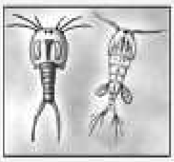
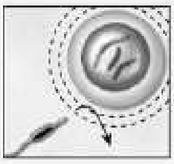
EVO-DEVO

Horse

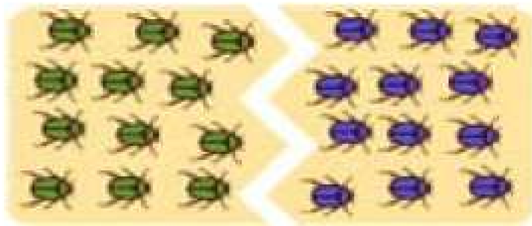
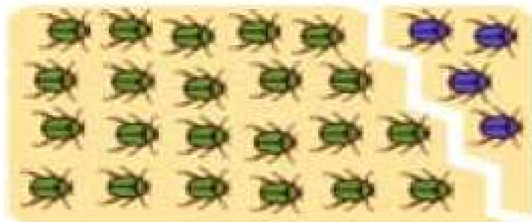
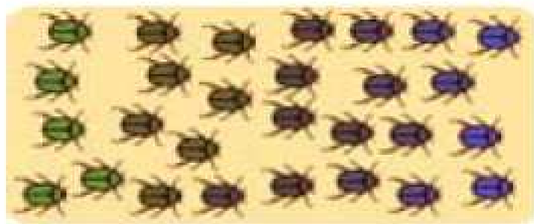
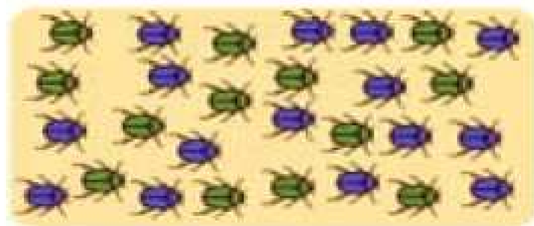
Mule (hybrid)

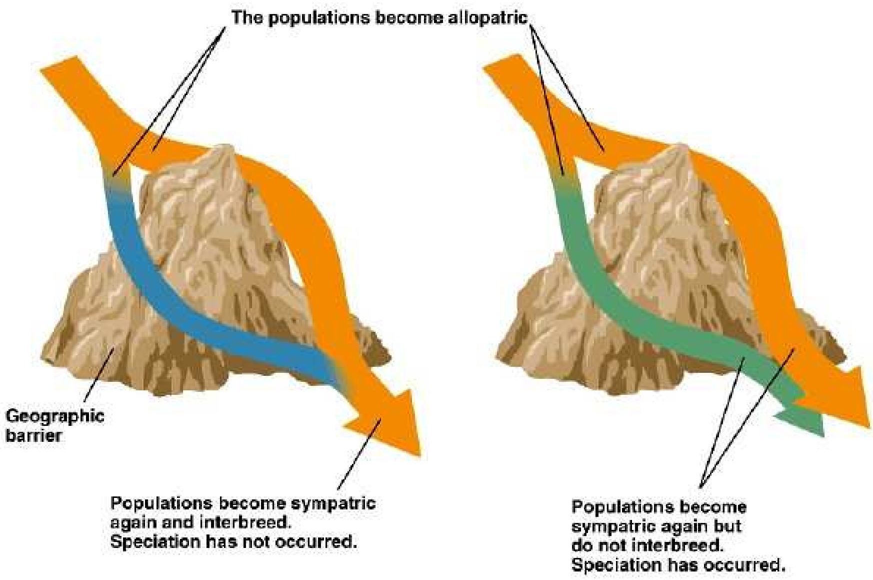
Donkey

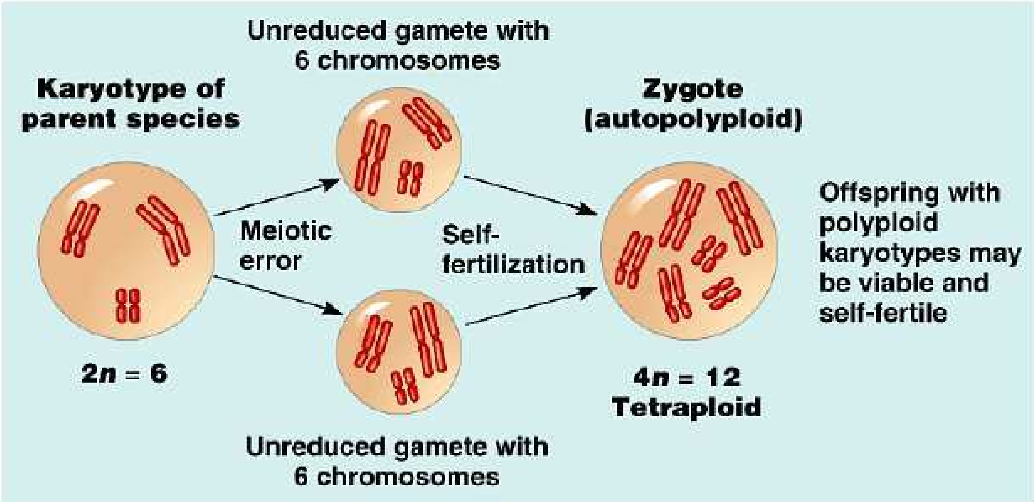
Mechanical and Gametic Isolation

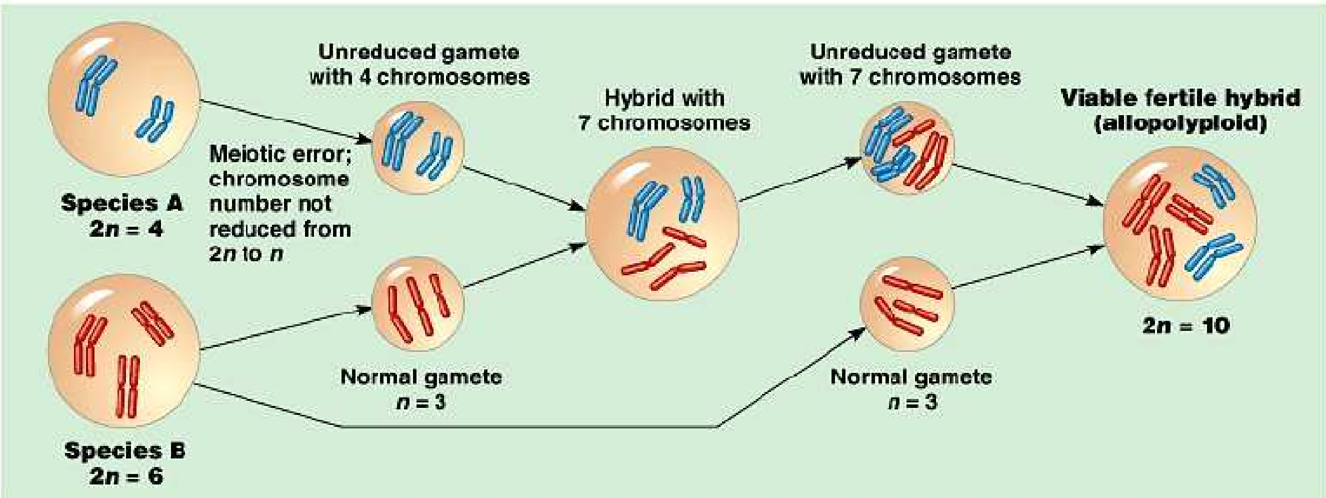
Mechanical isolation		Structural differences between species prevent mating.
Prevention of gamete fusion		Gametes of one species function poorly with the gametes of another species or within the reproductive tract of another species.

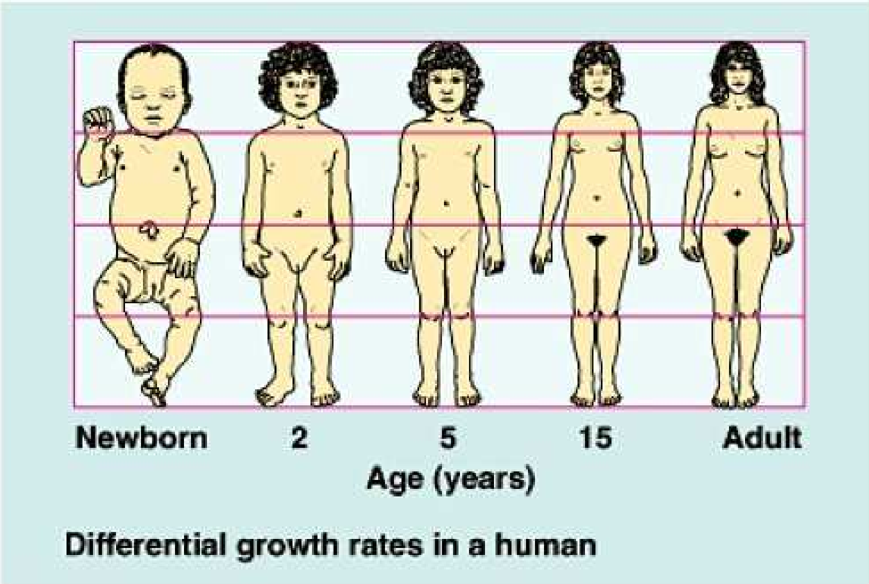
Summary of Modes of Speciation

Mode of speciation	New species formed from...	
Allopatric (allo = other, patric = place)	geographically isolated populations	
Peripatric (peri = near, patric = place)	a small population isolated at the edge of a larger population	
Parapatric (para = beside, patric = place)	a continuously distributed population	
Sympatric (sym = same, patric = place)	within the range of the ancestral population	



