UNIVERSITAS INDONESIA
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FMIPA
BIOLOGI

Evolution and Developmental Biology in Animal Diversity

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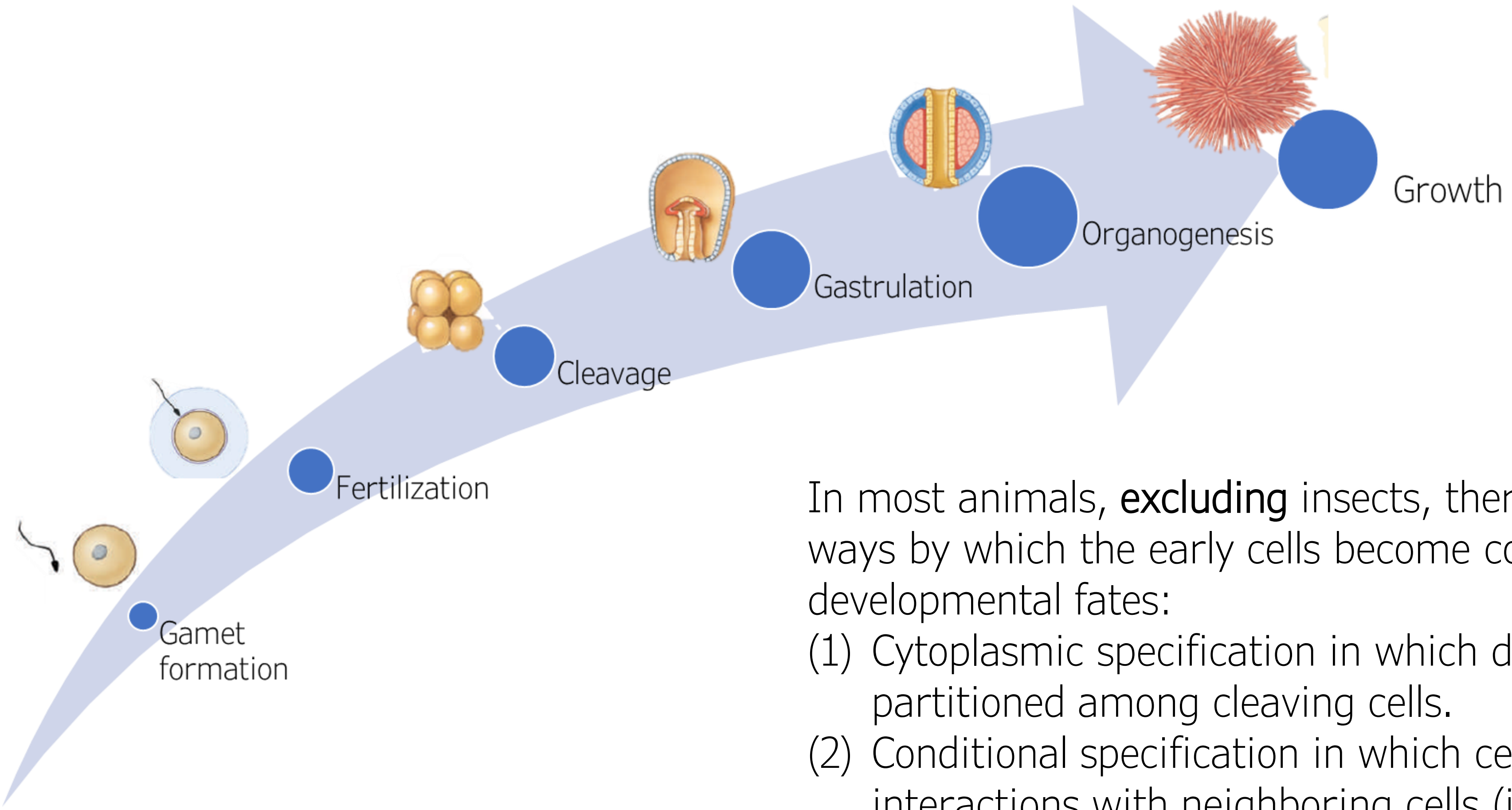
Learning Objective

- The students can explain the basic concept of biological development in animal.
- The students can explain the sources of variation in animal population.
- The students can explain the natural selection mechanism in the formation of animal phenotypic variation.

The basic concept of biological development in animal

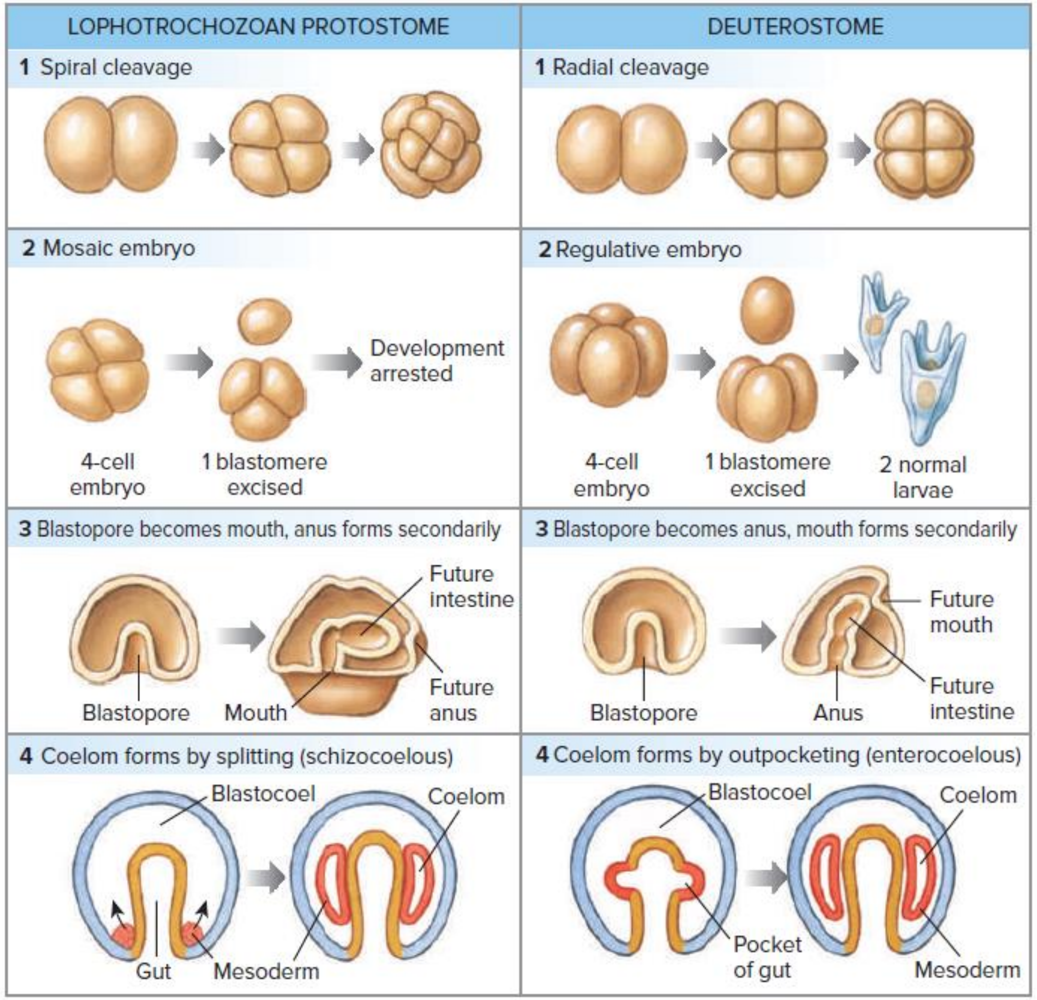
Key events in animal development



In most animals, **excluding** insects, there are two major ways by which the early cells become committed to particular developmental fates:

(1) Cytoplasmic specification in which determinative molecules are partitioned among cleaving cells.
(2) Conditional specification in which cell fates are determined by interactions with neighboring cells (induction).

