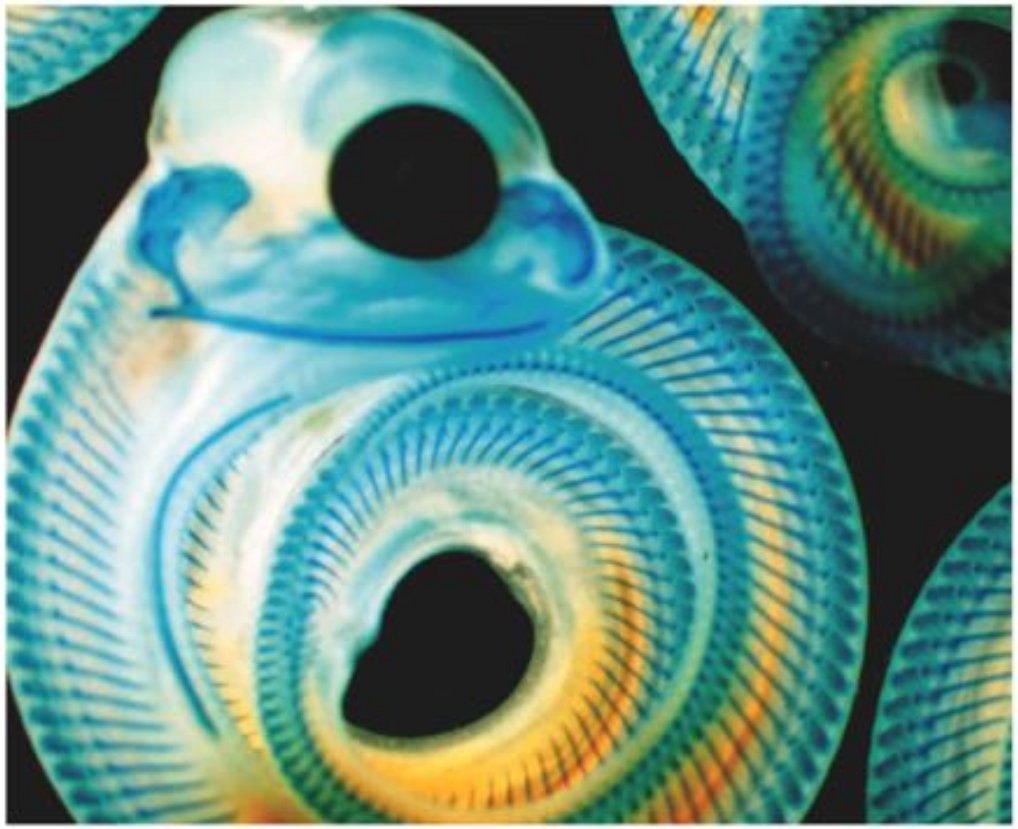
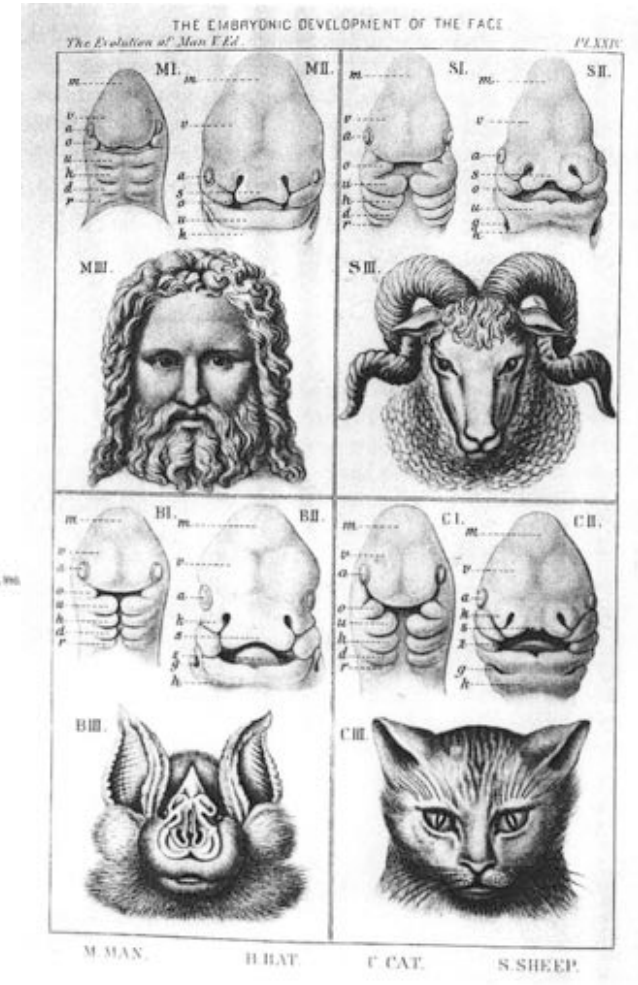
EVO-DEVO


DADDY, WHY ARE STARFISH SHAPED LIKE STARS?
UH...
THAT'S A VERY INTERESTING QUESTION, SADIE. FUNCTIONAL ADAPTABILITY AND ANATOMICAL DETERMINATION IN BIOLOGICAL SYSTEMS IS A FASCINATING ISSUE THAT CERTAINLY WARRANTS FURTHER INVESTIGATION.
DOES THAT MEAN YOU DON'T KNOW?
IT'S BEYOND THE SCOPE OF MY RESEARCH.
www.phdcomics.com

INTRO



DEVELOPMENTAL BIOLOGY, Eighth Edition, Chapter 22, Opener © 2006 Sinauer Associates, Inc.



O desenvolvimento biológico no pensamento evolutivo

XVII DC William Harvey propõe que todos os animais se desenvolvem a partir do ovo (1651)

El cientifico:

Ernst Haeckel
Feb 16th 1834 – Aug 9th 1919

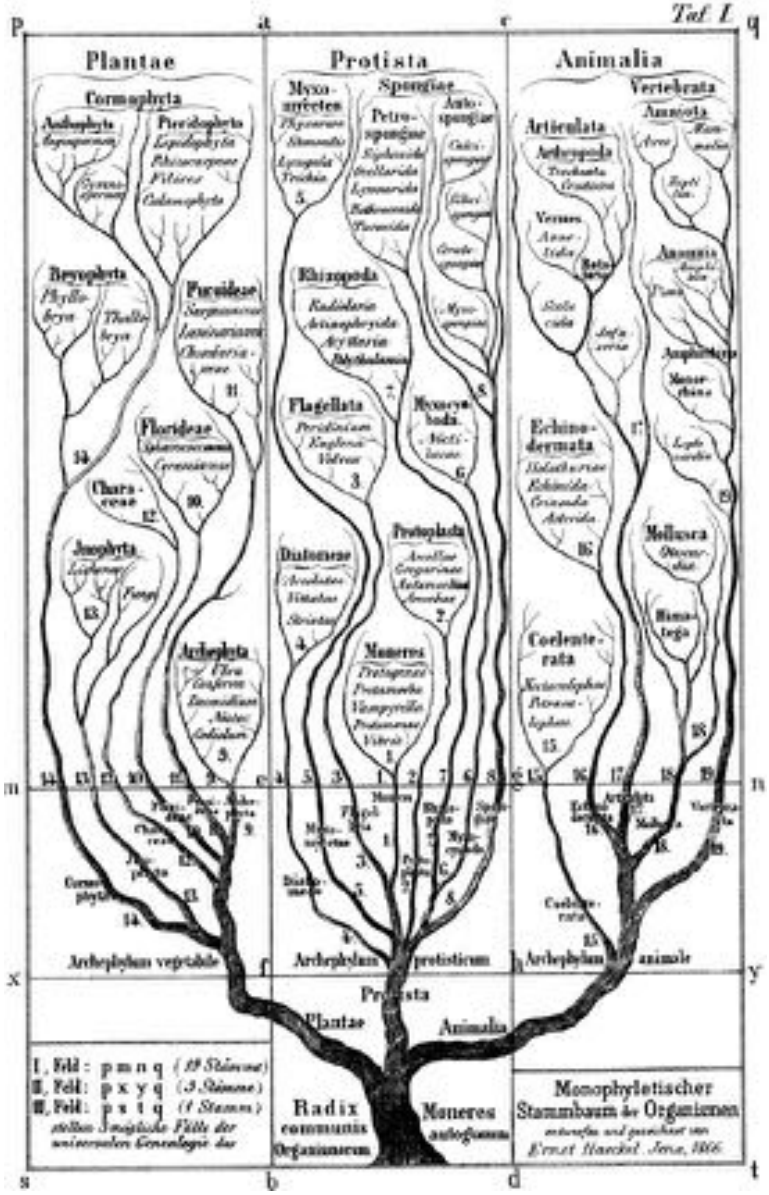
Ernst Heinrich Philipp August also written von Haeckel, was an eminent German biologist, naturalist, philosopher, physician, professor and artist who discovered, described and named thousands of new species, mapped a genealogical tree relating all life forms, and coined many terms in biology, including phylum, phylogeny, ecology and the kingdom Protista. Haeckel promoted and popularized Charles Darwin's work in Germany and developed the controversial recapitulation theory ("ontogeny recapitulates phylogeny") claiming that an individual organism's biological development, or ontogeny, parallels and summarizes its species' entire evolutionary development, or phylogeny.

Ernst Haeckel

El artista:

Contribuições de Haeckel nosso entendimento de sistemática e evolucão

In 1866, Haeckel propõe o uso dos termos: *filogenia, ontogenia*, e *ecologia*.



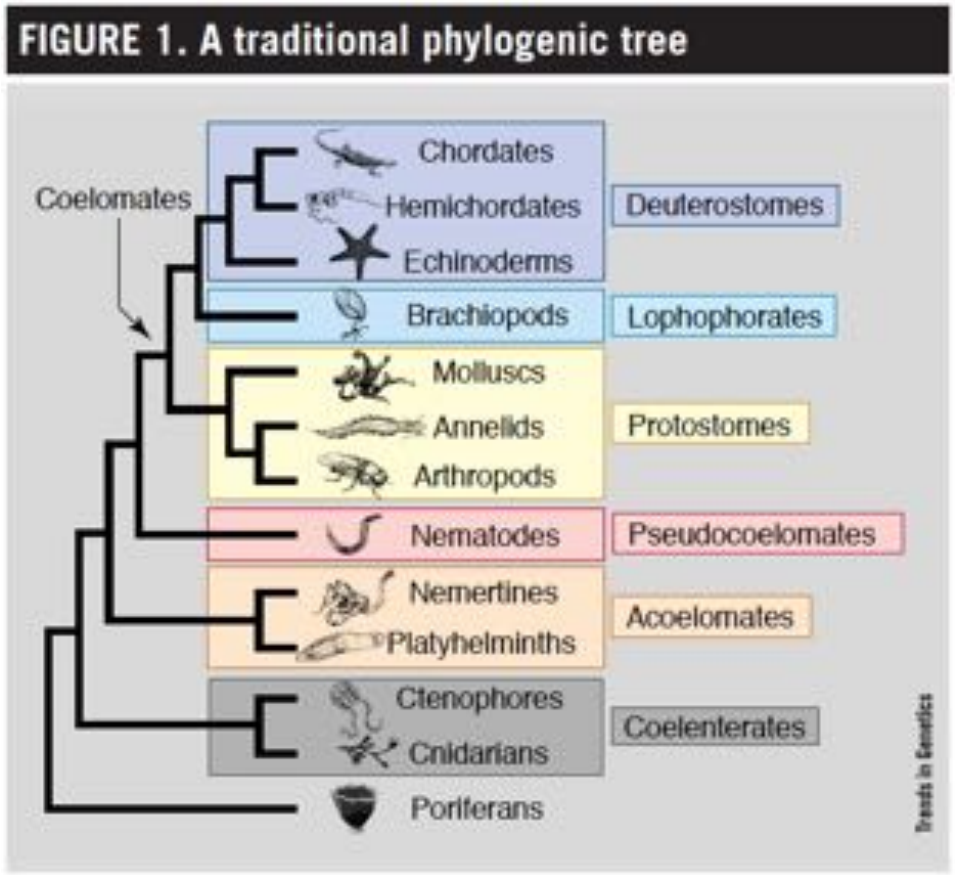
Principios unificadores de Haeckel:

Afirma que os animais compartem um origem comum e se originaram de uma forma unicelular. Intenta unificar principios evolutivos de Lamarck, Darwin, com principios da *naturphilosophie* de Shelling y Goethe. Esta retrospectiva evolutiva chega integrar visões da natureza com principios da religião e a arte.

Haeckel antecipa que alguns fatores hereditários podem ser transmitidos pelo núcleo.

Caracteres embriológicos e do desenvolvimento são usados nas primeiras filogenias de animais

Zoólogos geram propostas com base na morfologia comparativa para relacionar aos grandes grupos dos animais, dando grande importância aos processos do desenvolvimento.



Libbie Henrietta Hyman (1888-1969)

"I believe my interest in nature is primarily aesthetic."

FORMAS NA NATUREZA: COMO SE *GERAM, MANTEM* OU *PERDEM*?

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- ORIGEM DAS NOVEDADES EVOLUTIVAS
  - Restrições no desenvolvimento (planos corpóreos e reconstrução de estados ancestrais)
  - Alometria e campos morfogenéticos

- “TOOLKIT GENICO” E MODULARIDADE
  - Genes Hox
  - Modularidade nas formas animais

- ACOMODAÇAO VS. ASIMILAÇAO
  - Acomodação fenotípica (quadrúpedes em duas pernas)
  - Assimilação genética (mosca HSP90)

- AMBIENTE E NOVEDADES EVOLUTIVAS
  - Polifenismos
  - Simbiose

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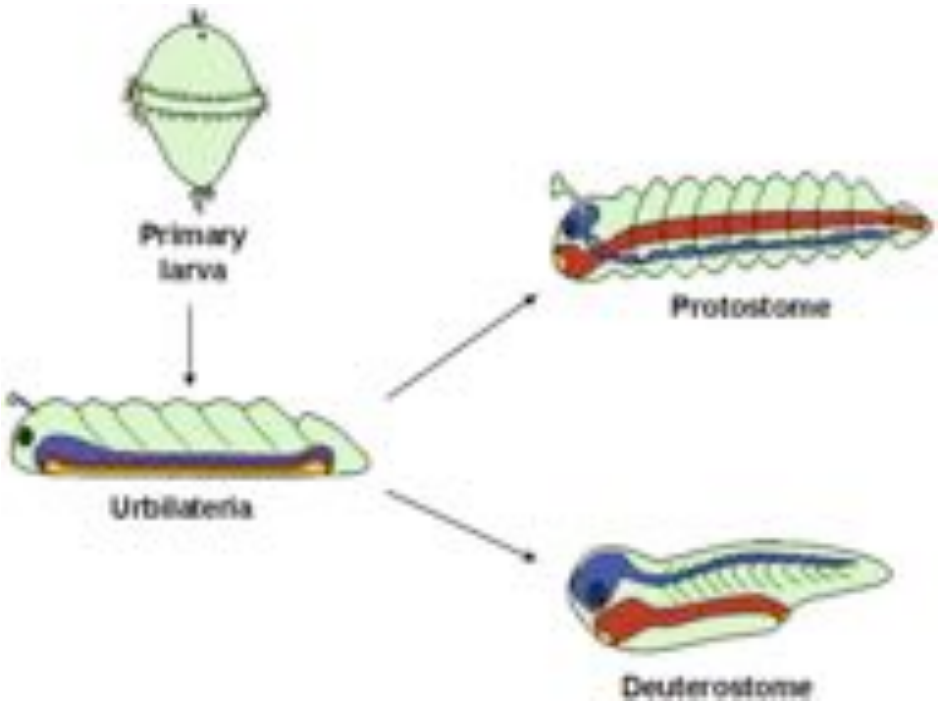
  - Simbiose

Evolução dos planos corpóreos (Burgess Shale)