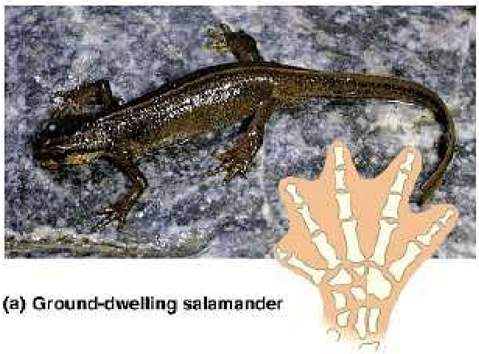

Unreduced gamete with
6 chromosomes
Karyotype of
parent species
Zygote
(autopolyploid)
Meiotic
error
Self-
fertilization
Offspring with
polyploid
karyotypes may
be viable and
self-fertile
2n = 6
4n = 12
Tetraploid
Unreduced gamete with
6 chromosomes


Unreduced gamete
with 4 chromosomes
Hybrid with
7 chromosomes
Unreduced gamete
with 7 chromosomes
Viable fertile hybrid
(allopolyploid)
Meiotic error;
chromosome
number not
reduced from
2n to n
Species A
2n = 4
Normal gamete
n = 3
Normal gamete
n = 3
2n = 10
Species B
2n = 6



