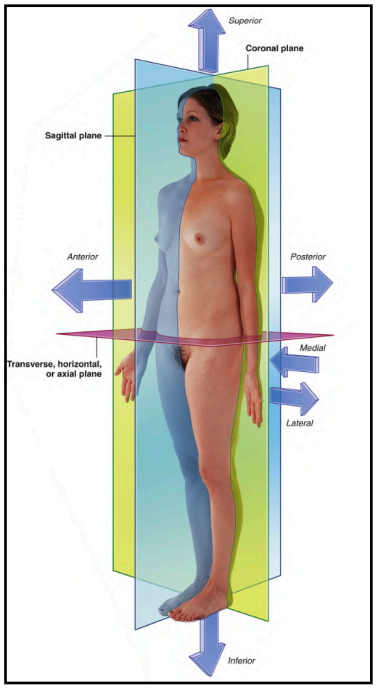


Introduction to Anatomy (W2)

Anatomical Terms and Reasoning(L1)

Anatomical position and terms

- What is the anatomical position and why do we use it?
- Cardinal planes:
  - **Sagittal plane**: divides left from right
    - Midsagittal plane: the absolute midline
    - Parasagittal planes: any over sagittal section
    - Origin: “sagitta” = arrow
  - Frontal/**coronal plane**: divides front from back
    - Origin: “corona” = crown
  - **Transverse**/axial **plane**: horizontally divides up from down

General directional terms

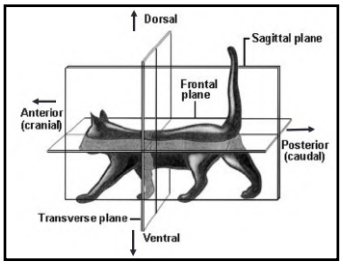
- **Anterior/posterior**: forward and backward
  - In front/behind the animal in the full environment, not just the body itself
  - Think about standing in the middle of an empty room. Nominate one wall as the “front” wall, that is the anterior direction for both quadrupeds (includes human embryo/foetus) and bipeds
- Definition is the same, but application differs
- **Superior/inferior**: up and down (not used for limbs)
  - “Towards ceiling or floor”

Absolute reference point based: A single landmark used as base reference point

- **Dorsal/ventral**: back side and belly side
  - The spine is dorsal to the stomach = the spine is closer to the back compared to the stomach
- **Cranial/caudal**: towards the head and towards the tail
  - The mouth is cranial to the anus = the mouth is closer to the cranial end compared to the anus
- **Medial/lateral**: closer to or further from the midline
  - MOSTLY uses the midsagittal plane as the base reference point
  - Hands and feet have their own ‘midline’ used in their own context
- **Superficial/deep**: close to the external surface or deeper in cross-section
  - The bones of the forearm are deep to the skin
  - Organs of the abdomen are deep to the subcutaneous fat
- **Proximal/distal**: close to trunk or further away (used for limbs, not trunk)
  - The elbow is distal to the shoulder = the elbow is further from the trunk compared to the shoulder

Defining directions in an embryo/foetus

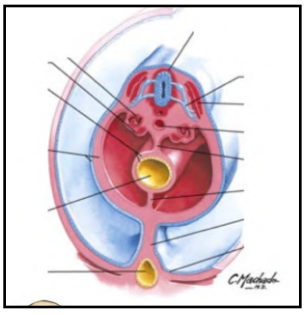
- Embryo/foetal direction terms ≠ adult
- We are **born as quadrupeds (spine is parallel to ground)**
  - Only **bipeds from ~12 months of age**
    - When we actually get about on two limbs, not 4
- **Embryos are considered quadrupeds**
  - Thus, embryonic direction are the same as quadrupedal directions
  - Extremely common cause of lost marks in assessment



The first 3 weeks (L2)

The vertebrate body plan: tube within a tube

- Embryo is folded into first basic morphological form by week 4
  - Tube of **endoderm** (**gut**)
    - Within a tube of **ectoderm** (**skin**)
      - **Mesoderm** creates **space** between gut tube and body tube
- Outlines an ancient pattern shared by all vertebrates
  - Hence, method to the madness



