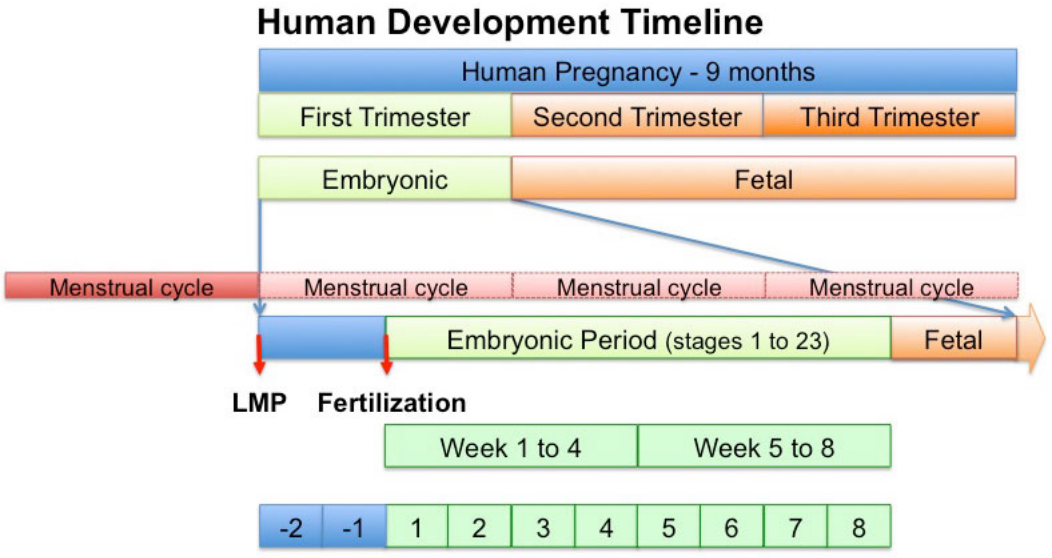
BGDA Lecture - Development of the Embryo/Fetus 1

Introduction



In medicine foundations you were given a broad overview of human development. Now in BGDA we will be working through the human development process in more detail, focussing on key events.

2017 Lecture PDF

- Begin by reviewing the recent Foundations Lecture and Practical.
- This BGDA lecture covers conceptus development from fertilization to implantation to trilaminar embryo formation.
    - Note that fertilization and week 1 concepts have already been covered in an earlier BGDA lecture.
- The lecture will also introduce early fetal membranes and placentation.

1 Minute Embryology | UNSW theBox

Lecture Archive [Expand]

Textbooks [Collapse]

UNSW Embryology

The Developing Human: Clinically Oriented Embryology

Moore, K.L., Persaud, T.V.N. & Torchia, M.G. (2015). *The developing human: clinically oriented embryology* (10th ed.). Philadelphia: Saunders. (links only function with UNSW connection)

Larsen's Human Embryology

Schoenwolf, G.C., Bleyl, S.B., Brauer, P.R., Francis-West, P.H. & Philippa H. (2015). *Larsen's human embryology* (5th ed.). New York; Edinburgh: Churchill Livingstone. (links only function with UNSW connection)

More Textbooks?

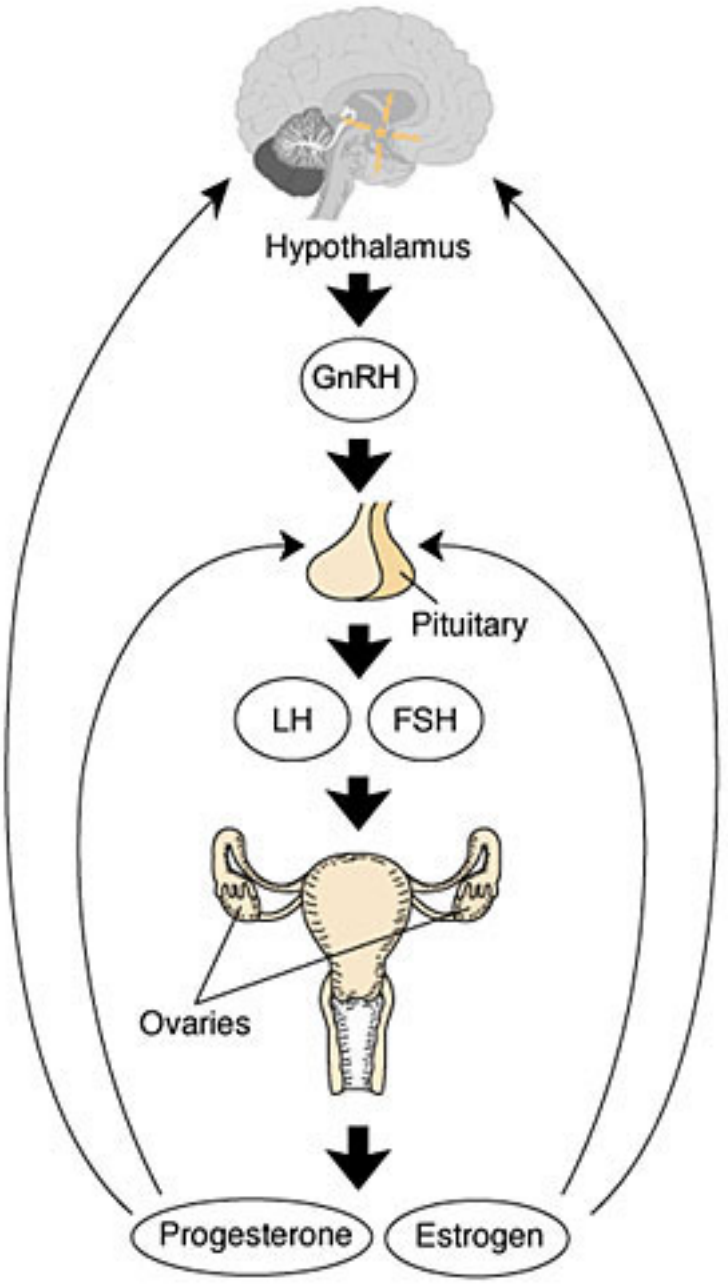
BGDA Practical Classes

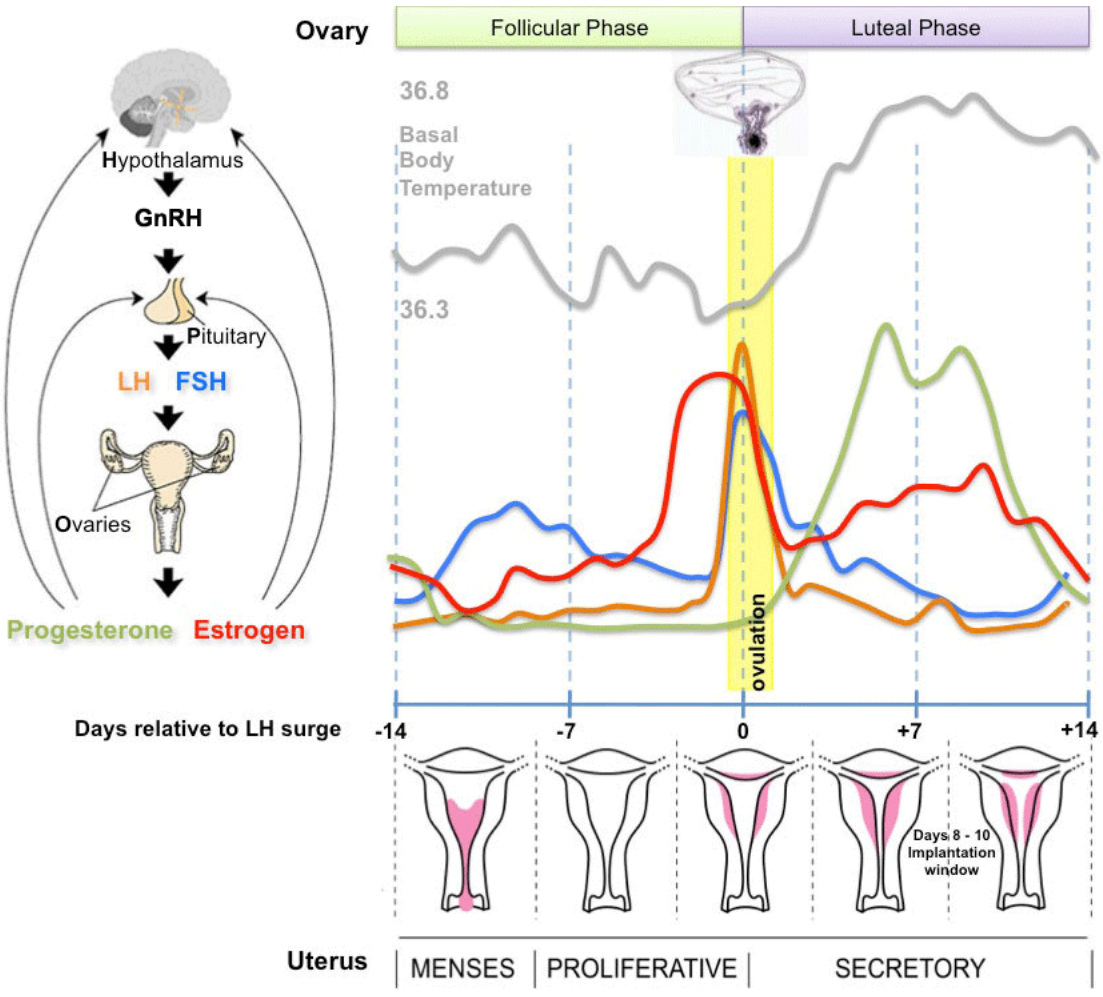
Practical 3 - Fertilization to Implantation	**Practical 6 - Implantation to 8 Weeks**	**Practical 12 - Fetal Period**
	Practical 14 - Placenta and Fetal Membranes	

