K12 Comparative Embryology

All human and animal embryos go through very similar stages of early development. See also Humans and Animal Embryology.

What are the key things in development that we share?

This page introduces a few of the concepts of comparative development shared with all animals.

> Ernst Haeckel (1834 – 1919) "ontogeny recapitulates phylogeny" claimed that an individual organism's biological development (ontogeny), parallels and summarises its species evolutionary development (phylogeny). First a single-celled organism, then evolve into a fish, then an amphibian, then a reptile, then a bird, and finally reach a mammal.
>
> Current developmental biology shows that animals follow similar developmental programs, but do not go through a "species change" during development.

Meiosis | Mitosis | Gastrulation | Body Plan | Limbs | Tissue Development | Organ Development

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Teacher Note

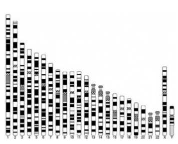
Meiosis

In the male and female in all animals (and plants) that reproduce sexually to form an embryo, these very first cells form by meiosis. Meiosis a reductive form of cell division that only occurs in the egg (oocyte) and sperm (spermatozoa)	

and allows new genetic combinations of offspring to be generated.

Meiosis has 2 key components:

1. Genetic reorganisation - the genetic material (chromosomes) that you have from your mother and father are recombined.
2. Genetic reductive - the chromosome number is halved and only fertilisation will allow the paired chromosomes that we all contain in all our cells.



Meiosis in all mammals:

- Female embryo **XX** - X chromosome from egg and X chromosome from sperm
- Male embryo **XY** - X chromosome from egg and Y chromosome from sperm
- Both male and female embryos - get the recombined 22 autosomes and the mother's mitochondrial DNA

This movie shows the egg (oocyte) completing the first part of meiosis (meiosis I). The chromosomes are coloured blue, the cell membrane is green. The small structure on the left are chromosomes that will not be used in the embryo.

Mitosis

Mitosis is the type of normal cell division that allows growth and development of all animal embryos.

After the first cell has been formed by the egg (oocyte) and sperm (spermatozoa) fusing, every cell division in the embryo forms 2 genetically identical daughter cells. Every mitosis in all animal cells has the same features.

Mitosis has 2 key components:

1. Chromosome duplication - has to occur before cell division can occur.
2. Mitosis - a set of 5 standard phases dividing the nucleus (and the chromosomes it contains) before the cytoplasm divides.

Mitosis is a biological process that is the same (evolutionarily conserved) in all plants and animals.

This movie shows a cell that has already begun mitosis separating the chromosomes in the nucleus then the cell cytoplasm. The chromosomes are white.

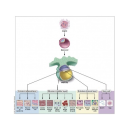
Gastrulation

Development of any animal requires the differentiation of different cell types and tissues from essentially the same initial cells. One of the first shared steps is the process of "gastrulation" (means gut formation). This forms the 3 cell layers that will form all the embryo, they are often described as the "germ layers" and this stage of development as the "gastrula". The same layers form the same structures in all these animals.

3 Germ Layers:

1. **Ectoderm** - outer layer of skin (epidermis) and nervous system (central nervous system and peripheral nervous system).
2. **Mesoderm** - bone, muscle, cartilage, blood (connective tissues)
3. **Endoderm** - lining of the gut, lungs, endocrine organs.

Gastrulation is a process that occurs in nearly all animals and each germ layer contributes the same body components to all animal embryos.



Body Plan

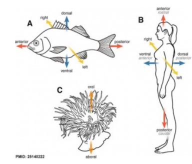
The next step in development of any animal requires the embryo body plan (axes) by a patterning process.

Body plan (axes)

1. head and body
2. left and right side
3. front and back

Many signals used to establish this patterning have been identified and are shared (similar or the same) between different animals. Note that some of the signals used to establish the overall body plan can be reused later at other stages in embryo development and within the body organs and tissues.

Body plan genes and signaling pathways are similar for all animals.