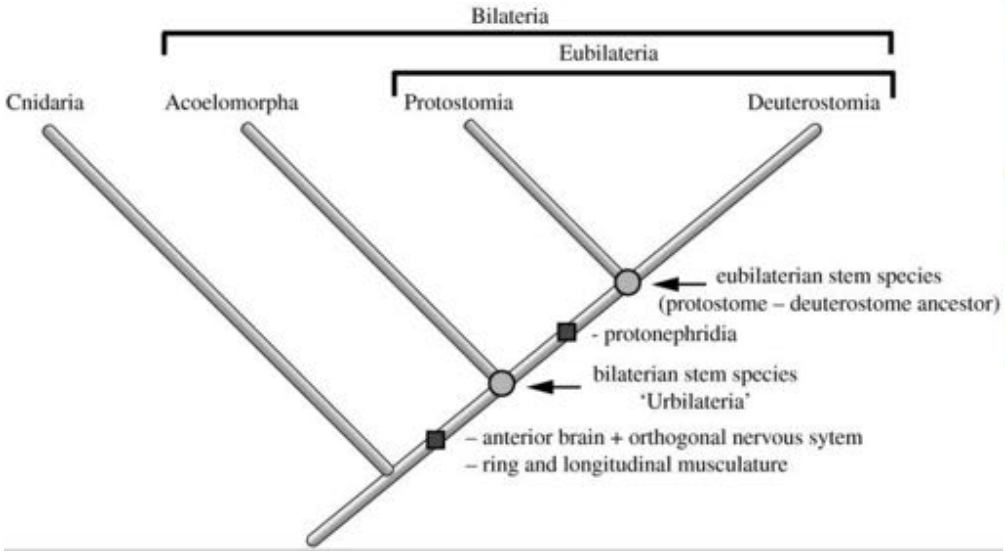
Evolução dos planos corpóreos (Burgess Shale)

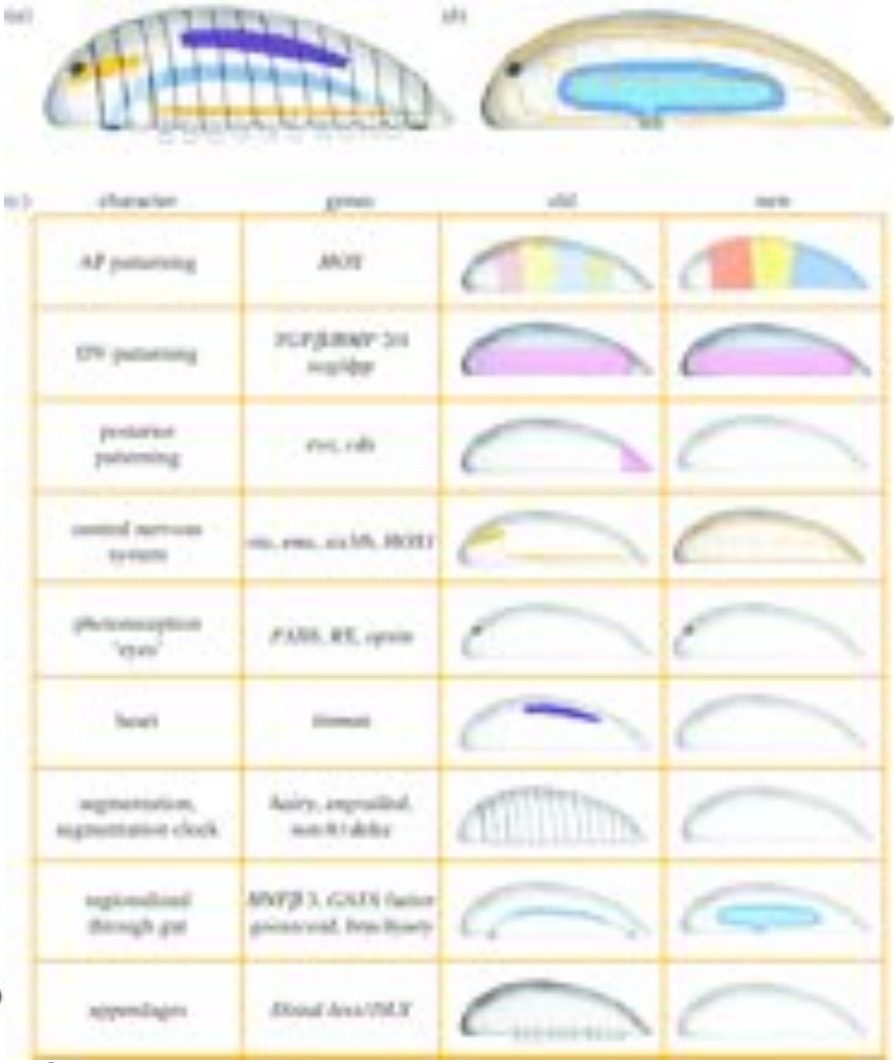
Evolução dos planos corpóreos (Burgess Shale)

Evolução dos planos corpóreos : Inversão Protostomo-Deuterostomo e o ancestro dos urbilatérios



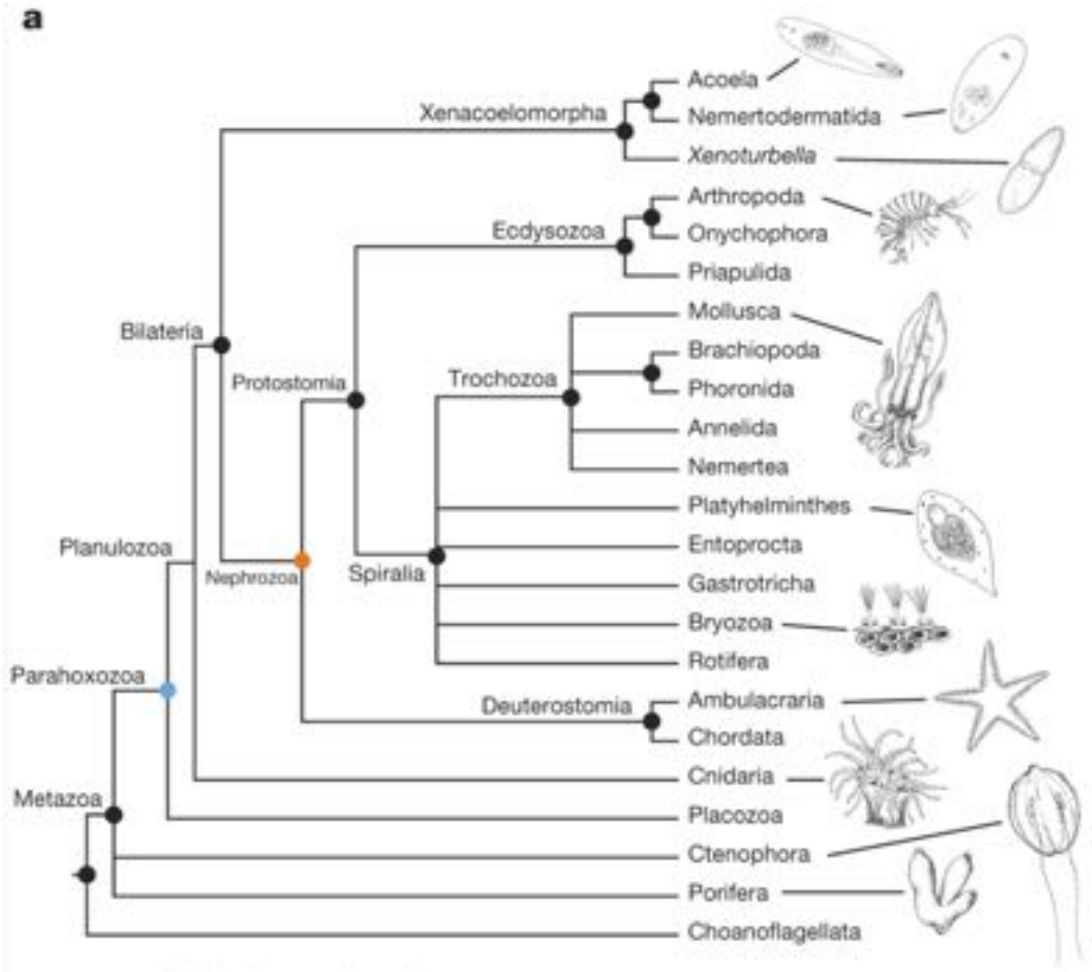
Complex Urbilaterian (De Robertis 2008)





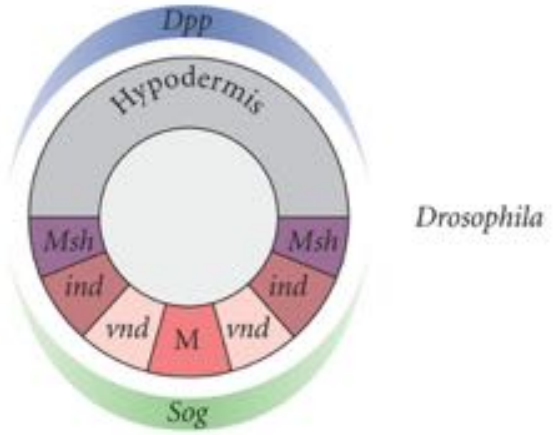
Simple Urbilaterian, assumption based on Acoels as sister group to the bilateria (Hejnol&Martindale, 2008)

Evolution of body plans: Dorso-ventral patterning (DV)

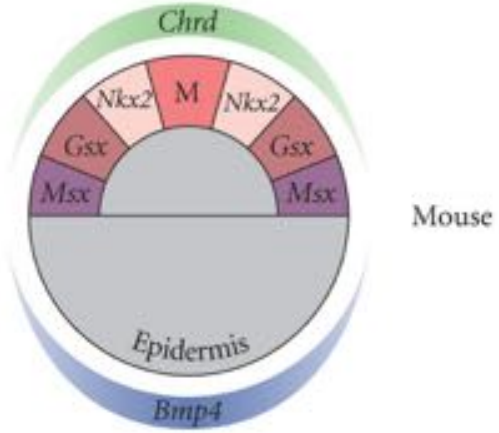


Cannon et al. 2016

Protostome:



Deuterostome:



Evolution of body plans: Hox genes

TABLE 23.1 Developmental regulatory genes conserved between protostomes and deuterostomes

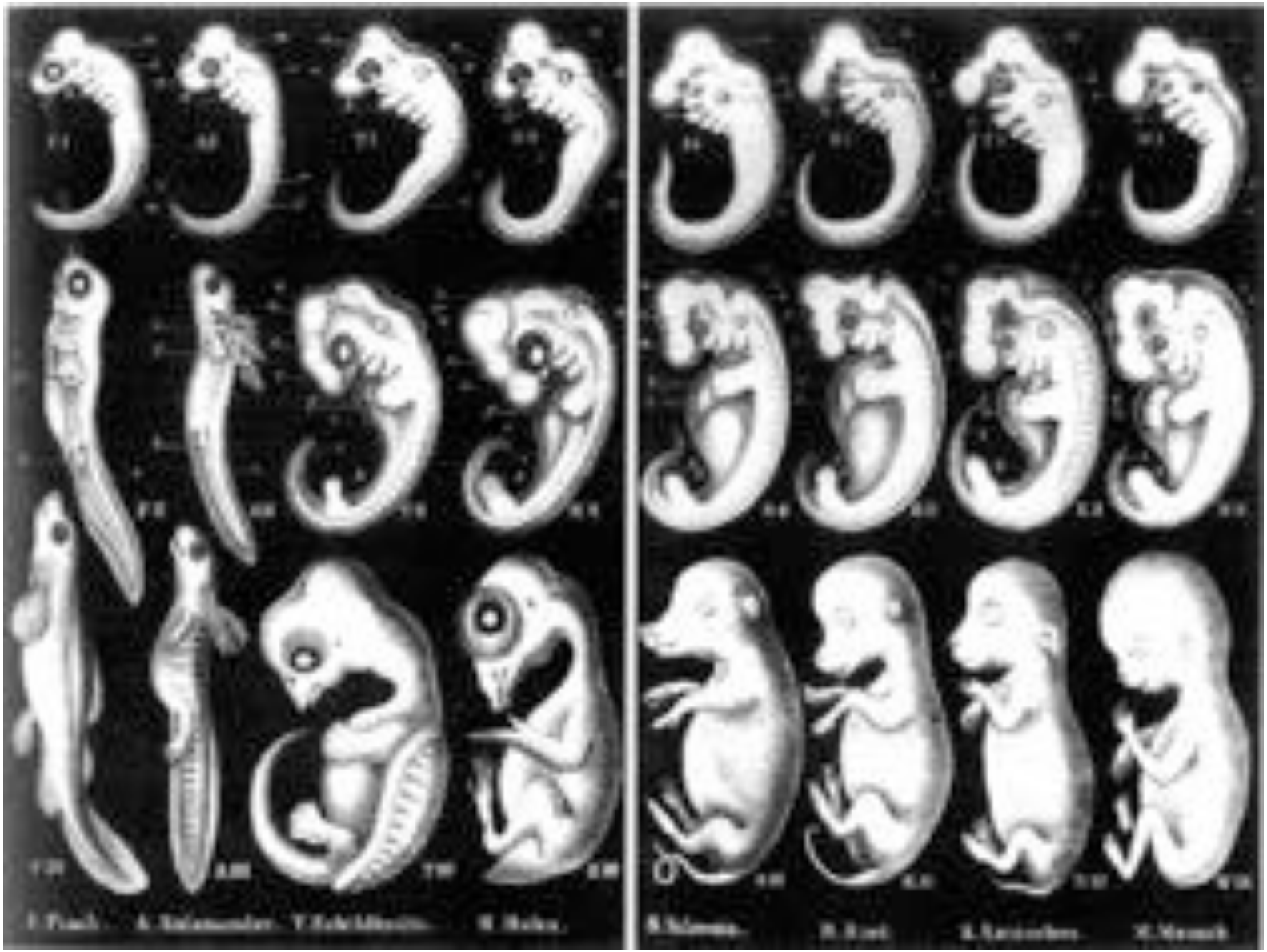
Gene	Function	Distribution
achaete-scute group	Cell fate specification	Cnidarians, *Drosophila*, vertebrates
Bcl2/Drob-1/ced9	Programmed cell death	*Drosophila*, nematodes, vertebrates
Caudal	Posterior differentiation	*Drosophila*, vertebrates
delta/Xdelta-1	Primary neurogenesis	*Drosophila*, *Xenopus*
Distal-less/DLX	Appendage formation (proximal-distal axis)	Numerous phyla of protostomes and deuterostomes
Dorsal/NFkB	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
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
Polycomb group	Controls Hox expression/ cell differentiation	*Drosophila*, vertebrates
Netrins, Split proteins, and their receptors	Axon guidance	*Drosophila*, vertebrates
RAS	Signal transduction	*Drosophila*, vertebrates
sine oculus/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.