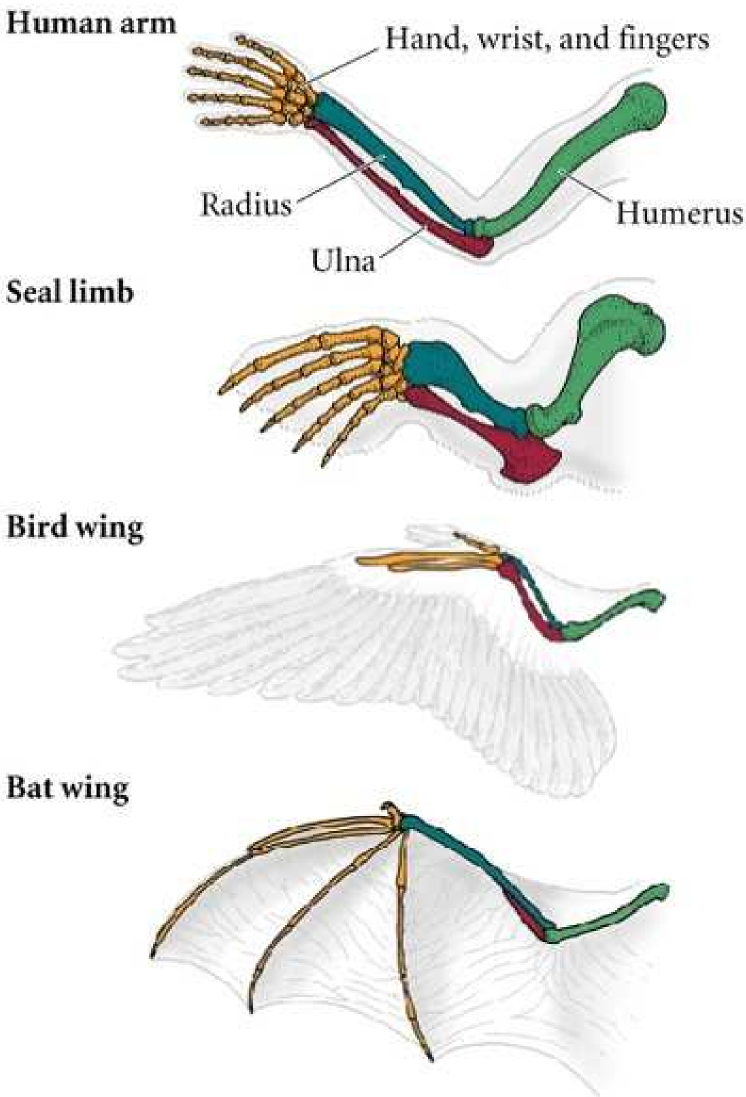
-exemple axolotl

-exemple pattes de salamandres

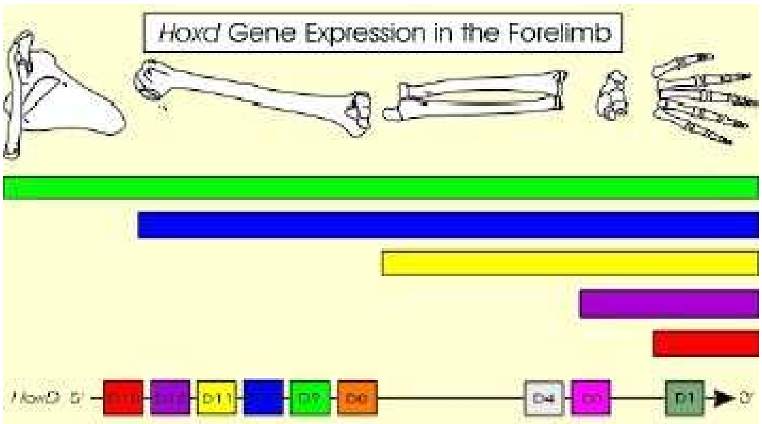


(a) Ground-dwelling salamander

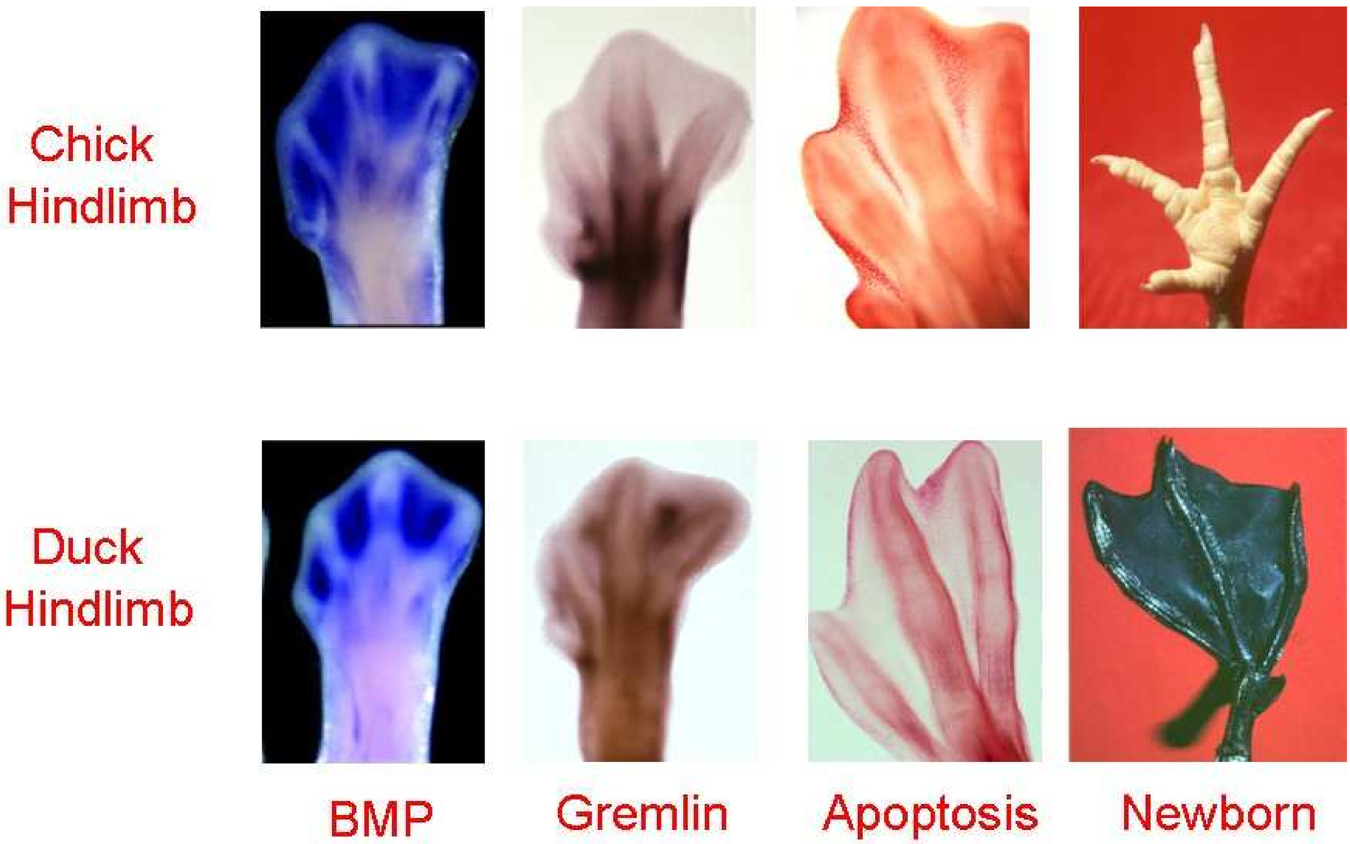
(b) Tree-dwelling salamander

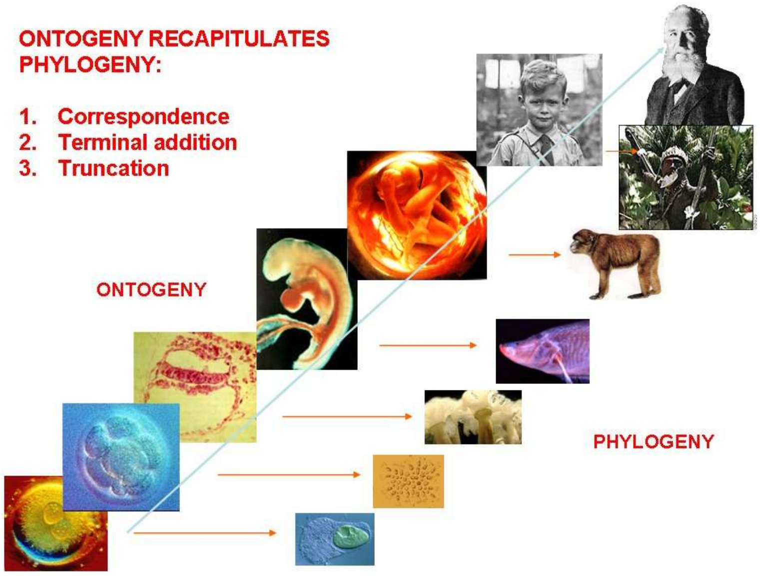


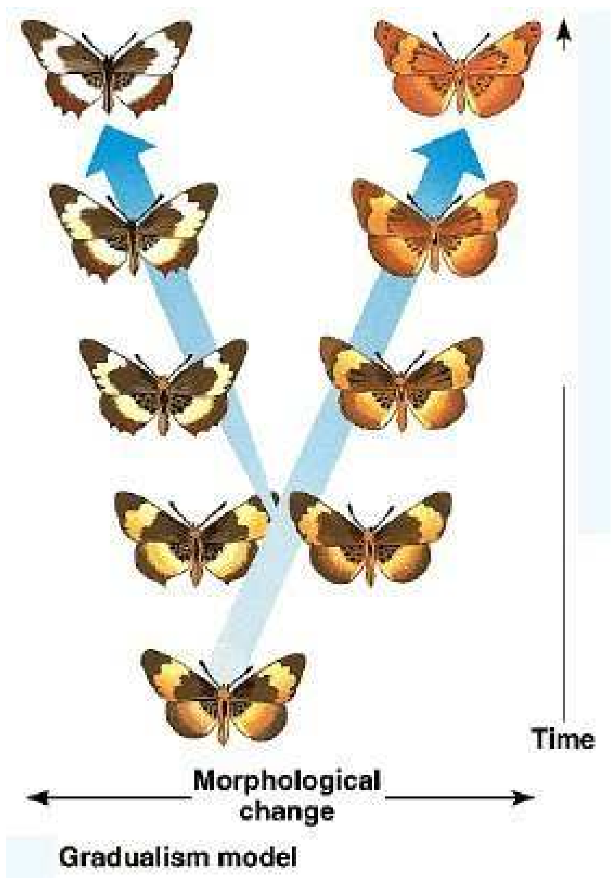
Human arm
Hand, wrist, and fingers
Radius
Humerus
Ulna
Seal limb
Bird wing
Bat wing

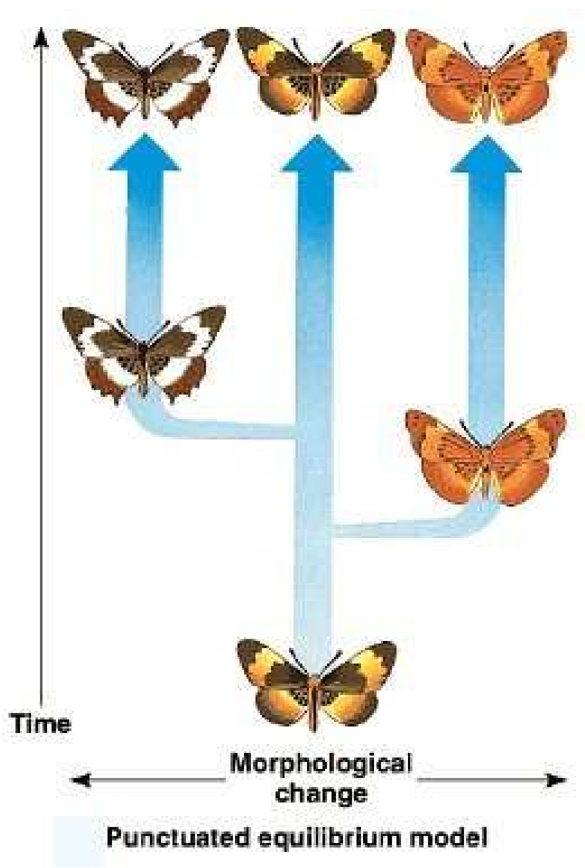


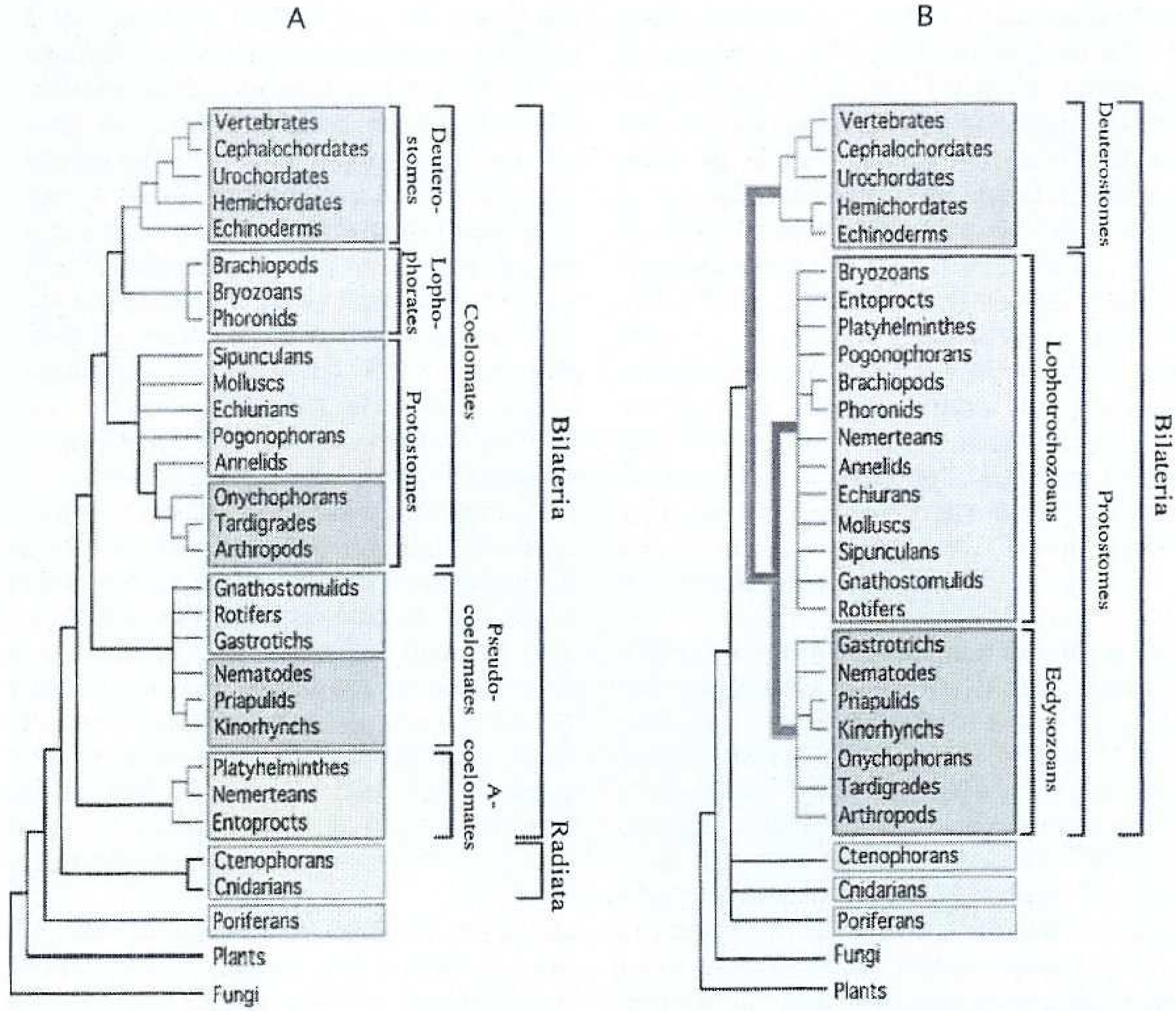
Hoxd Gene Expression in the Forelimb
D11
D9
D4
D1


Chick
Hindlimb
Duck
Hindlimb
BMP
Gremlin
Apoptosis
Newborn

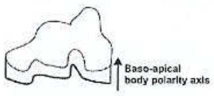
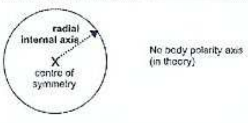
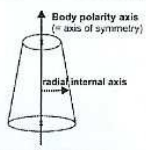
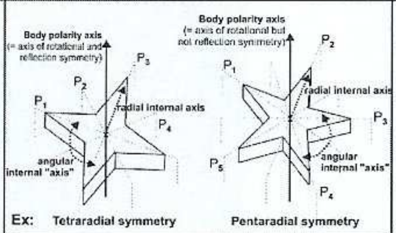
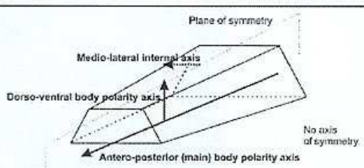