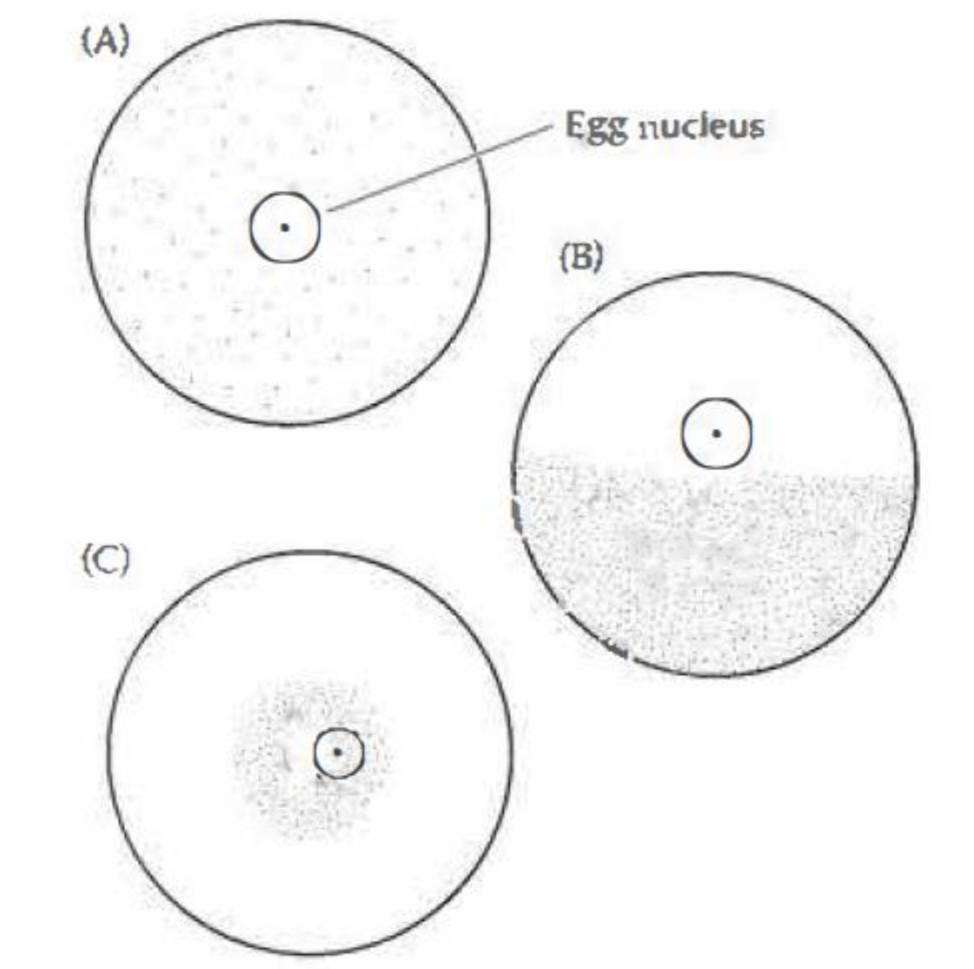
Developmental patterns in animals



Types of eggs based on distribution of yolk

- **Isolecithal** : eggs with very little yolk, evenly distributed throughout the egg. Ex. → sea star, nemertean worm, mouse.
- **Mesolecithal** : eggs have a moderate amount of yolk concentrated at the vegetal pole. Ex. → frog.
- **Telolecithal** : eggs contain an abundance of yolk densely concentrated at the vegetal pole of the egg. Ex. → chicken.
- **Centrolecithal** : eggs have a large, centrally located mass of yolk. Ex. → insect.

