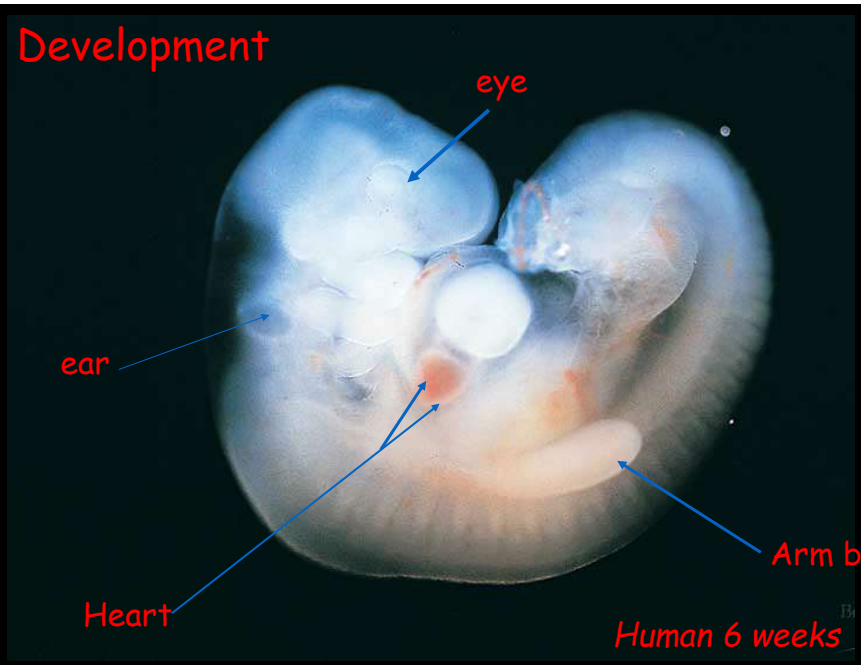
SLE 132 – Form and Function
Development

DEAKIN COLLEGE in association with DEAKIN UNIVERSITY AUSTRALIA



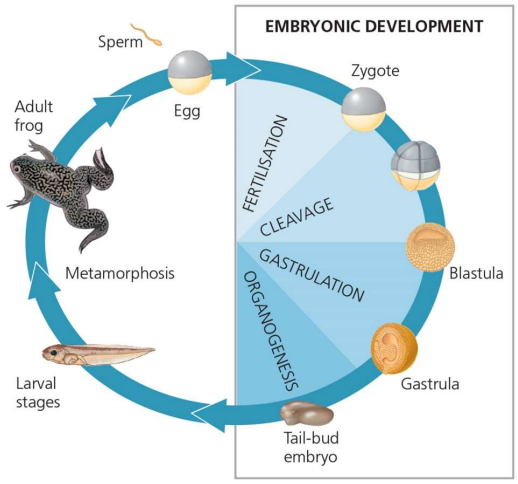
Learning Objectives

- Understand how embryonic development involves cell division, differentiation and morphogenesis
- Describe the changes induced by fertilisation
- Describe how a blastula is formed
- Describe the process of gastrulation and identify the three tissue layers that are formed
- Describe pattern formation and organogenesis

Sea Urchin Development

https://www.youtube.com/watch?v=NXX578SYE4E

Development



▲ **Figure 47.2** Developmental events in the life cycle of a frog.

Fertilization

- Activates egg and brings together nuclei of sperm and egg

Embryonic Development

- Cell division → different cells → different environments
- Differential gene expression → cell differentiation
- Differential morphogenesis

Development starts with fertilization: Sea Urchin

- Fertilization:
  - sperm(n) + egg (n) -> diploid zygote (2*n*)
  - the sequence of events in fertilization:

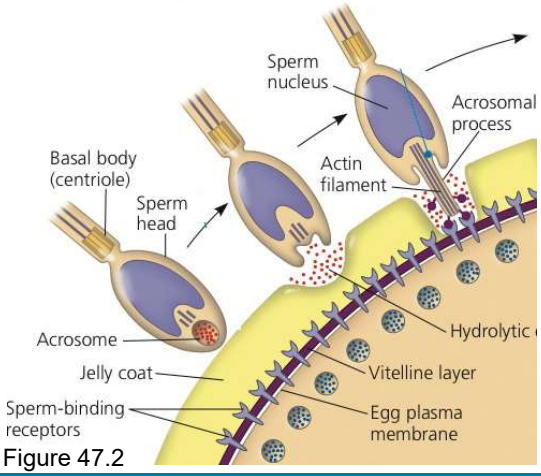


Figure 47.2

1. **Contact** – sperm makes contact with jelly coating on egg
2. **Acrosomal reaction** – enzymes released from sperm form hole in jelly coat of egg
3. **Actin filaments** grow and bind to receptors on egg
4. Contact and fusion of sperm and egg membranes – **membrane depolarizes**

