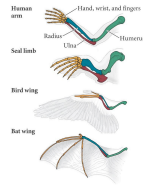


What can be more curious than that the hand of a man, formed for grasping, that of a mole for digging, the leg of a horse, the paddle of a porpoise, and the wing of a bat should all be constructed on the same pattern and should include similar bones, and in the same relative positions?

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

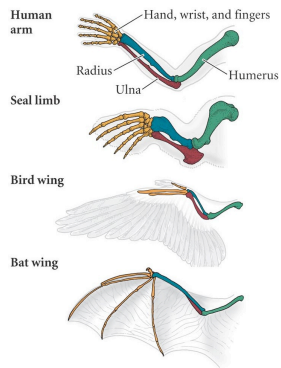


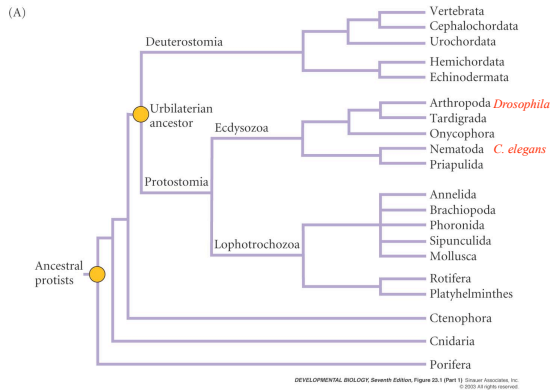
Figure 1.5 The Similarities and Differences among Different Vertebrate Embryos



Human Opossum Chicken Salamander (axolotl) Fish (gar)

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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
<i>achaete-scute</i> group	Cell fate specification	Cnidarians, <i>Drosophila</i> , vertebrates
<i>Bcl2/Dros-1/ccd9</i>	Programmed cell death	<i>Drosophila</i> , nematodes, vertebrates
<i>Caudal</i>	Posterior differentiation	<i>Drosophila</i> , vertebrates
<i>delta/Xdelta-1</i>	Primary neurogenesis	<i>Drosophila</i> , <i>Xenopus</i>
<i>Distal-less/DLX</i>	Appendage formation (proximal-distal axis)	Numerous phyla of protostomes and deuterostomes
(PCD pathways)		
<i>Dorsal/NFκB</i>	Immune response	<i>Drosophila</i> , vertebrates
<i>forkhead/Fox</i>	Terminal differentiation	<i>Drosophila</i> , vertebrates
<i>Fringed/radical fringe</i>	Formation of limb margin (apical ectodermal ridge in vertebrates)	<i>Drosophila</i> , chick
<i>Hac-1/Apaf/ccd 4</i>	Programmed cell death	<i>Drosophila</i> , nematodes, vertebrates
Hox complex	Anterior-posterior patterning	Widespread among metazoans
<i>lin-12/Notch</i>	Cell fate specification	<i>C. elegans</i> , <i>Drosophila</i> , vertebrates

Source: After Erwin 1999.

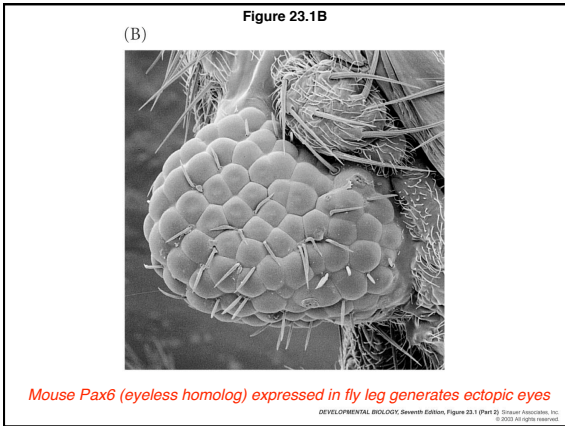
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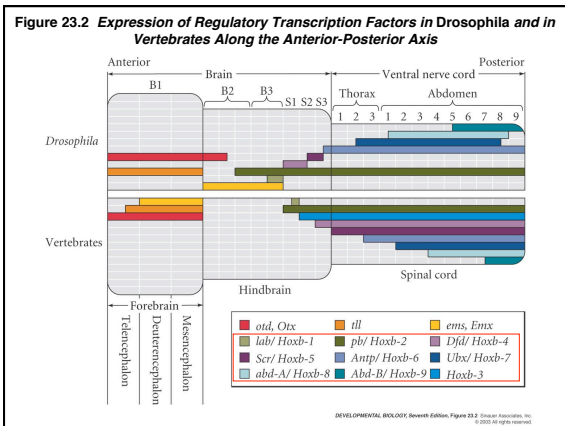
TABLE 23.1 Developmental regulatory genes conserved between protostomes and deuterostomes (Part 2)

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

Source: After Erwin 1999.