Yolk distribution in the egg

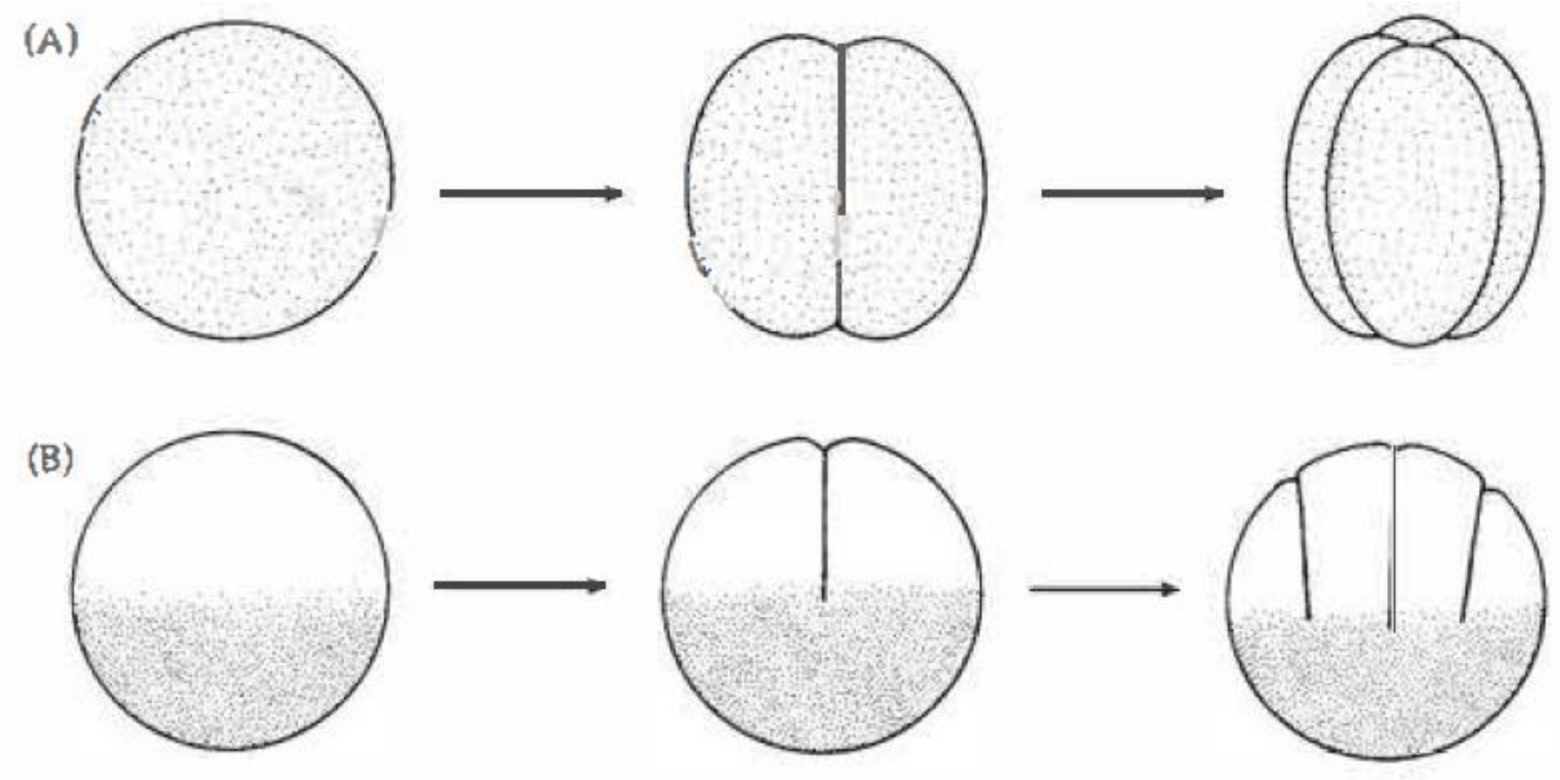


A. Isolecithal
B. Mesolecithal & Telolecithal
C. Centrolecithal

Types of cleavage

A. **Holoblastic** : eggs have a moderate amount of yolk concentrated at the vegetal pole.

B. **Meroblastic** : eggs with very little yolk, evenly distributed throughout the egg.

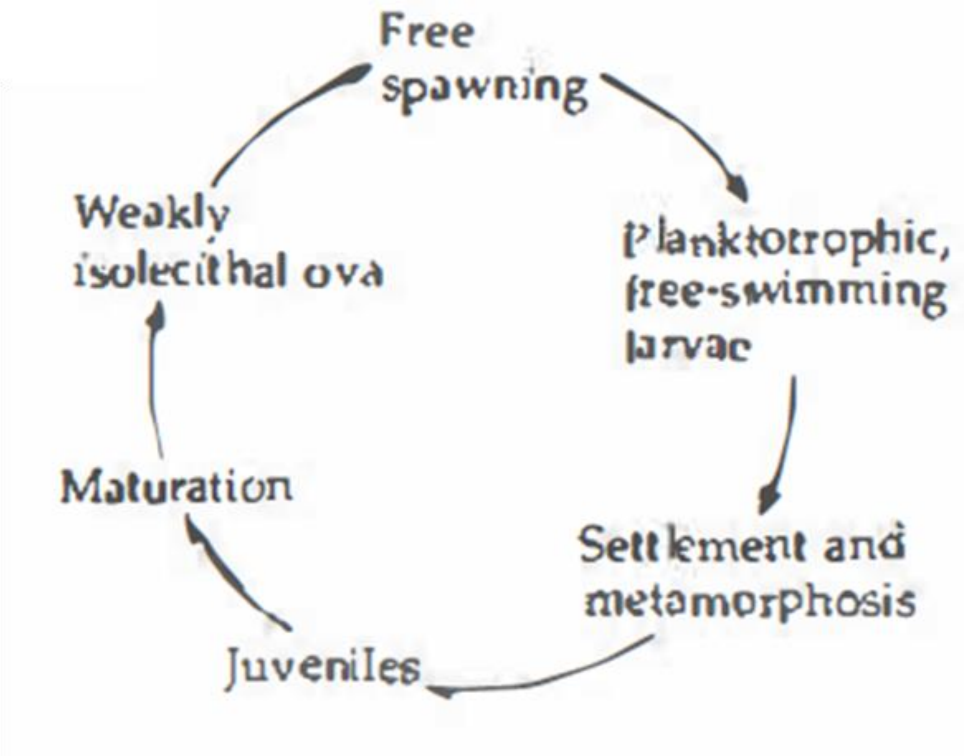


Life cycles strategy in animals

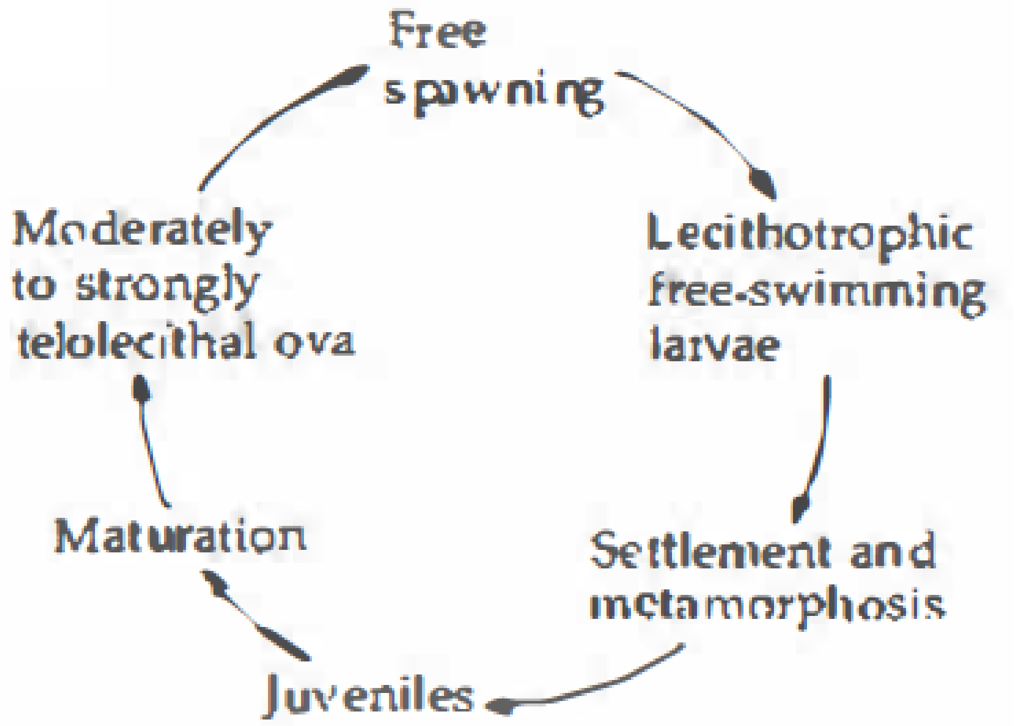
1. **Indirect development** : free spawning of gametes followed by the development of a free larval stage (usually a swimming form), which is distinctly different from the adult and must undergo a more or less drastic metamorphosis to reach the juvenile or young adult stage.
   - Planktotrophic larvae : survives primarily by feeding, usually on plankton.
   - Lecithotrophic larvae : survives primarily on yolk supplied to the egg by the mother.
2. **Direct development** : does not include a free larva. In these cases the embryos are cared for by the parents in one way or another (generally by brooding or encapsulation) until they emerge as juveniles.
3. **Mixed development** : involves brooding or encapsulation of the embryos at early stages of development and subsequent release of free planktotrophic or lecithotrophic larvae.