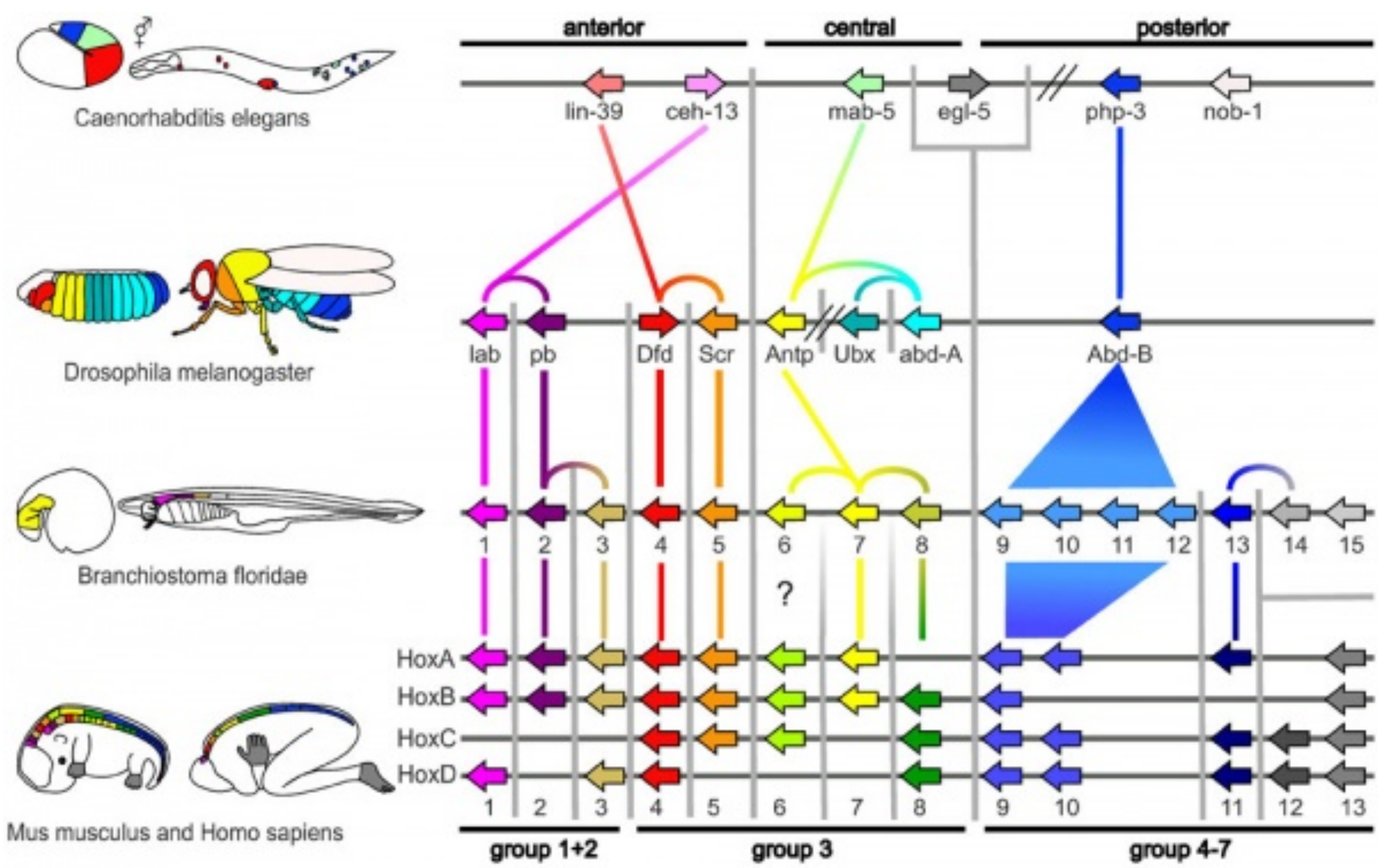


Different animal body plan axes.

Below is an example of what happens in a fly if these patterning signals get disrupted, putting legs from the body on the head where antenna should be located.

This fly mutation identified a common patterning gene family called Hox that establishes the head to tail axes in the embryo.

This complicated picture shows how different Hox genes are expressed at different embryo levels in different species (worms, flies, mouse and human).

