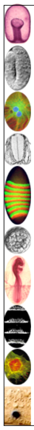
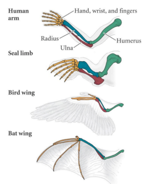


What can be more curious than that the hand of a man, formed for grasping, that of a mole for digging, the leg of a horse, the paddle of a porpoise, and the wing of a bat should all be constructed on the same pattern and should include similar bones, and in the same relative positions?

Charles Darwin, 1859



Evolutionary Developmental Biology (Evo-Devo)

"It is generally acknowledged that all organic beings have been formed on two great laws - *Unity of Type* and *Conditions of Existence*."

Charles Darwin, 1859

Evolutionary Developmental Biology (Evo-Devo)

"Unity of Type" - emphasizes similarities: homologies

"Conditions of Existence"- emphasizes differences - adaptations

Descent with Modification

Fig. 1.13 - Homology in Structures

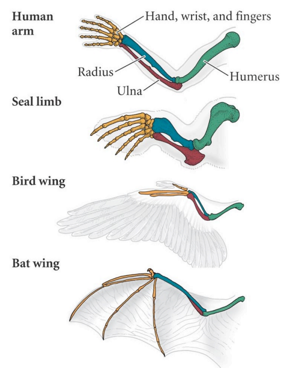


Figure 1.5 ***The Similarities and Differences among Different Vertebrate Embryos***

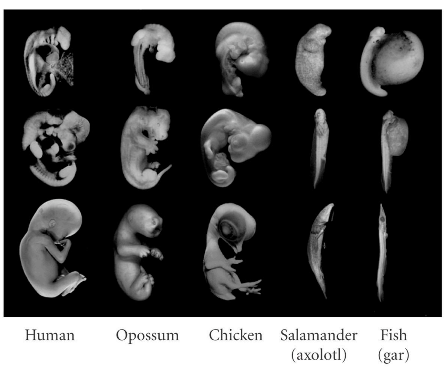


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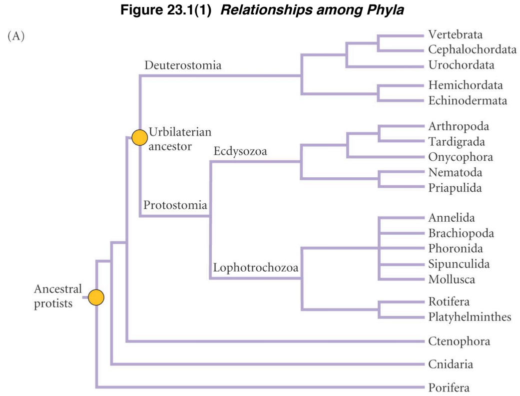
Figure 23.1(1) ***Relationships among Phyla***



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Features of the Common Ancestor of Protostomes and Deuterostomes ('the PDA')

Triploblastic (3 cell layers)

Bilaterally symmetric

Molecular pathways / systems in common

TABLE 23.1 Developmental regulatory genes conserved between protostomes and deuterostomes *(Part 1)*

Gene	Function	Distribution
achaete-scute group	Cell fate specification	Cnidarians, *Drosophila*, vertebrates
Bcl2/Drob-1/ced9	Programmed cell death	*Drosophila*, nematodes, vertebrates
Caudal	Posterior differentiation	*Drosophila*, vertebrates
delta/Xdelta-1	Primary neurogenesis	*Drosophila*, *Xenopus*
Distal-less/DLX	Appendage formation (proximal-distal axis)	Numerous phyla of protostomes and deuterostomes
Dorsal/NFκB	Immune response	*Drosophila*, vertebrates
forkhead/Fox	Terminal differentiation	*Drosophila*, vertebrates
Fringe/radical fringe	Formation of limb margin (apical ectodermal ridge in vertebrates)	*Drosophila*, chick
Hac-1/Apaf/ced 4	Programmed cell death	*Drosophila*, nematodes, vertebrates
Hox complex	Anterior-posterior patterning	Widespread among metazoans
lin-12/Notch	Cell fate specification	*C. elegans, Drosophila* vertebrates

(PCD pathways)

Source: After Erwin 1999.