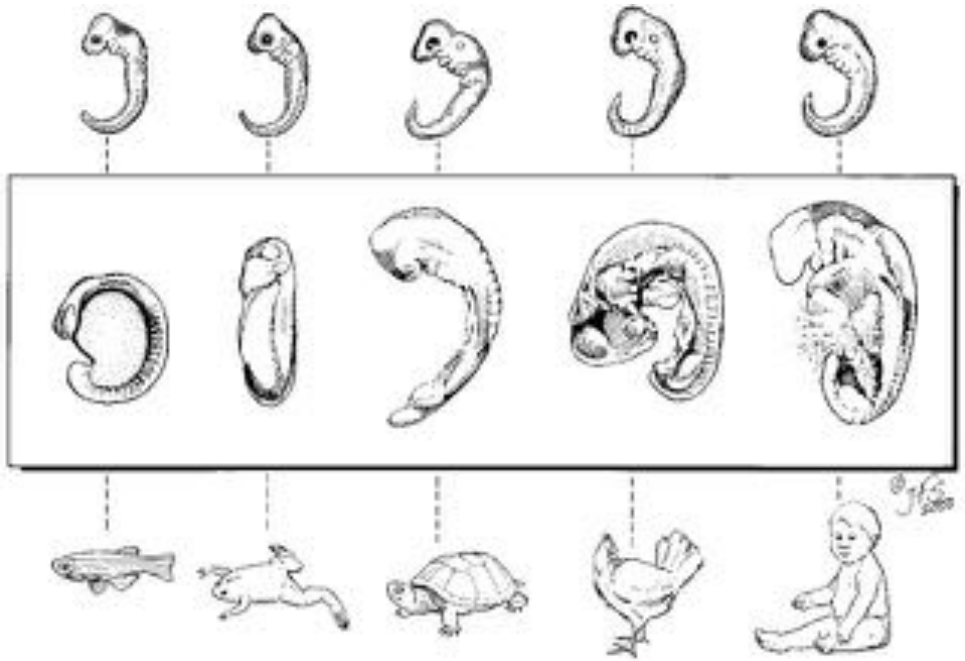
Reconstruyendo estadios del desarrollo ancestrales

“Ontogeny recapitulaes phylogeny”

Heackel integrated embryology and evolution, and proposed the recapitulation theory:

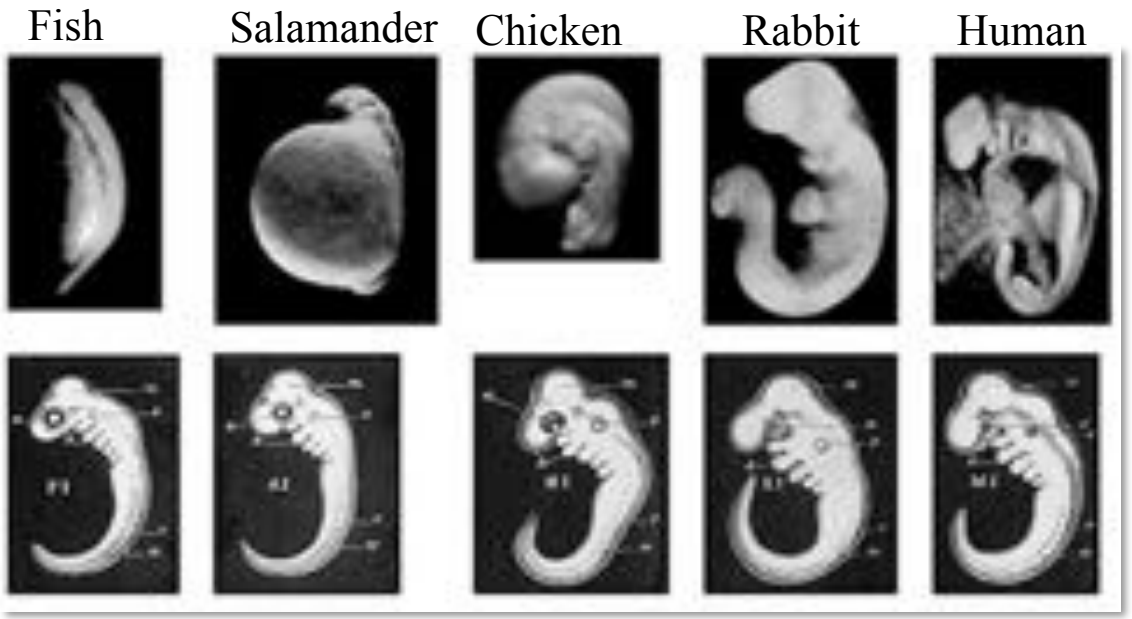


Recapitulation Theory: Science or myth?



Haeckel's drawings compared with actual embryos

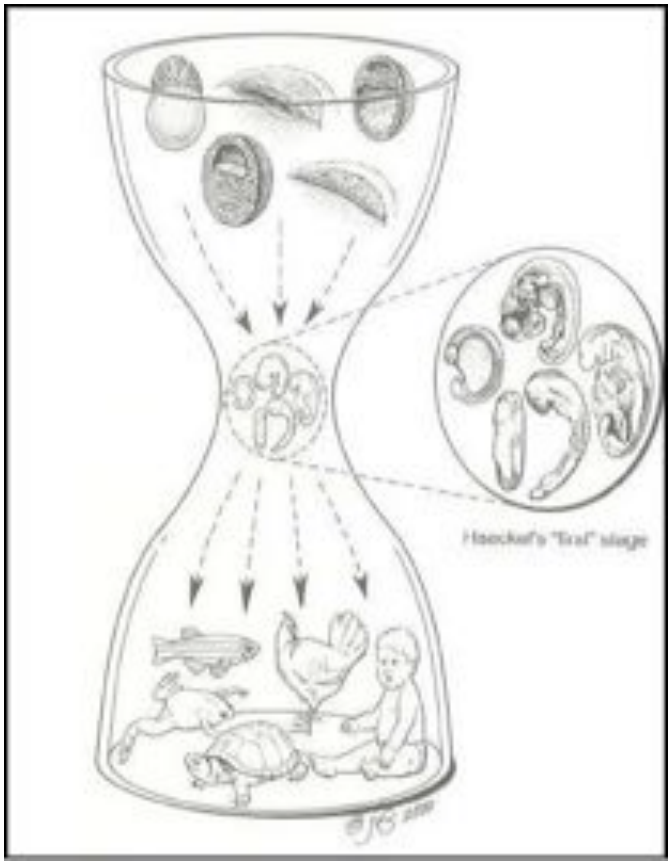
J. Wells, 'Icons of Evolution: Science or myth?'
Regnery Publishing, Washington DC, 2000



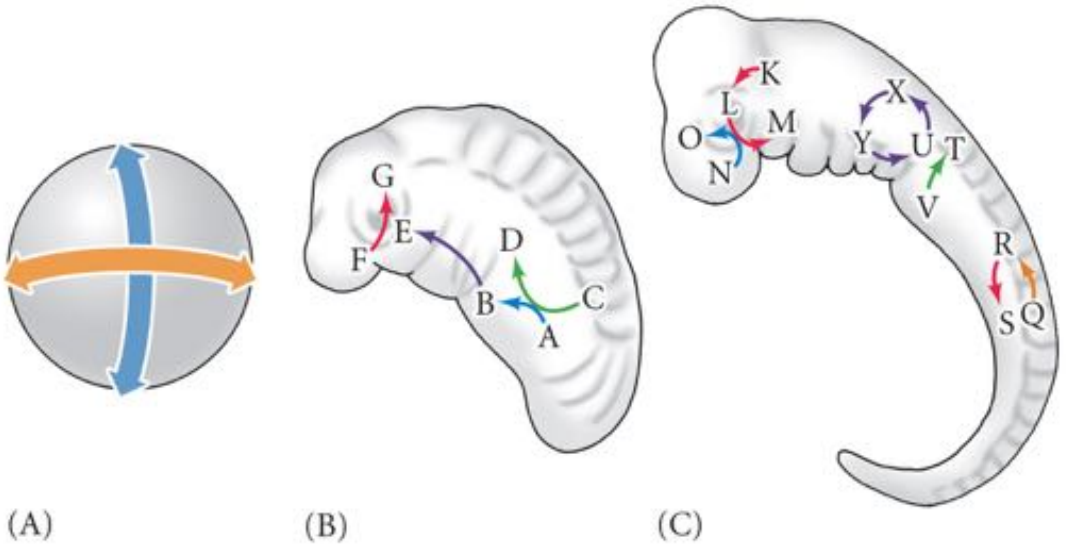
Cortesy Marcela Guzman

Recapitulation Theory: Science or myth?

Hourglass or bottleneck of ontogeny (Richardson, 1997):



Pharyngula (Gilbert, 1991):



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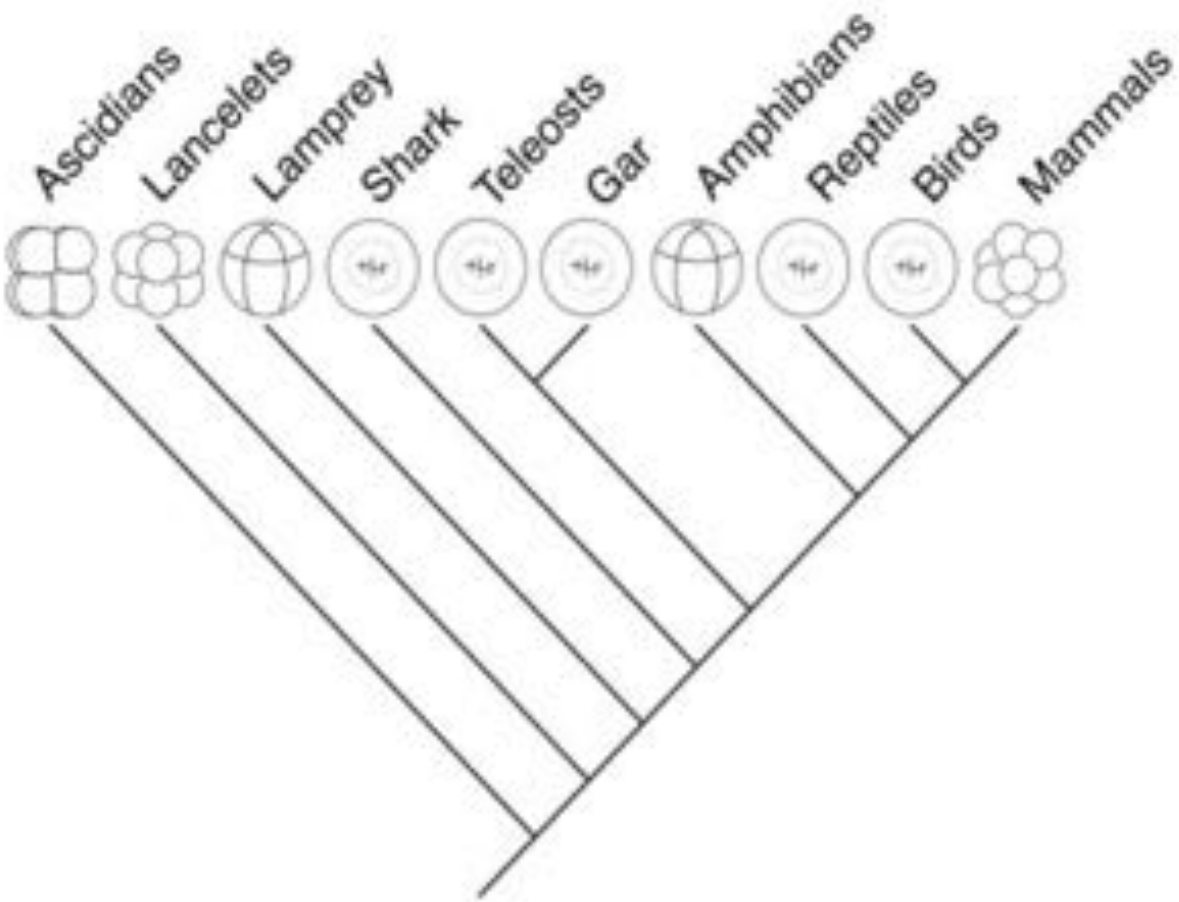
Evolutionary patterns: Deuterostome cleavage patterns



Ancestral mode of cleavage was likely holoblastic

(Chea, et al., 2005)

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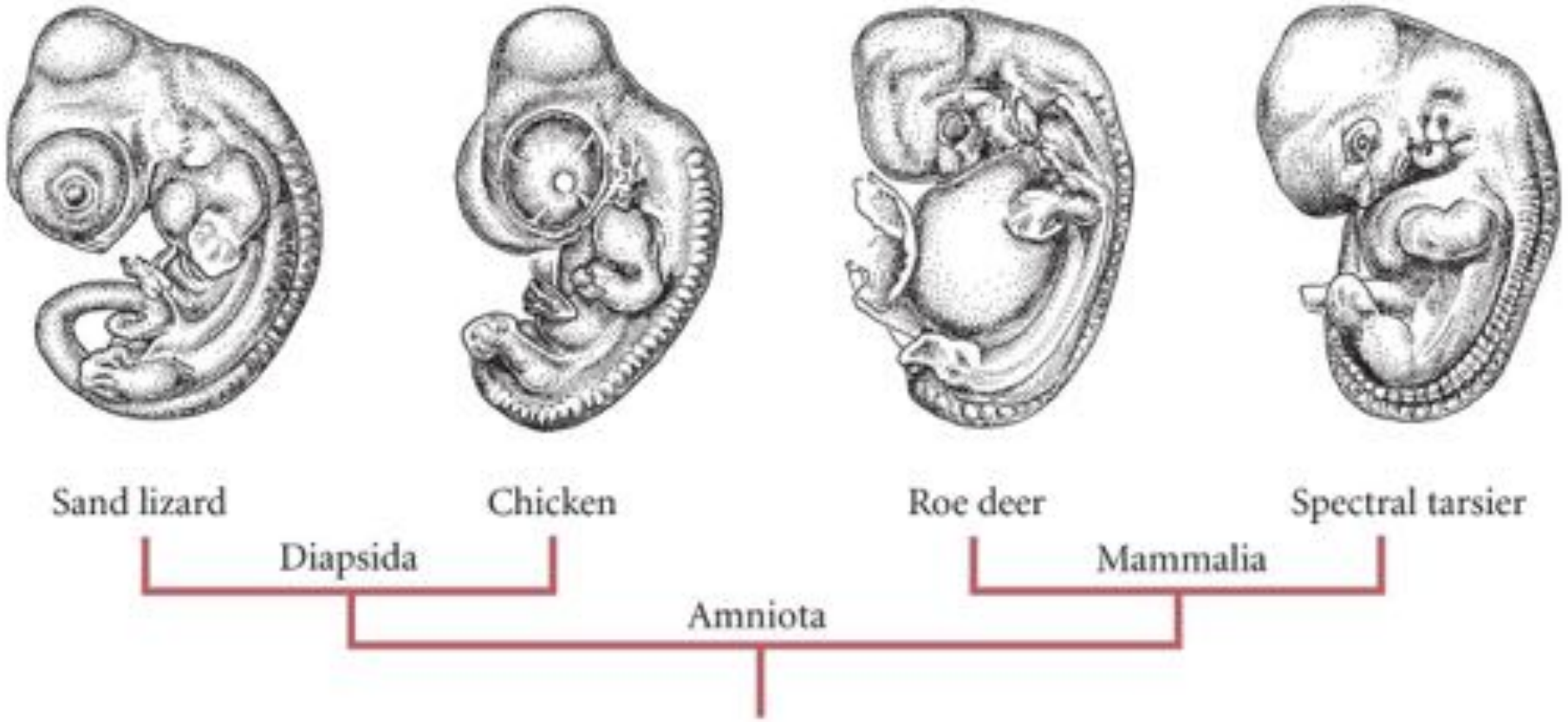
Allometry and modularity in the vertebrate eye



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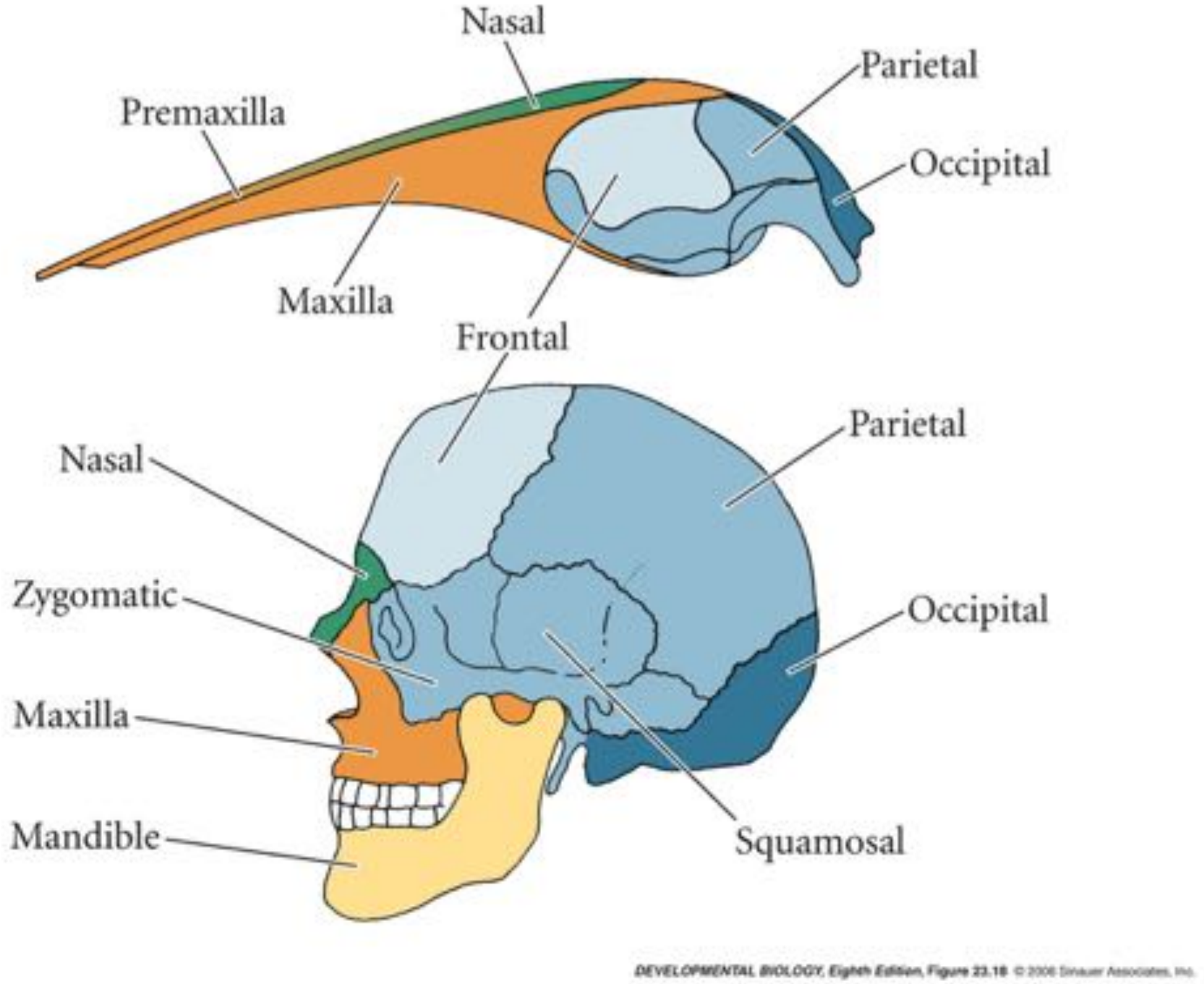
Allometric growth in the whale head