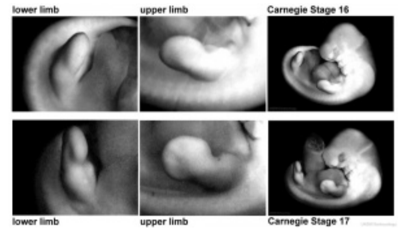


Teacher Note

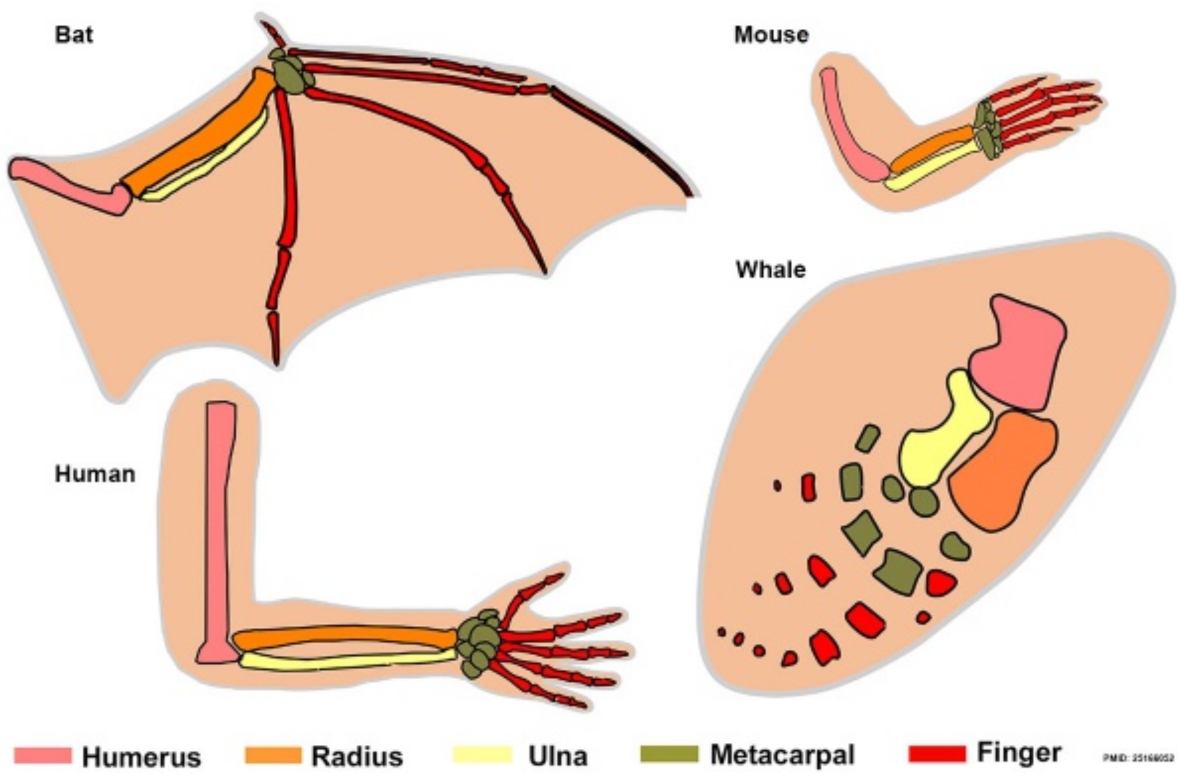
Limbs

Many different animals form limbs (arms and legs). During embryo development there are common signalling molecules and regions that form the initial limb structure. A similar process occurs for both the upper (arm) and low (leg) limb development.

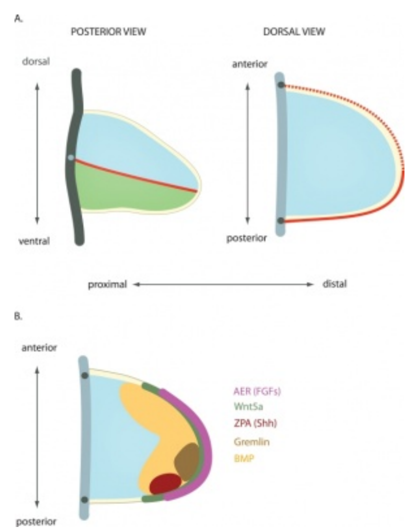
The final limb structures formed can appear different, but the bones shows that they share a pattern of development.



Early human embryo upper and lower limbs.



Upper limb bones of 4 different species. Each limb is significantly different in size and function, but all contain the same basic skeletal structures.



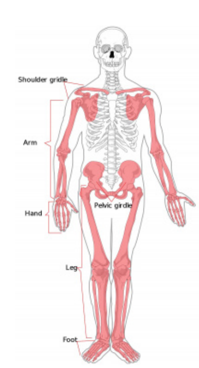
Cartoon of the early limb showing regions that establish the developmental patterning.

Limbs even though animal arms, legs, flippers and wings appear externally different their skeletons show common features and have a common function (motility).

Tissue Development

All animal embryos have similar tissues (connective, muscle, nervous, and epithelial) that that develop in different regions of the embryo. The development of these tissues is different from embryo patterning and is separate for each tissue.

The developmental signals that control say a connective tissue, like bone, are the same for all bones throughout the body. These



mechanisms are the same in other animals. Therefore bone development will go through similar stages in all animals bodies even though different bones are eventually formed. **Tissue Development** - the genes and signals that control embryonic development of these tissues are closely related in all animals.	The limb skeleton.

Teacher Note

Organ Development

Many animals have common organs used for digestion (stomach, liver, pancreas), breathing (lungs), waste (kidneys) and cardiovascular (heart).

The signalling mechanisms that are used to control their initial development and later internal patterning are the same in many different species embryos.