Indirect development

Planktotrophic larvae

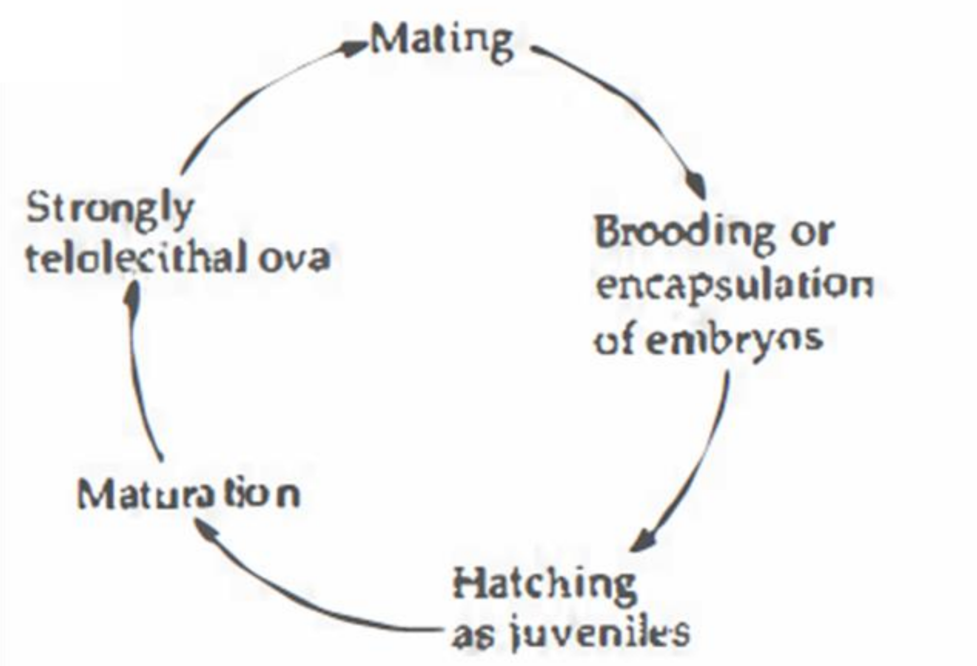


Lecithotrophic larvae

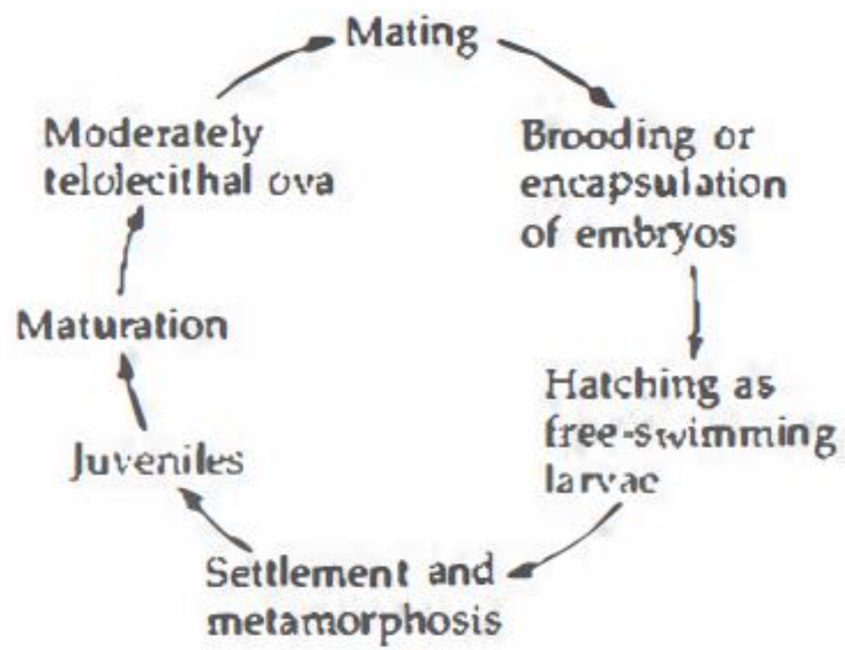


Direct & mixed development

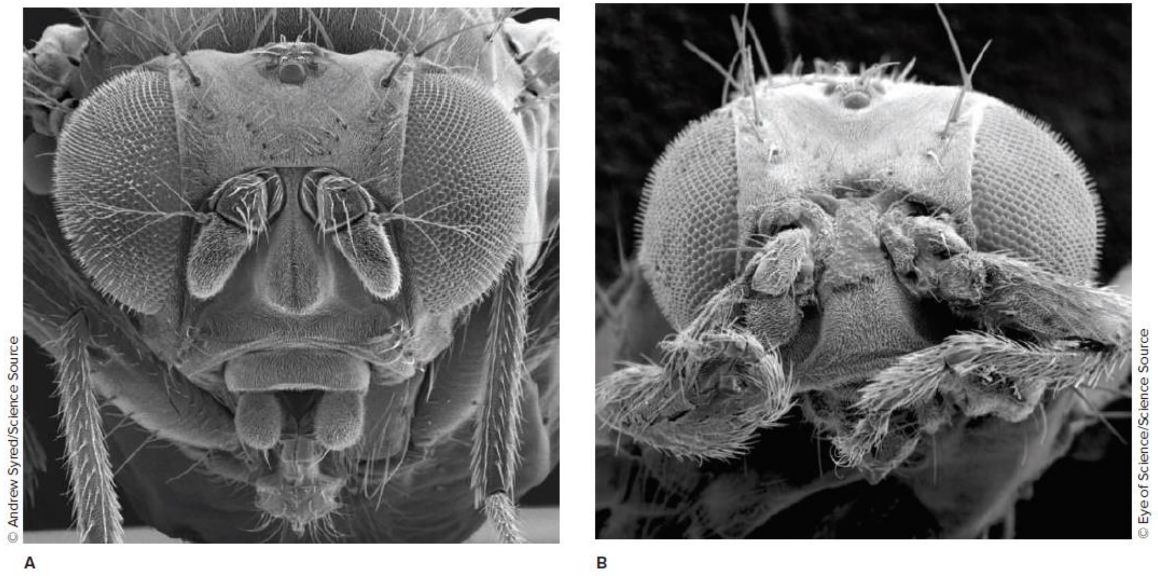
Direct



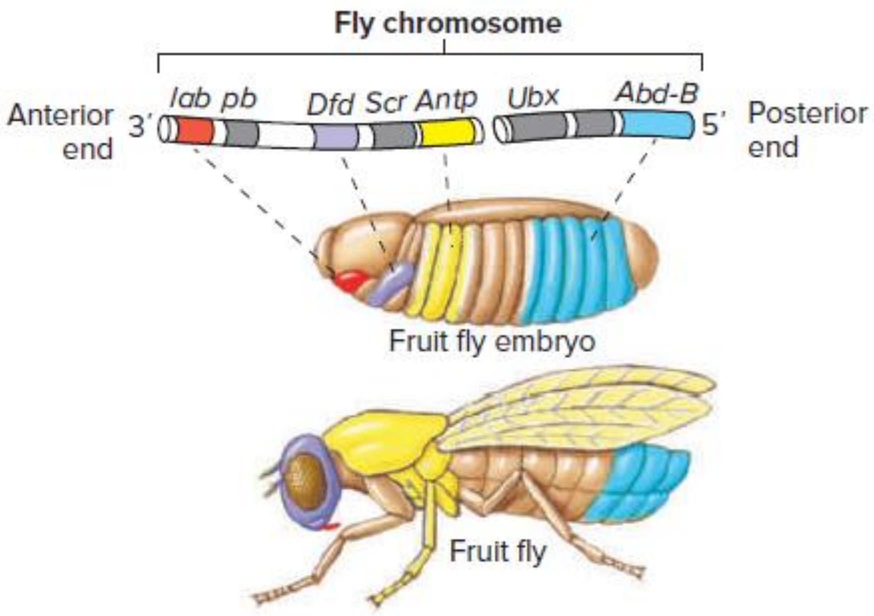
Mixed



Homeotic and Hox genes

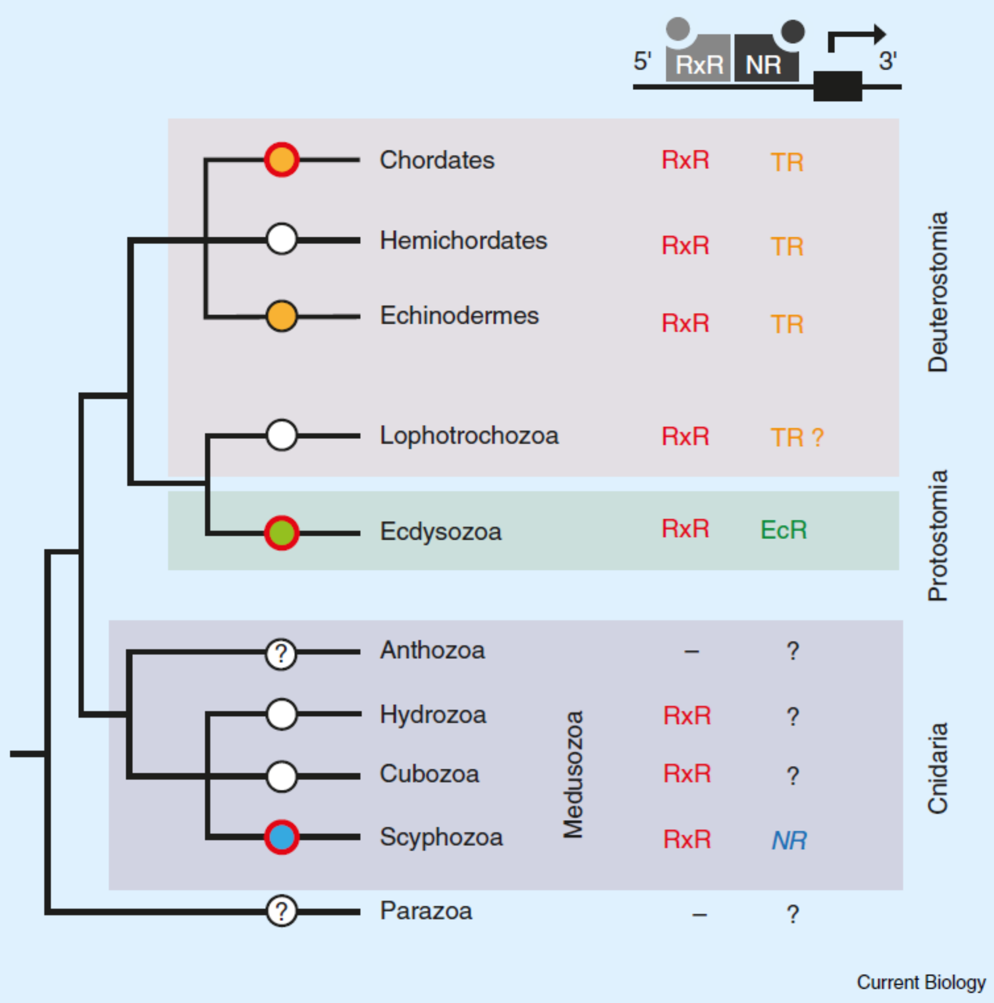


A. Head of a normal fruit fly with two antennae.
B. Head of a fruit fly with a pair of legs growing out of head sockets where antennae normally grow. The Antennapedia homeotic gene normally specifies the second thoracic segment (with legs), but the dominant mutation of this gene leads to this bizarre phenotype.



- Several other homeotic and nonhomeotic genes that are clustered close to Antennapedia on the same chromosome in *Drosophila* also include a homeobox.
- Genes in this cluster are called Hom genes, do not encode specific limbs and organs. Instead, they function by specifying the location in the body along the anteroposterior axis.

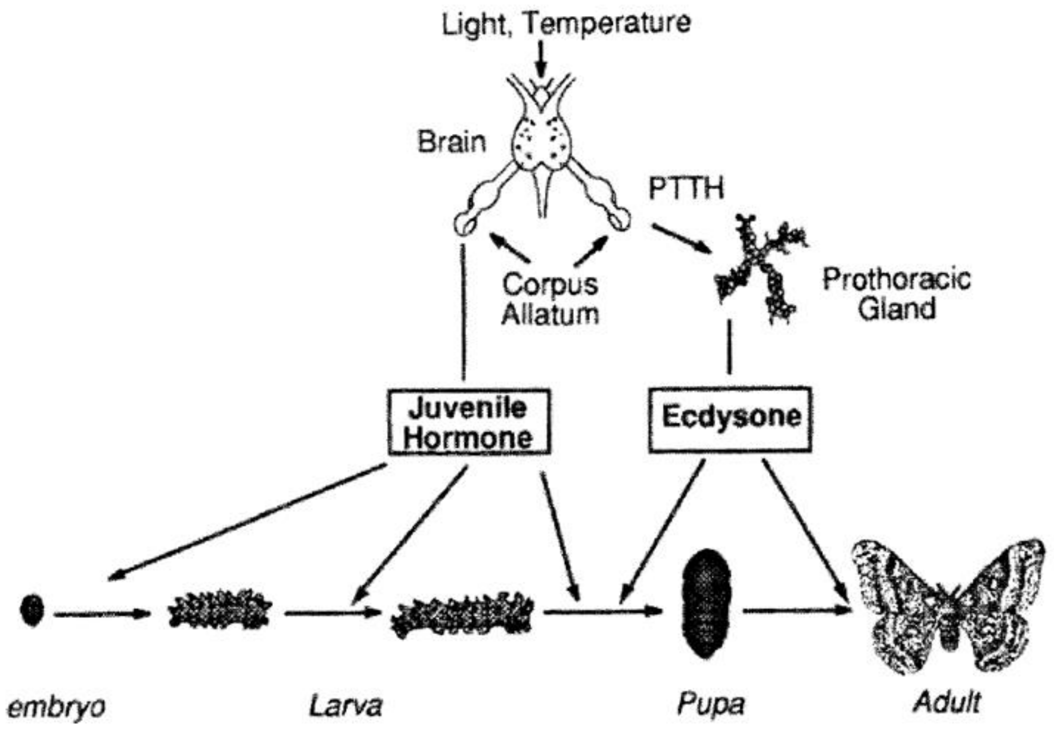
Comparative molecular aspects of metazoan indirect development