The Acrosomal reaction

- Membrane potential of egg changes
  - Depolarization prevents additional sperm fusing with plasma membrane of the egg
  - Reaction only lasts a few minutes
  - Referred to as **a fast block** to polyspermy (prevention of multiple sperm fertilizing egg – important in maintaining correct number of chromosomes in zygote)

Development starts with fertilisation

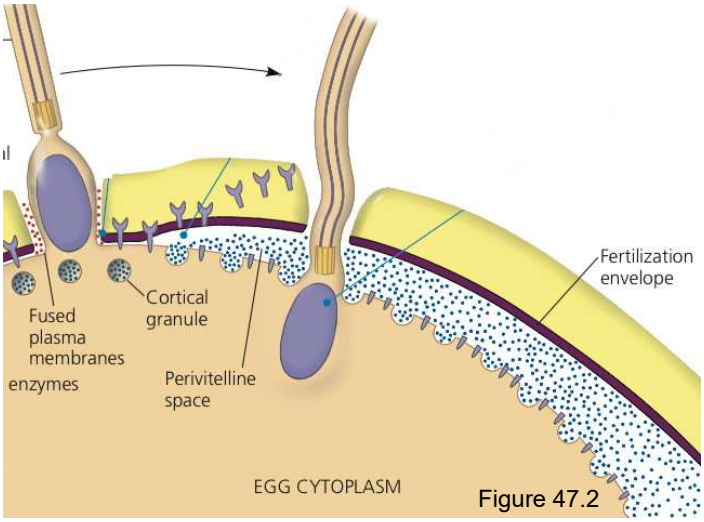


Figure 47.2

5. Entry of the nucleus from sperm
6. **Cortical reaction** – fusion of gametes triggers release of Calcium from ER

Cortical reaction

- Cortical granules fuse with membrane, releasing contents between vitelline space and membrane of egg.
  - Separates membranes
  - Osmotic gradient
  - Enzymes harden vitelline layer – physical barrier

- **Slow block** to polyspermy

Cortical reaction

- Ca^{2+} released into the cytoplasm from ER (endoplasmic reticulum)
- Release of Ca^{2+} begins from the site of entry of sperm – propagates in a wave across the fertilised egg

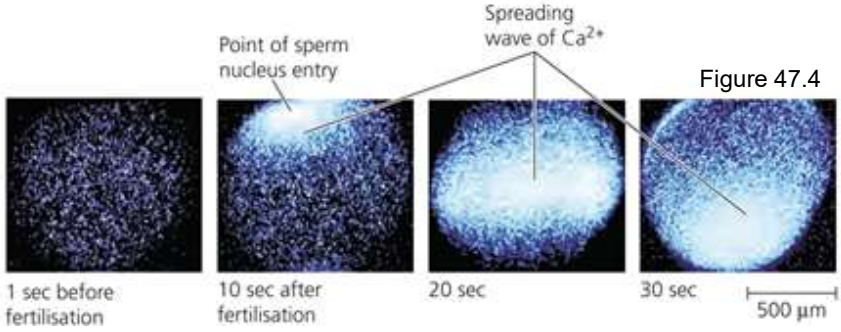


Figure 47.4

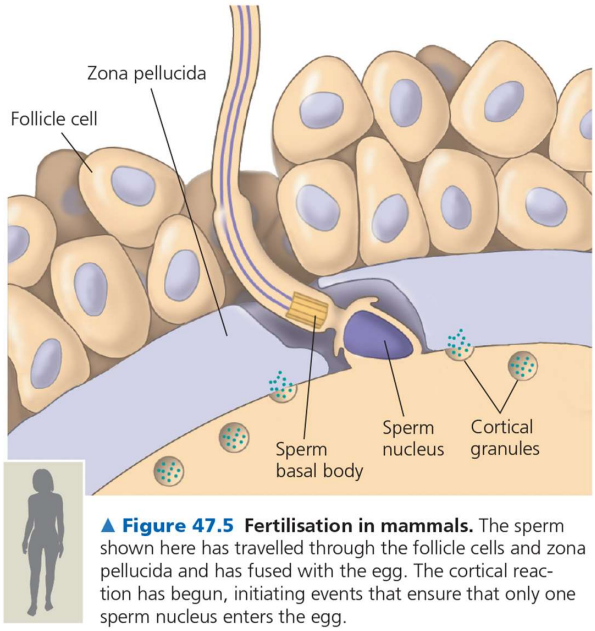
https://www.youtube.com/watch?v=T6BtSMerBmw