ONTOGENY RECAPITULATES PHYLOGENY:
1. Correspondence
2. Terminal addition
3. Truncation
ONTOGENY
PHYLOGENY

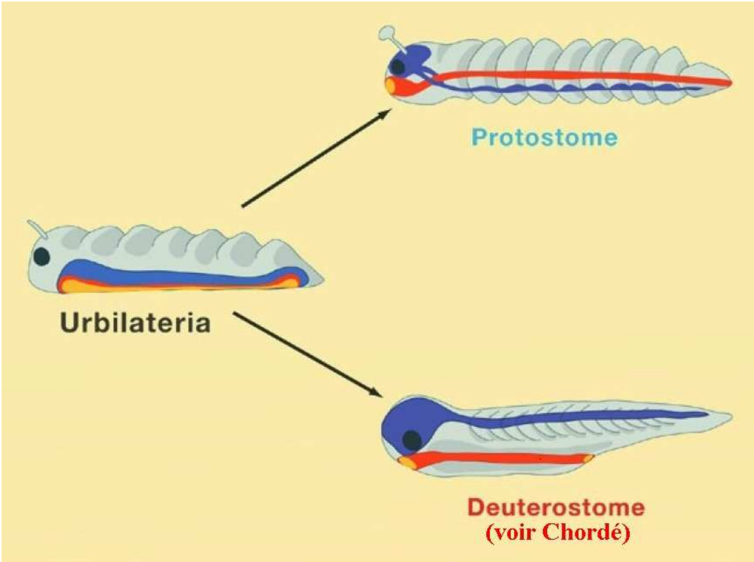

Time
Morphological change
Gradualism model

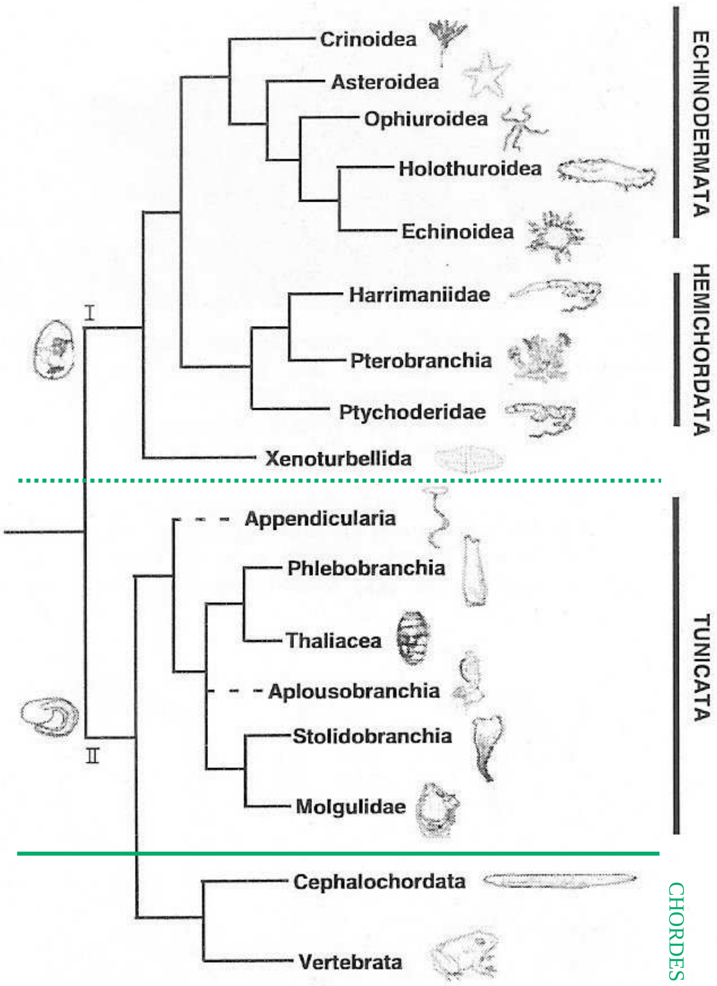

Time
Morphological change
Punctuated equilibrium model



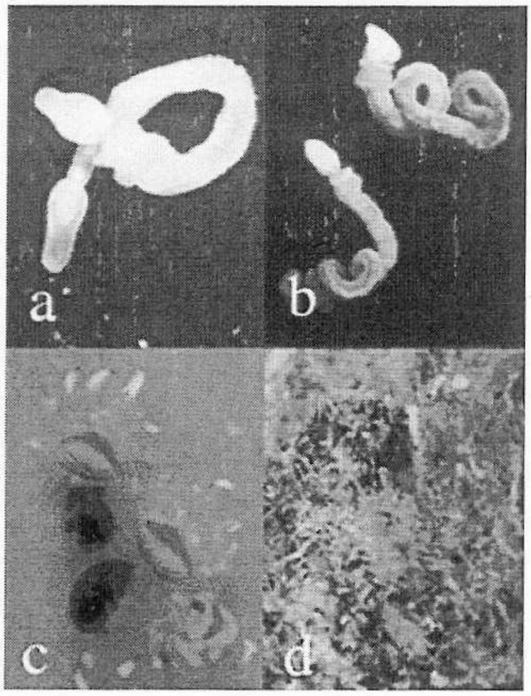
Metazoan phylogenies. (*A*) The traditional phylogeny based on morphology and embryology, adapted from Hyman (11). (*B*) The new molecule-based phylogeny. A conservative approach was taken in *B*: i.e., some datasets provide resolution within some of the unresolved multifurcations displayed, but we have limited the extent of resolution displayed to that solidly provided by rRNA only.

	Simplified representation	Examples	Planes of symmetry	Axes of symmetry	Body polarity axes	Spatial coordinates
Asymmetry		*Trichoplax* Most demosponges	**0**	**0**	**1**	**1**
Spherical symmetry		Eggs and equally cleaving blastulae (but not at the subcellular scale) Adult sponge *Tethya aurantia*	**∞** Any plane containing the centre of symmetry is a plane of symmetry	**∞** (axes of rotational and reflection symmetry)	**0** in theory (In practice there is generally one, but this is disruption of spherical symmetry)	**1**
Cylindrical symmetry		Most animal embryos before gastrulation; sponge and cnidarian larvae Hydrozoan polyps (at the column level) Asconoid calcisponges	**∞** Any plane containing the axis of symmetry is a plane of symmetry	**1** (axis of rotational and reflection symmetry)	**1**	**2**
n-radial symmetry		Syconoid calcareous sponges Most hexactinellid sponges Anthozoan polyps, cnidarian medusae Ctenophores Adult echinoderms	**n (>1)** A discrete number of planes of symmetry indicated by a prefix: n=2 --> **biradial** n=4 --> **tetraradial** n=5 --> **pentaradial** etc.	**1** (axis of rotational symmetry - and of reflection symmetry only if n is even)	**1**	**3**
Bilateral symmetry		Anthozoan polyps (in combination with n-radial symmetry) Rare instances in hydrozoans Bilaterian animals (except most adult echinoderms)	**1**	**0**	**2**	**3**



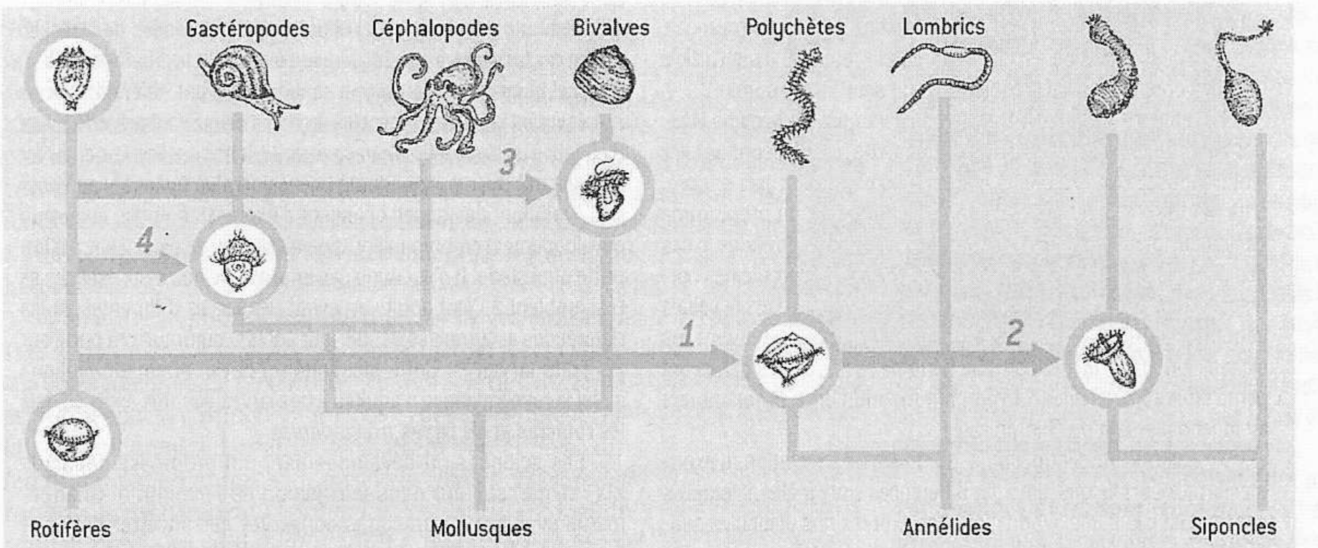


Current deuterostome phylogeny, with the three major invertebrate clades marked on the right: Echinodermata, Hemichordata and Tunicata. Vertebrates and Cephalochordata (lancelets) form a fourth clade, Chordata. Ciliated Ambulacraria larvae (I) and Tunicata tadpole larvae (II) are likely to have separate origins. Uncertainties in the Tunicata phylogeny are marked by dotted lines. Modified from Zeng and Swalla (2005).