Human Reproductive Cycle

- Meiosis in gonad produces haploid gametes (egg and sperm)

Female	Male
• Menstrual Cycle a regular cycle of reproduction (28 days) • begins at puberty, release of 1 egg (oocyte) every cycle • Endocrine controlled (HPG axis) **H**ypothalamus - **P**ituitary - **G**onad	• continuous production of sperm (spermatozoa) • begins at puberty, release millions of spermatozoa • Endocrine controlled (HPG axis) **H**ypothalamus - **P**ituitary - **G**onad





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Gametogenesis

Male

The testes have two functions.

1. produce the male gametes or **spermatozoa**
2. produce male sexual hormone, **testosterone** (internal and external genitalia, sex characteristics)

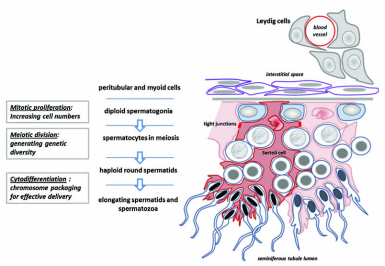
- Historic testis drawing
- Child Seminiferous tubule
- Adult Seminiferous tubule showing spermatozoa developmental stages
- Seminiferous tubule cross-section and supporting cells
-

Human spermatozoa take about **48 days** from entering meiosis until morphologically mature spermatozoa.

- Spermatogonia - are the first cells of spermatogenesis
- Primary spermatocytes - large, enter the prophase of the first meiotic division
- Secondary spermatocytes - small, complete the second meiotic division
- Spermatid - immature spermatozoa
- Spermatozoa - differentiated gamete

Spermatozoa development: primordial germ cell - spermatogonia - primary spermatocyte - secondary spermatocytes - spermatid - spermatozoa

Sertoli cells (support cells) **Interstitial cells** or Leydig cells (produce hormone)



Spermatozoa Development **(expand to see terms)** [Expand]

Female

The ovary has two main functions.

1. produce the female gametes or **oocytes**
2. produce female hormones, **estrogen** and **progesterone** (secondary sex characteristics, menstrual cycle)

-
-

- three stages of follicle development

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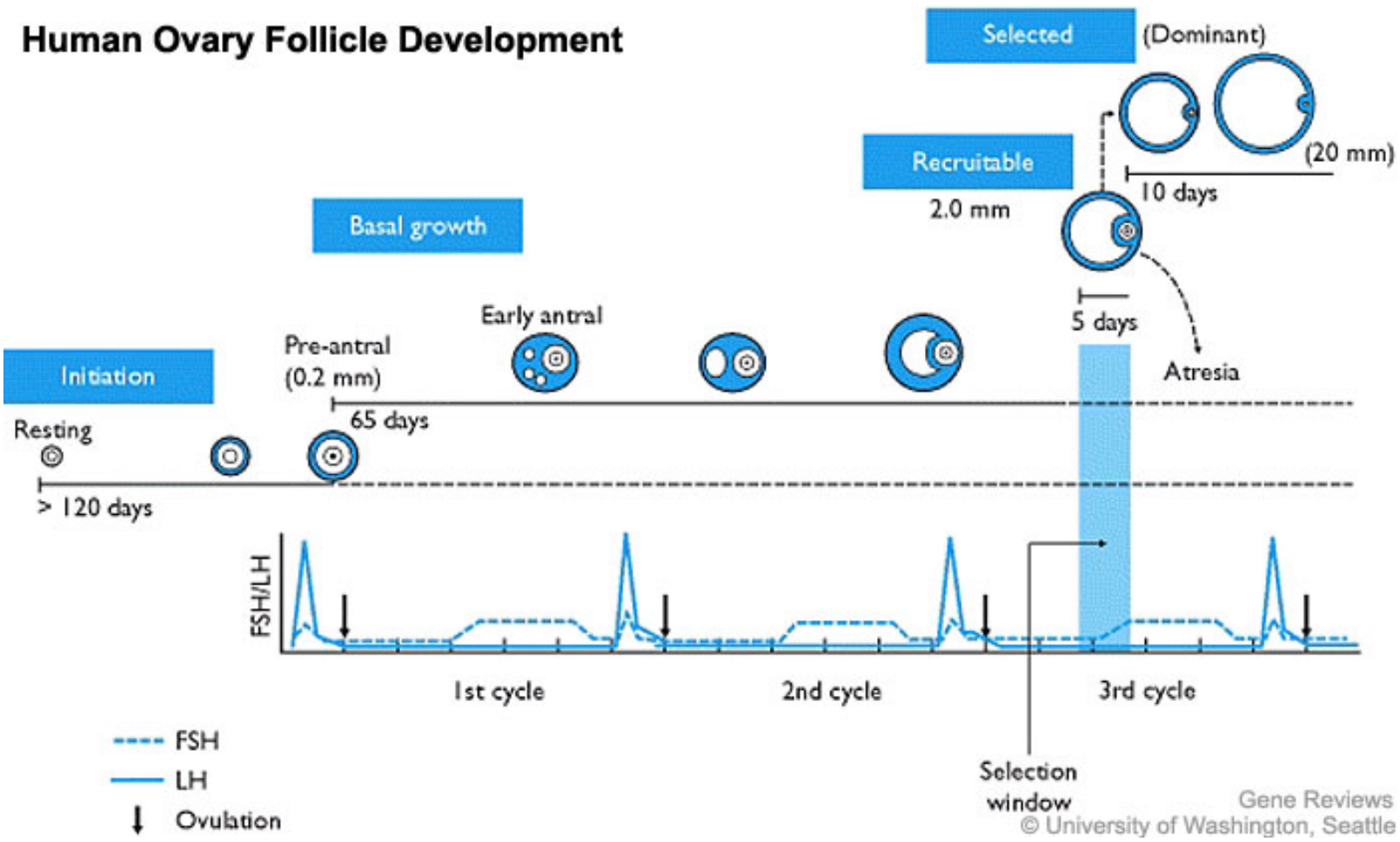
In an adult human female the development of a primordial follicle containing an oocyte to a preovulatory follicle takes in excess of **120 days**.



Human ovary follicle development

> **Ovarian Follicle Stages:** primordial follicle - primary follicle - secondary follicle - preovulatory follicle

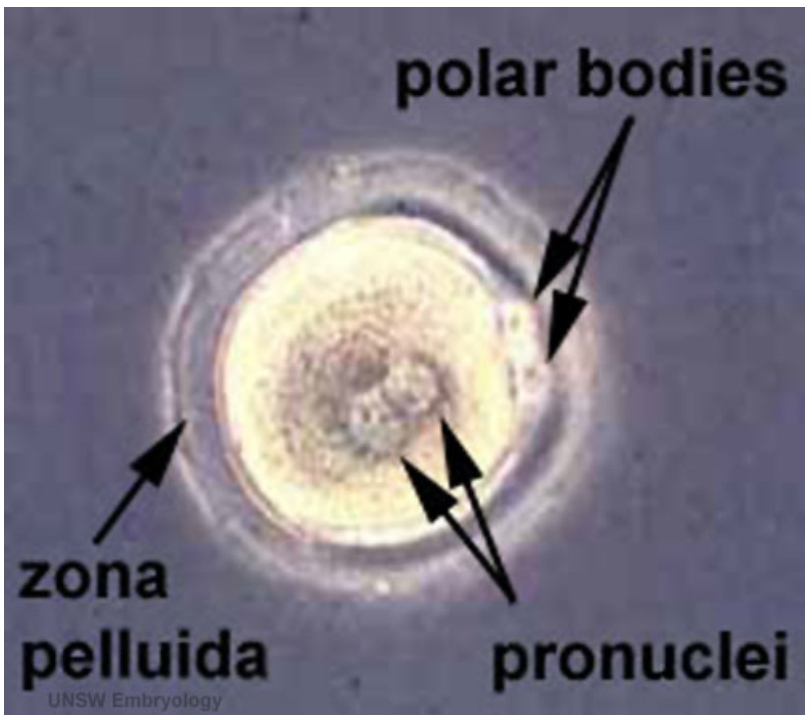
Follicle cells (support cells) **Theca cells** (produce hormone)