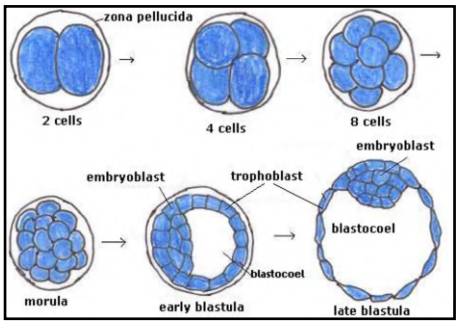
- Outlines common ancestry
- In all Animalia ecto/meso/endo-derm derive similar products

Karl Ernst Von Baer (1792-1876)
- Estonian naturalist
- Described and named the germ layers
- **Discovered each germ layer** services **specific organs**
  - Preserved pattern of **all vertebrates**
- Embryos of different species share profound similarities that aren't observed in respective adults
  - Dissolves eg shells to observe developing beasties
- More closely related species are increasingly similar as embryos

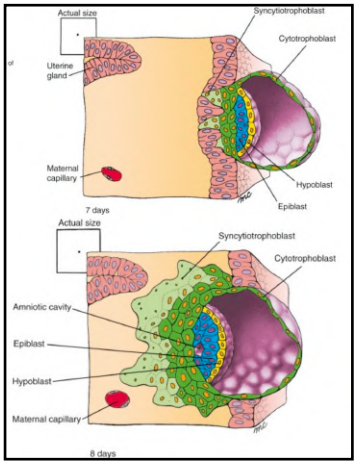
Von Baer laws of embryology
1. **General characteristics** precede **special characteristic** (evolutionarily speaking)
   - **Vertebral column before limbs**
2. **General structural relationships** likewise **precede special appearances**
   - **Head is above shoulders before facial features** arise
3. The **form** of any given embryo **diverges** from others as it develops
   - Embryos look **increasingly different with age**
4. The **embryo** of a **higher animal-form** will **never** resemble the **adult** of a **lower animal form**, such as one less evolved, but **only its embryo**
   - Human embryo will never resemble an adult chicken. But human embryo can resemble a chicken embryo

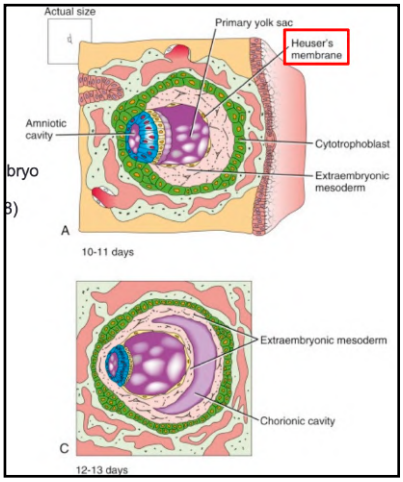
We are starting from here
- **2-celled stage** of cleavage
  - Subsequently produce **4-celled stage**, **8-celled stage**, **morula** (16+ cells), **blastocyst**, implanted blastocyst…
- Skip zygote

Week 1: cleavage and hatching
- Pronuclei —> Zygote ("to pair") —> Morula (16+ cells)
  - AKA Mulberry (originates from morula, latin)
- Series of **mitotic divisions** occurring over 3-4 day period
  - Journey from **ampulla** (distal fallopian tube) to **uterus**
- Incarcerated by the **zona pellucida**: **glycoprotein** layer
  - Cells within **cannot expand** individually
  - Cells called **blastomeres** (cells inside during cleavage)
- Morula has a drink: **becomes blastocyst**
  - **Blastocoel** ("fluid pocket") forms and separates the **inner cell mass (embryoblast) and the outer cell mass (trophoblast)**
- "Jailbreak": **hatching** (enzymatically tunnels out, break down zona pellucida)



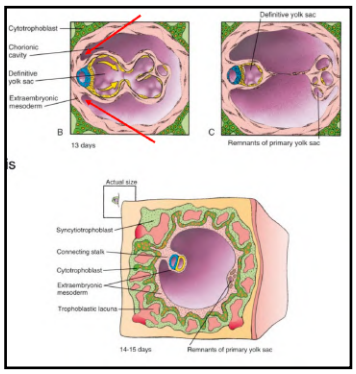
Weel 1: implantation
- Implants into the **endometrium**
- **Trophoblast**: first cells to interface the uterus
  - **Trophoblast** becomes the placenta
    - **Cytotrophoblast** (cyto: cell, tropho: grow/feed, blast: germinate)
    - **Syncytiotrophoblast** (invades and embeds into endometrium)
- **Inner cell mass** (ICM) —> forms the **embryo**
- The syncytium gets to work:
  - **Syncytium** means "**collective**"
  - **Giant multinucleate** cell - one big cell, connected cytoplasm
  - First explorer: searching for **maternal blood and uterine milk (glands)**