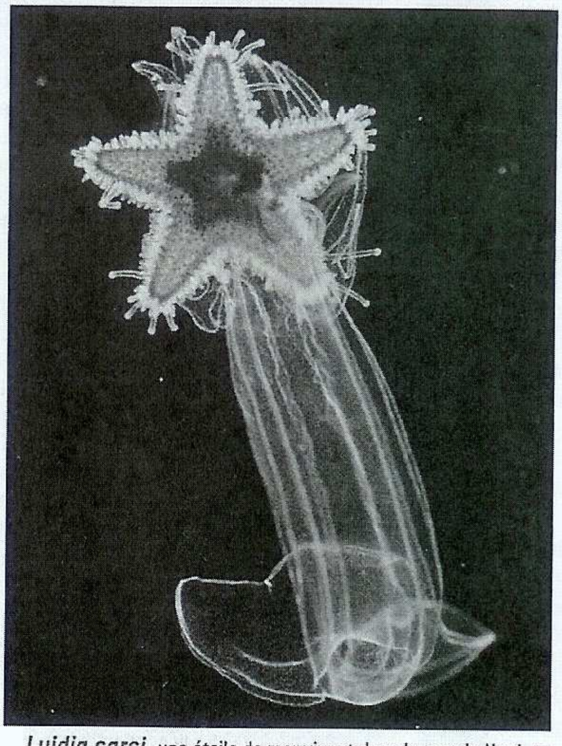


Photographs of the adults of the hemichordate species represented in this study. (*a*) *Ptychodera bahamensis*; (*b*) *Harrimania* species; (*c*) *Cephalodiscus gracilus* individuals; (*d*) *Cephalodiscus gracilus* colony. Our results suggest that members of the family Ptychoderidae (*a*) form one clade of Enteropneusta, whereas the family Harrimanidae (*b*) plus Pterobranchia (*c* and *d*) form another.

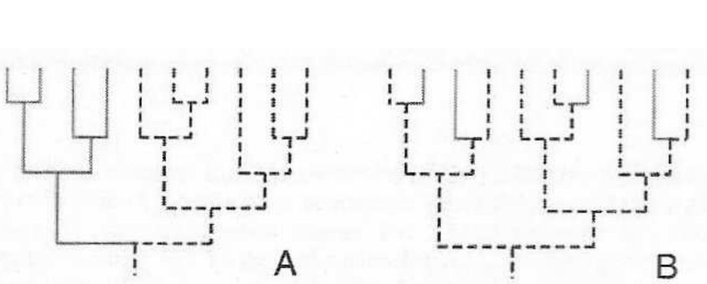
Ascidie



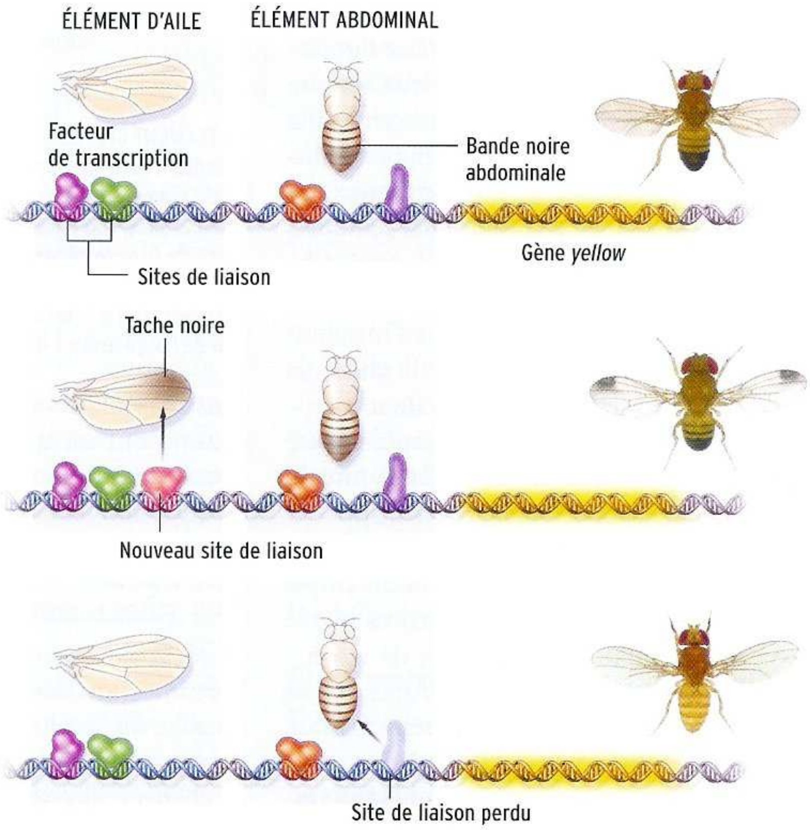
Les rotifères sont des petits animaux marins et d'eau douce *(à gauche)* qui auraient été intégrés dans le cycle de vie d'autres animaux, d'embranchements différents, sous la forme d'un stade larvaire. Ici, un ver polychète s'est hybridé avec un rotifère et a ainsi acquis une larve dite *trochophore (1)*. Puis, la partie du génome du polychète correspondant au stade larvaire a été transférée à un ver siponcle lors d'une seconde hybridation *(2)*. D'autres hybridations avec des rotifères ont conféré des larves de type *trochophore* aux ancêtres de certains mollusques actuels, les bivalves *(3)* et les escargots marins *(4)*. Leurs proches parents, les pieuvres et les calmars, sont dépourvus de larves. Cette hypothèse du transfert larvaire expliquerait pourquoi les larves d'espèces éloignées se ressemblent.



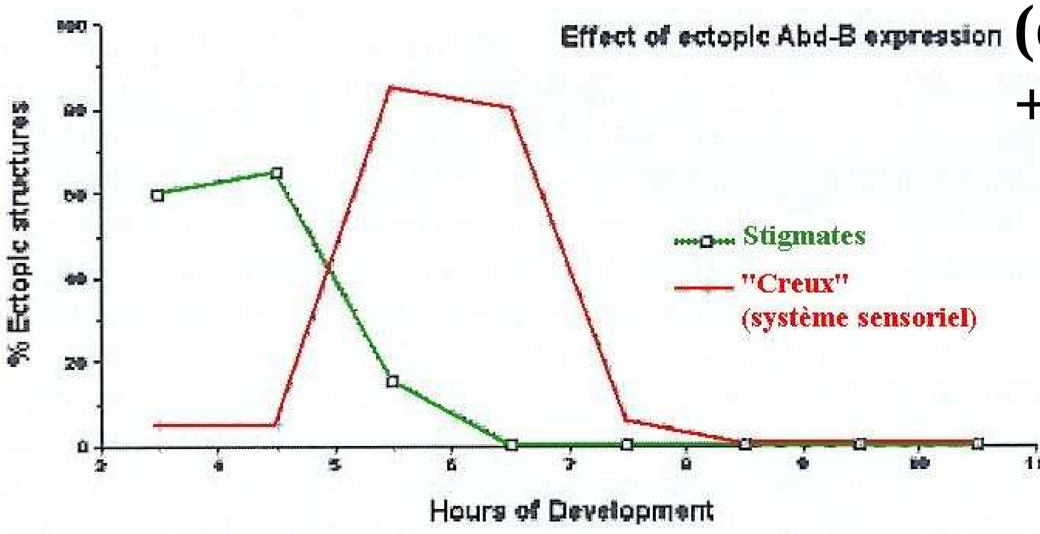
Luidia sarsi, une étoile de mer vivant dans la mer du Nord, se développe, à partir d'un œuf fécondé, en une larve à symétrie bilatérale, à l'intérieur de laquelle grandit une forme juvénile à symétrie radiale. Ensuite, le juvénile *(en haut)* migre vers l'extérieur et se détache de la larve flottante *(la forme translucide)*. Tous deux continuent à vivre indépendamment pendant plus de trois mois.