Mammals

- Mammalian egg surrounded by follicle cells
- **Zona Pellucida** – extracellular matrix of the egg (functions as a receptor for sperm)

Binding of the head induces an **acrosomal reaction** – punches a hole in the zona pellucida allowing the sperm cell to reach cell membrane of egg

No fast block to **polyspermy** –
ONLY SLOW BLOCK
- no change in membrane potential

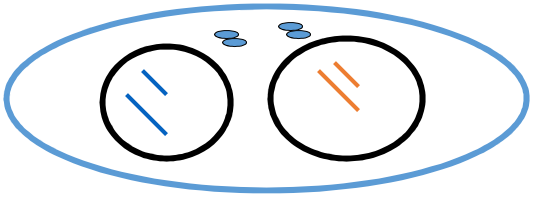


▲ **Figure 47.5 Fertilisation in mammals.** The sperm shown here has travelled through the follicle cells and zona pellucida and has fused with the egg. The cortical reaction has begun, initiating events that ensure that only one sperm nucleus enters the egg.

- Binding of sperm cell to plasma membrane of egg – starts cortical reaction
- Cortical granules release enzymes – catalyse reaction of the zona pellucida = <u>slow block to polyspermy</u>
- Whole sperm – tail and all taken into the egg which lacks a centrosome
- Centrosome forms around the centriole which comes from the basal body of flagellum of sperm.

Fertilisation in mammals doesn't happen immediately

- Occurs over 12-36 hours
- Nuclei stay distinct initially in mammals
- Nuclear membranes disperse
- Chromosomes all attach to spindle fibres

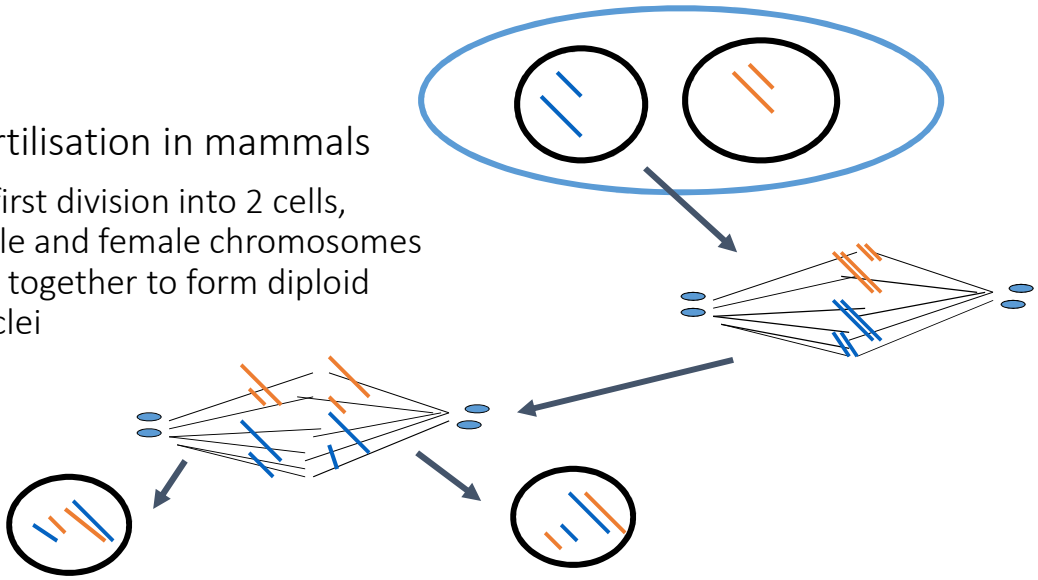


- Only when daughter cells form do we see diploid cells

2 haploid nuclei (from sperm & egg in zygote)

Fertilisation in mammals

at first division into 2 cells, male and female chromosomes get together to form diploid nuclei