Oocyte Development (expand to see terms) [Expand]

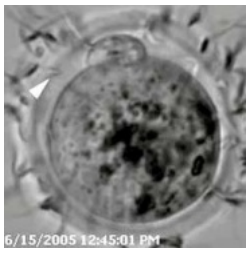
Links: spermatozoa | oocyte | MBoC - Figure 20-18. Influence of Sry on gonad development | Endocrinology - Comparative anatomy of male and female reproductive tracts

Fertilization

- Oogenesis - 1 gamete produced/meiosis + 3 polar bodies, meiosis is slow, 1 egg produced and released at ovulation
- Spermatogenesis - 4 gametes produced/meiosis, meiosis is fast, 200-600 million sperm released at ejaculation



Early zygote showing polar bodies



Fertilization Site

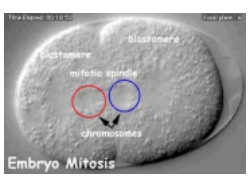
- Fertilization usually occurs in first 1/3 of uterine tube (oviduct, Fallopian tube)
- Fertilization can also occur outside uterine tube associated with Assisted Reproductive Technologies (IVF, GIFT, ZIFT...) and ectopic pregnancy
- The majority of fertilized eggs do not go on to form an embryo

Fertilization - Spermatozoa

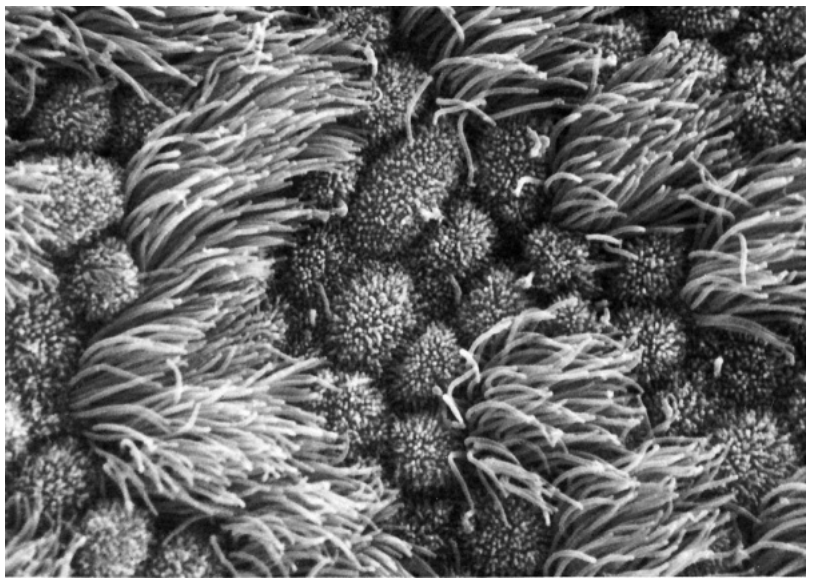
- **Capacitation** - alteration of the spermatozoa metabolism and surface proteins
- **Sperm Binding** - zona pellucida protein ZP3 acts as receptor for sperm
- Acrosome Reaction - exocytosis of acrosome contents (Calcium mediated) MBoC - Figure 20-31. The acrosome reaction that occurs when a mammalian sperm fertilizes an egg
    - enzymes to digest the zona pellucida
    - exposes sperm surface proteins to bind ZP2
- **Membrane Fusion** - between sperm and egg, allows sperm nuclei passage into egg cytoplasm

Fertilization - Oocyte

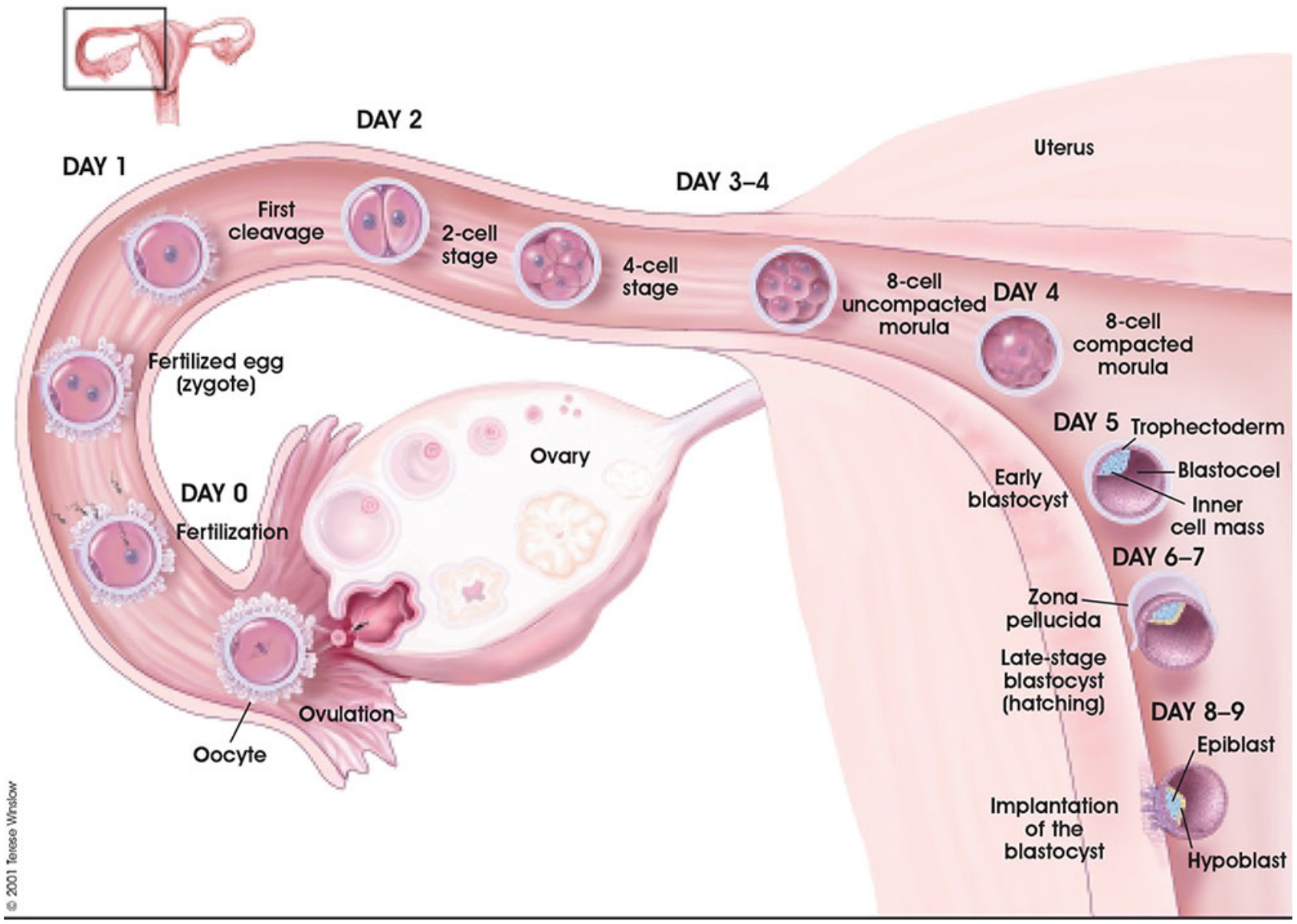
- **Membrane Depolarization** - caused by sperm membrane fusion, primary block to polyspermy
- Cortical Reaction - IP3 pathway elevates intracellular Calcium, exocytosis of cortical granules MBoC - Figure 20-32. How the cortical reaction in a mouse egg is thought to prevent additional sperm from entering the egg
    - enzyme alters ZP3 so it will no longer bind sperm plasma membrane
- **Meiosis 2** - completion of 2nd meiotic division
    - forms second polar body (a third polar body may be formed by meiotic division of the first polar body)