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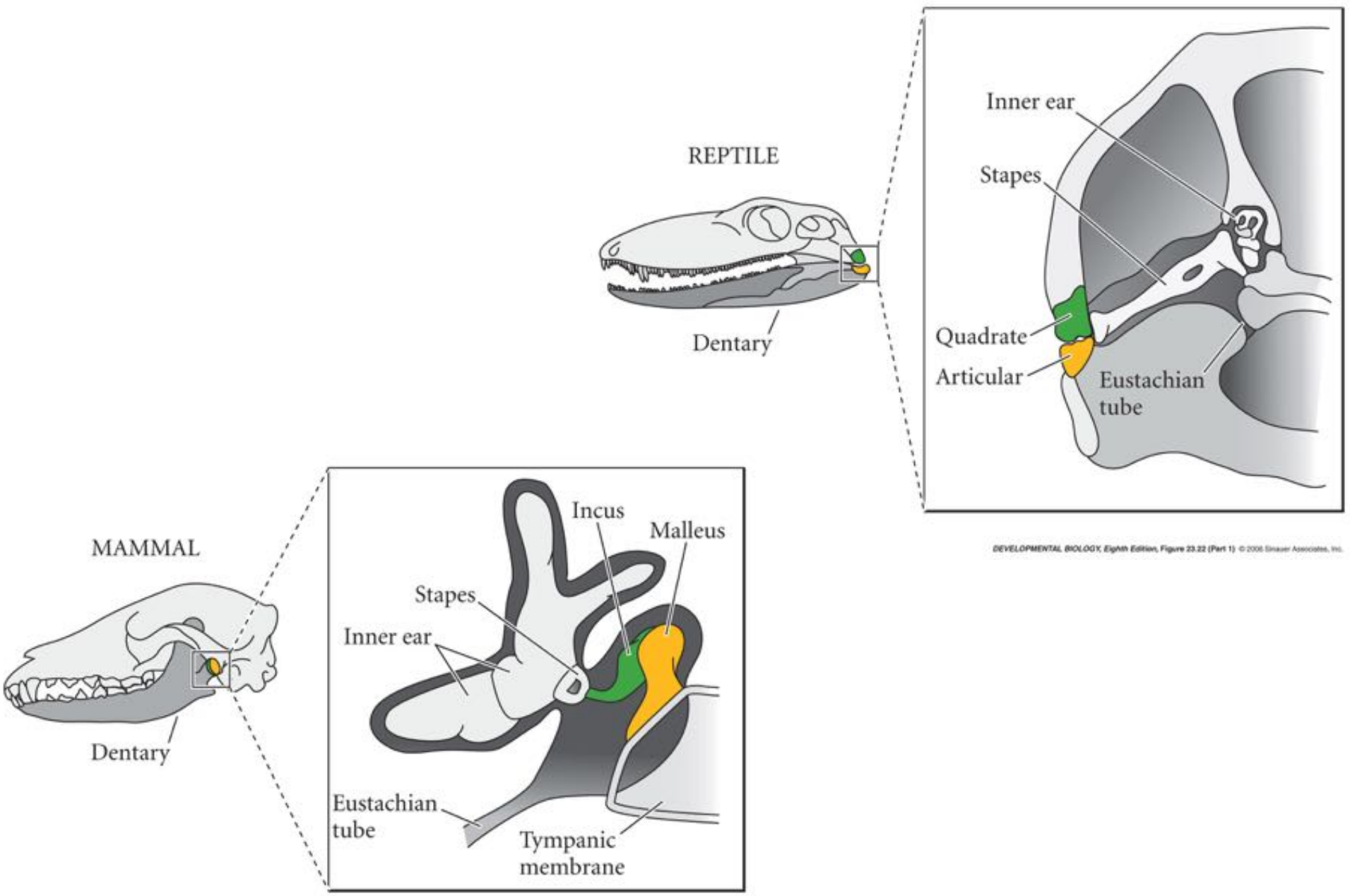
Evolution of the mammalian middle ear bones from the reptilian jaw



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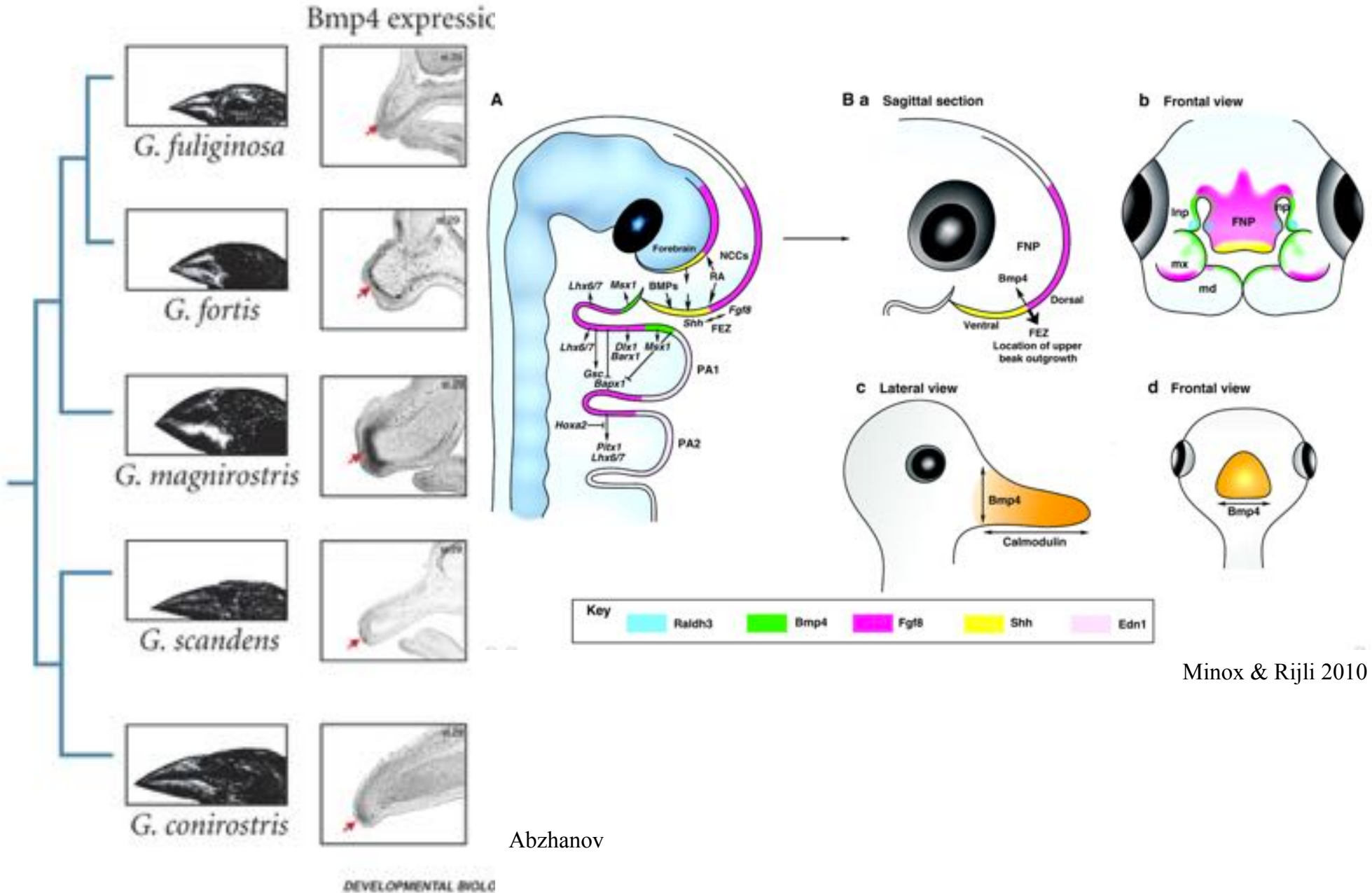
Correlation between beak shape and the expression of *Bmp4* and Calmodulin in birds



Minox & Rijli 2010

Abzhanov

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Descubrimientos importantes de los genes Hox en el establecimiento del eje antero-posterior de los animales

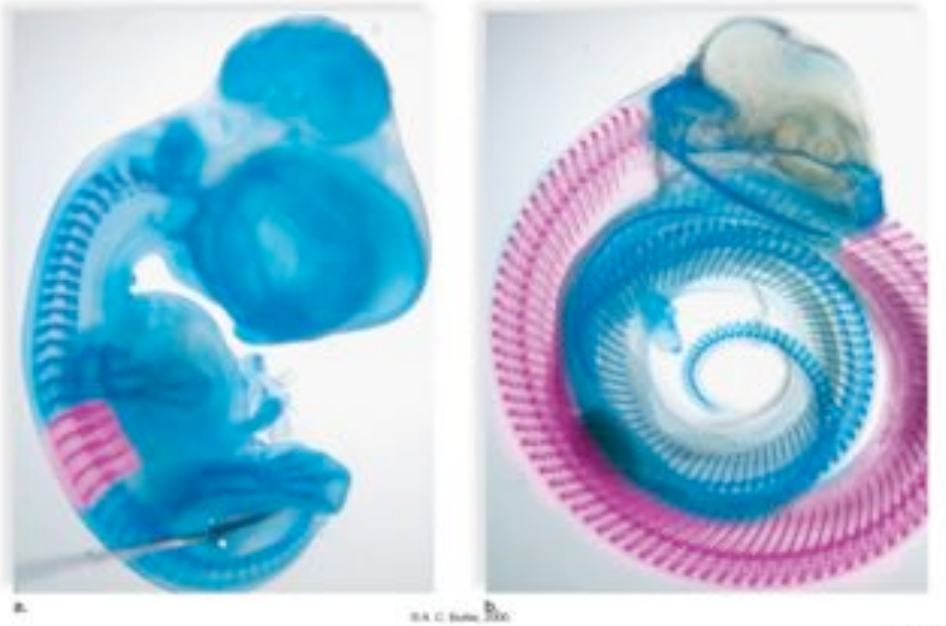
- Bateson (1894) encontró variantes naturales con alteraciones en la identidad de segmentos: homeosis. Morgan descubrió que la homeosis se heredaba.

- Calvin Bridges describe la mutación Bithorax (1915).

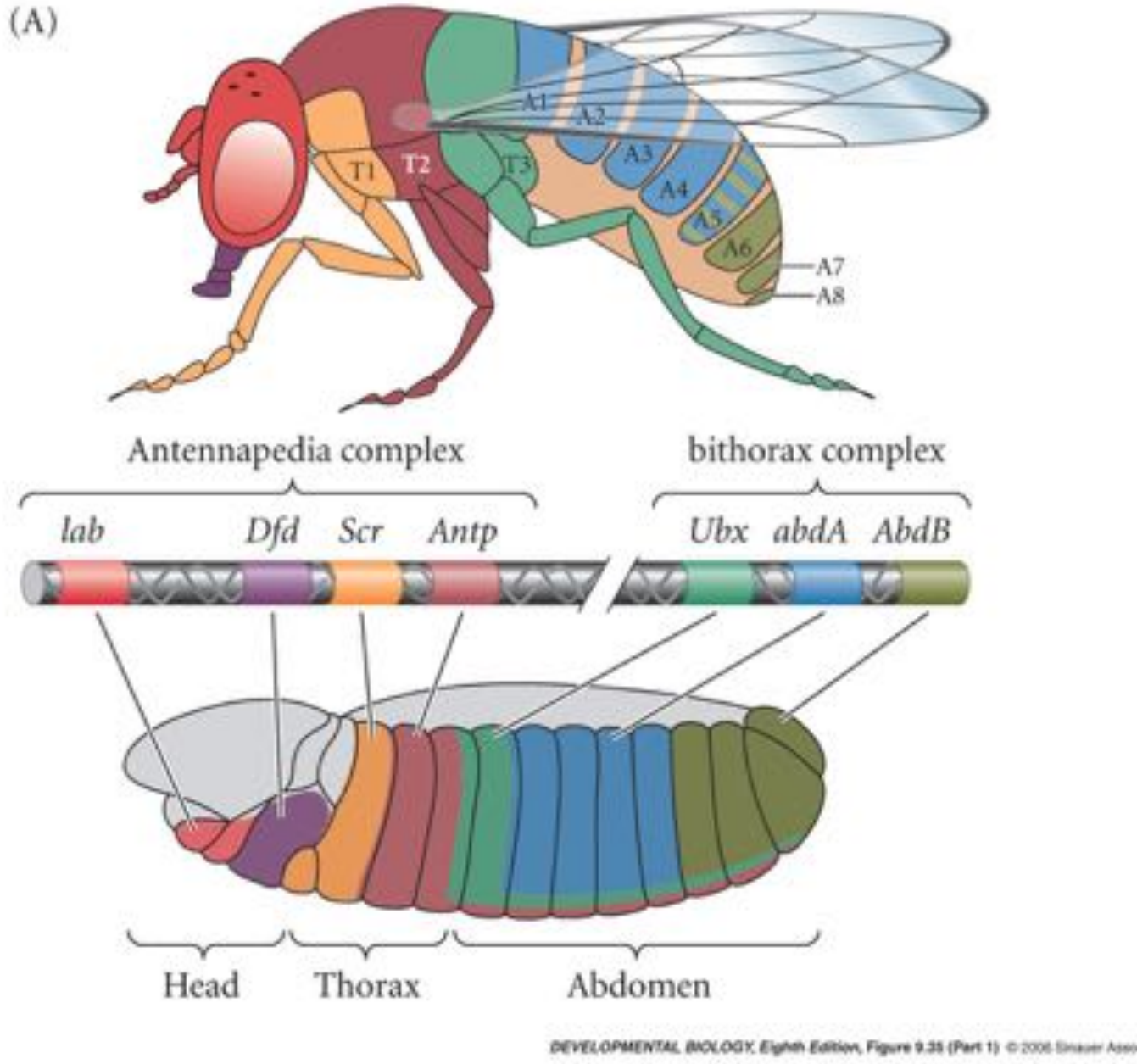
- Ed Lewis estudia BX-C y lo define como una regulación genica antero-posterior (colinealidad espacial) y lo define como consecuencia de un gradiente.