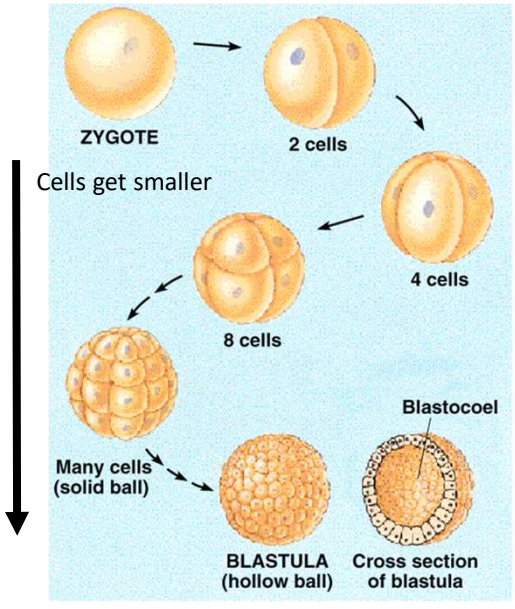
Differences in fertilization process between mammals and sea urchins

- In Mammals
  - Fertilization is generally internal
  - Entire sperm enters egg
  - No fast block to polyspermy
  - Two sets of chromosomes (one from each gamete) only come together after first cell division
  - Fertilization process in mammals is slower (12 – 36 hrs) than sea urchin (90 min)

Cleavage

In a multi cellular organism the fertilised cell gives rise to all other cells of the organism through successive **mitotic** cell divisions

- This process is referred to as cell cleavage.
- With each division, the number of cells doubles.
- **Cells get smaller with each division.**
- **Ends up as a ball of cells**
- **Embryo does not enlarge during this stage**



Cleavage

(a) Fertilised egg. Shown here is the zygote shortly before the first cleavage division, surrounded by the fertilisation envelope.

(b) Four-cell stage. Remnants of the mitotic spindle can be seen between the two pairs of cells that have just completed the second cleavage division.

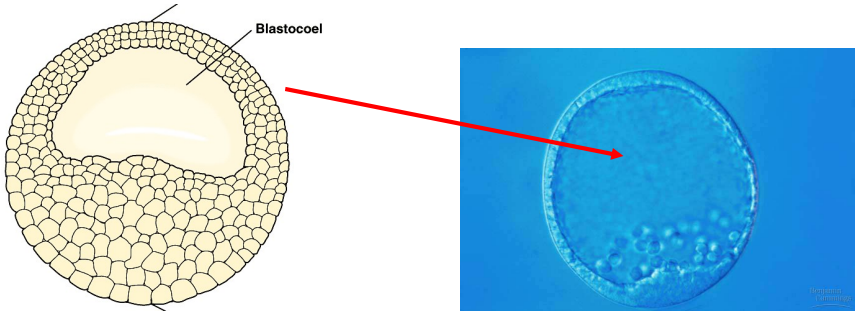
(c) Early blastula. After further cleavage divisions, the embryo is a multicellular ball that is still surrounded by the fertilisation envelope. The blastocoel has begun to form in the centre.

(d) Later blastula. A single layer of cells surrounds a large blastocoel. (Although not visible here, the fertilisation envelope is still present at this stage.)

▲ **Figure 47.6** **Cleavage in an echinoderm embryo.** Cleavage is a series of mitotic cell divisions that transform the fertilised egg into a blastula, a hollow ball composed of cells called blastomeres. These light micrographs show the cleavage stages of a sand dollar embryo, which are virtually identical to those of a sea urchin.

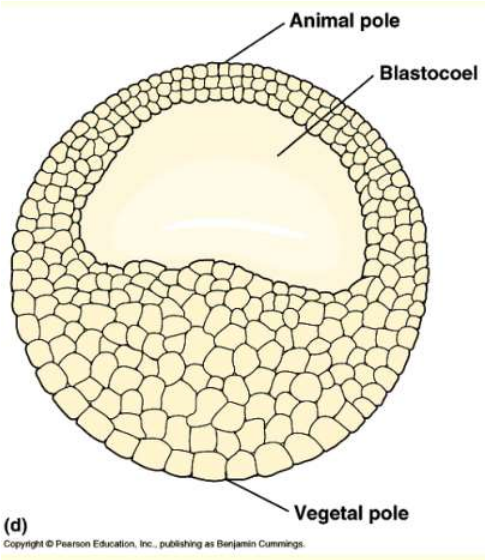
Cell cleavage creates a Blastula

- The ball of cells develops a hollow inside, and is now a **Blastula** (Blastocyct in humans)
- The blastula consists of a one or more layers of cells surrounding a fluid-filled cavity, called the **Blastocoel**