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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

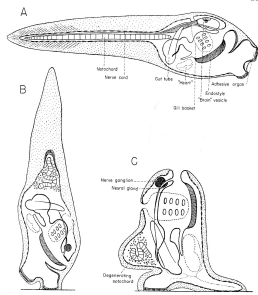
One type of heterochrony: **Neoteny**



Classic example: the Axolotl

Other examples of Neoteny:

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

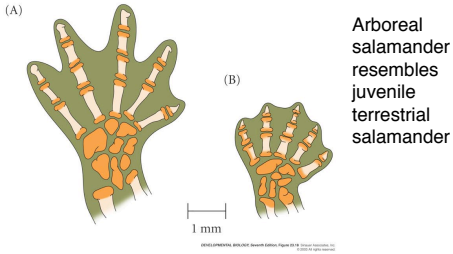


Other examples of Neoteny:

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



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

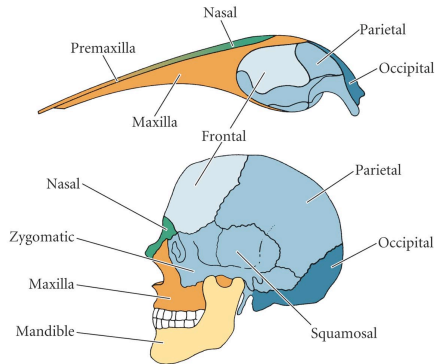


Important Evo-Devo concepts

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

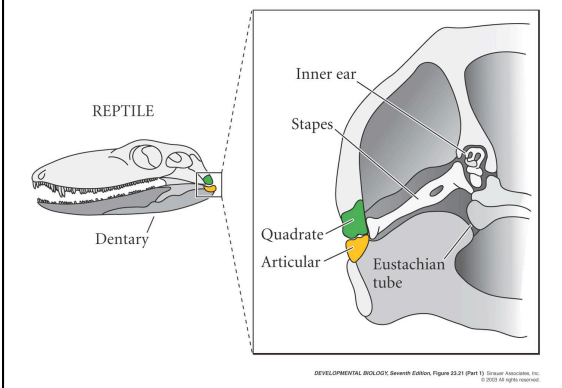
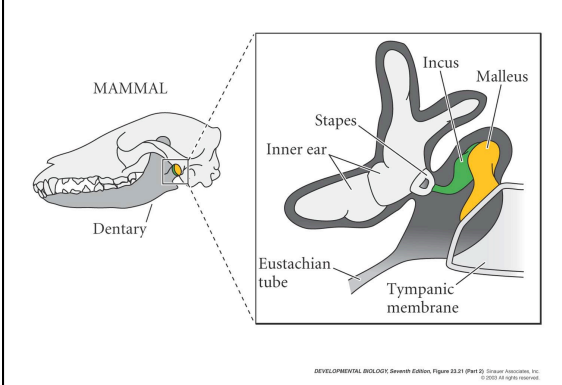


Figure 23.21(2) Evolution of Mammalian Middle Ear Bones From the Reptilian Jaw

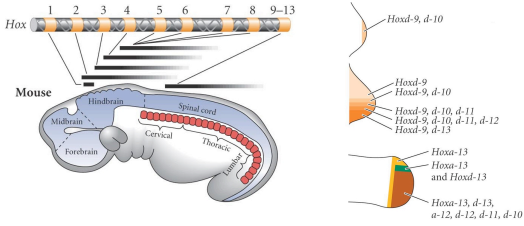


Important Evo-Devo concepts

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

Example co-opted genes:

Hox A9-13, D9-13 from body A-P patterning used in tetrapod limb patterning

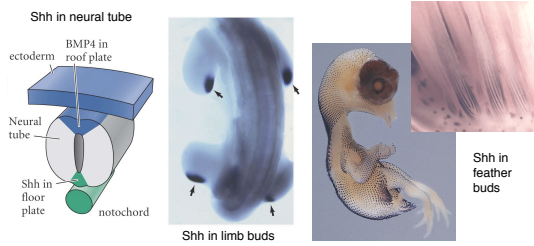


Important Evo-Devo concepts

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

Example co-opted genes:

Sonic Hedgehog (Shh) in limb and feather specification



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