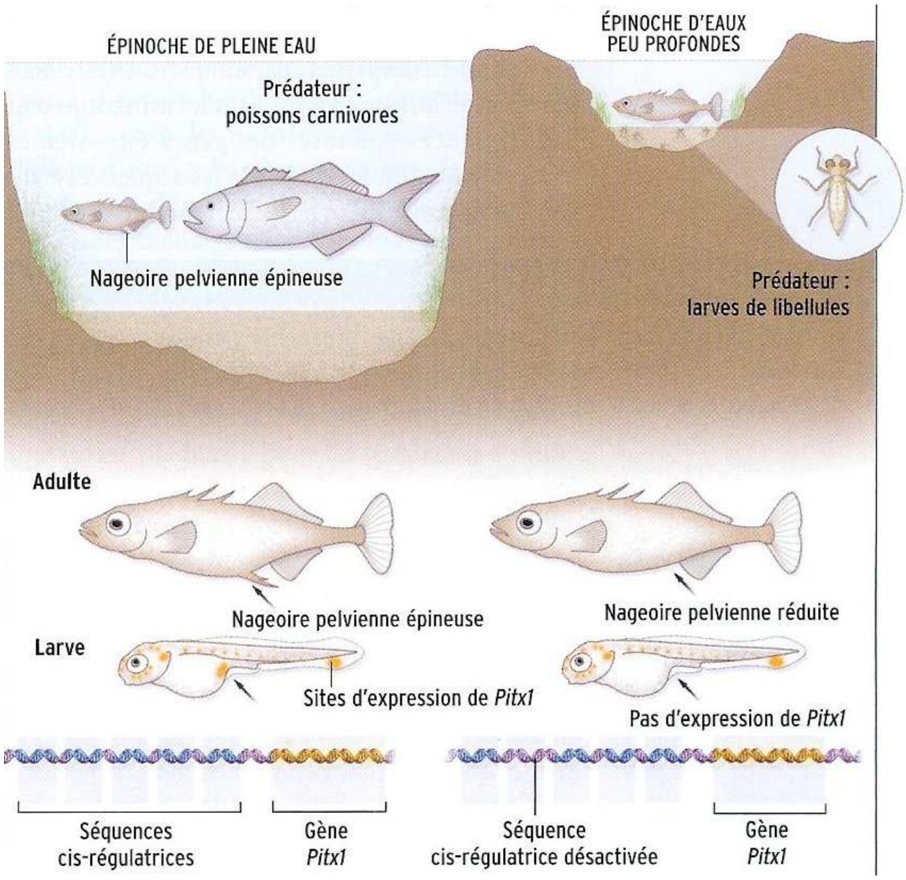
Models for the generation of homeodomain repertoires. Dashed lines represent branches and taxa shared with other species; solid lines represent gene acquisitions. (*A*) Scenario 1 postulates that gene acquisitions were associated with "novelty" so that the diversity of the prior repertoire was expanded in species-specific fashion by novel sequences and their subsequent duplications and divergence. (*B*) Scenario 2 postulates that the diversity of the repertoire is not fundamentally altered but is elaborated further by the creation of new branches as "intercalations" within the existing repertoire.

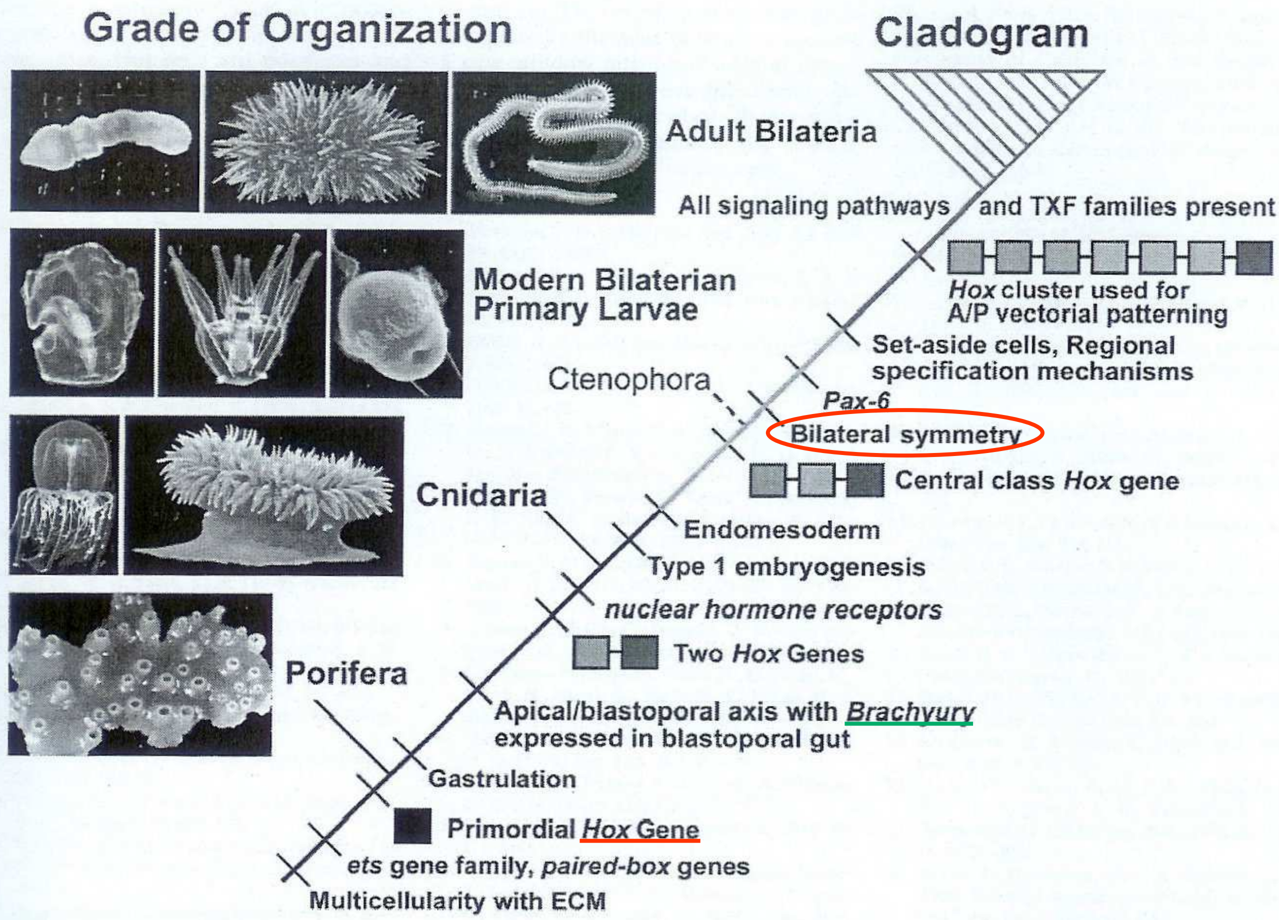


(situation ancestrale)

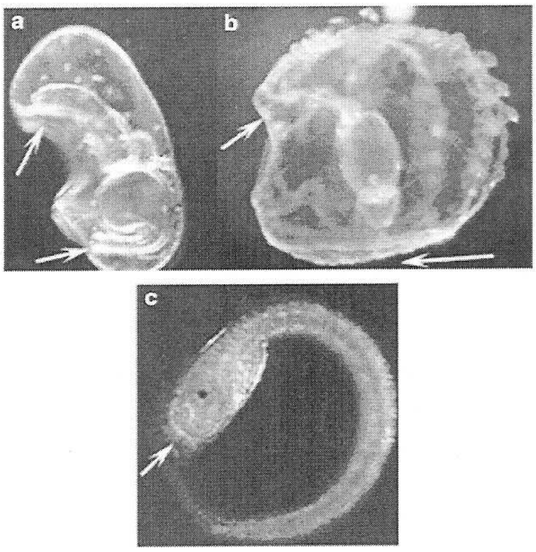


(dans partie +antérieure)

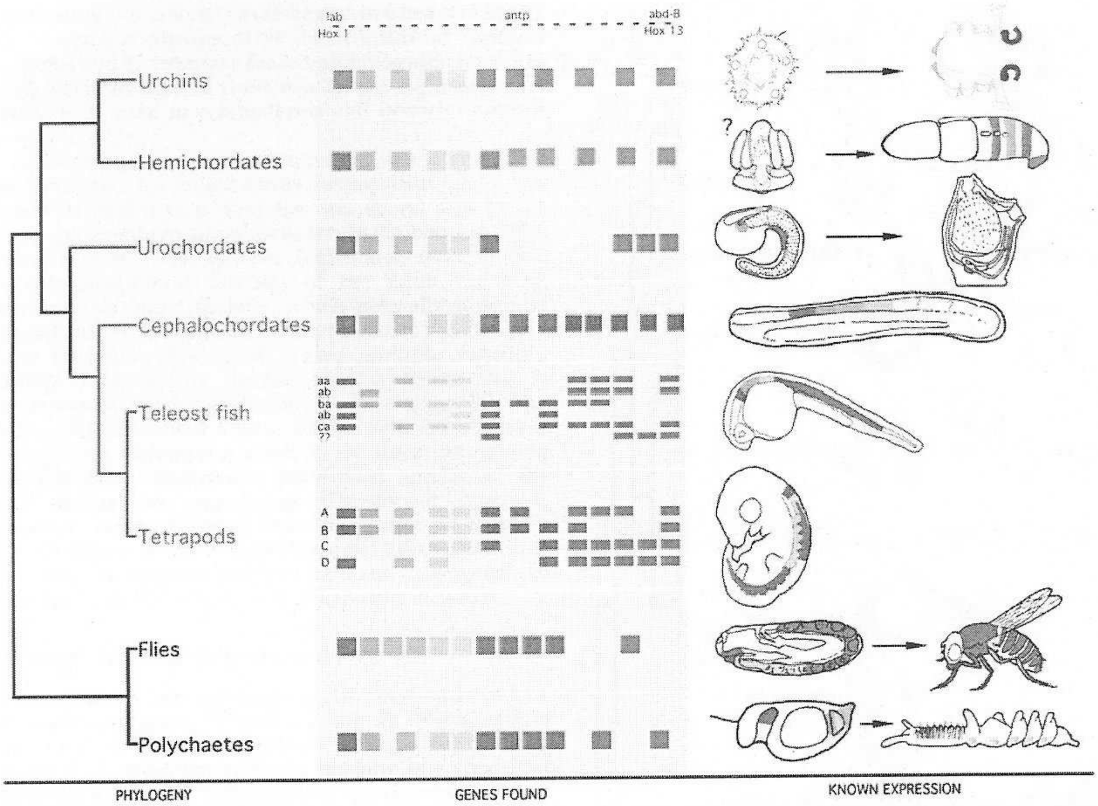

ÉPINOCHE DE PLEINE EAU
Prédateur :
poissons carnivores
Nageoire pelvienne épineuse
ÉPINOCHE D'EAUX
PEU PROFONDES
Prédateur :
larves de libellules
Adulte
Nageoire pelvienne épineuse
Nageoire pelvienne réduite
Larve
Sites d'expression de *Pitx1*
Pas d'expression de *Pitx1*
Séquences
cis-régulatrices
Gène
Pitx1
Séquence
cis-régulatrice désactivée
Gène
Pitx1