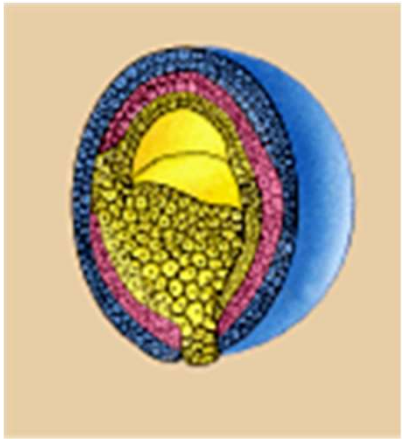
Blastula

- Blastula has 2 poles
  - **Animal pole** (which has smaller cells)
  - **Vegetal pole** (*NOT* vegetable… *Latin vegetāre* to quicken)
    - larger cells here that contain yolk granules
- Different parts contain different chemicals which determine the type of cells that will develop



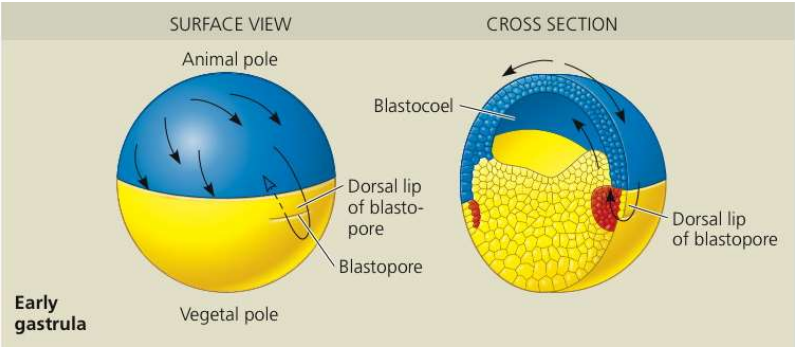
Formation of the Gastrula "gastrulation"

- Cells rearrange to form a 3 -layered embryo
  - except for 2-layered invertebrates
- 3 layers:
  - Ectoderm - outer layer of gastrula
  - Endoderm – forms an embryonic digestive tract
  - Mesoderm – middle layer



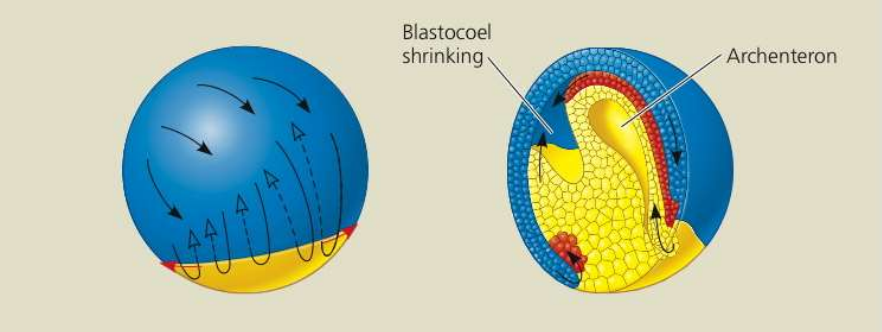
- Each layer develops into different parts of the adult animal.

Blastopore formation



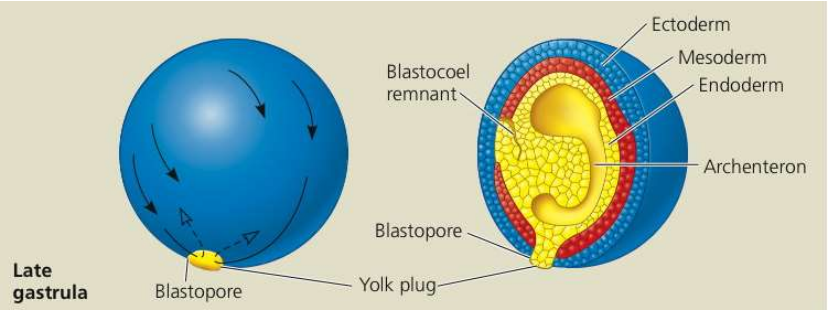
- The beginning of gastrulation
- A small groove (the blastopore) forms on one side of the **blastula**
- The blastopore is the place where cells will move inward from the surface of the embryo

Gastrulation cont.