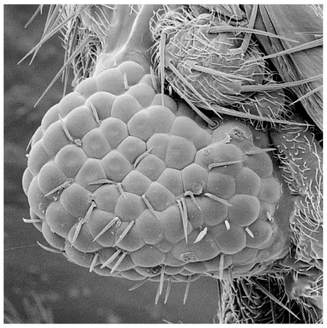
TABLE 23.1 Developmental regulatory genes conserved between protostomes and deuterostomes *(Part 2)*

Gene	Function	Distribution
Otx-1, Otx-2/Otd, Emx-1, Emx-2/ems	Anterior patterning, cephalization	*Drosophila*, vertebrates
Pax6/eyeless; Eyes absent/eya	Anterior CNS/eye regulation	*Drosophila*, vertebrates *C. elegans*
Polycomb group	Controls Hox expression/ cell differentiation	*Drosophila*, vertebrates
Netrins, Split proteins, and their receptors	Axon guidance	*Drosophila*, vertebrates *C. elegans*
RAS (RTK signaling)	Signal transduction	*C. elegans, Drosophila*, vertebrates
sine occulus/Six3	Anterior CNS/eye pattern formation	*Drosophila*, vertebrates
sog/chordin, dpp/BMP4	Dorsal-ventral patterning, neurogenesis	*Drosophila*, *Xenopus*
tinman/Nkx 2-5	Heart/blood vascular system	*Drosophila*, mouse
vnd, msh	Neural tube patterning	*Drosophila*, vertebrates

Source: After Erwin 1999.

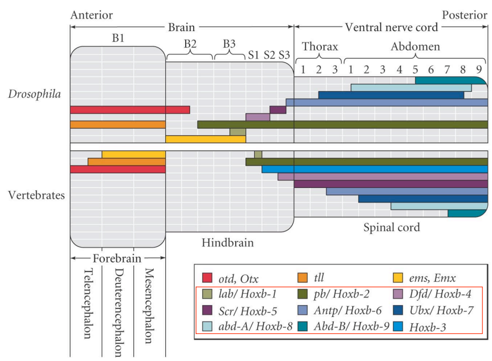
Figure 23.1B

(B)



Mouse Pax6 (eyeless homolog) expressed in fly leg generates ectopic eyes

Figure 23.2 ***Expression of Regulatory Transcription Factors in*** **Drosophila** ***and in Vertebrates Along the Anterior-Posterior Axis***



Molecular pathways/systems likely in the PDA
(just some of them)

- RTK signaling
- HOX genes in homeotic complex
- Programmed cell death / apoptosis pathway
- Wnt signaling
- Hedgehog signaling

Some important Evo-Devo concepts

- Modularity
- Dissociation

Important Evo-Devo concepts

- Modularity
- Module examples:
  - morphogenetic fields (limb, eye, vulva)
  - segments
  - cell lineages
  - genetic pathways
  - signaling pathways (RTK, Wnt, etc.)

Important Evo-Devo concepts

- Dissociation is allowed by modularity
  - Temporal: Heterochrony
  - Spatial: Allometry

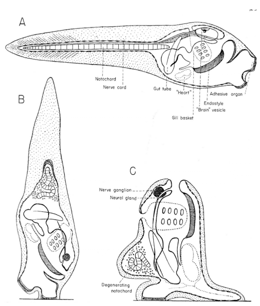
Important Evo-Devo concepts

One type of heterochrony: ***Neoteny***

Classic example: the Axolotl

Other examples of Neoteny:

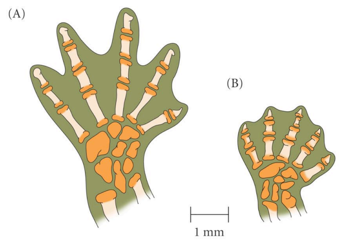
Vertebrate evolution: the first vertebrate may have been a neotenous chordate (looked like a tunicate larva).



Other examples of Neoteny:

Human evolution: Note the similarity of baby chimpanzee to adult human.