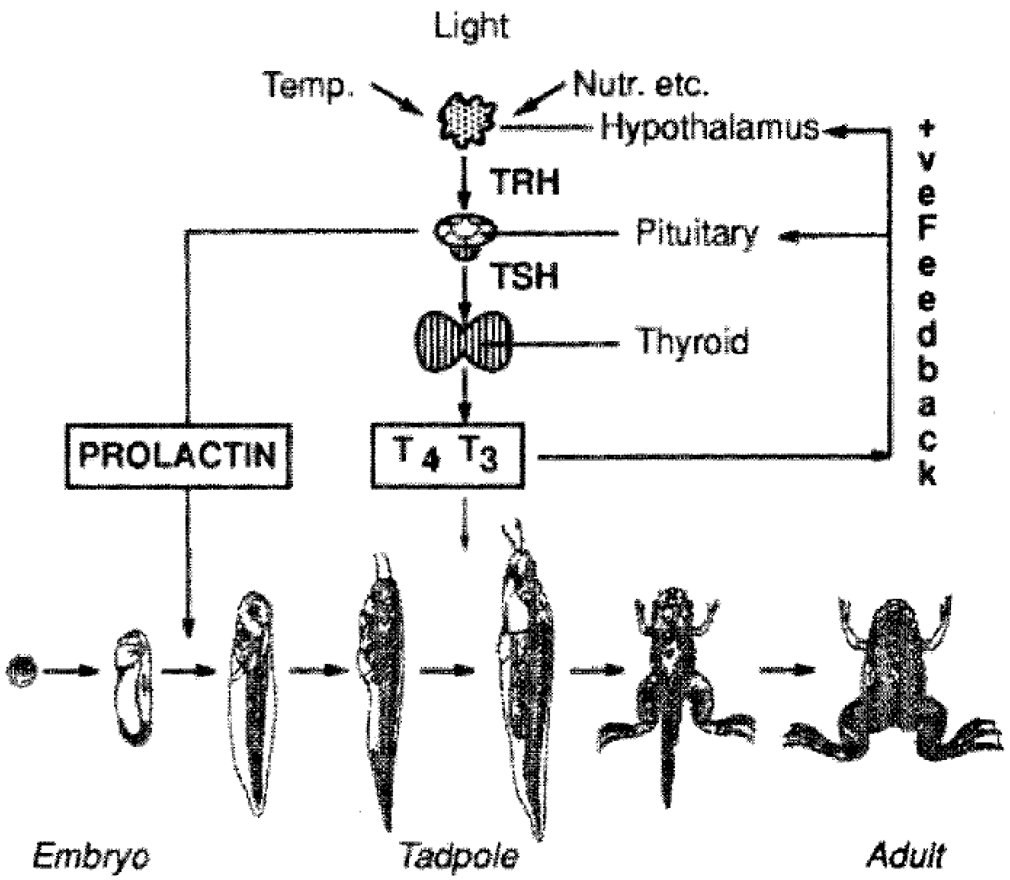
- Nuclear retinoid acid receptor (RxR) and an interacting nuclear receptor (NR) induce downstream target genes of metamorphosis.
- NRs are the thyroid hormone receptor (TR, yellow) from vertebrates (chordates), the ecdysone receptor (EcR) of the ecdysozoans, or unknown NRs (blue). In scyphozoans (Cnidarian) there is evidence for a peptide interacting NR (filled blue circle). Evidence for thyrosine and ecdysone are symbolized by filled yellow and green circles, respectively. Red circles indicate a proven function of RxR in indirect development.