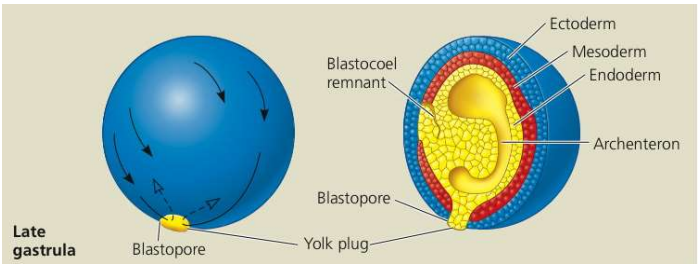
- Cells migrate to form the 3 cell layers
- The blastocoel is shrinking
- A very simple digestive cavity forms - called the archenteron
- The ectoderm and the endoderm are being separated by another group of cells, the mesoderm.

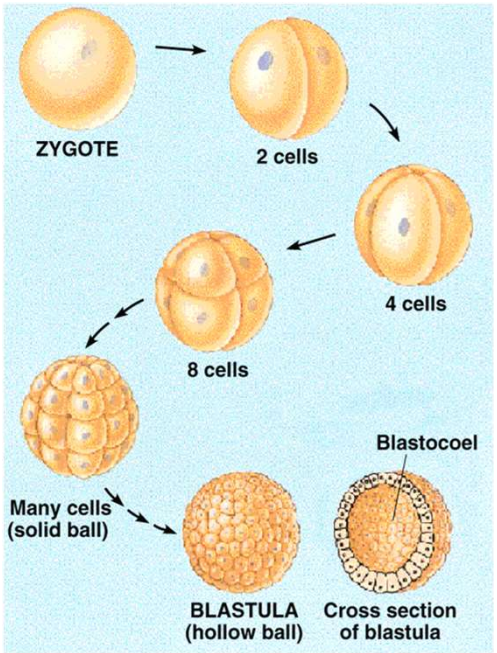
Gastrulation is completed



- The embryo is now called a **Gastrula**
- The 3 cell layers are established
- Ectoderm now completely covers the gastrula except for the yolk plug (endoderm) – this forms the anus (in frog)
- The blastocoel has gone – replaced with archenteron and endoderm.
- The mesoderm is now fully formed between the ectoderm and endoderm.

1.Cleavage of the **Zygote** leads to **Blastula.**
2.Blastopore formation
3. **Gastrulation –**
Cells migrate to form the 3 cell layers
4. Gastrulation is completed
(Embryo is a form of a **Gastrula**)





▼ **Figure 47.9** Major derivatives of the three embryonic germ layers in vertebrates.

ECTODERM (outer layer of embryo)	MESODERM (middle layer of embryo)	ENDODERM (inner layer of embryo)
• Epidermis of skin and its derivatives (including sweat glands, hair follicles) • Nervous and sensory systems • Pituitary gland, adrenal medulla • Jaws and teeth • Germ cells	• Skeletal and muscular systems • Circulatory and lymphatic systems • Excretory and reproductive systems (except germ cells) • Dermis of skin • Adrenal cortex	• Epithelial lining of digestive tract and associated organs (liver, pancreas) • Epithelial lining of respiratory, excretory, and reproductive tracts and ducts • Thymus, thyroid, and parathyroid glands

DEAKIN COLLEGE

Quick Question

1. During Fertilization, the acrosomal contents:

a. Help propel more sperm toward the egg
b. Digest the protective coat on the surface of the egg
c. Nourish the mitochondria of the sperm
d. Trigger the completion of meiosis by the sperm

DEAKIN COLLEGE

Quick Question

2. The archenteron of the developing frog eventually develops into which structure?

a. Reproductive organs
b. The blastocoel
c. Heart and lungs
d. Digestive tract

Quick Question

3. After gastrulation, the outer-to-inner sequence of tissue layers in a vertebrate is:

a. endoderm, ectoderm, mesoderm
b. Mesoderm, endoderm, ectoderm
c. Ectoderm, mesoderm, endoderm
d. Endoderm, mesoderm, ectoderm

