, in addition, replacement of cells which are damaged by trauma, infectious diseases or other degenerative changes associated with ageing.
- The ability of a cell to survive and function as a stem cell is strongly influenced by the microenvironment in which the cell resides
- Three reasons for a special environment for these cells are proposed:
- 1) stem cells require special support to ensure viability,
- 2) the growth factors and cell surface molecules produced by niche cells may collectively control stem cell pools
- 3) niches function to coordinate different cell types within tissue compartments.

- The bone marrow is a typical example of a stem cell niche which supplies the appropriate conditions for self-renewal and proliferation of haematopoietic stem cells, including stromal cells, chondrocytes and adipocytes, which maintain blood cell types and numbers throughout adult life

Establishment of the basic body plan

- The establishment of the mammalian body plan is directed by highly conserved gene regulatory networks (GRNs).
- In the course of evolution, embryos from different species are at their most morphologically divergent state during the earliest and latest stages of development.
- The notochord and the primitive node act as key signaling centers during this period of development in establishing the cranial–caudal axis and left–right asymmetry.
- Ectoderm, the outer germ layer, differentiates into neuroectoderm and surface ectoderm.
- Cells of the middle germ layer, mesoderm, proliferate and develop into three distinct components (paraxial, intermediate and lateral plate mesoderm).
- The inner germ layer, endoderm, lines the embryonic gut tube and the developing respiratory tract.
- With the exception of the primordial germ cells and their derivatives, the cells, tissues, organs and body structures are derived from these three germ layers.


Zygote
Morula
Blastocyst
Inner cell mass
Ectoderm
Surface ectoderm
Adenohypophysis
Anal canal
Enamel of teeth
Epidermis
Epithelial layer of cornea, lens
Extra-embryonic ectoderm of amnion and chorion
Feathers
Hair, sebaceous and sweat glands
Mammary glands
Membranous structures of inner ear
Nails, horns, hooves
Oral, nasal and olfactory epithelium
Salivary gland parenchyma
Neuroectoderm
Neural tube
Brain
Ependyma
Interneurons
Macroglia
Motor neurons
Neurohypophysis
Pineal gland
Pupillary muscles
Retina
Spinal cord
Neural crest
Adrenal medulla
Autonomic ganglia
Contribution to cardiac septa and valves
Enteric ganglia
Head mesenchyme
Neurilemmal cells
Neuroendocrine cells
Pigment-producing cells
Sensory ganglia of cranial nerves
Spinal ganglia
Stroma of thymus
Arachnoid and pia mater
Cartilage, bones and connective tissue of skull
Choroid layer of eye
Dermis and hypodermis of face and neck
Odontoblasts
Stroma of cornea, ciliary muscles
Stroma of thyroid, parathyroid, lacrimal and salivary glands
Mesoderm
Lateral mesoderm
Somatic mesoderm
Appendicular skeleton
Extra-embryonic mesoderm of amnion and chorion
Parietal pleura, pericardium, parietal peritoneum
Splanchnic mesoderm
Epicardium, myocardium, endocardium
Extra-embryonic mesoderm of yolk sac and allantois
Blood cells
Vascular endothelium
Mesenchyme
Mesenteries
Septum transversum
Central tendon of diaphragm
Stroma of liver
Visceral peritoneum
Visceral pleura
Connective tissue and smooth muscle of alimentary and respiratory tracts and blood vessels
Lymph nodes
Spleen
Stroma of gonads
Intermediate mesoderm
Adrenal cortex
Mesonephric duct
Mesonephros
Metanephros, kidney tubules
Paramesonephric duct
Pronephros
Sex cords of gonads
Ductus deferens, ductus epididymis
Ureters, renal pelvis, collecting tubules
Vesicular glands
Body of uterus, cervix
Cranial portion of vagina
Uterine tubes, horns of uterus
Paraxial mesoderm
Dermatomes
Connective tissue layers of dermis
Myotomes
Axial and limb muscles
Skeletal muscles of head
Sclerotomes
Axial skeleton
Mesenchyme
Dura mater
Loose connective tissue
Microglia
Synovial membranes
Endoderm
Epithelium of yolk sac and allantois
Epithelial components of primitive alimentary and respiratory tracts
Epithelial lining of gastrointestinal tract
Epithelial lining of larynx, trachea, bronchi and alveoli
Epithelial lining of pharynx
Pharyngeal pouches 1 to 5
Thyroid gland
1. Tympanic cavity
2. Non-lymphoid tonsillar tissue
3. Non-lymphoid components of thymus
4. Parathyroid glands, non-lymphoid components of thymus
Epithelial lining of urogenital sinus
Epithelial lining of caudal portion of vagina
Epithelial lining of prostate and bulbo-urethral glands
Epithelial lining of urethra
Epithelial lining of urinary bladder
Liver parenchyma
Pancreas, gallbladder
Primordial germ cells
Pluripotent stem cells
Oogonia — Oocytes
Spermatogonia — Spermatozoa