- Scott por un lado y McGinnis, Levine y Gehring por el otro descubren al homeobox (1984)

- Duboule, Dollé y Krumlauf (1989) encuentran que ratones y moscas comparten la organización espacial y funcional, se descubre la colinealidad temporal en expresión y orden en los cromosomas



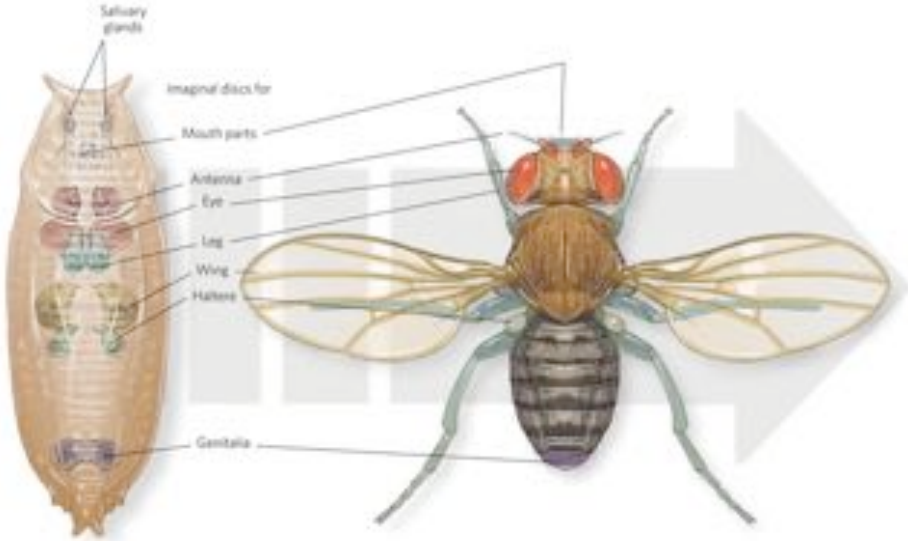
Expresão de genes homeóticos em *Drosophila*



DEVELOPMENTAL BIOLOGY, Eighth Edition, Figure 9.35 (Part 1) © 2006 Sinauer Asso

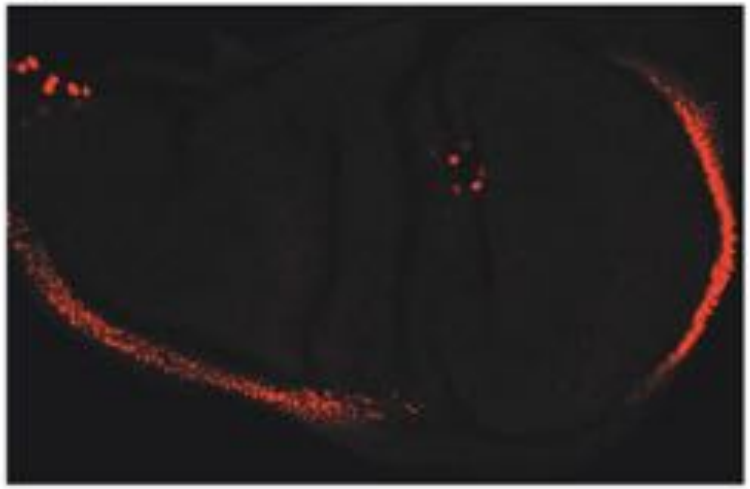
Antibody staining of the Ultrabithorax protein in (A) the wing disc and (B) the haltere disc of third instar *Drosophila* larvae

Ubx expression in imaginal discs:

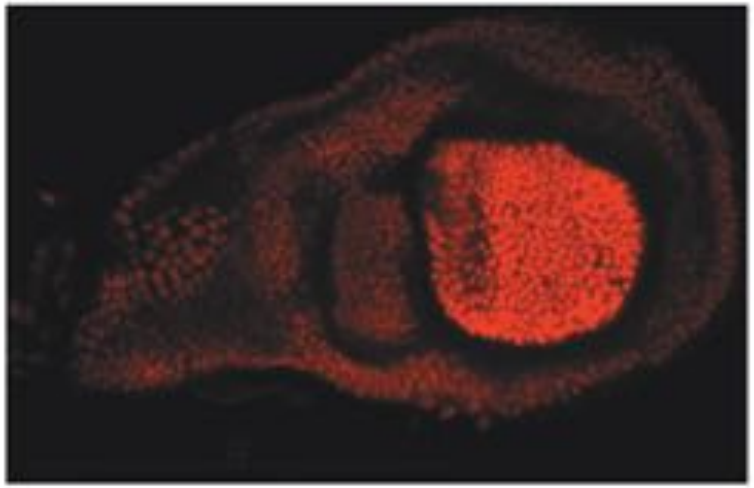


Grewal, 2013 *The Scientist*

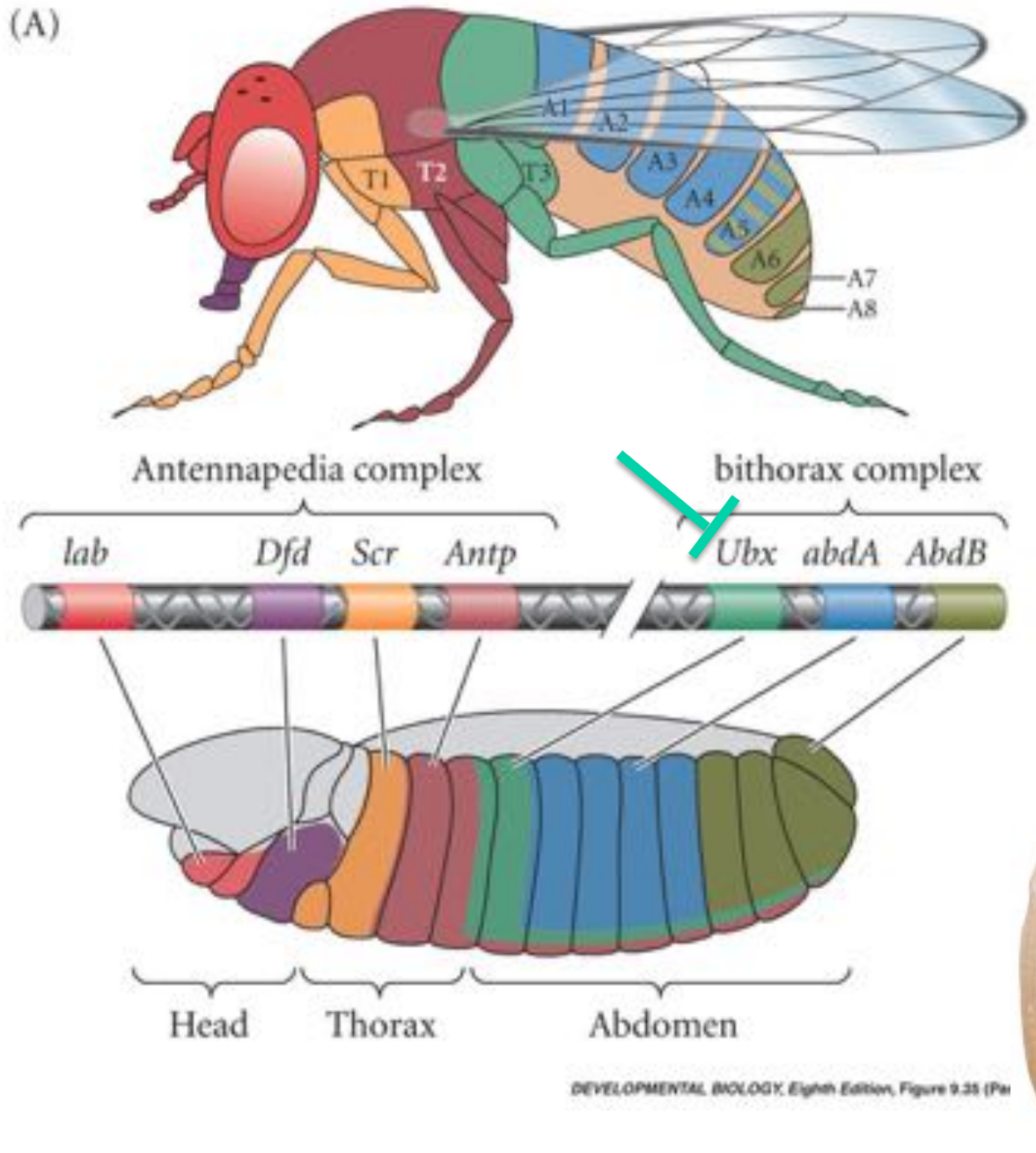
(A)

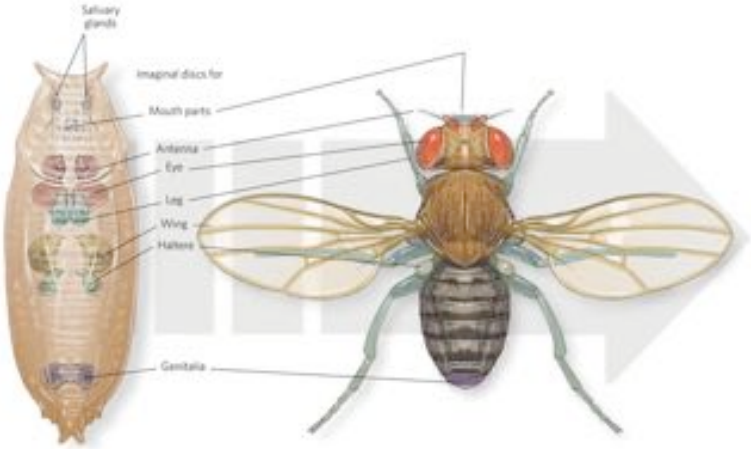


(B)



Represão de Ubx em *Drosophila*





Mosca de 4 alas generada por mutaciones en reguladores cis del gen *Ultrabithorax* en la mosca

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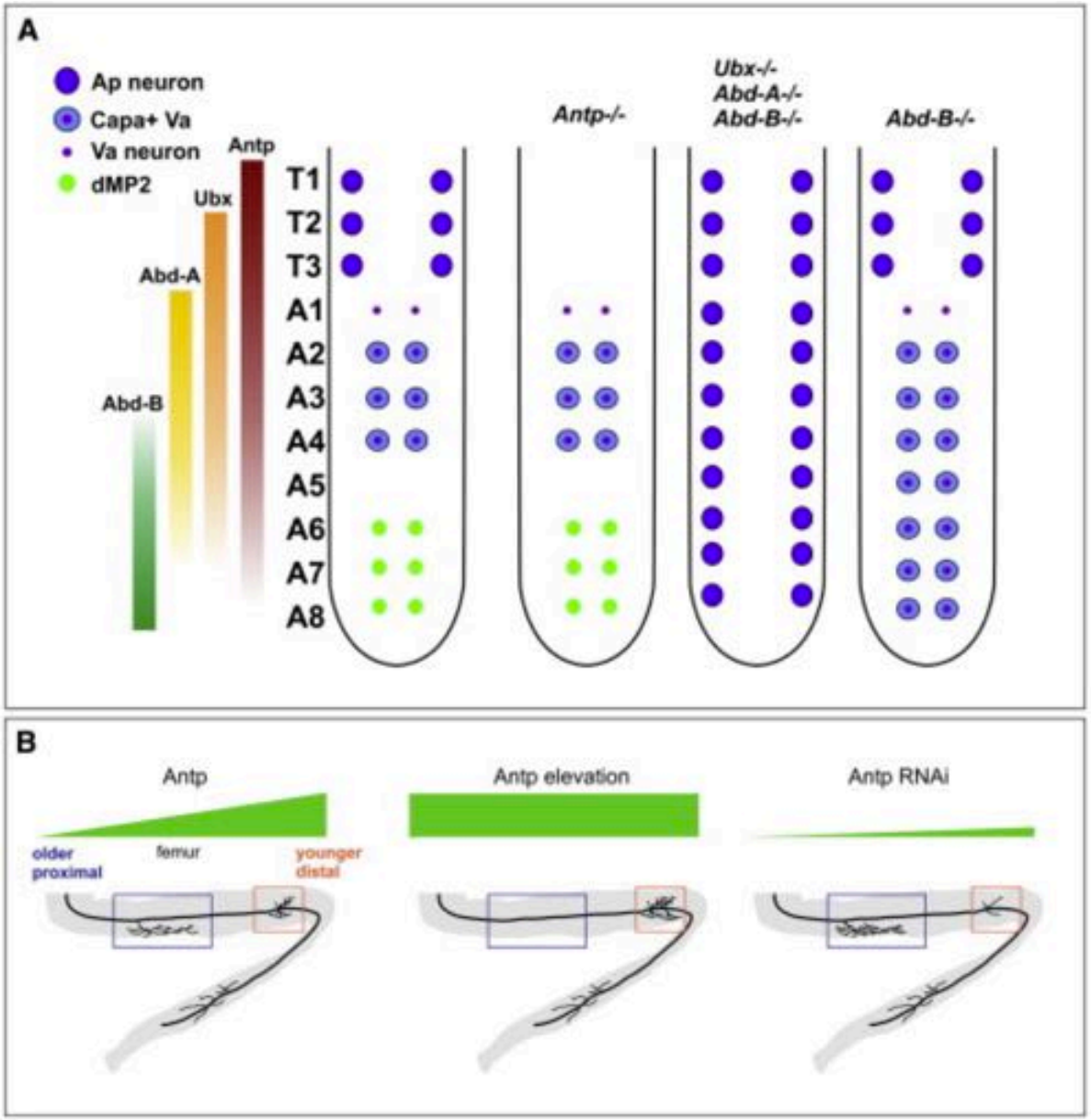
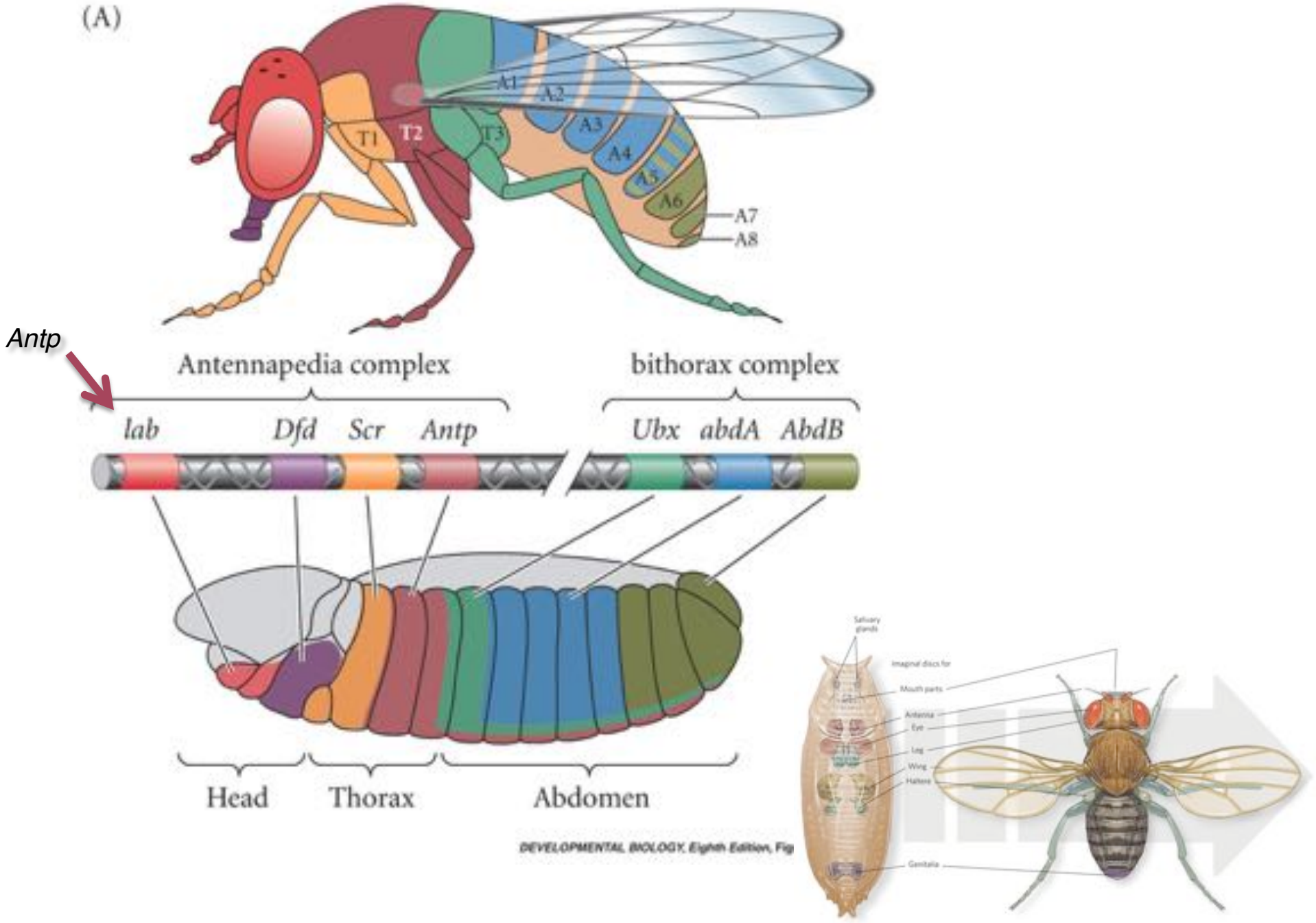
Hox Genes Contribute to Neuronal Identity in the CNS of *Drosophila*