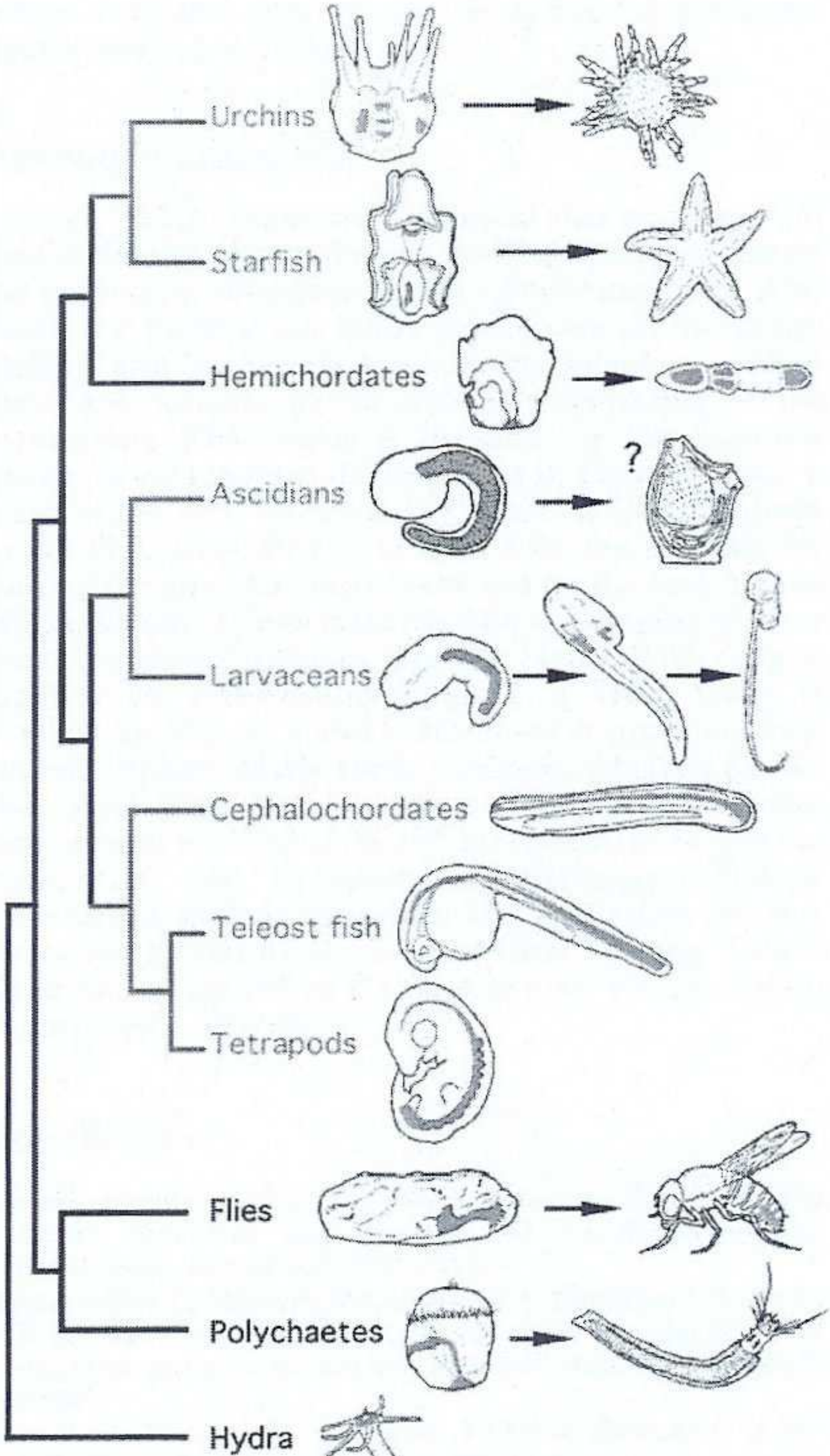
A cladogram of basal metazoans and some of the important regulatory inventions leading to the crown group bilaterians (purple triangle). The dotted line leading to Ctenophora reflects the equivocal nature of evidence regarding their phylogenetic position. The change in grade of organization from a two-dimensional to a three-dimensional form required the evolution of endomesoderm. This stage is indicated by the light-blue line. With the evolution of set-aside cells and regional specification mechanisms, macroscopic bilaterian body plans are now evolvable, and this change is indicated by the purple line. By the time the crown group evolved, all signaling pathways and transcription factor (TXF) families had appeared. The single "primordial" *Hox* gene found in sponges is shown by the black box. Presumably this gene underwent tandem gene duplication resulting in two genes, an "anterior" gene related to *Hox 1* and *Hox 2* of bilaterians (shown in red) and a posterior gene related to *Hox 9–13* (i.e., *Abd-B* relatives, shown in blue). A central class *Hox* gene has been found in ctenophores (*Hox 4–8*, shown in green). The latest common ancestor must have had at least seven *Hox* genes involving both gene duplications of previous classes (e.g., multiple anterior and middle genes) and new classes (*Hox 3*, violet box). This view of *Hox* cluster evolution devolves from studies of de Rosa *et al.* (33), Finnerty and Martindale (30), and others (see text). The adult enteropneust, the larval enteropneust, and the larval sea urchin photographs are from the authors' collections; the rest of the animal pictures are from ref. 40 [reproduced with permission from ref. 40 (Copyright 1980, Stanford University Press)].



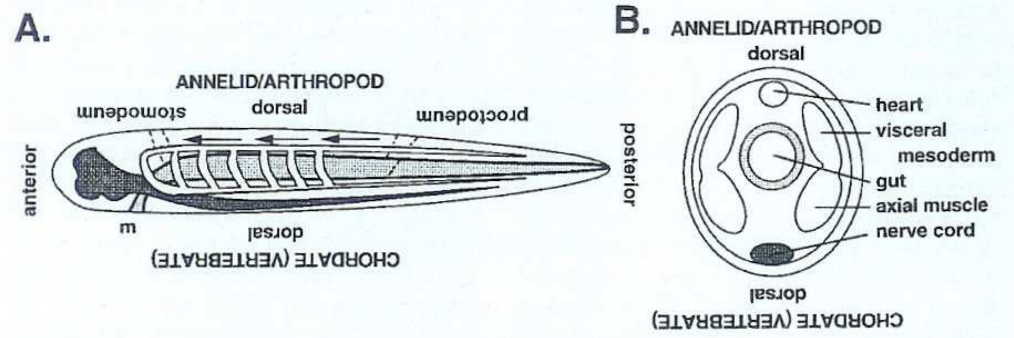
Deuterostome larvae, showing (**a**) a sea star echinoderm larvae, (**b**) a hemichordate tornaria larva and (**c**) a tunicate larva, all oriented with the mouth to the left and anus to the bottom. (**a**) Sea star larvae have an anterior (top left), which was the original animal pole of the egg. (**b**) Anterior in the hemichordate tornaria larva is the apical tuft (top of photo). (**a, b**) Both of these larvae feed with ciliary beating and have well-developed guts and coeloms. The mouth of the sea star and hemichordate larvae are seen to the left (arrow). The posterior anus forms at the former vegetal pole (arrows at bottom). In hemichordates, the larval mouth becomes the adult mouth and the proboscis develops anterior to the mouth. The gill slits and abdomen of the worm will develop posteriorly. (**c**) The tunicate larva is nonfeeding and lacks a heart, blood and gut, which will develop after metamorphosis. An arrow marks the anterior, where the mouth will form after metamorphosis, but is not yet open. There is no anus at this stage.



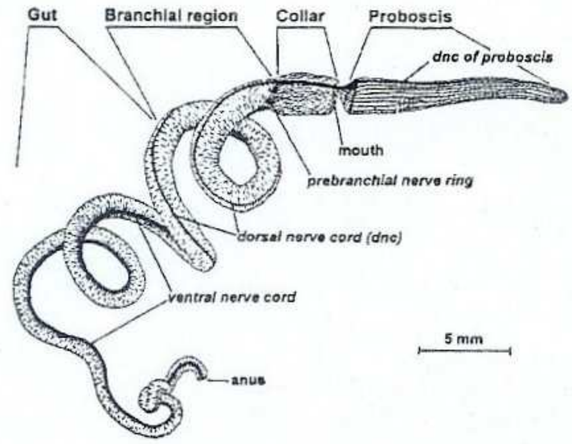
Expression of *Hox* genes in deuterostomes – the *Hox* gene cluster is duplicated in vertebrates. There are eight *Hox* gene clusters in teleost fishes, showing an additional duplication from the four *Hox* gene clusters found in the tetrapod vertebrates. In contrast, the invertebrate deuterostomes each have a single cluster. Ascidians lack some of the middle *Hox* genes, and the cluster is broken up onto two chromosomes. Echinoderms and hemichordates share an independent duplication of the posterior genes, called *Hox 11/13a*, *Hox 11/13b* and *Hox 11/13c*. Hemichordates show anterior to posterior expression in the ectoderm, which will produce a nerve net later in development. Echinoderms show adult expression in the nerve ring with the oral side corresponding to anterior in chordates and hemichordates.