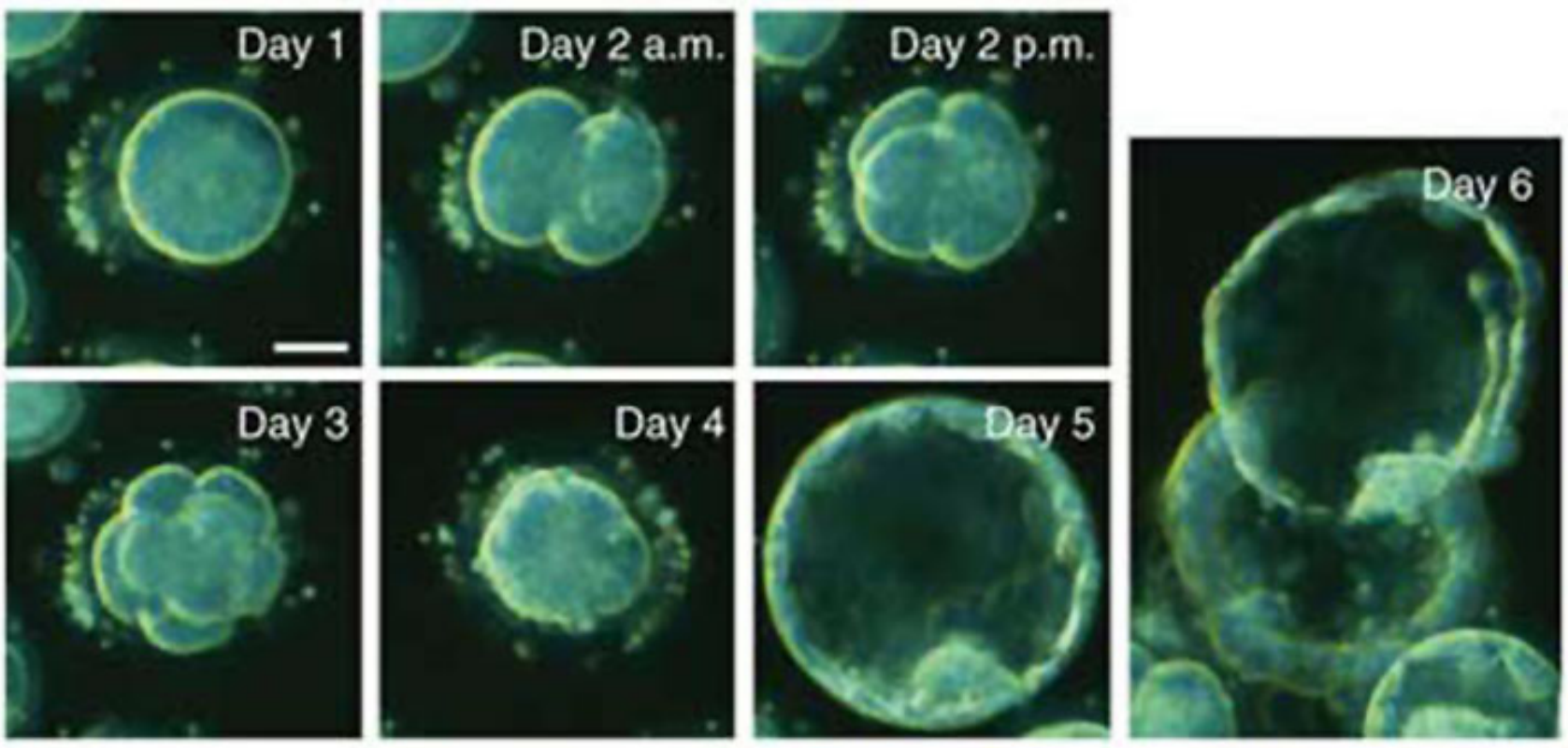


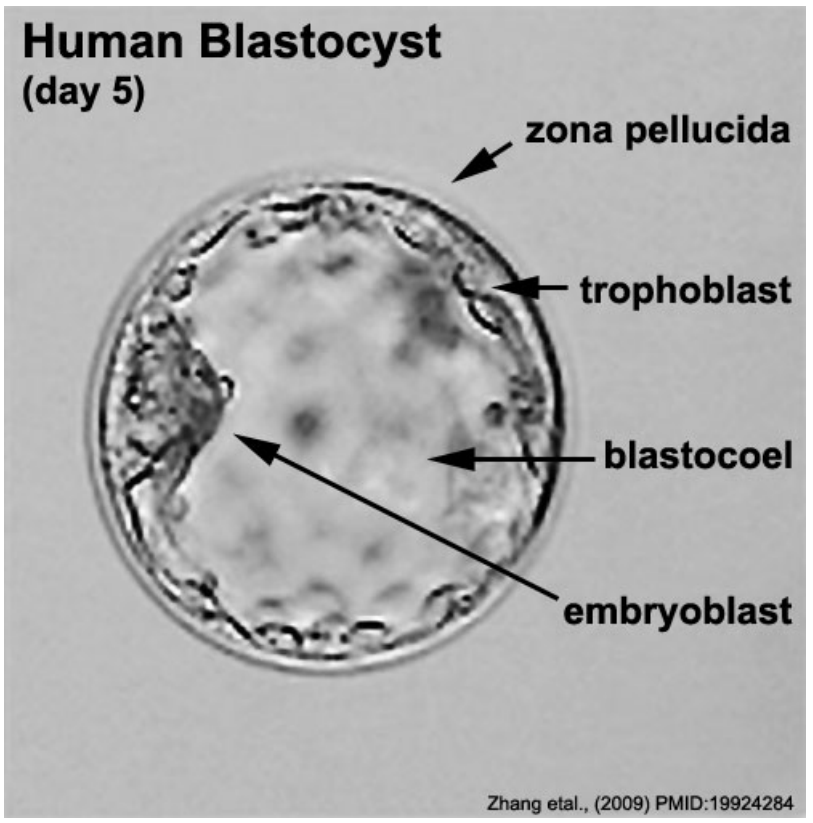
Week 1 and 2

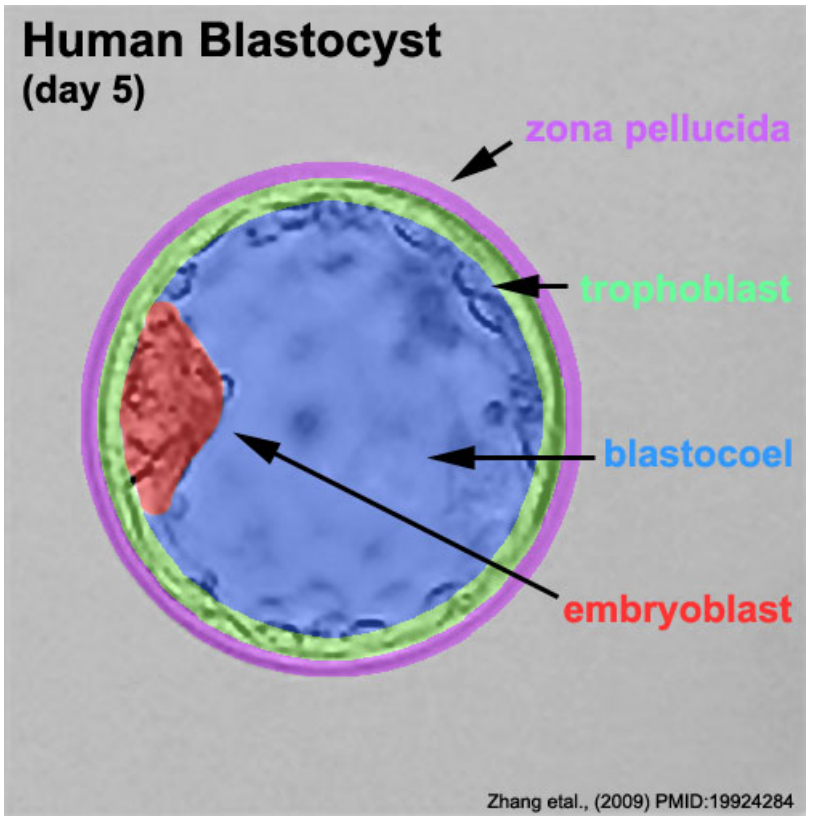


Human uterine tube ciliated epithelium (SEM)



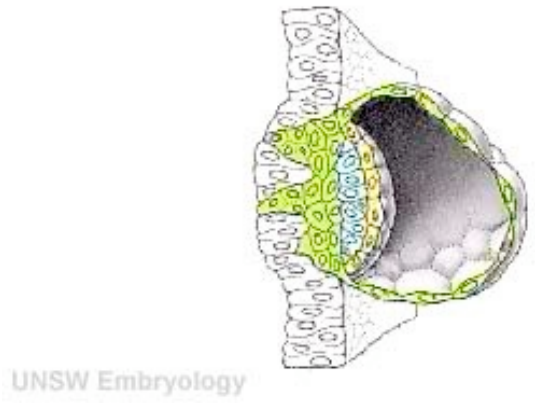

Day 1
Day 2 a.m.
Day 2 p.m.
Day 6
Day 3
Day 4
Day 5

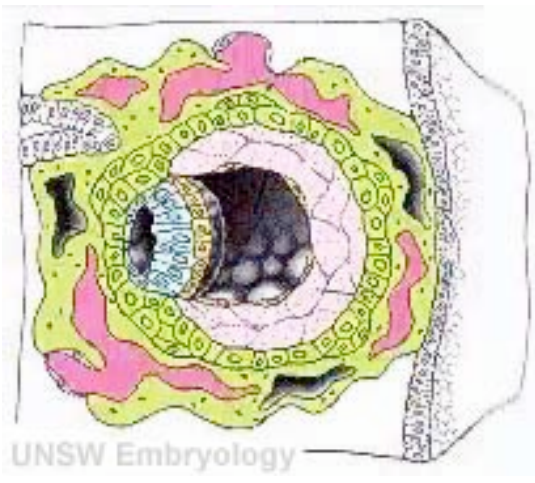

Human Blastocyst
(day 5)
zona pellucida
trophoblast
blastocoel
embryoblast
Zhang etal., (2009) PMID:19924284