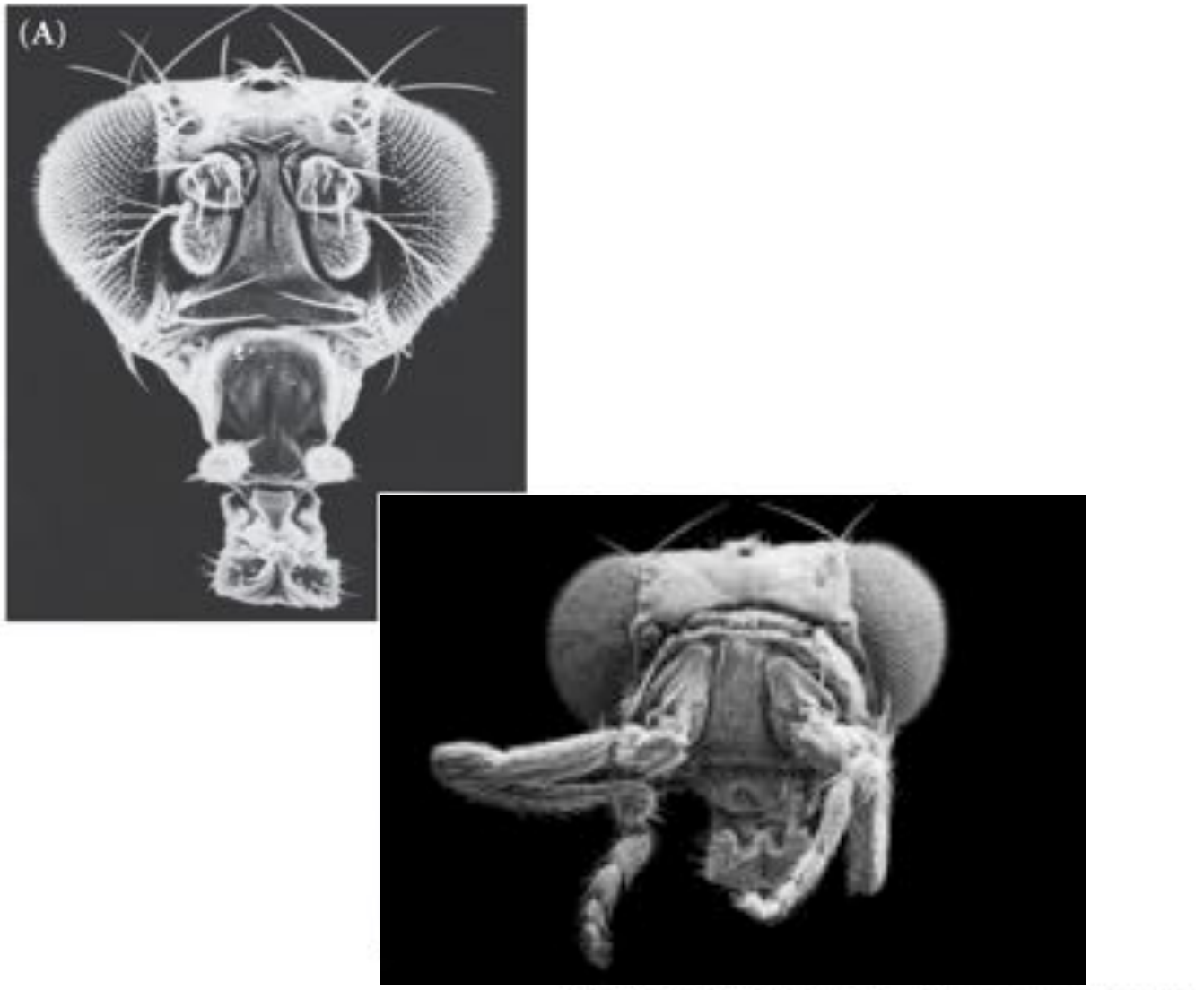


Phillipidou et al. 2013

Expresão de genes homeóticos em *Drosophila*



(A) Head of a wild-type fruit fly. (B) Head of a fly containing the *Antennapedia* mutation that converts antennae into legs



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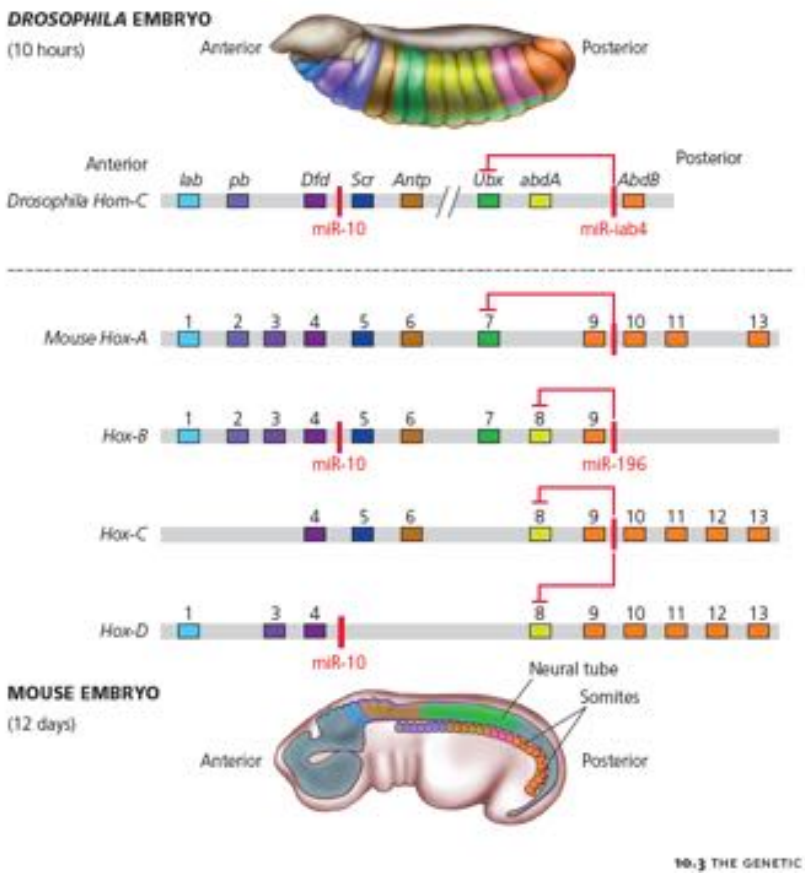
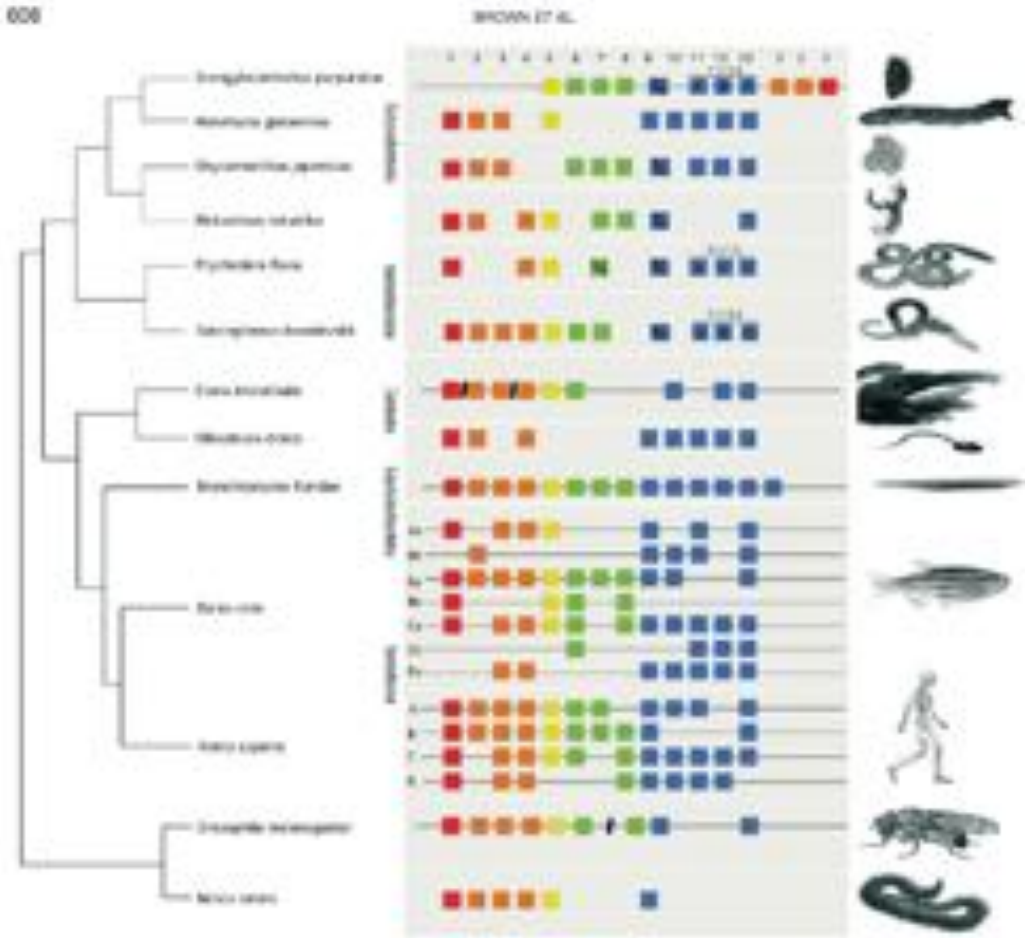
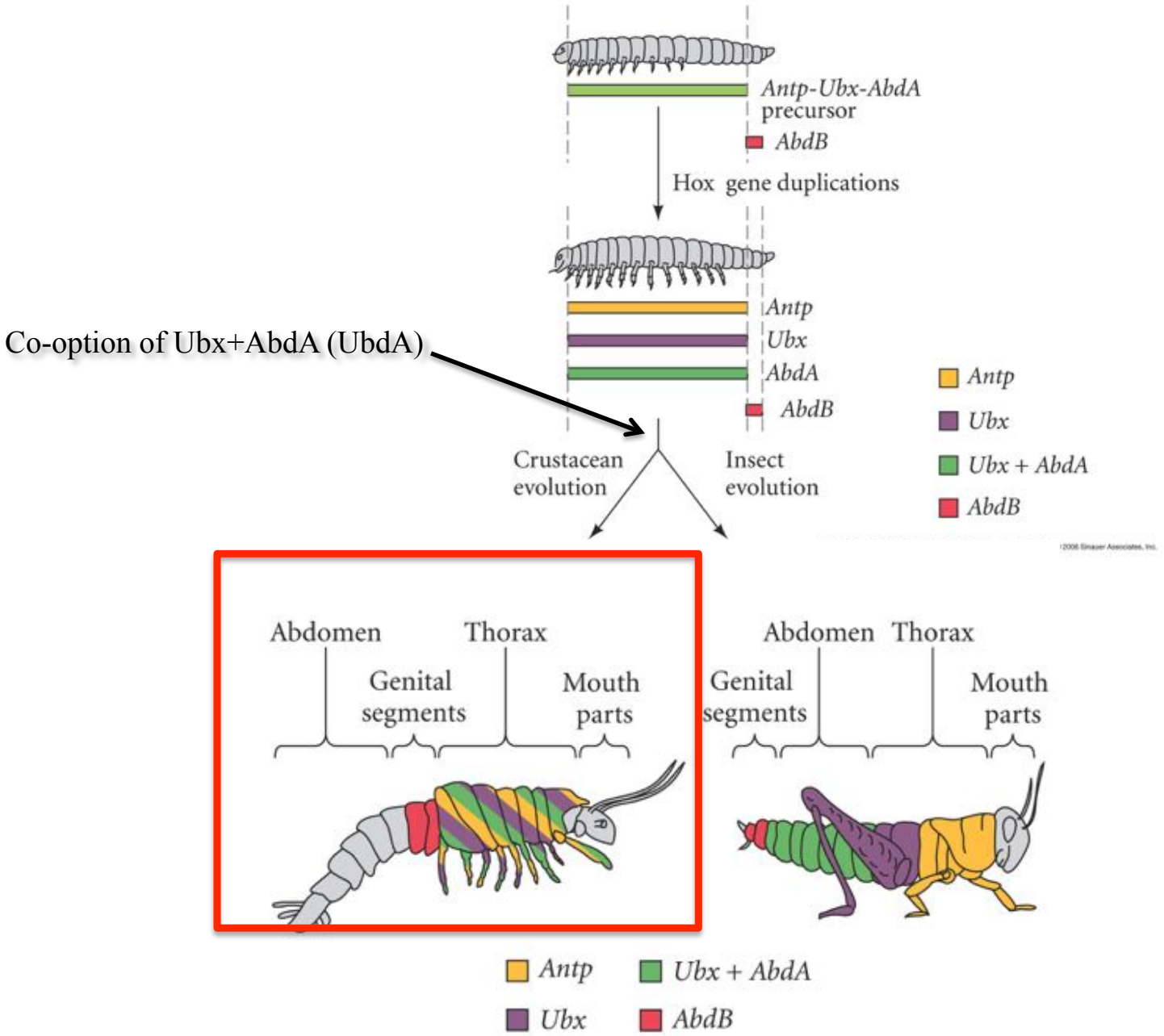
Genes Hox: Homeotic genes and colinearity (1978)