Hormonal control of metamorphosis

Insect

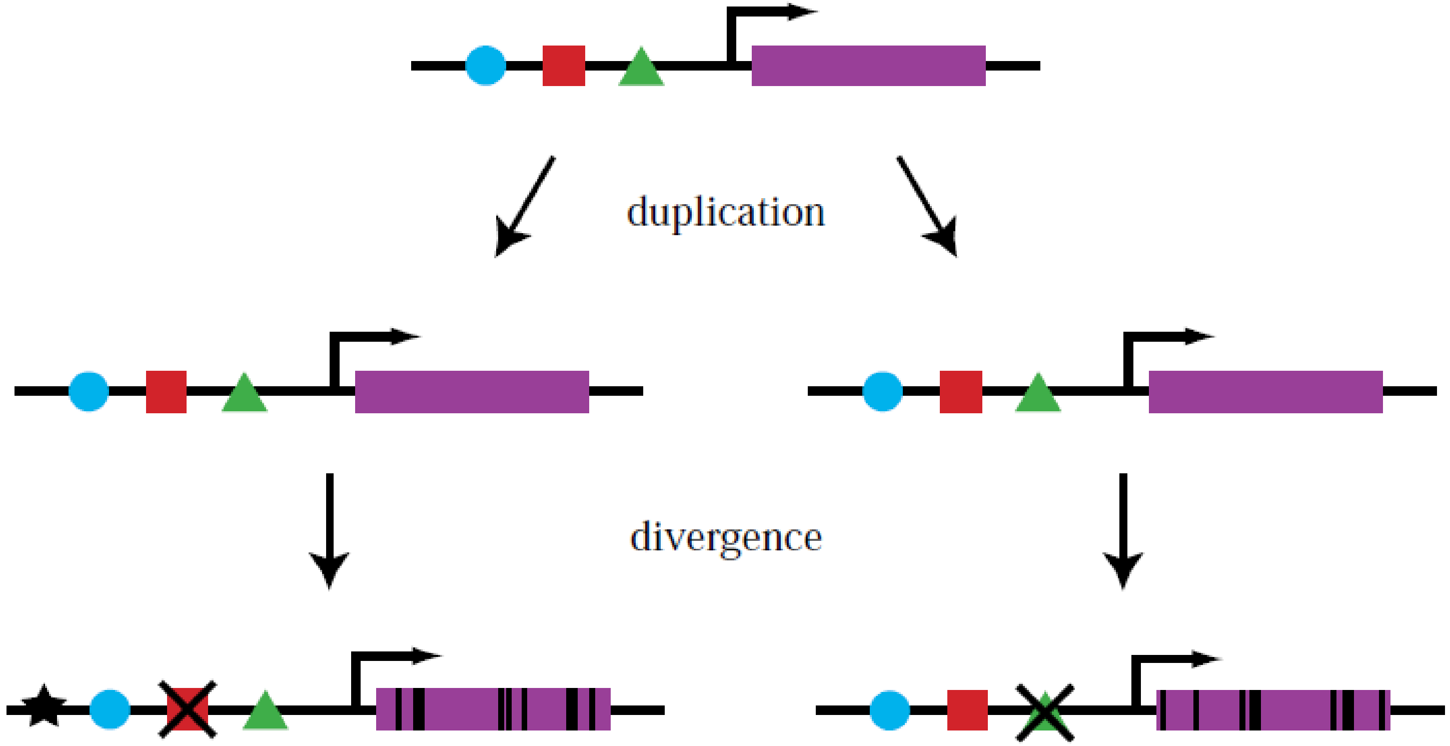


Amphibian



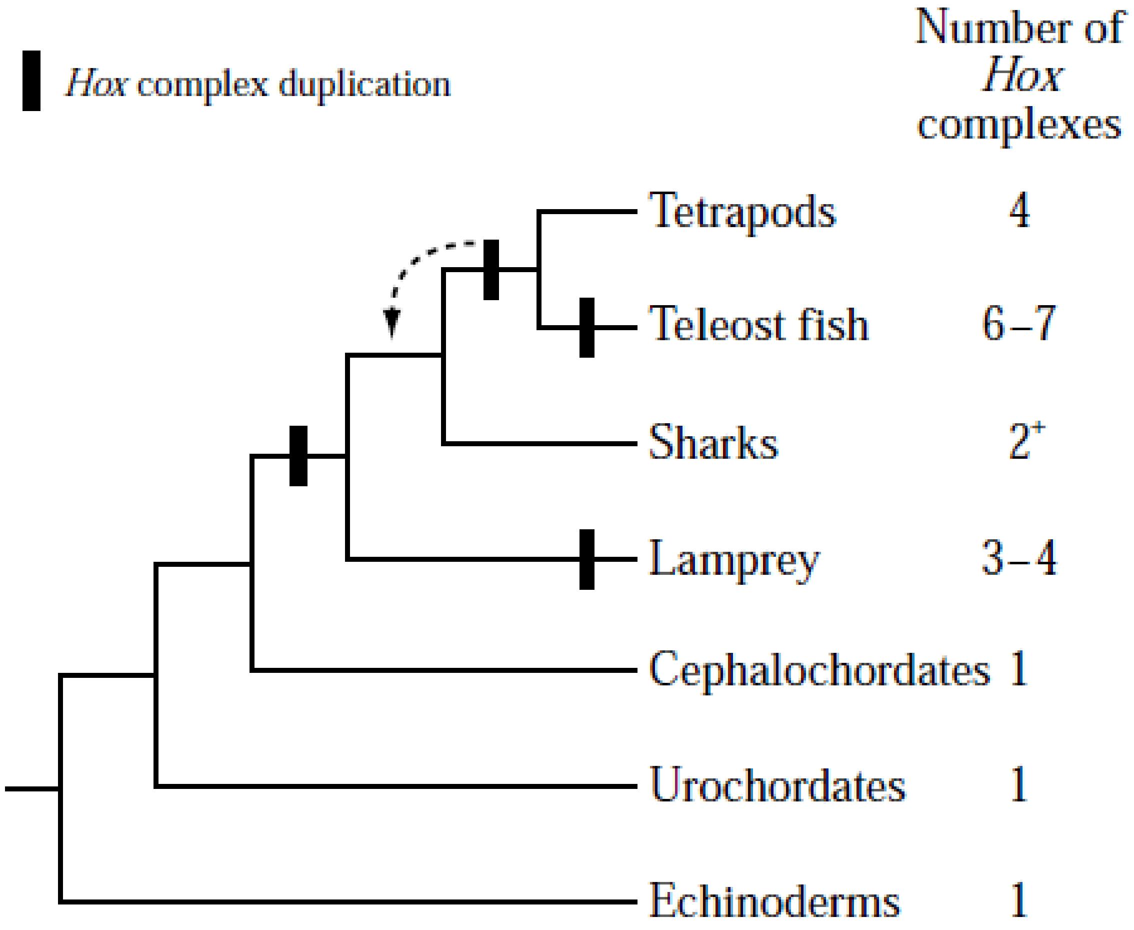
The sources of animal variation

Gene divergence



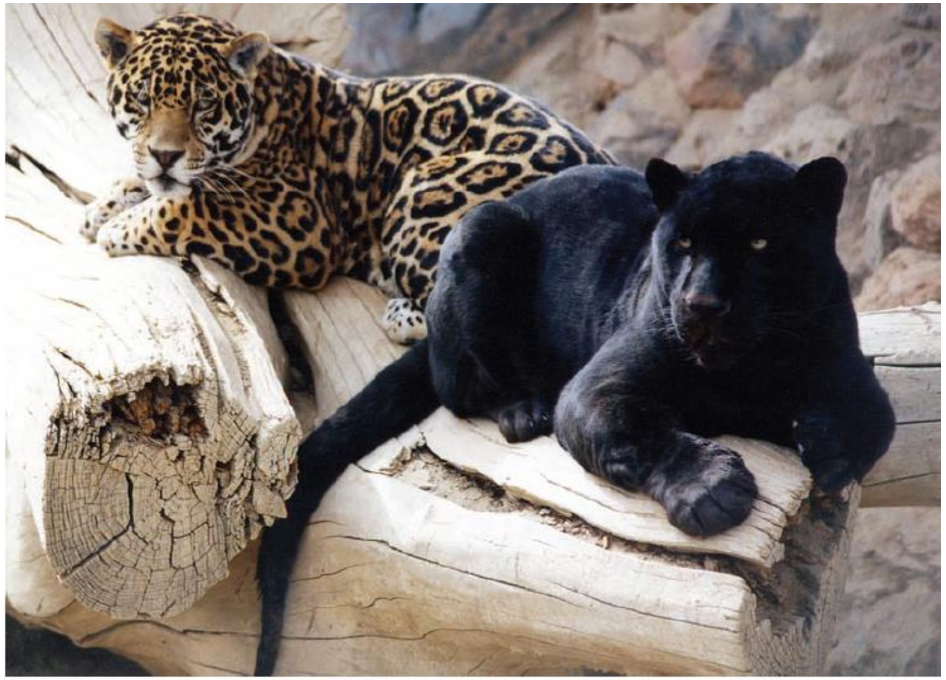
- Gene duplication can create two identical copies of a gene, including both cis-regulatory regions (blue, red, and green shapes) and the coding sequence (purple rectangle).
- The coding sequences will accumulate changes (indicated in black), which may alter protein function.
- The ancestral function may be retained by both proteins split between them, or retained by a single copy, freeing the other to evolve new functions.

Evolution of deuterostome Hox genes



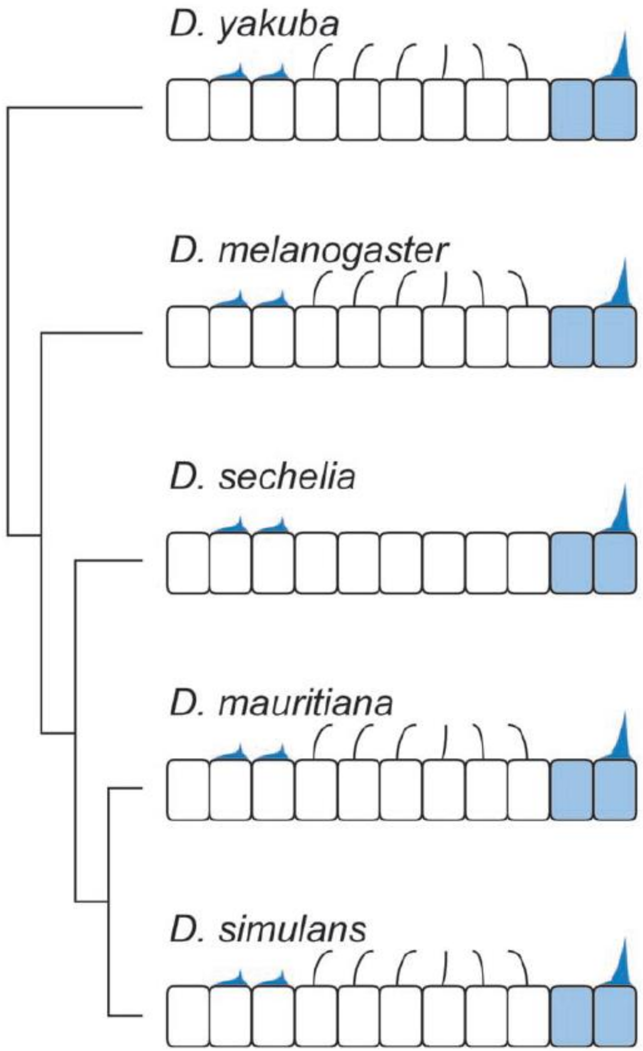
Evolution of animal color patterns

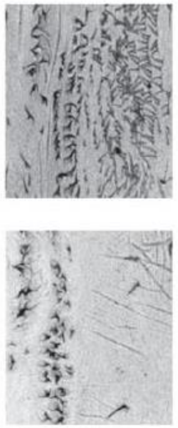
- The most widespread pigment in the animal kingdom is melanin.
- In mammals, two types of melanin are produced in melanocytes (the pigment cells of the epidermis and hair follicles), eumelanin and phaeomelanin, which produce black/brown and red/yellow coloration respectively.
- The relative amounts of eumelanin and phaeomelanin are controlled by the products of several genes.
- Two key proteins are the melanocortin 1 receptor (MC1R) and the Agouti protein.
- During the hair growth cycle, α-melanocyte stimulating hormone (α-MSH) binds to the
- MC1R, which triggers elevated cAMP levels and activation of tyrosinase, the rate-limiting enzyme in melanin synthesis.



The two phases of *Panthera anca*

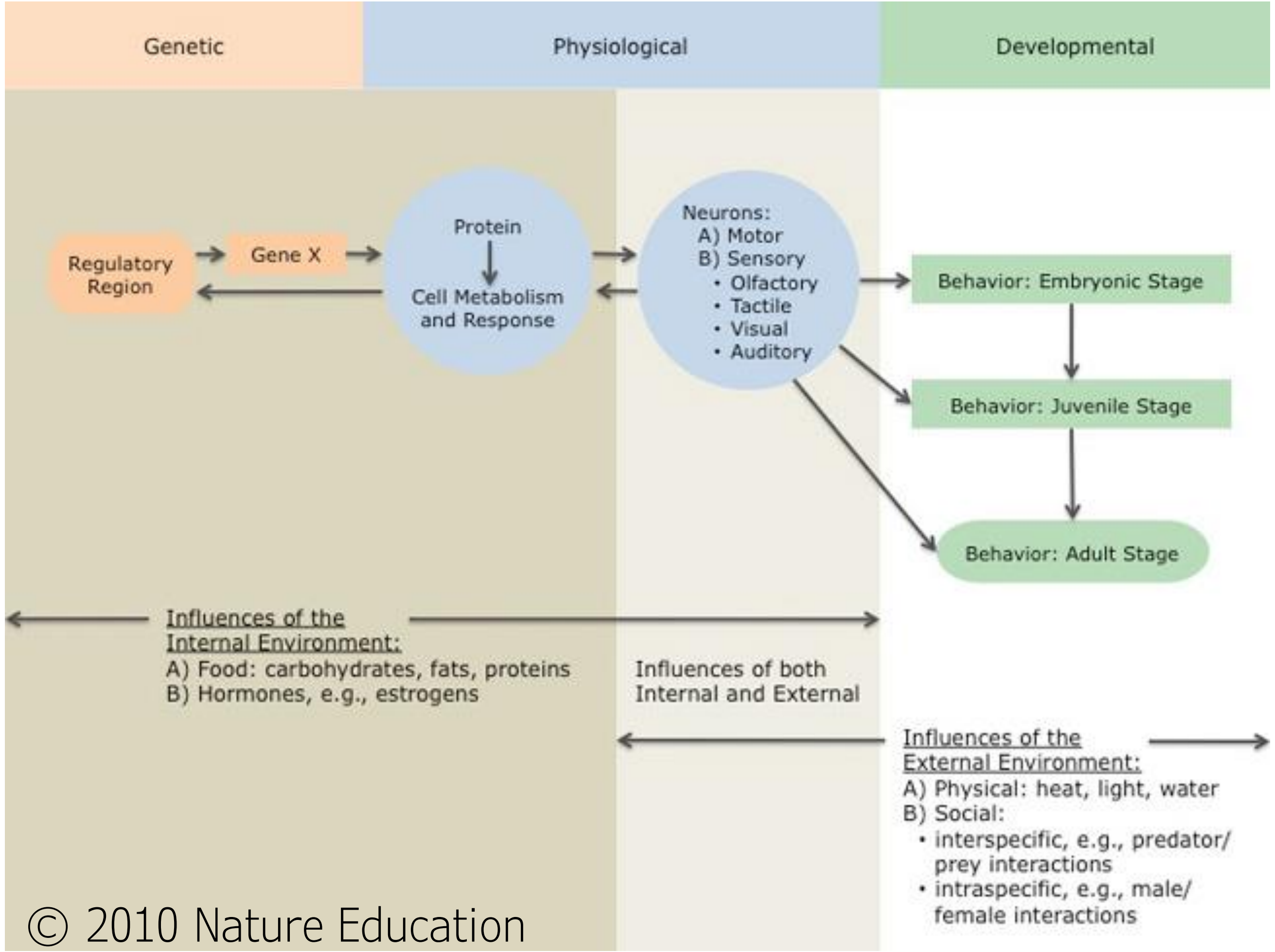
Evolution of trichome patterns via regulatory evolution at the shavenbaby gene