Teacher Note

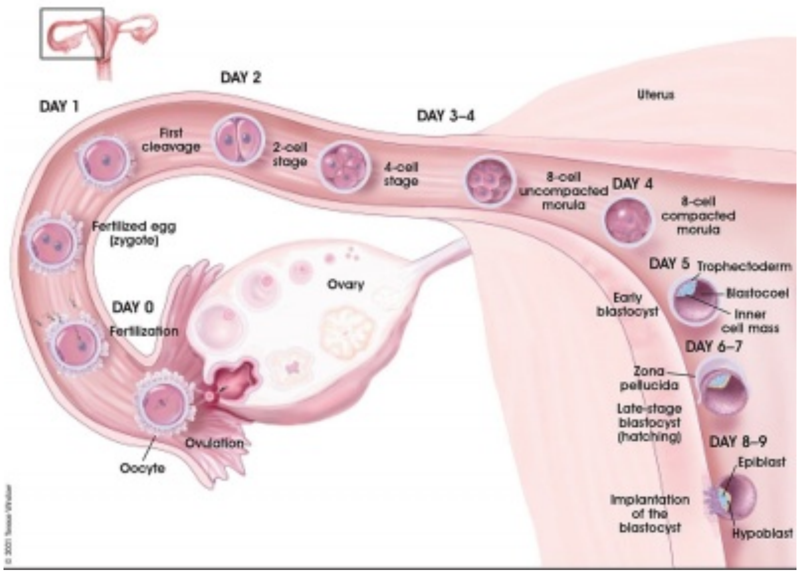
Animal Models

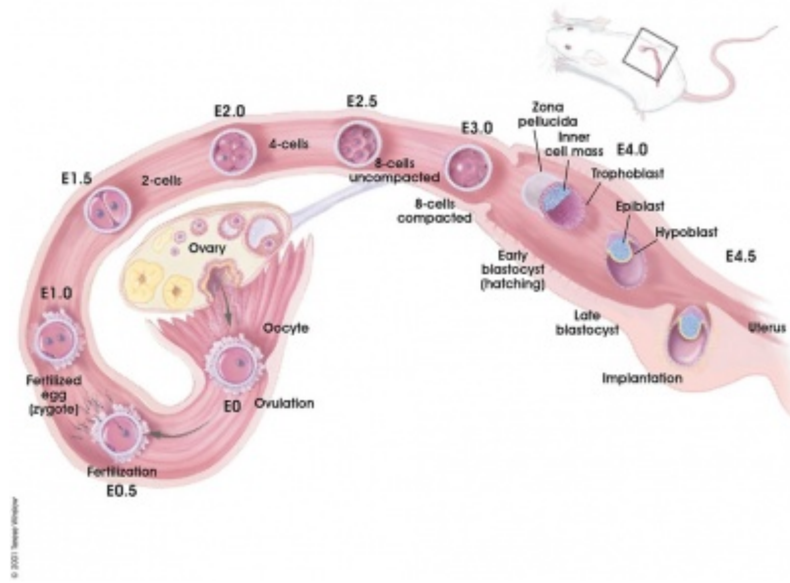
These shared signalling mechanisms allow us to use animal development to study both normal and abnormal human development.

Common animal "models" used include mouse (mammal), chicken (bird) and zebrafish (fish). Though very different species, current research shows that these embryos share common signalling mechanisms that form similar structures in different animals.

- **Mouse** - (mammal) good model for easy genetic manipulation.
- **Chicken** - (bird) develops in an egg so the earlier stages of development can be observed in the living embryo.
- **Zebrafish** - (fish) good model of vertebrate (backbone) animal development as the embryos are "see through" and can be observed while growing.

Fertilisation to Implantation	
Human (9 days)	Mouse (5 days)





Human embryo summary of the events from fertilisation not implantation. Humans take about 37 weeks to develop before birth.	Mouse embryo summary of the events from fertilisation not implantation. Mice take about 3 weeks to develop before birth.

Human and Mouse - In mammals, there is a difference in overall timing but the processes, organs and tissues are shared.

Zebrafish embryo development from the 1-cell stage to 85 hours post fertilisation.

Zebrafish take about 3 days to develop before hatching.

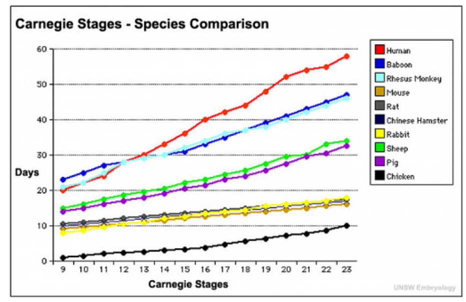
Animal Models - because of these shared (common) mechanisms we can use animals to model human development.

Comparing Embryos

Whats difference in humans?

The long fetal growth period allows extensive neural growth and development, though humans are not the longest prenatal period, so its not just about time.

Developmental Times - the graph compares different animals time to reach the same stage in embryo development.



Animal Development Time

Now looks at Human and Other Animal Development

Teacher Note

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