10.3 THE GENETIC TOOLKIT

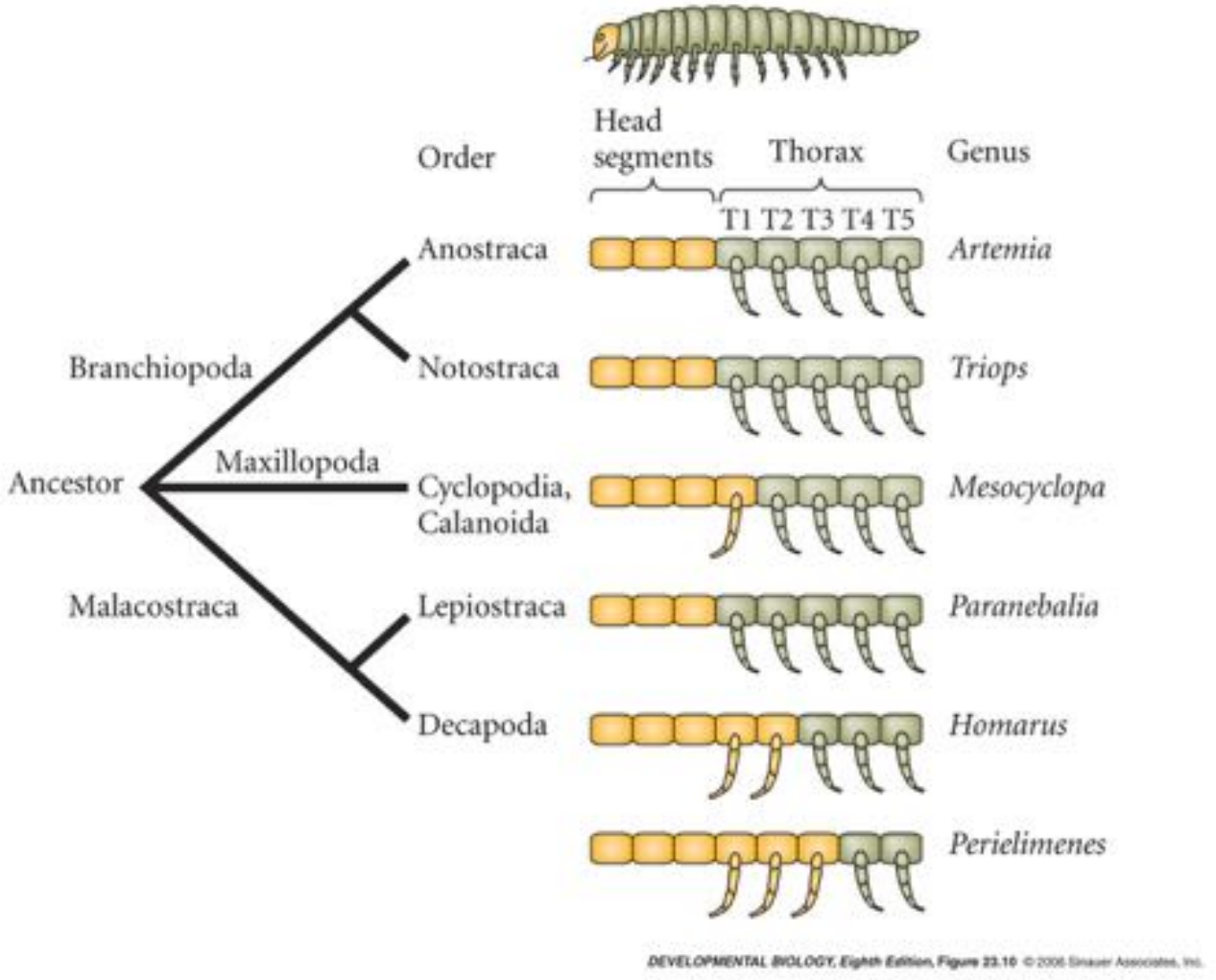


Hox gene expression and morphological change in arthropods



The expression of *Ubx* and *abdA* (green) in the thoracic segments of different types of crustaceans

Ubx + abdA ➔ legs



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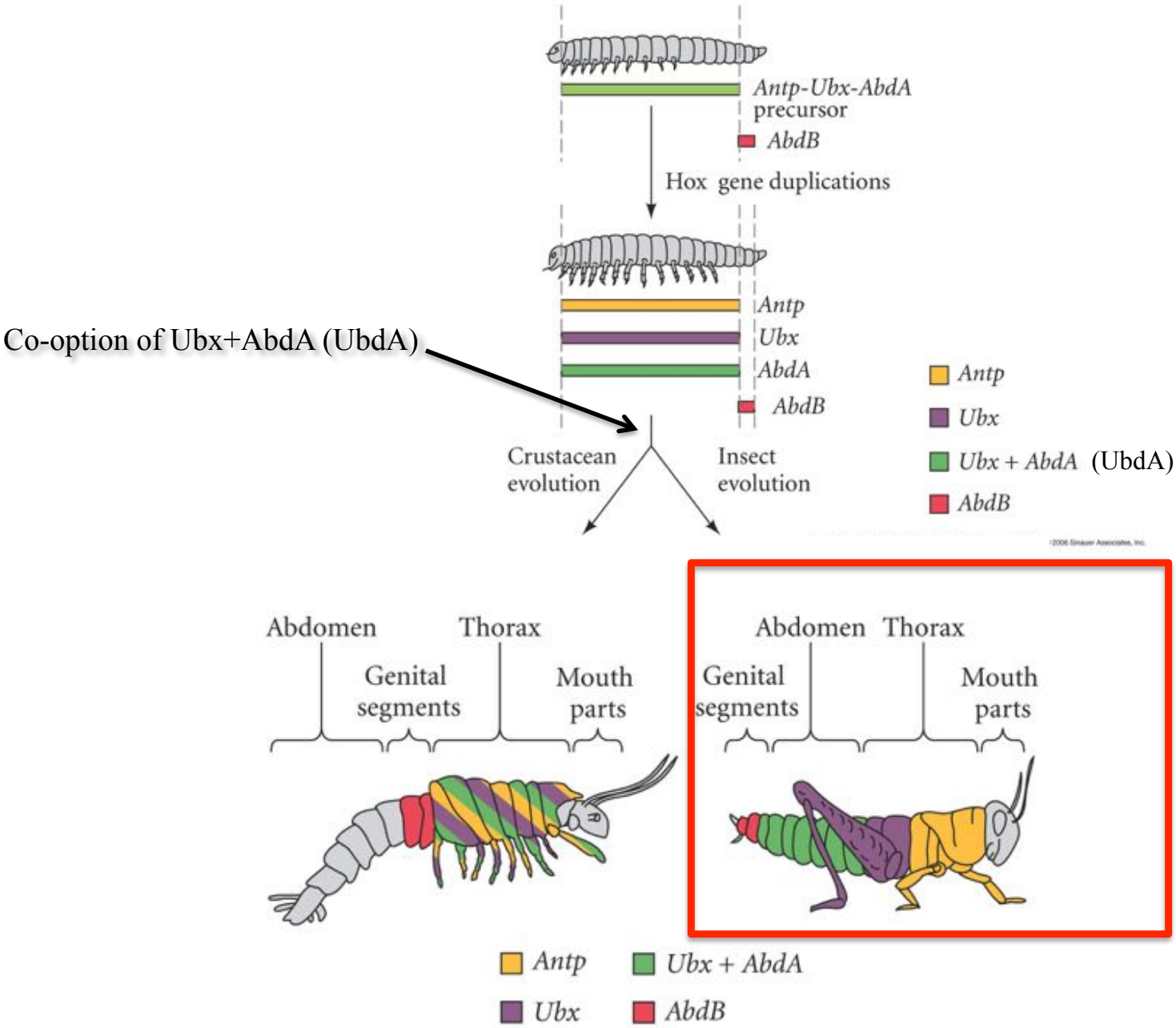
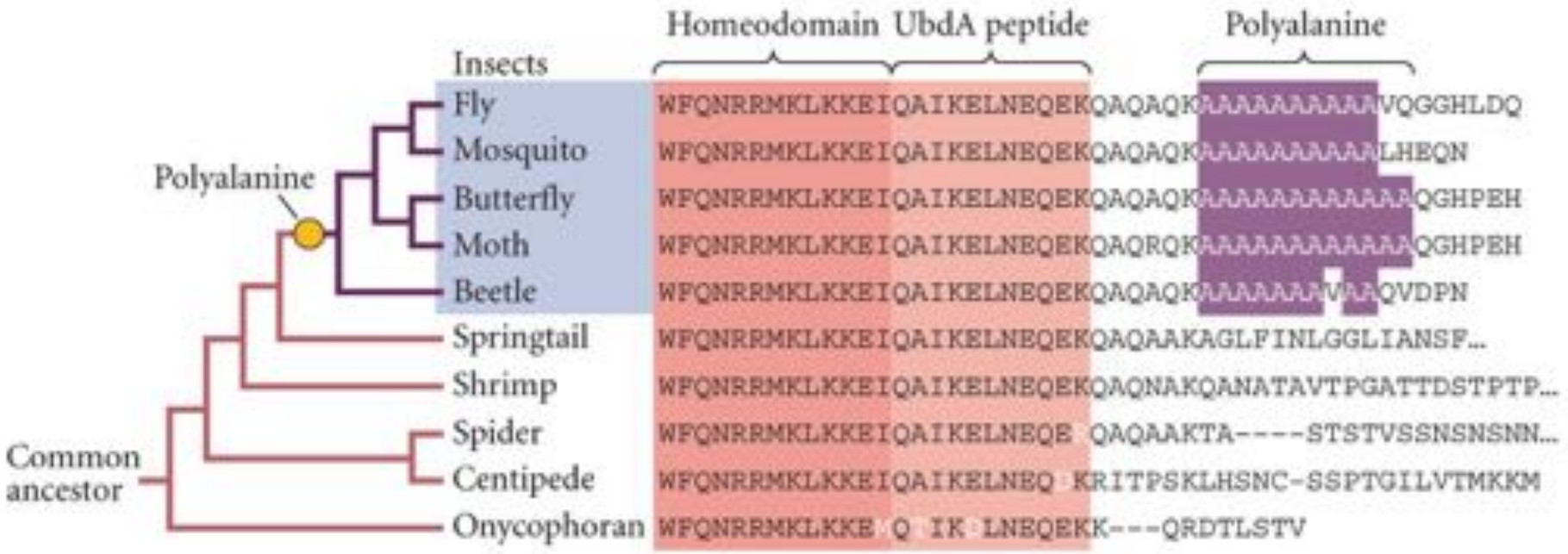
⬇Ubx + ⬇abdA ➔ head segments

Hox gene expression and morphological change in arthropods



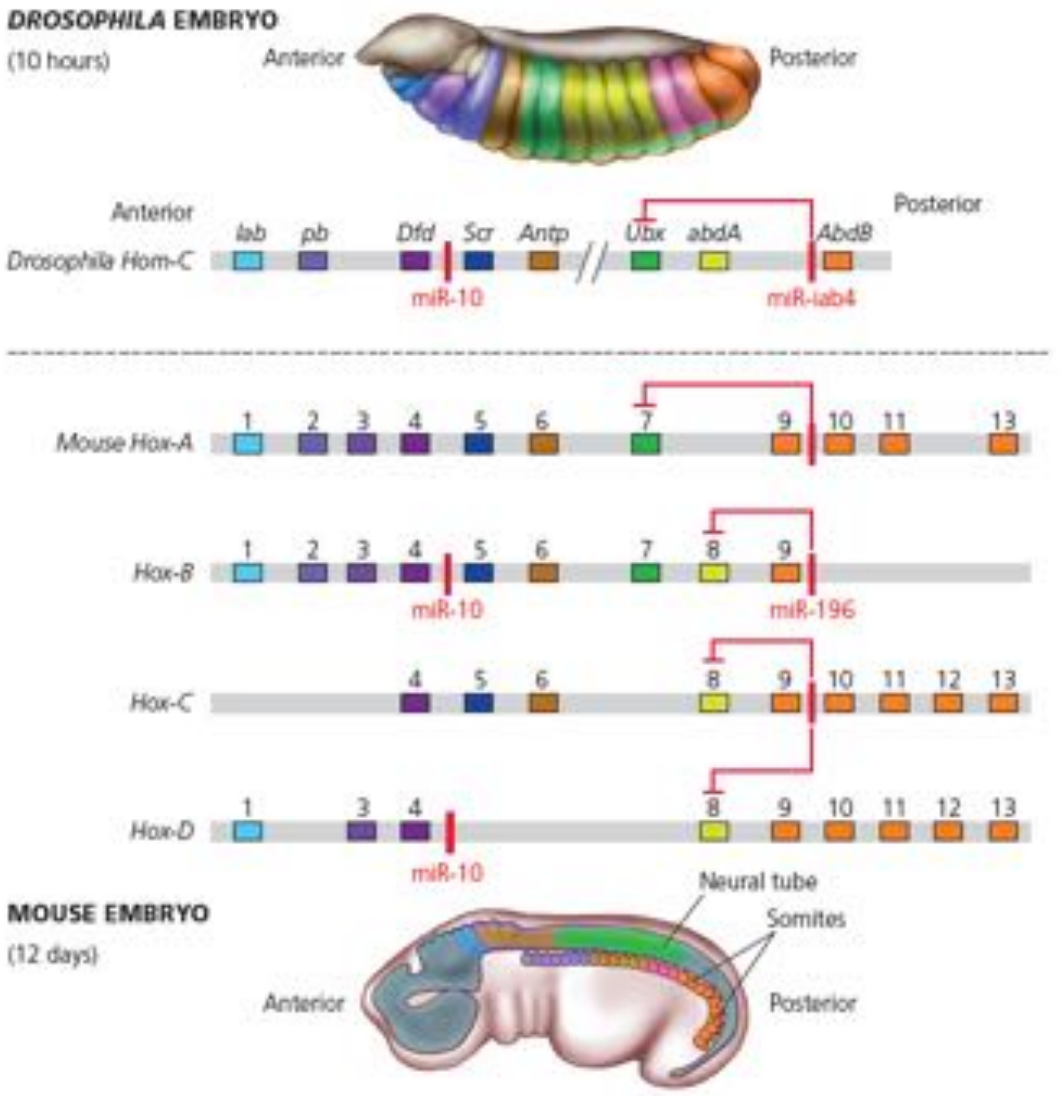
Changes in UbdA protein associated with the insect clade in the evolution of arthropods

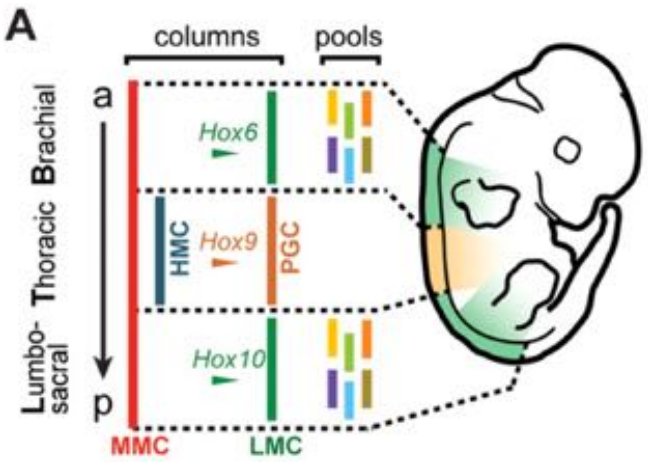
Dominio de represión regional



Polyalanine repeats in UbdA represses leg formation in abdomen of insects

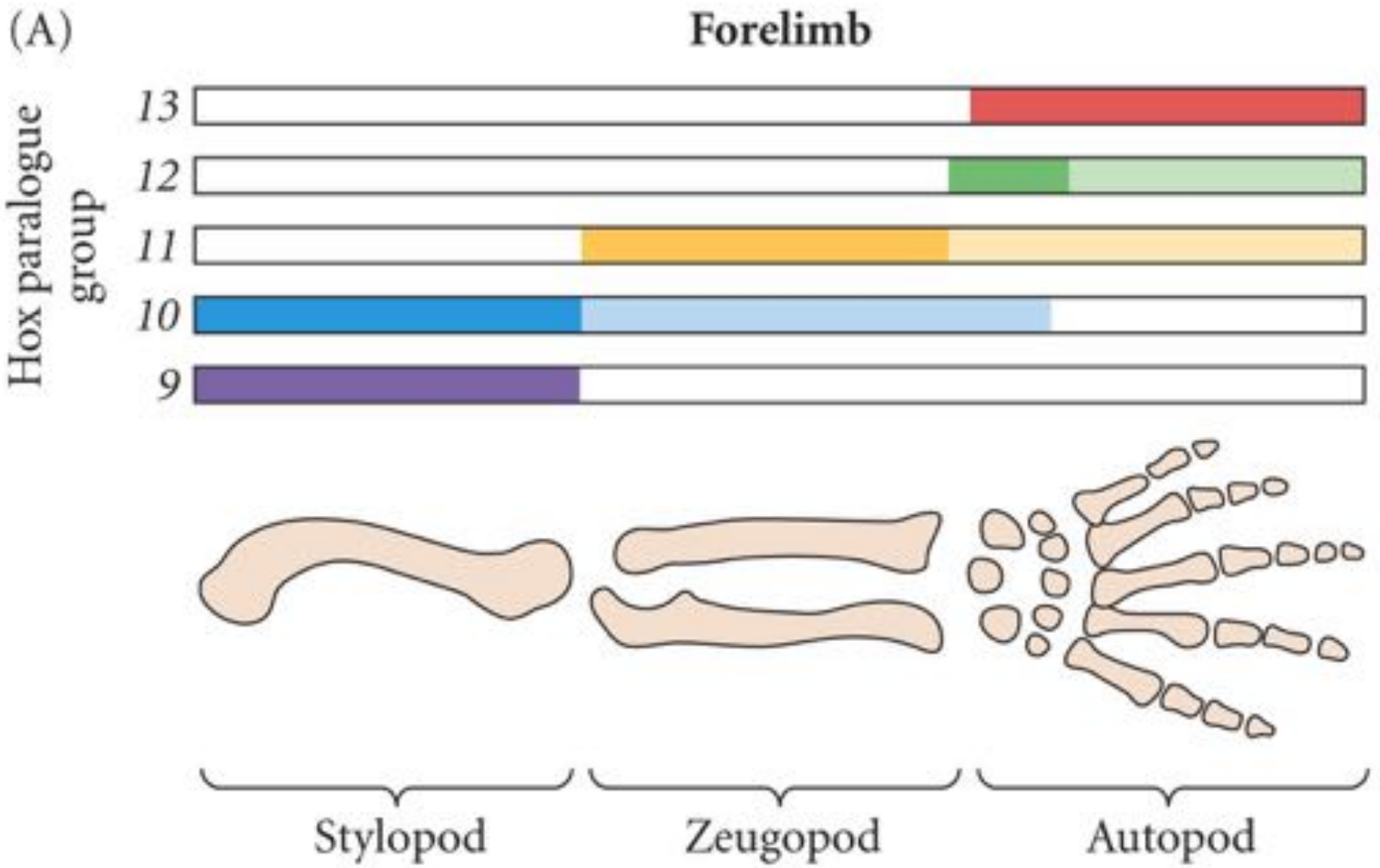
Genes Hox en vertebrados





Tschopp et al. 2012

Deletion of limb bone elements by the deletion of paralogous Hox genes (Part 1)