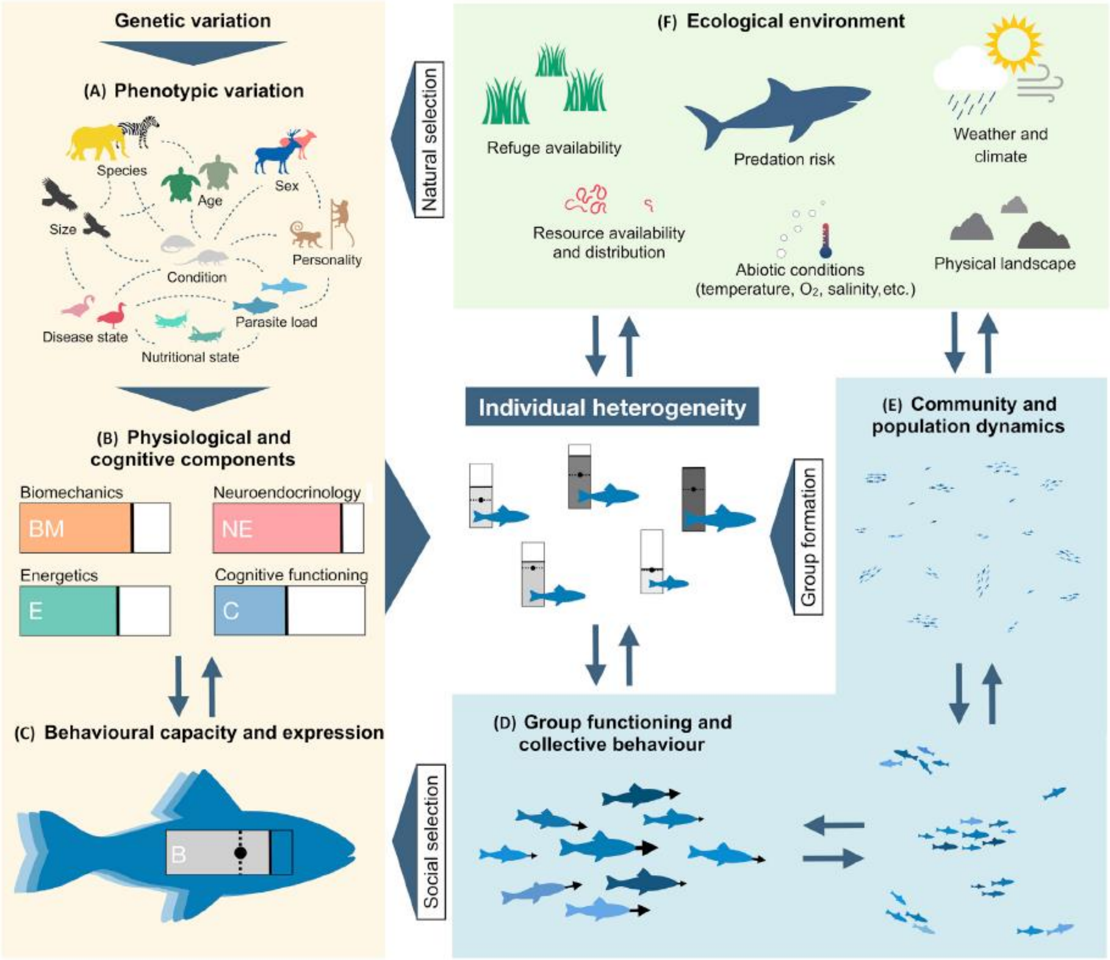


- In *D. melanogaster*, the formation of hairs covering requires the activity of the aptly-named Shavenbaby (Svb) transcription factor (mutants in svb lack hairs, appearing "shaven"), whose expression precisely foreshadows the position of denticles and hairs in the larval epidermis.
- In the *melanogaster* species group, all members except for *D. sechelia* bear rows of fine hairs on the dorsal part of larval segments.
- The difference in *D. sechelia* is entirely due to changes at the svb locus, and is correlated with the lack of svb transcription in the region where the hairs form in other species.

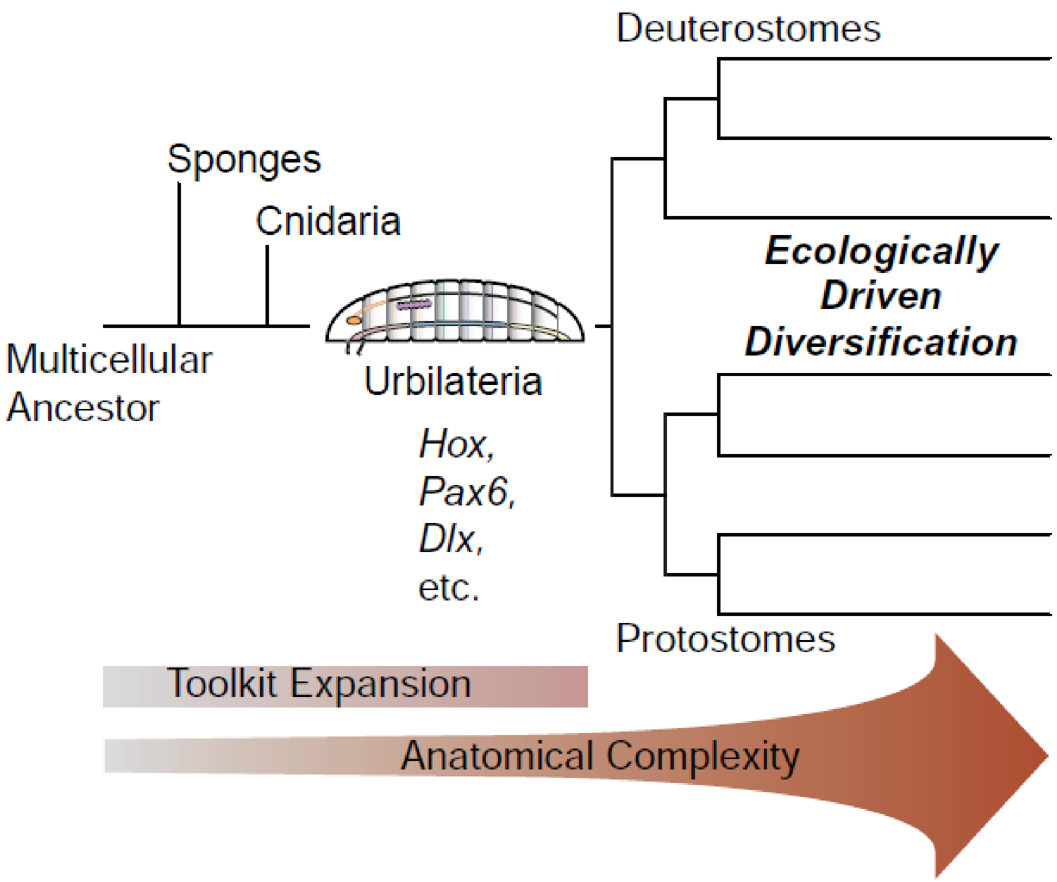
An integrative model for the short-term causes of behavior in the life of an animal



The effects of phenotypic variation in collective animal behaviour



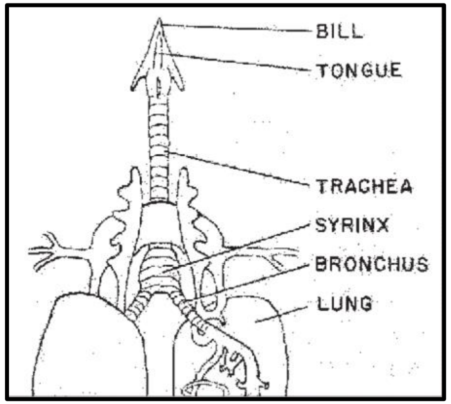
Evolution of animal morphological complexity