Frog Development

https://www.youtube.com/watch?v=dXpAbezdOho

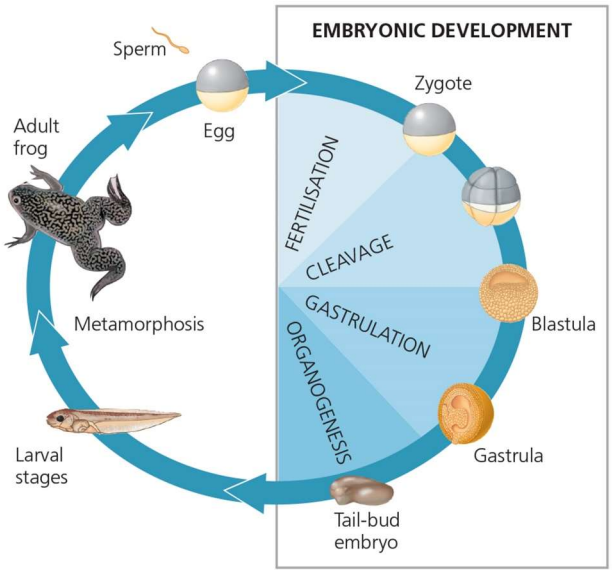
Development

Gastrulation

Mass movement of cells

Organogenesis

More localised changes in cells



▲ **Figure 47.2** Developmental events in the life cycle of a frog.

Formation of organs – "organogenesis"

Different cell layers give rise to different tissues and organs

Here we see the **ectoderm infolding** and giving rise to structures such as the brain and spinal chord.

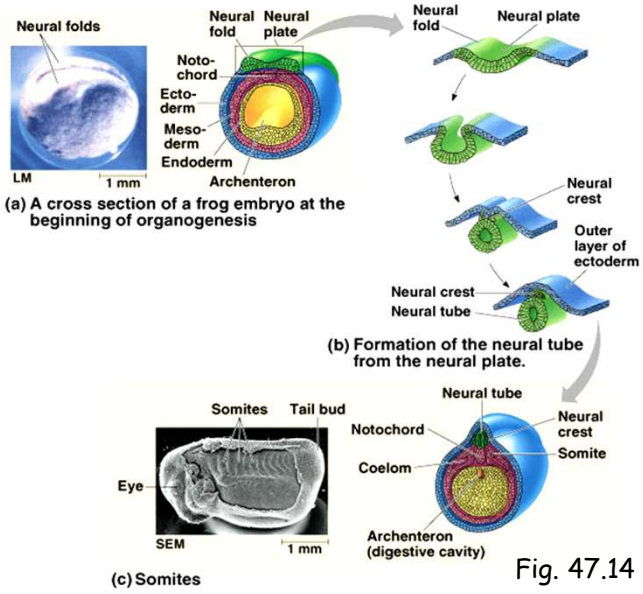
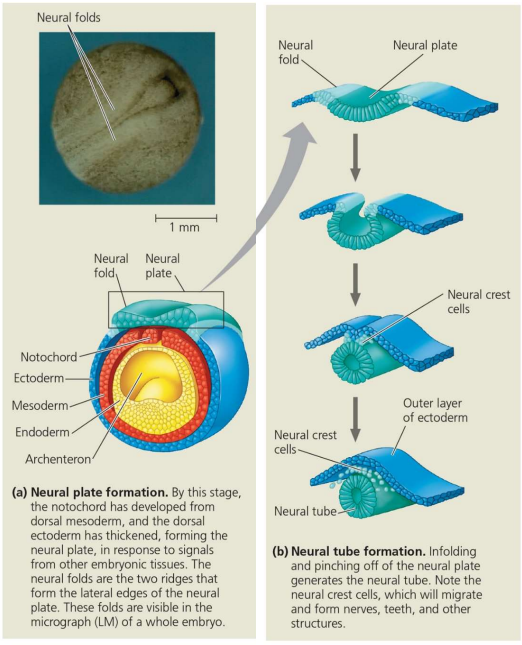


Fig. 47.14

Neurulation is the first step in the formation of the brain and spinal cord in vertebrates

1. **Notochord** (rod that extends along the dorsal side of the chordate embryo) develops from the cells of the dorsal mesoderm.
2. These and other cells secrete signalling molecules that induce the nearby ectodermal cells to form the **neural plate.**
3. The neural plate change shape and punch off form the ectoderm to form the **neural tube**. The neural tube becomes the **brain and spinal cord.**



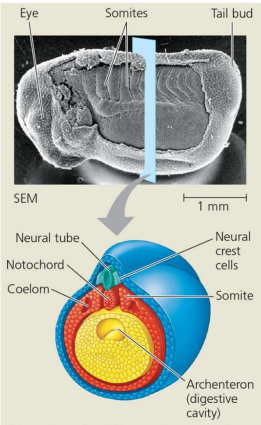
Neurulation is the first step in the formation of the brain and spinal cord in vertebrates

4. Neural Crest cells migrate to various parts of the embryo for form peripheral nerves, teeth parts of the skull etc

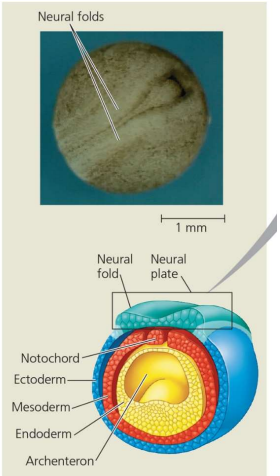
5. **Mesodermal cells** adjacent to the notochord **migrate** and separate into blocks of cells called somites.