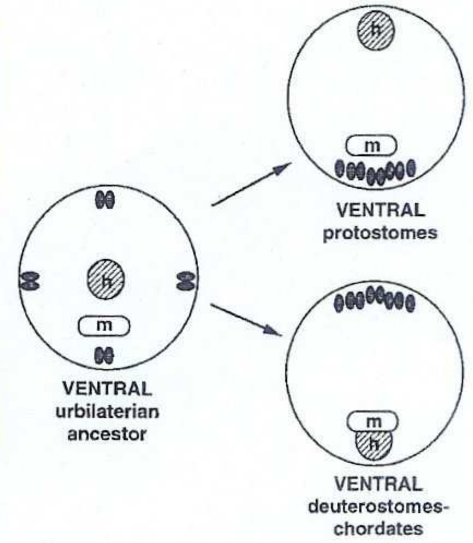
Expression of *Brachyury (T)* in animals. *Brachyury* is expressed in the hindgut in flies and in the gut during larval development in polychaete worms. In echinoderms and hemichordates, *brachyury* is expressed in the anus during gastrulation, then later where the mouth is formed. *Brachyury* was co-opted into the notochord in chordates, but in larvaceans, it is expressed in notochord and later in the mouth and anus after metamorphosis.



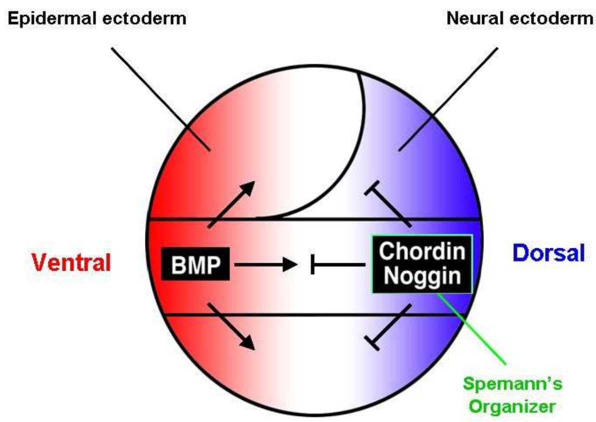
The inversion hypothesis. (*A*) An annelid worm, side view. The mouth (m) and nerve cord (dark shading) are ventral. The gut (light shading) is midlevel. Arrows indicate the direction of blood flow. Inverted, it is a chordate, with the nerve cord dorsal, the gut ventral, and the blood flowing in the opposite direction. A new mouth (stomadeum) and anus (proctodeum) evolve in the chordate. Modified from ref. 2. (*B*) The dorsoventral axis in cross section, trunk level.

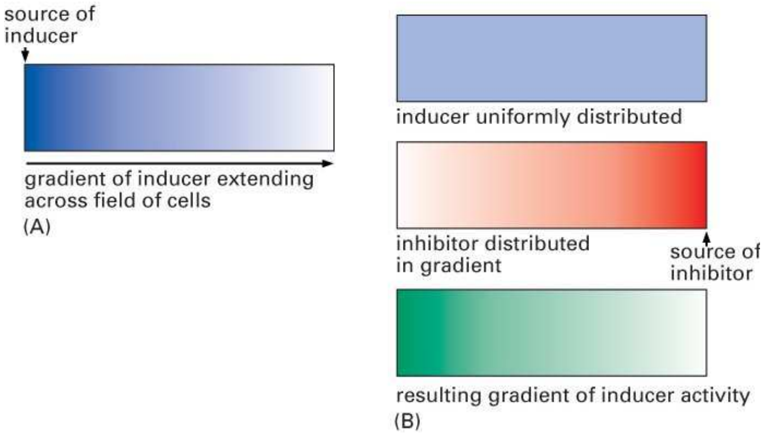


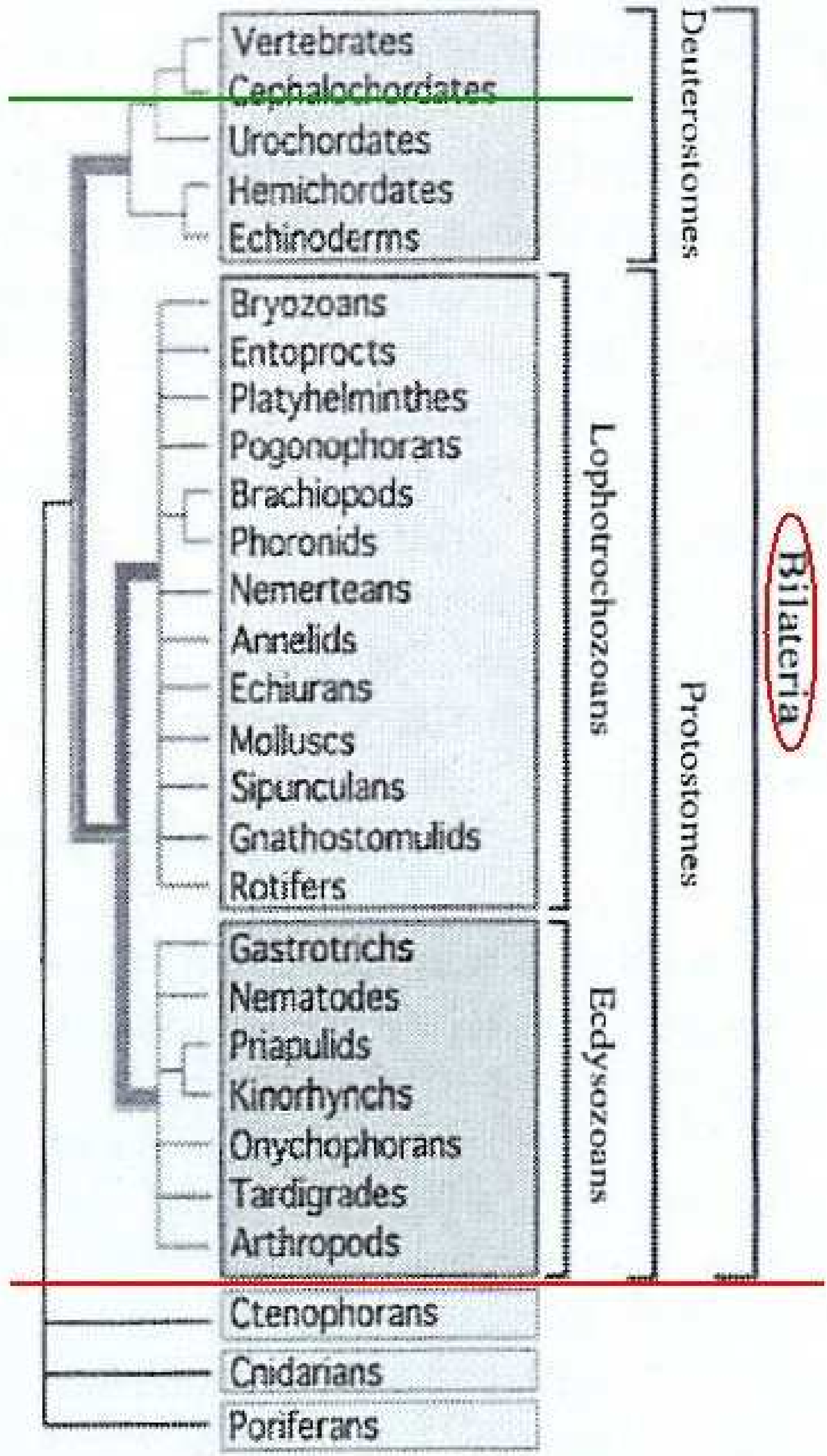
Two nerve cords of an enteropneust hemichordate, *Saccoglossus cambrensis*. The animal is shown in semitransparent view. Nerves and nerve bundles, drawn in black, have been silver-stained.



An alternative to inversion. The hypothetical ancestor (*Left*, cross section) has little dorsoventral differentiation except for the mouth on the ventral side. Anterior is toward the reader. The body has multiple nerve cords and a centrally located anterior heart. In the protostome line (*Upper Right*), the cords coalesce toward the mouth side (ventral) and the heart shifts dorsally whereas, in the deuterostome line (*Lower Right*), the opposite occurs. Two body plans thus arise with inverse dorsoventral organization, without inversion.






Vertebrates
Cephalochordates
Urochordates
Hemichordates
Echinoderms
Bryozoans
Entoprocts
Platyhelminthes
Pogonophorans
Brachiopods
Phoronids
Nemerteans
Annelids
Echiurans
Molluscs
Sipunculans
Gnathostomulids
Rotifers
Gastrotrichs
Nematodes
Priapulids
Kinorhynchs
Onychophorans
Tardigrades
Arthropods
Ctenophorans
Cnidarians
Poriferans
Deuterostomes
Lophotrochozoans
Ecdysozoans
Protostomes
Bilateria