Week 2: fully implanted embryo

- 2 primitive germ layers appear between days 6-9
  - **Epiblast** and **Hypoblast** — Bilaminar Embryonic Disk
- **Lacunae** (little lake) of maternal blood and uterine milk form around embryo
- **Extraembryonic mesoderm** (EEM) (area surrounding **chorionic cavity**) and **primary yolk sac** (below hypoblast, ventral) develop (day 8)
  - **Heuser's membrane** (surrounded by EEM) ≠ Hypoblast
    - Surrounds **primary yolk sac**
  - Extra vs intra embryonic cells?
    - Will they contribute to the embryonic disk, or not? NO
  - EEM is formed from **epiblast cells** that migrated
- **Ventral EEM** begins to split - form **chorionic cavity** within EEM
  - Small cavities form in extracellular matrix
  - Later fuse together to form single large cavity — the **chorionic cavity**
- Creates 3 cavities:
  1. **Amniotic cavity** (dorsal)
  2. **Yolk sac** (ventral)
  3. **Chorionic cavity** (most ventral)

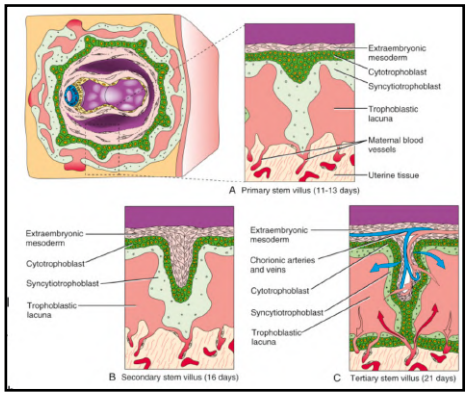


Week 2: bilaminar embryo

- **Epiblast and hypoblast** formed
- **Chorion** continues to **expand**
  - Creates a stalk on dorsal side where epiblast is, impinges on side
    - Creates **connecting stalk of EEM (pink)**
  - Cavity: extraembryonic coelom… remember this
    - AKA **chorionic cavity** - massive
- **Primary yolk sac** (remnants moved to **other side** of chorionic cavity) replaced by **definitive yolk sac**
  - **Definitive yolk sac** is derived from **hypoblast**
    - **Hypoblast** is **extraembryonic**, thus… definitive yolk sac does not contribute to embryo
    - Extraembryonic: not found in the embryo

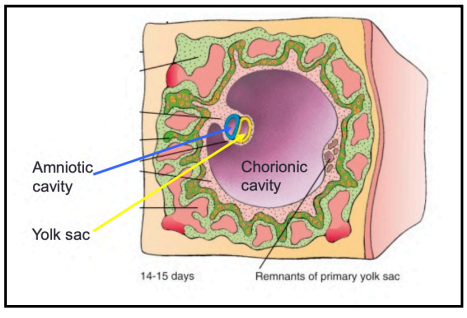
Blood supply

- Big picture: **trophoblast** —> becomes **placenta**
- First 3 weeks embryo survives from diffusion
  - Nutrients from **trophoblastic lacunae**
- Trophoblast create **chorionic villi (pink) - made from EEM**
  - **EEM** carries **foetal blood vessels** into these villi and towards **maternal capillary network**
- More substantial nutrient supply required to support ongoing embryonic growth rate/size
- **Trophoblast cells of chorionic villi create placenta**
  - **Cytotrophoblastic cells** form **basal layers** on foetal and maternal sides of **lacunae** (pit of blood)
  - **Syncytiotrophoblastic cells** form a **multinucleate** and highly **selective barrier**
    - **Maternal:foetal barrier -** blood never mixes directly
    - Nutrients and wastes must diffuse or be transported through