Human Blastocyst
(day 5)
zona pellucida
trophoblast
blastocoel
embryoblast
Zhang etal., (2009) PMID:19924284

Week 2 Implantation

- Bilaminar embryo - Epiblast and Hypoblast
- Bilaminar trophoblast - Cytotrophoblast and Syncytiotrophoblast





Early Placenta

- interaction between implanting conceptus and uterine wall (endometrium)
- The uterine lining following implantation (Decidua)
  - forms 3 distinct regions, at approx 3 weeks
  - **Decidua Basalis** - implantation site
  - **Decidua Capsularis** - enclosing the conceptus
  - **Decidua Parietalis** - remainder of uterus
- uterine cavity is lost by 12 weeks

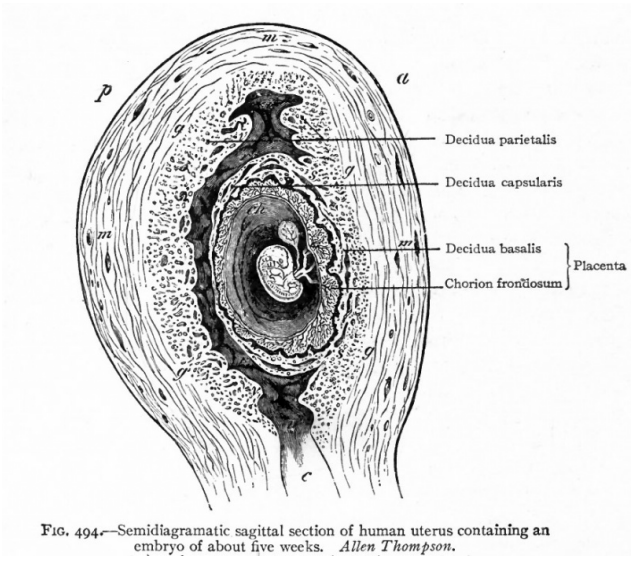


FIG. 494.—Semidiagramatic sagittal section of human uterus containing an embryo of about five weeks. *Allen Thompson.*

Week 3 Gastrulation

- **Primitive node** - region in the middle of the early embryonic disc epiblast from which the primitive streak extends caudally (tail)

- nodal cilia establish the embryo left/right axis
- axial process extends from the nodal epiblast

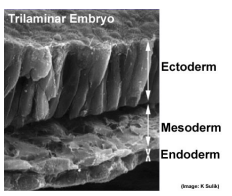
- **Primitive streak** - region of cell migration (gastrulation) from the epiblast layer forming sequentially the two germ cell layers (endoderm and mesoderm)

Gastrulation, (Greek = belly)

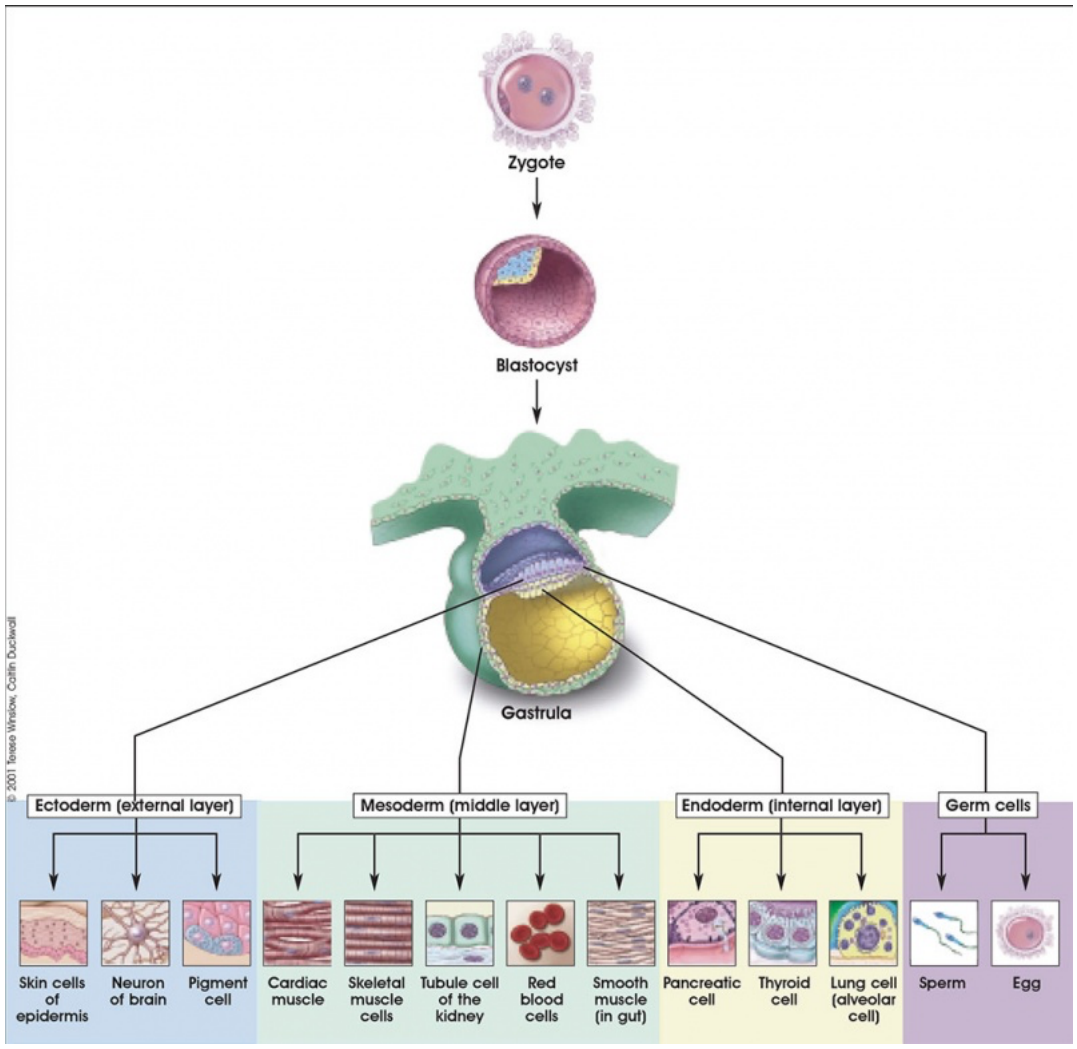
Means the formation of gut, but has been used in a more looser sense to to describe the formation of the trilaminar embryo. The epiblast layer, consisting of totipotential cells, derives all 3 embryo layers:

1. ectoderm
2. mesoderm
3. endoderm

The primitive streak is the visible feature which represents the site of cell migration to form the additional layers. Historically, gastrulation was one of the earliest observable morphological event occurring in the frog embryo.



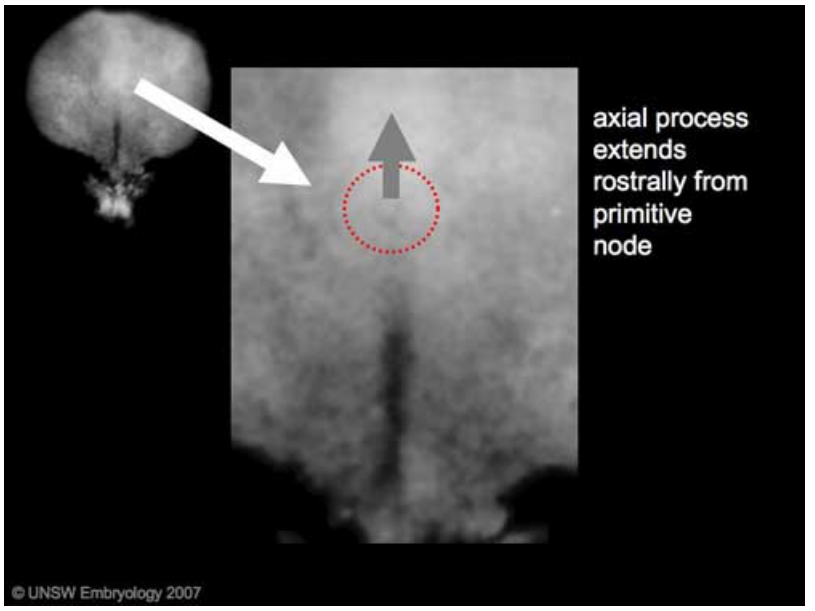
Trilaminar embryo (SEM)

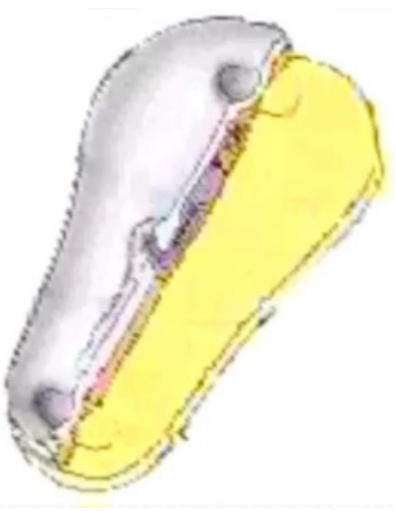


Virtual Slides - Human Embryo (stage 7) [Expand]

Notochord

The notochord is a structure which has an early **mechanical role** in embryonic disc folding and a major **signaling role** in patterning surrounding embryonic tissue development. This signaling role patterns many different tissues (neural plate, neural tube, somites, endodermal organs). It has its own sequence of development from a primitive axial process and is a developmental feature not present in the adult anatomy.