Figure 23.18 ***Heterochrony in*** **Bolitoglossa** ***Can Create a Tree-Climbing Salamander***



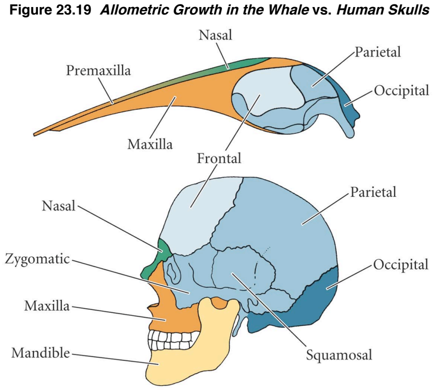
Arboreal salamander resembles juvenile terrestrial salamander

Important Evo-Devo concepts

Spatial Dissociation: Allometry

Different regions (modules) of the body grow at different rates.

Figure 23.19 ***Allometric Growth in the Whale*** **vs.** ***Human Skulls***



Important Evo-Devo concepts

- Duplication and divergence of modules
- Co-option - taking one structure or pathway for a new purpose

Figure 23.21(1) ***Evolution of Mammalian Middle Ear Bones From the Reptilian Jaw***

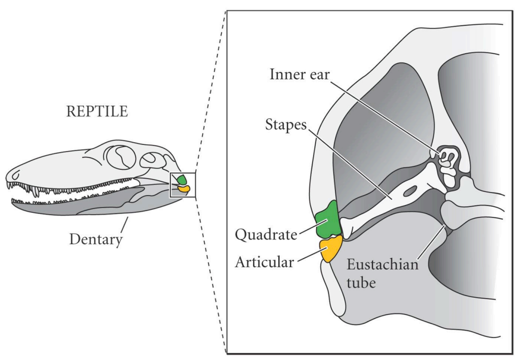
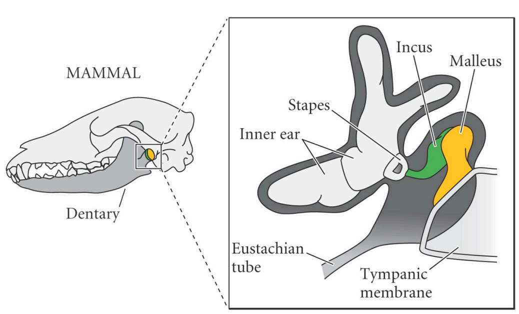


Figure 23.21(2) ***Evolution of Mammalian Middle Ear Bones From the Reptilian Jaw***



Important Evo-Devo concepts

Co-option - use of molecular/genetic pathways / signaling pathways for new purposes

Important Evo-Devo concepts

Co-option - use of molecular/genetic pathways / signaling pathways for new purposes

Important Evo-Devo concepts

Constraints on evolution of development

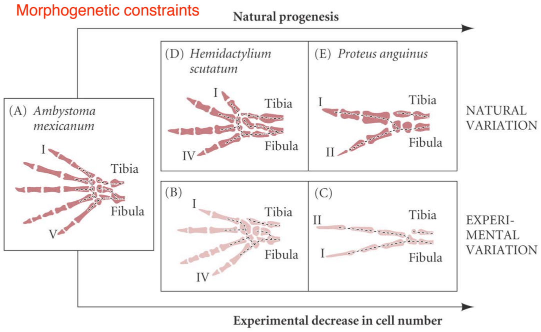
Physical constraints - limits arising by law of physics (such as diffusion, etc.)

Morphogenetic constraints - options limited by rules present in system

Phyletic constraints - historical limits on variation

Fig 23.27 ***Relationship Between Cell Number & Number of Digits in Salamanders***

Morphogenetic constraints



Important Evo-Devo concepts

The "Phylotypic stage"

Early development can diverge

All organisms of a given type converge upon a common similar structure

Global inductive interactions constrain form

Later development again diverges

Fig 23.28 ***Mechanism for Bottleneck at Pharyngula Stage of Vertebrate Development***

The "Pharyngula" - the Phylotypic stage of the vertebrate

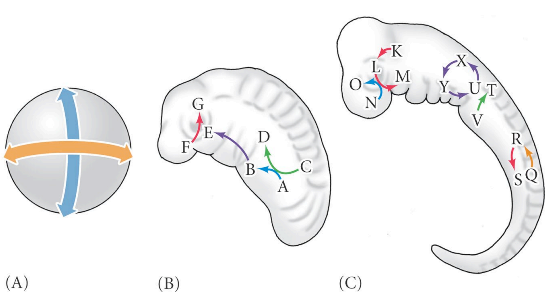


Figure 1.5 ***The Similarities and Differences among Different Vertebrate Embryos***