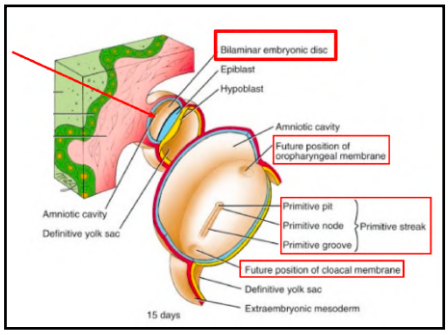
Week 3: gastrulation

- **Gastrulation** is the formation of the **3 embryonic germ layers**
  1. **Ectoderm**
  2. **Mesoderm**
  3. **Endoderm**
- Always note position and relative size of cavities
  - **Amniotic, yolk sac, chorionic** (massive)



- Site: **embryonic disk**
  - Where the **epi/hypo -blast layers are in contact**
- **Epiblast**: omnipotent stem cells - form 3 germ layers
- **Hypoblast**: Makes extraembryonic endoderm

<u>The embryonic disk</u>

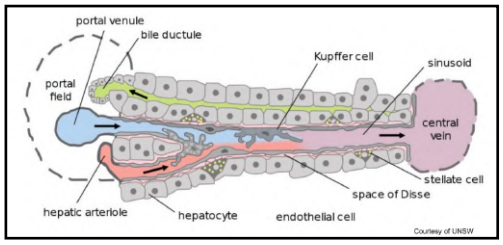


- Bilaminar embryonic disc (**epiblast** and **hypoblast**)
- Future position of **oropharyngeal membrane** (cranial) (between ectoderm and endoderm cranially)
  - Pharynx begins
- Primitive streak: **primitive pit** is within **primitive node** which is at the cranial end of **primitive groove** (epiblast cells)
- Future position of **cloacal membrane/plate** (caudal) — between ectoderm and endoderm caudally
  - Anus forms here
- Sets the first body axes
  - **Cranial/caudal** (oropharyngeal membrane/cloacal membrane)
  - **Dorsal/ventral** (epiblast/hypoblast)

<u>Embryonic mechanisms</u>

1. Proliferate
   - Growth of cell number
2. Differentiation
   - Alter their developmental trajectory
     - Change their minds
3. Migration
   - Cells move from one area to another
4. Induction
   - Change other cells minds
     - **Signal neighbouring cells to differentiate**
     - Modulated by differential **gene expression** (e.g. Hox)
     - Incorrect gene expression can put legs on face of fly (e.g.) or extra pair of wings
5. Combination
   - Most whole organs are formed by **multiple germ layers**

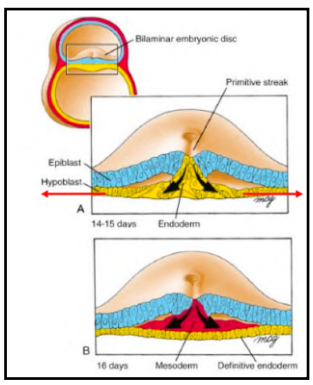
- Induction example: Cerberus protein
  - Cerberus: aka the Hound of Hades
  - Involved in head formation and L/R asymmetry
  - Overexpression leads to ‘ectopic heads’



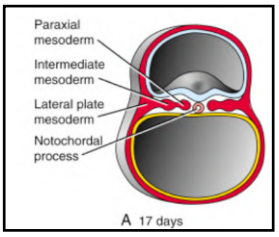
<u>Example of combination: liver</u>

- Most of what is specific to liver is **endodermal**
  - **Biliary system** and **hepatocytes**
- Blood supply and some CT from **mesoderm**
- Nerves invade from **ectoderm**

<u>Process of **gastrulation**: epiblast migrations</u>



- **2 migrations** of **epiblast cells** form **all 3 germ layers**
  - Migration occurs in the **primitive streak** (the **primitive groove**)
- **1st migration** (day **14-15**) - 2 WEEKS
  - **Epiblast** cells migrate and differentiate into **endodermal cells**
    - **Displaces hypoblast** from embryonic disk - **move ventrally**
    - Hypoblast can form extraembryonic tissue, endoderm can’t
- **2nd migration** (day **16**)
  - **Epiblast** cells migrate and differentiate into **mesodermal cells**
  - Already have definitive endoderm
    - **Remaining** surface **epiblast differentiates into ectoderm**
      - **Mesoderm** separates **ectoderm from endoderm**
        - Except for the oral and cloacal membranes:

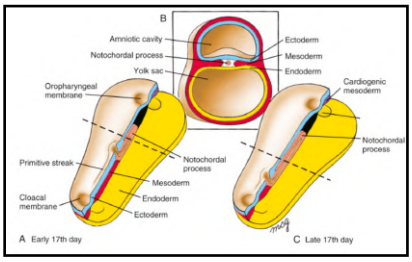


- **Ectoderm** and **endoderm** are in **direct contact here (cran/caud)**

Mesodermal development and divisions (day 16-17)

- Mesoderm proliferates, differentiates and migrates, forming;
  1. **Axial mesoderm** -> the **notochord**
  2. **Paraxial mesoderm** -> **somites**
  3. **Intermediate mesoderm** -> '**paired glands**' e.g. adrenal glands, kidneys
  4. **Lateral plate mesoderm** -> **body wall** and **gut tube wall**
     - Also creates the **heart**, cardiogenic centre cranial to oropharyngeal membrane
     - **Brain** forms caudally to oropharyngeal membrane

Mesodermal development and the notochord (day 17)

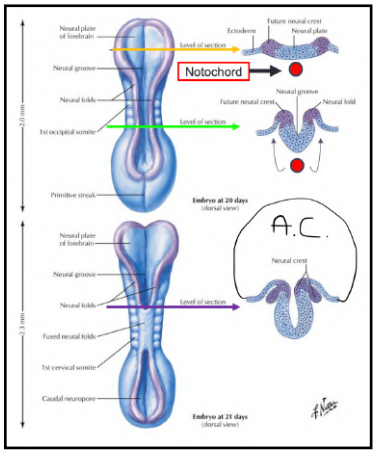


- **Mesoderm** from **primitive pit** differentiates to form the **notocord**
- A body plan signal integrator
  - Analogy: orchestral conductor - dictates which cells become which tissue
- Notochord **grows cranially**
  - Defines both axes
    - Cranial/caudal and L/R

Neurulation: neural tube formation

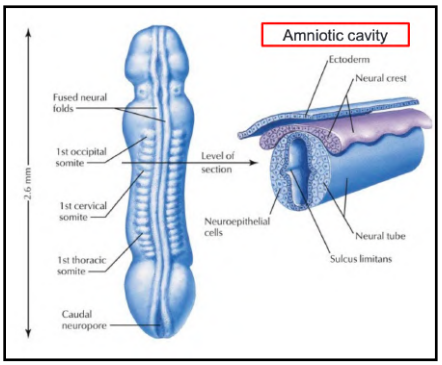
- Where are the cavities

1. **Neural plate** formation (D18)
   - **Notochord** induces overlying **ectoderm to proliferate and differentiate**
2. **Plate** begins to **fold** (D18)
   - Creates **neural groove** between neural folds (thick ectoderm), surrounded by **neural fold** which will form **neural crest**
   - Partially due to expanding mesoderm
3. Folds begin to **fuse** (D21-22)
   - Fusion in both directions
   - Forms the **neural tube and canal**
   - Openings at each end called **neuropores**
     - Will eventually seal cranially and caudally
   - Note the change in length (~15%)
   - Neural crests start to migrate away and form PNS
   - Amniotic cavity is dorsal to neural tube

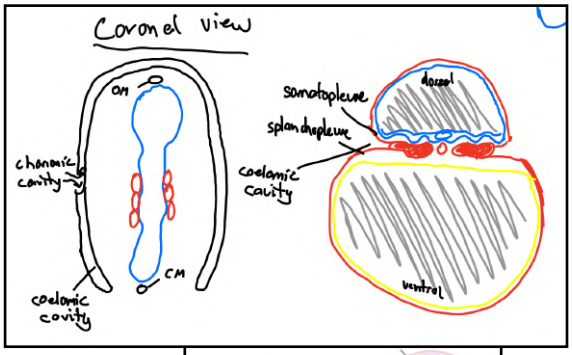


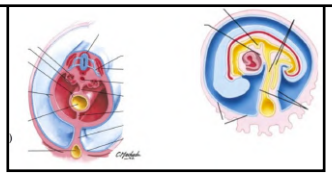
Neurulation: formation of neural tube

- Beginnings of different ectodermal development trajectories
  1. **Tube cells** (surrounding the canal) - form brain and spinal cord
  2. **Crest cells** (migrate to form PNS and are signalling cells)
  3. **Surface cells** (epidermis) - "ectoderm" in photo
- Basics:
- 'Neural crest cells' (NCC) migrate to neighbour the tube
  - **Peripheral nervous system**, and work as **signalling cells**
- Surface ectoderm -> **epidermis** and other stuff
- Neural tube -> **brain and spinal cord** (CNS)
- Failure of pores to close results in;
  - **Caudal** pore closure failure: **spina bifida**
  - **Cranial** pore closure failure: **anencephaly**