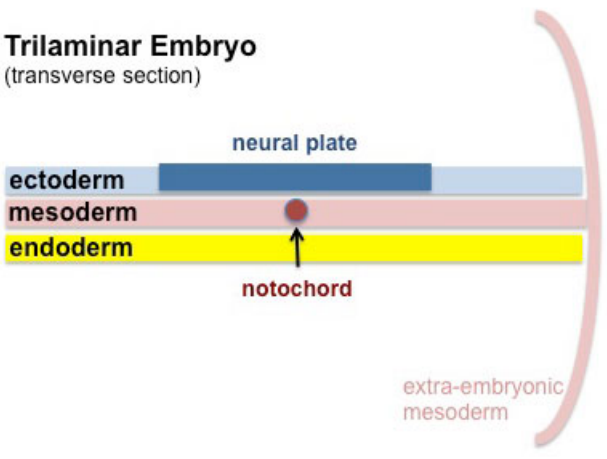
Page

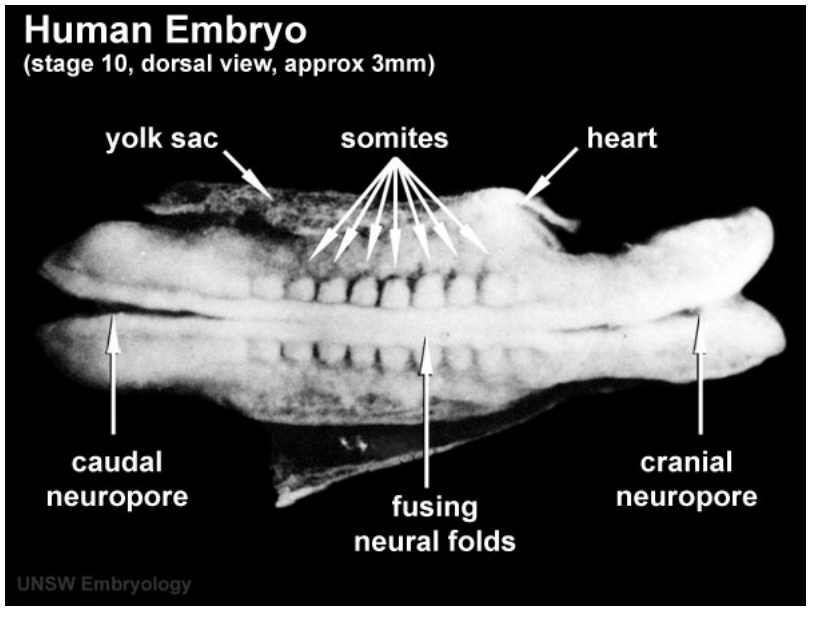
- **axial process** an initial epiblast hollow epithelial tube which extends in the midline from the primitive pit, cranially in the embryonic disc (toward the oral membrane).
    - **neuroenteric canal** is a transient communication between the amnionic cavity and the yolk sac cavity formed by the axial process.
- **notochordal plate** forms from the axial process merging with the endoderm layer.
- **notochord** forms from the notochordal plate which then separates back into the mesoderm layer as a solid column of cells lying in the midline of the embryonic disc and running rostro-caudally (head to tail).
    - An alternate name for the notochord is "axial mesoderm".

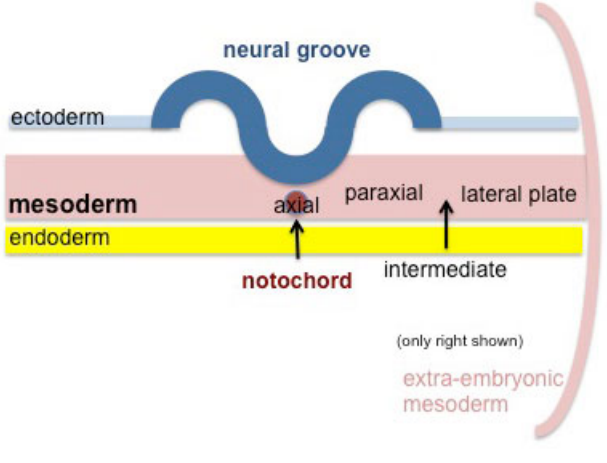
Somitogenesis

Mesoderm means the "middle layer" and it is from this layer that nearly all the bodies connective tissues are derived. In early mesoderm development a number of transient structures will form and then be lost as tissue structure is patterned and organised. Humans are vertebrates, with a "backbone", and the first mesoderm structure we will see form after the notochord will be **somites**.

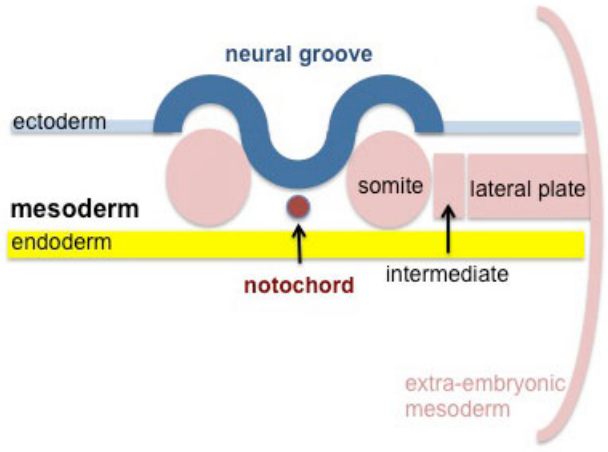
- **Mesoderm and Ectoderm Cartoons**







- Paraxial and Lateral Plate



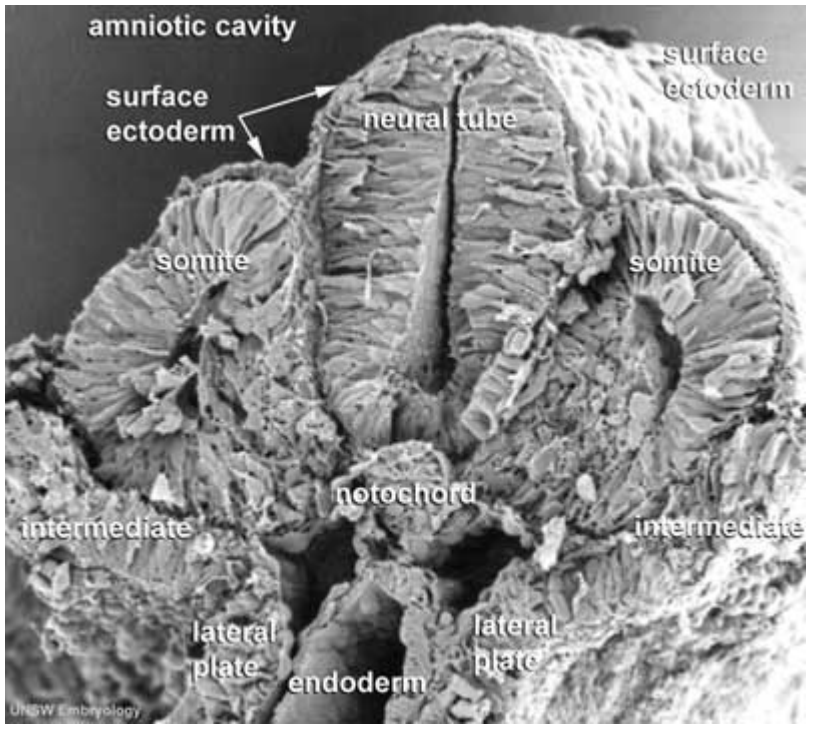
- Somatic and Splanchnic

Coelom, meaning "cavity", and major fluid-filled cavities can be seen to form both within the embryo (|intraembryonic coelom) and outside the embryo (extraembryonic coelom).