Somites are arranged serially along both sides of the anterior/posterior axis, play a major role in organising the segmented structures of the vertebrate embryo

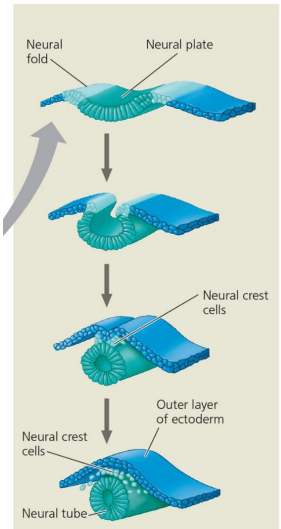
Somite-derived cells migrate and give rise to segmented structures e.g vertebrae, muscles



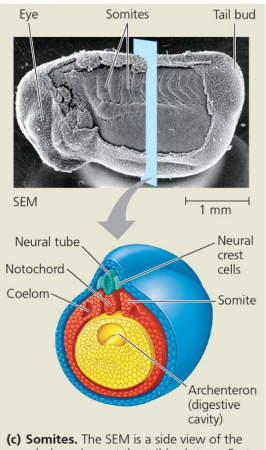
(c) Somites. The SEM is a side view of the whole embryo at the tail-bud stage. Part of the ectoderm has been removed to reveal the somites, blocks of tissue that will give rise to segmental structures such as vertebrae. The drawing shows a similar-stage embryo after formation of the neural tube, as if the embryo in the SEM were cut and viewed in cross-section. By this time, the lateral mesoderm has begun to separate into two tissue layers that line the coelom, or body cavity. The somites, formed from mesoderm, flank the notochord.



(a) Neural plate formation. By this stage, the notochord has developed from dorsal mesoderm, and the dorsal ectoderm has thickened, forming the neural plate, in response to signals from other embryonic tissues. The neural folds are the two ridges that form the lateral edges of the neural plate. These folds are visible in the micrograph (LM) of a whole embryo.



(b) Neural tube formation. Infolding and pinching off of the neural plate generates the neural tube. Note the neural crest cells, which will migrate and form nerves, teeth, and other structures.



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Formation of organs – "organogenesis"

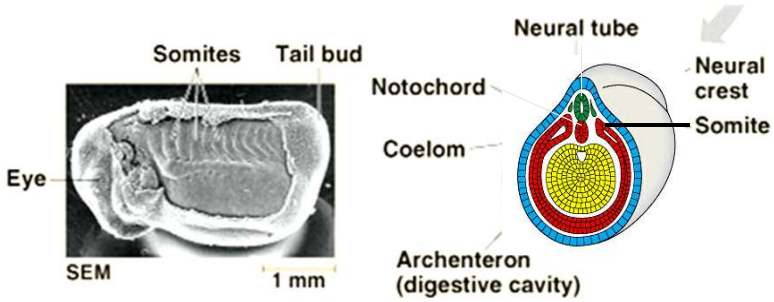

Fig. 47.14

- **Neural Tube** – develops from an in-folding of the ectoderm – will develop into the brain and spinal cord
- **Notochord in mesoderm** - will develop into the backbone/spinal column
- **Coelom** – the internal body cavity – this and the body parts that are constructed of repeating units (i.e. segmented) are basic features of chordates
- **Somites** – blocks of mesoderm that give rise to segmented structures e.g. vertebrae, muscles

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• Epidermis of skin and its derivatives (including sweat glands, hair follicles) • Nervous and sensory systems • Pituitary gland, adrenal medulla • Jaws and teeth • Germ cells	• Skeletal and muscular systems • Circulatory and lymphatic systems • Excretory and reproductive systems (except germ cells) • Dermis of skin • Adrenal cortex	• Epithelial lining of digestive tract and associated organs (liver, pancreas) • Epithelial lining of respiratory, excretory, and reproductive tracts and ducts • Thymus, thyroid, and parathyroid glands

In pairs or small groups construct a flow diagram of Embryonic development.

Include the four stages: fertilisation, cleavage, gastrulation and organogenesis, and the structures at each stage.