Creating a body - ‘tube within a tube’ (W3)

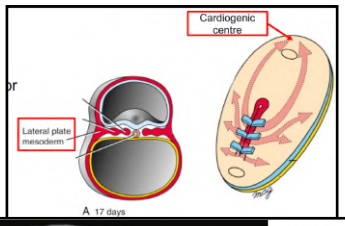


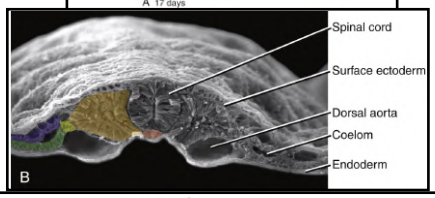


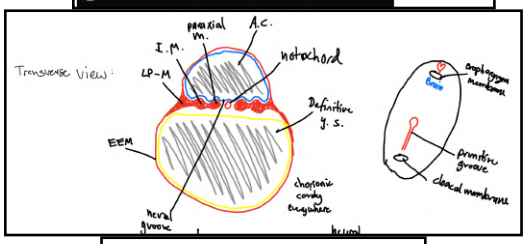
Folding (L1)

Folding

1. Turn **2 spheres and 3 tissue layers (endoderm, mesoderm, ectoderm)** into a **tube** with a series of **other tubes** in kit
   - **Embryo** currently **sitting** mostly within the **chorionic cavity (big)**
2. **Amnion ‘rolls’** over the top of the **yolk sac** and creates the **body wall:**
   - Drags a piece of **LP-mesoderm** with it
     - Embryo now sitting primarily in **amniotic cavity**
3. **Yolk sac** gets **pinched** into a ‘stalk’ by the movement of the amnion
   - From both lateral and head to tail directions
   - Makes it a strange T-shaped cavity
4. Results: tube within a tube, with space in between
   - **Tube** lined on the inside by **endoderm** (gut tube)
     - Yellow/red wall - splanchnopleure
   - **Within a tube** lined on the outside by **ectoderm** (body well)
     - Red/blue wall - somatopleure
   - With ‘**space**’ lined by **mesoderm** in between (coelom: pleura, pericardium, peritoneum)

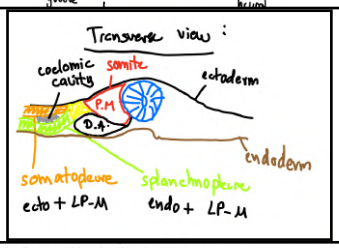






Mesoderm and the coelomic spaces

- Where is the chorionic cavity (extraembryonic cavity)
  - **Lateral plate mesoderm** (LP-M) forms a looped shape on the embryo
    - migrates cranially
    - **Cardiogenic centre** at apex of ‘loop’
    - Brain is caudal to OM.
    - Diaphragm is cranial to heart
  - **Intraembryonic coelom** (coelomic cavity/coelom) - in LP-M
    - Eventually split LP-M in two
  - **Amniotic cavity and yolk sac is covered by EEM.** Everything **around the EEM is chorionic cavity**
  - Lateral plate has 2 components (split by coelomic cavity)
    1. **Somatopleure**: **LP-M fused to ectoderm “bodywall”**
       - Meaning: Somato - body; pleure - wall
    2. **Splanchnopleure**: **LP-M fused to endoderm “gutwall”**
       - Meaning: Splancho - entrails/guts; pleure - wall
       - Alternative: visceropleure



Mesoderm and the coelomic spaces

- They begin to ‘bubble’ and split (day 19-21)
  - Starts as isolated spaces (bubbles) made by serous (fluid) secreting cells
  - Bubbles fuse and form a ‘horseshoe-like’ space in the LP-M
    - **Horseshoe-like space** = **intraembryonic coelom** (AKA **coelomic cavity**)
    - Coel: means cavity
    - ‘Potential space’ around the future thoracic and abdominal viscera
    - Opens to **chorionic cavity** in the **umbilical region** (the extraembryonic coelom)