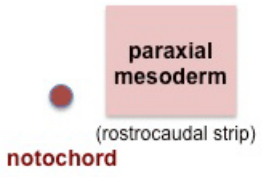
The **intraembryonic coelom** is the single primitive cavity that lies within the mesoderm layer that will eventually form the 3 major anatomical body cavities (**pericardial, pleural, peritoneal**).

Somite initially forms 2 main components

- **sclerotome** - (ventromedial) forms axial skeleton - vertebral body and intervertebral disc
- **dermomyotome** - (dorsolateral) forms dermis and skeletal muscle



- **Somite Cartoons**
-



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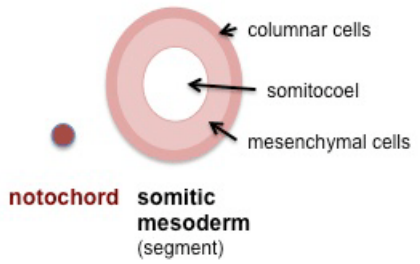
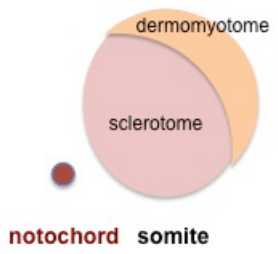




- sclerotome and dermomyotome
- dermatome and myotome
-

Week 4

Week 3 ectoderm - 2 parts

- midline - neural plate (columnar cells) CNS
- lateral - surface ectoderm (cuboidal cells)
  - epidermis of skin, hair, glands, anterior pituitary, teeth enamel
  - head region - sensory placodes

Neuralation

- **Ectoderm**
-
-
-

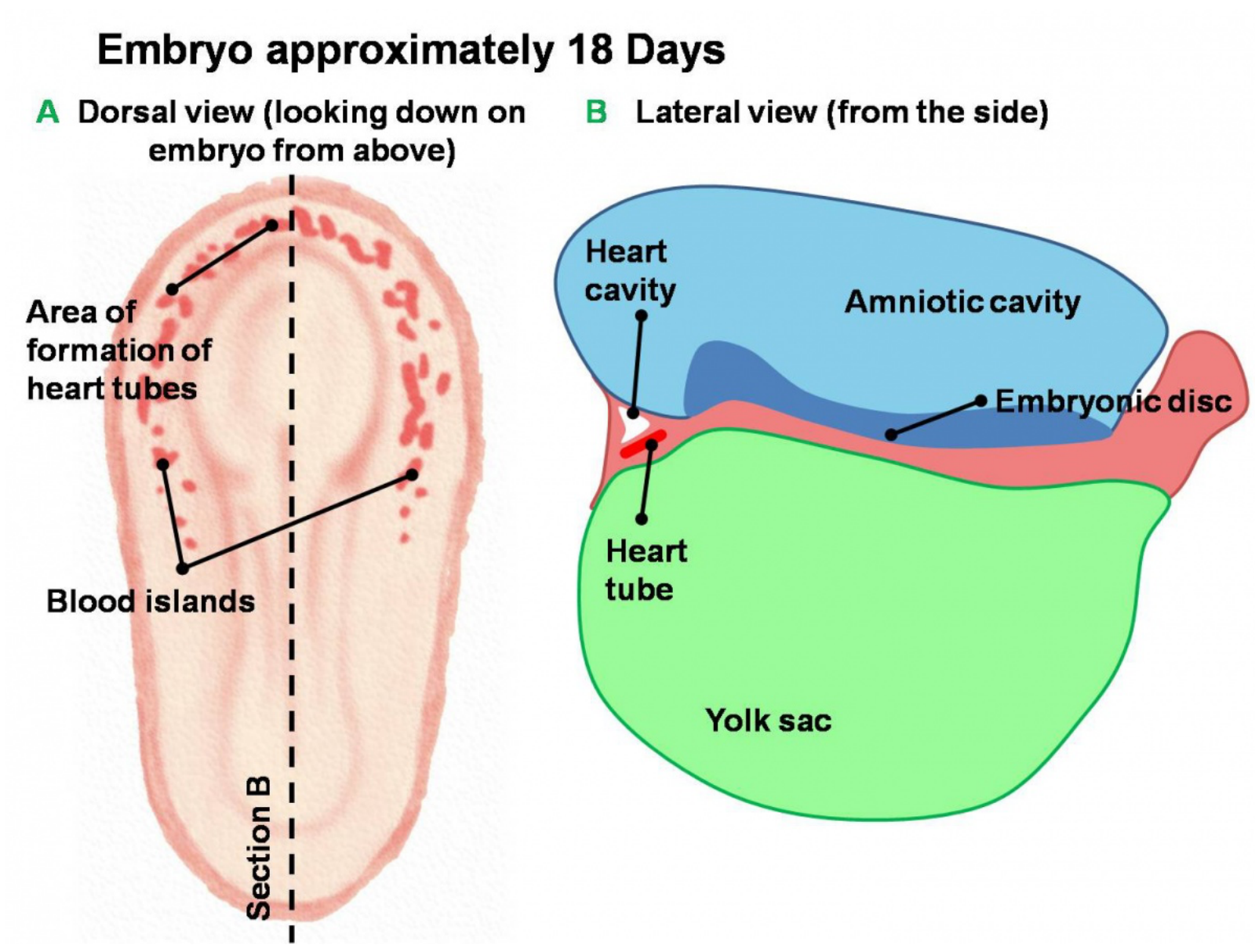
- Neural tube and Neural crest

- extends from buccopharyngeal membrane to primitive node
- forms above notochord and paraxial mesoderm
- neuroectodermal cells
    - broad brain plate
    - narrower spinal cord
- 3 components form: floor plate,neural plate, neural crest

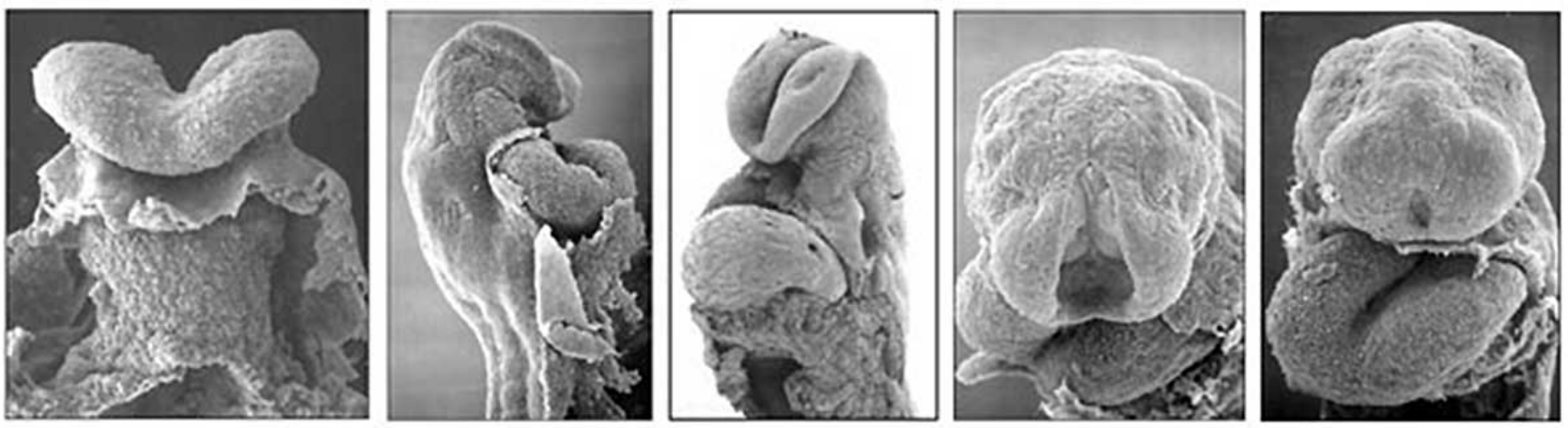
Week 4 Embryo (dorsal view) [Expand]

Links: Neural System - Abnormalities | Folic Acid and Neural Tube Defects

Cardiogenesis



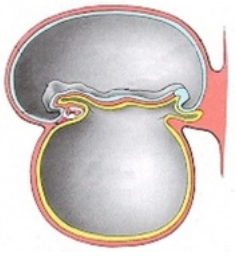
Early Development of Heart Tube



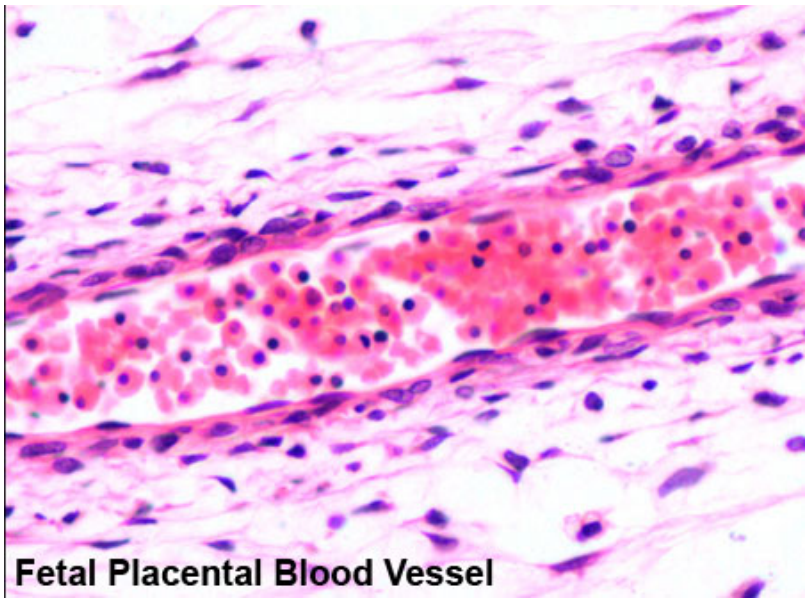
The Human Heart from day 10 to 25 (scanning electron micrograph)