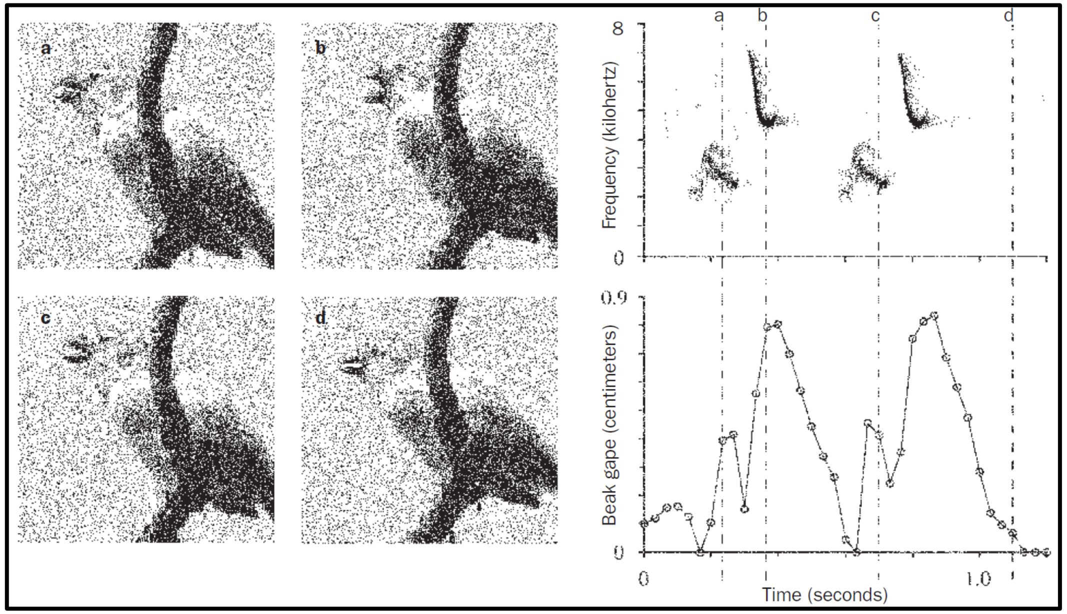


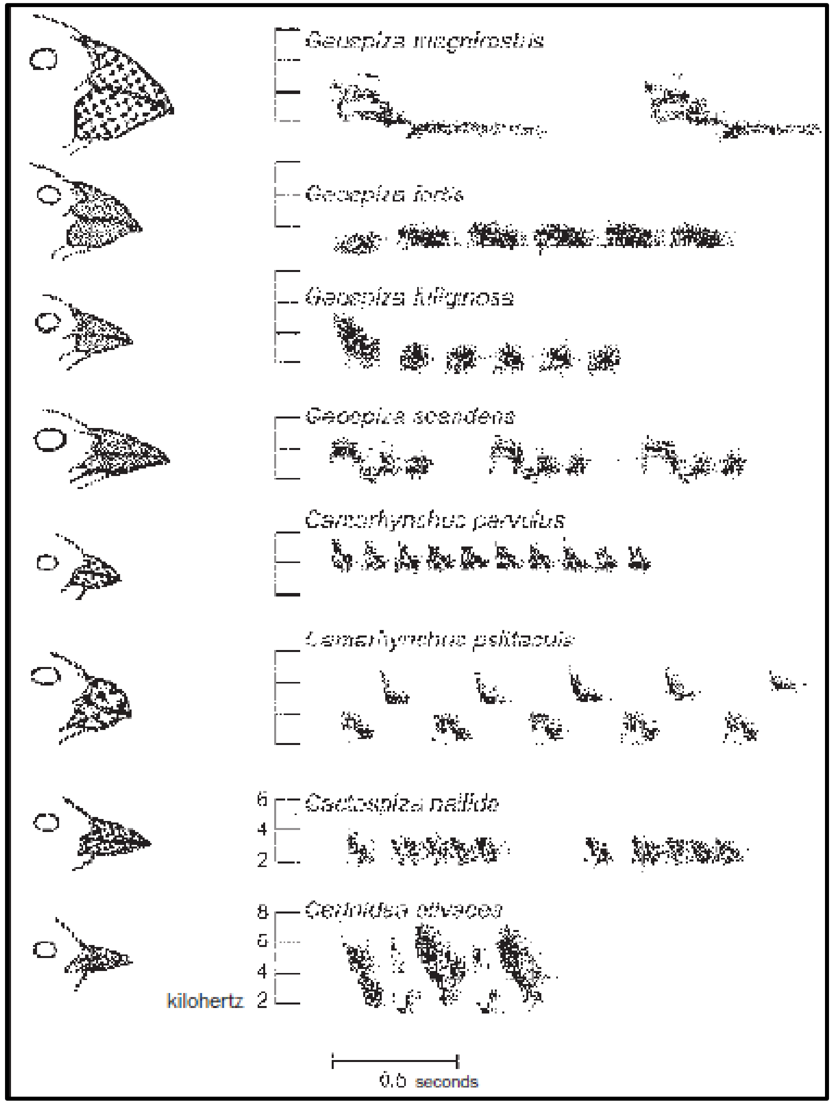
- The evolution of diverse animal forms followed the radiation of bilaterian phyla in the Cambrian.
- The ecological forces of the Cambrian may have facilitated the evolution of animal morphology using an established set of developmental regulatory genes and networks to build diverse body parts and body plans.

The formation of animal phenotypic variation by natural selection

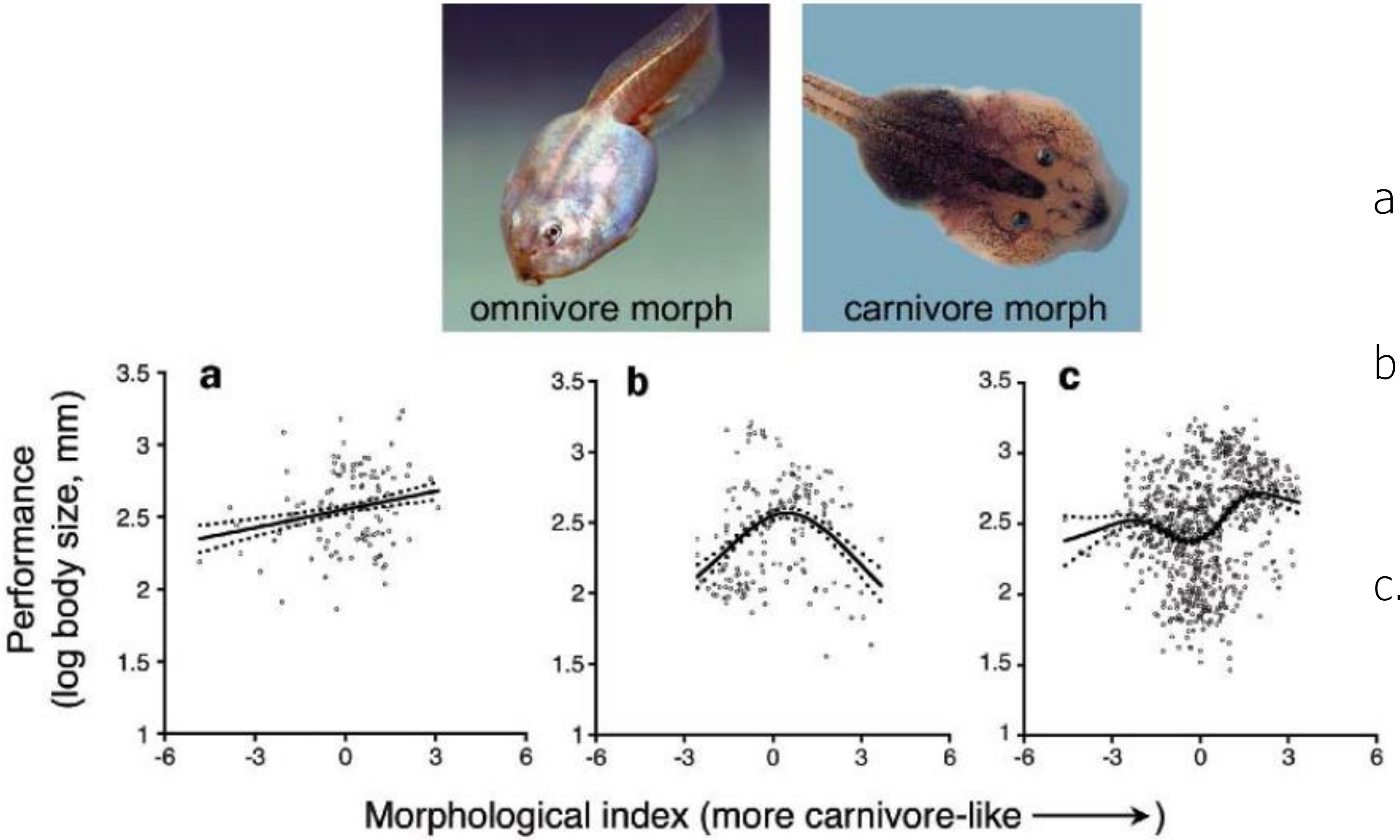
Beaks, Adaptation, and Vocal Evolution in Darwin's Finches







Different modes of selection in natural populations



a. mixed-species ponds, directional selction, the most carnivore-like *Spea bombifrons* tadpoles were the largest.
b. mixed-species ponds, stabilizing selection, intermediate *Spea multiplicata* appears to favor individuals with intermediate phenotypes.
c. single-species ponds, disruptive selection, *Spea multiplicata* favors extreme trophic phenotypes.