- forms initially in splanchnic mesoderm of prechordal plate region - **cardiogenic region**
  - growth and folding of the embryo moves heart ventrallly and downward into anatomical position
- week 3 begins as paired heart tubes that fuse to form single heart tube
- begins to beat in Humans- day 22-23

Blood Islands



- 2 populations of cells
  - peripheral- form endothelial cells that form the lining of all blood vessels
  - core- form blood cells (haemocytoblasts)
- all vessels (arteries and veins) appear initially the same


Fetal Placental Blood Vessel

Blood Formation

- blood formation from stem cells occurs initially in the extra-embryonic mesoderm of the yolk sac
- then later (week 5) throughout embryonic mesenchyme
- blood stem cells then migrate into the liver
  - then spleen, bone marrow, lymph nodes

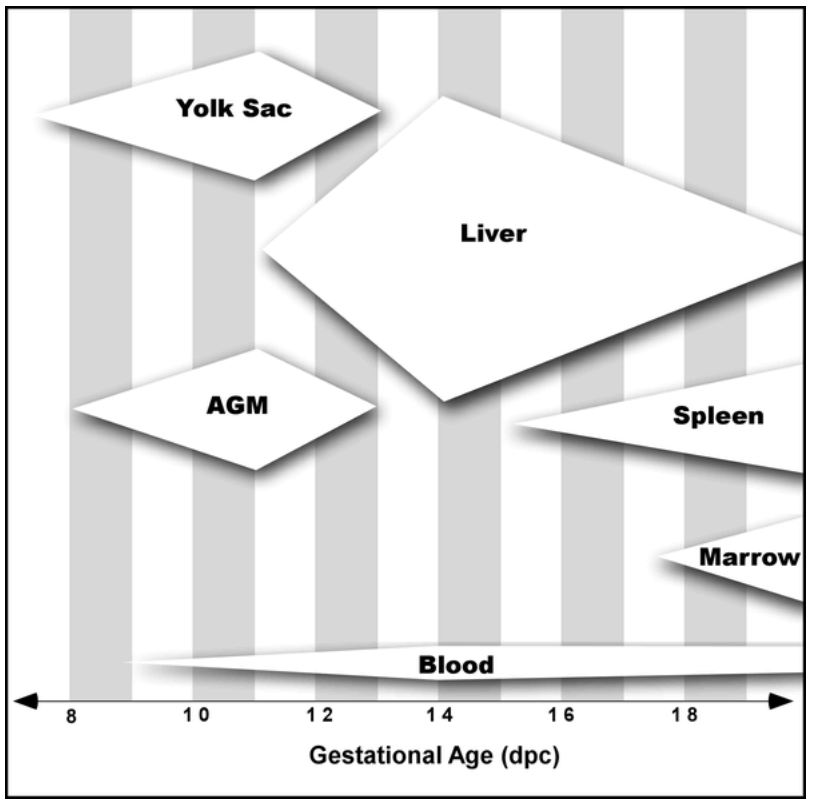
Red Blood Cells

The only cells in the blood are initially entirely fetal red blood cells (RBC).

These red blood cells differ from adult red blood cells in:

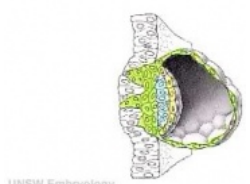
- may remaining nucleated
- contain fetal haemoglobin - has different oxygen and carbon dioxide binding characteristics

Links: Basic Cardiac Embryology



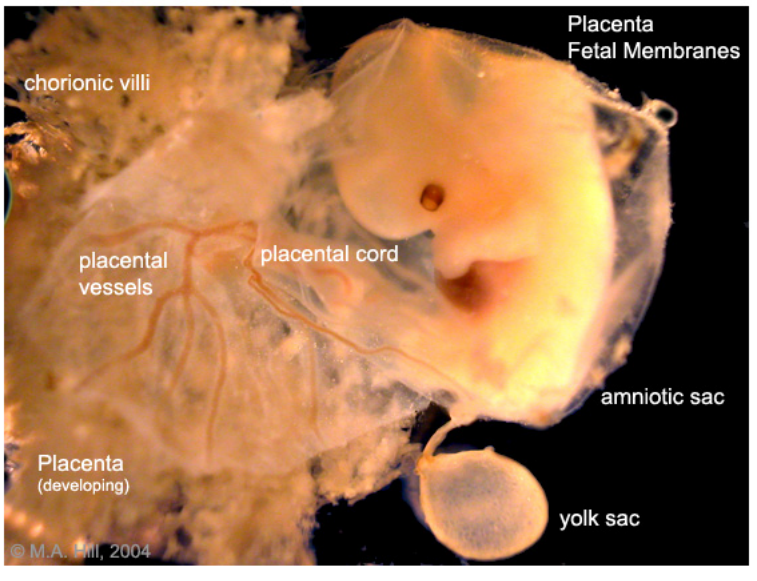
Mouse hematopoietic stem cell location

Early Placentation



The trophoblast layer has now differentiated into two morphologically distinct cellular layers.

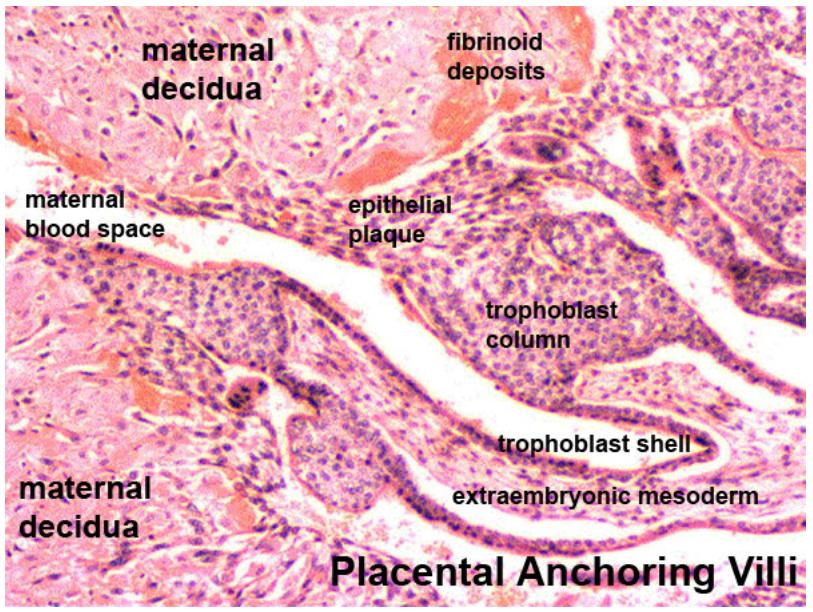
- **Syncitiotrophoblasts** - form a multinucleated cytoplasmic mass by cytotrophoblast cell fusion and both invade the decidua and secrete hCG
- **Cytotrophoblasts** - form a cellular layer around the blastocyst, proliferates and extends behind syncitiotrophoblasts



Placenta and placental membranes

Early Utero-Placental exchange - transfer of nutrition from maternal lacunae filled with secretions from uterine glands and maternal blood from blood vessels. The development of trophoblast villi extending into the

uterine decidua.



There are three stages of villi development:

1. **Primary Villi** - cytotrophoblast
2. **Secondary Villi** - cytotrophoblast + extraembryonic mesoderm
3. **Tertiary Villi** - cytotrophoblast + extraembryonic mesoderm + blood vessels

- Primary chorionic villi
- Tertiary chorionic villi
- Placenta anchoring villi

There are two main types of early villi:

- **Anchoring villi** - attached to decidua
- **Floating villi** - not attached to decidua, floating in maternal lacunae.

Abnormalities

Critical periods, Genetic and Environmental factors leading to abnormal development will be covered in the associated practical classes.

BGDA: Lecture 1 | Lecture 2 | Practical 3 | Practical 6 | Practical 12 | Lecture Neural | Practical 14 | *Histology Support* - Female | Male | Tutorial

Glossary Links

Glossary: A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z | Numbers | Symbols

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