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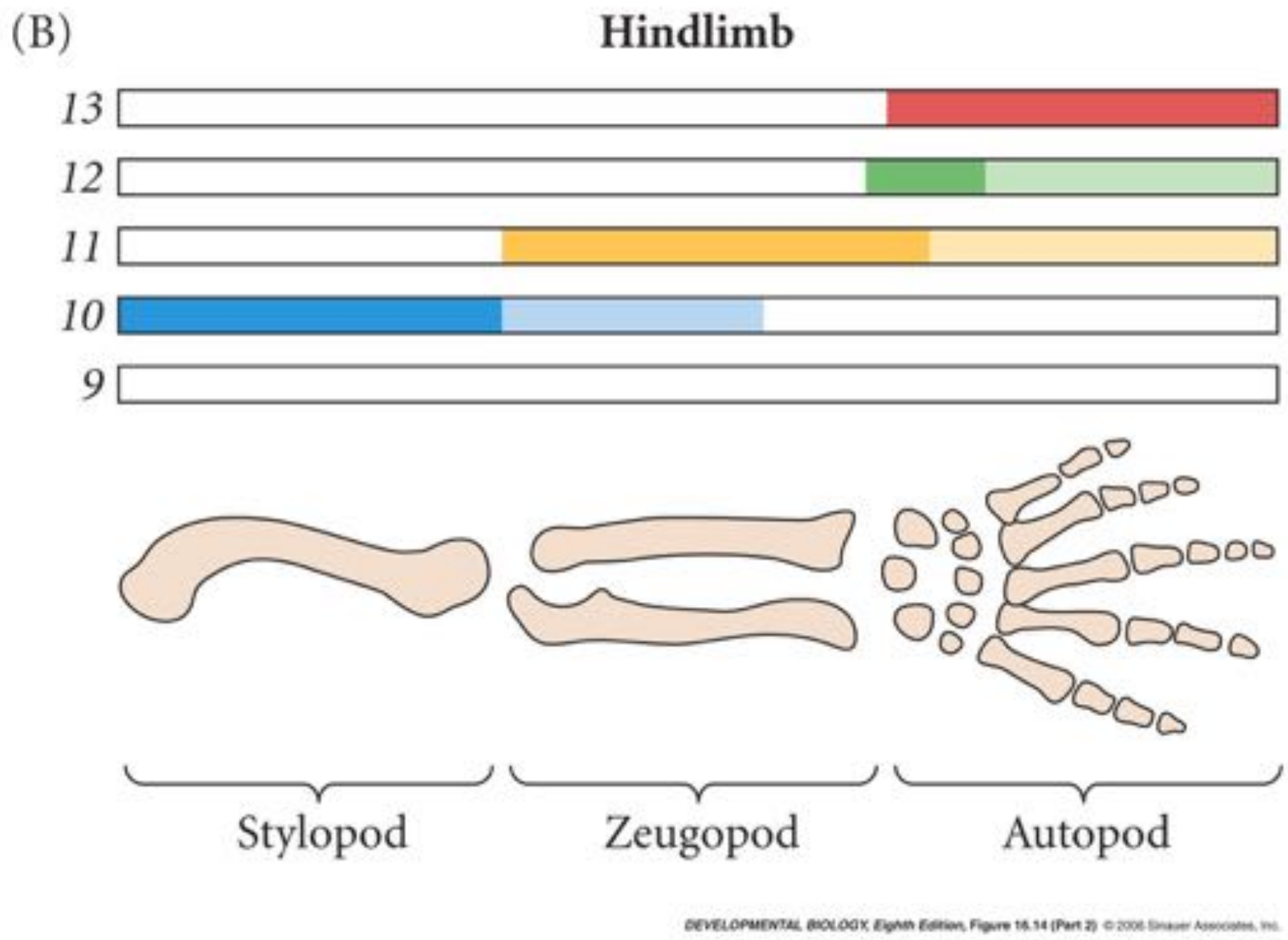
Deletion of limb bone elements by the deletion of paralogous Hox genes (Part 2)



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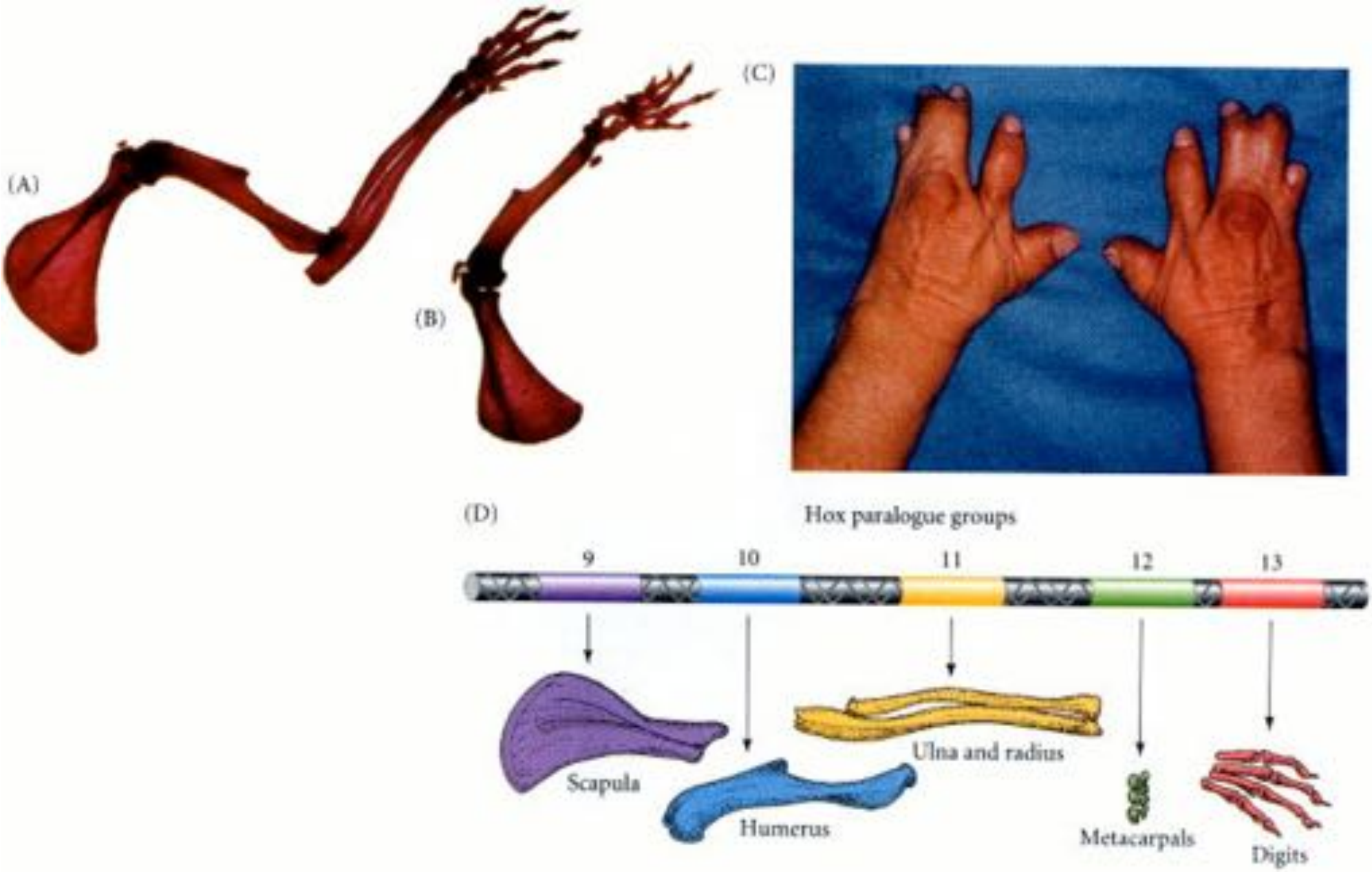
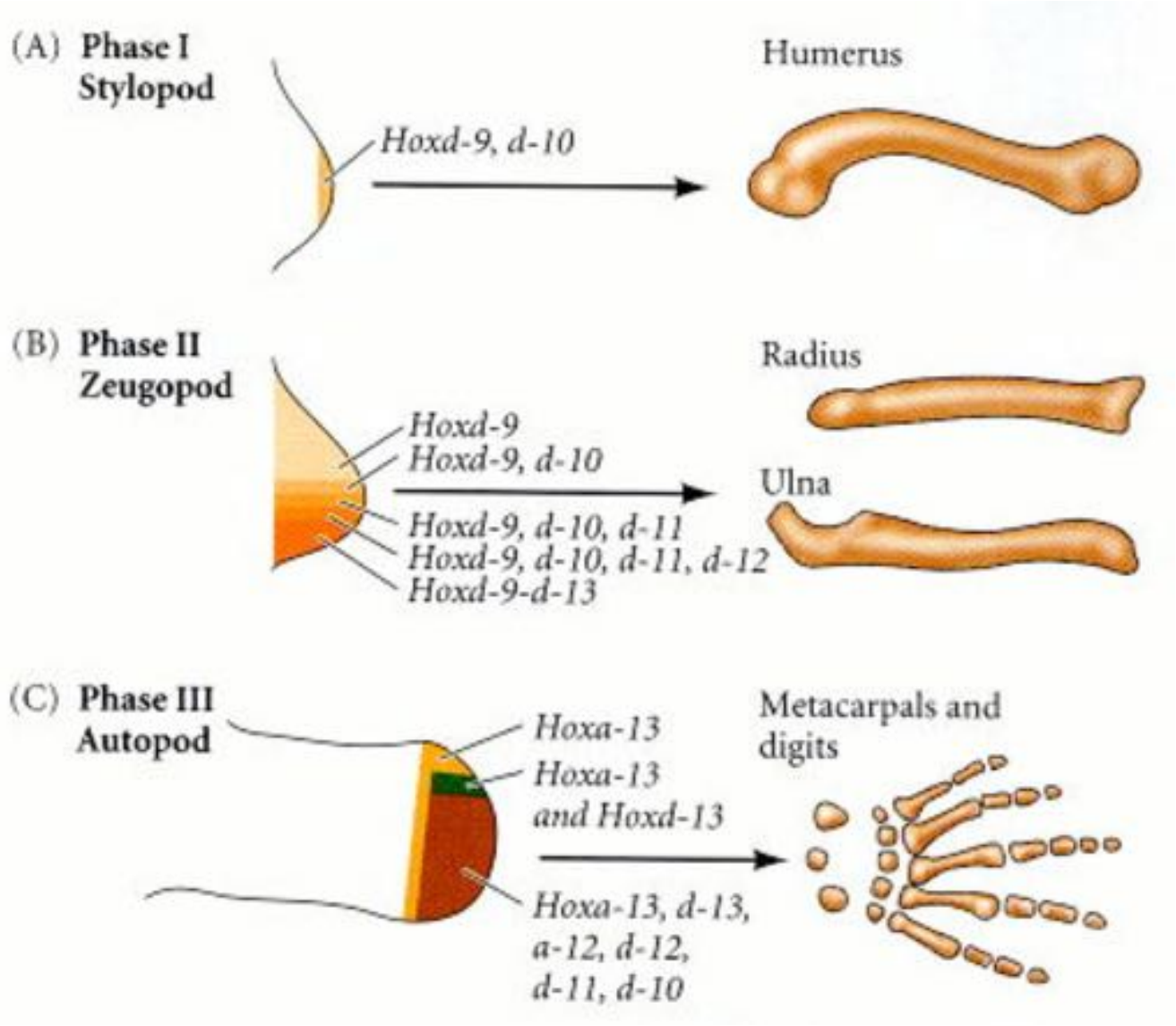
Hox e desenvolvimento dos membros



Hox e desenvolvimento dos membros



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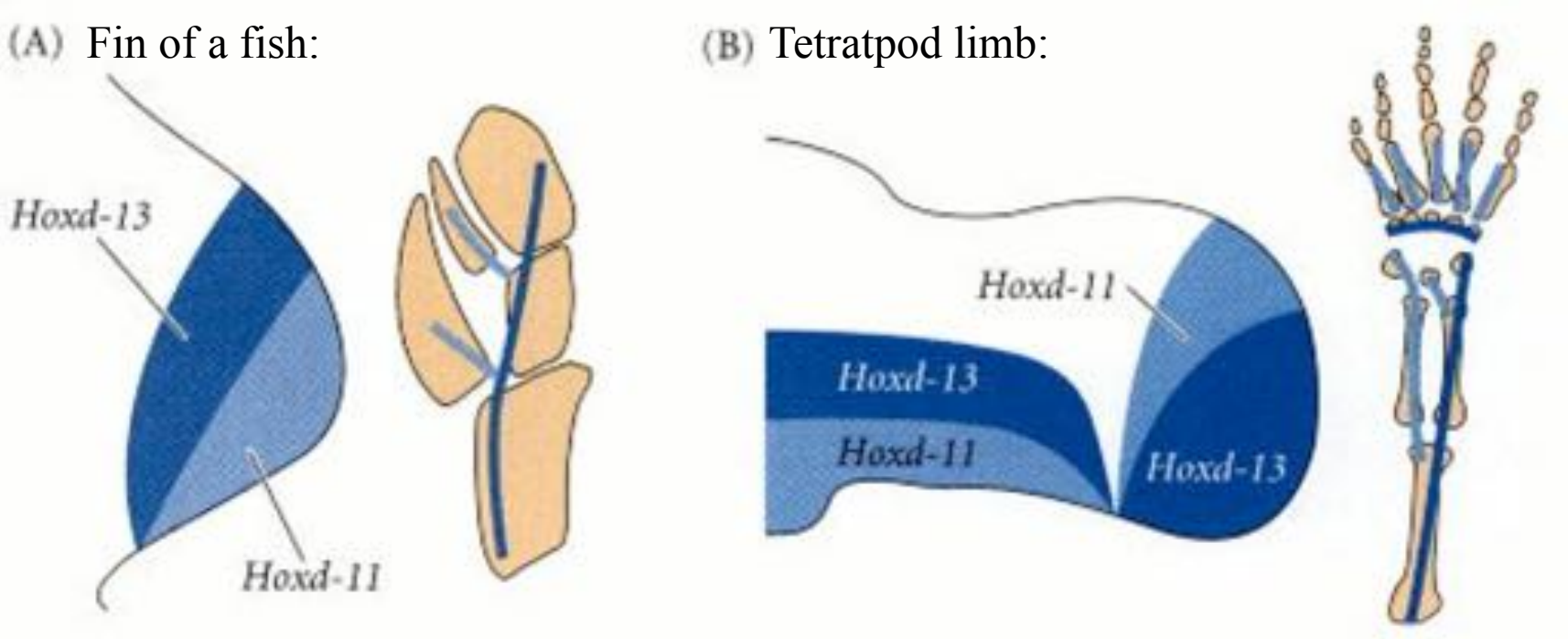
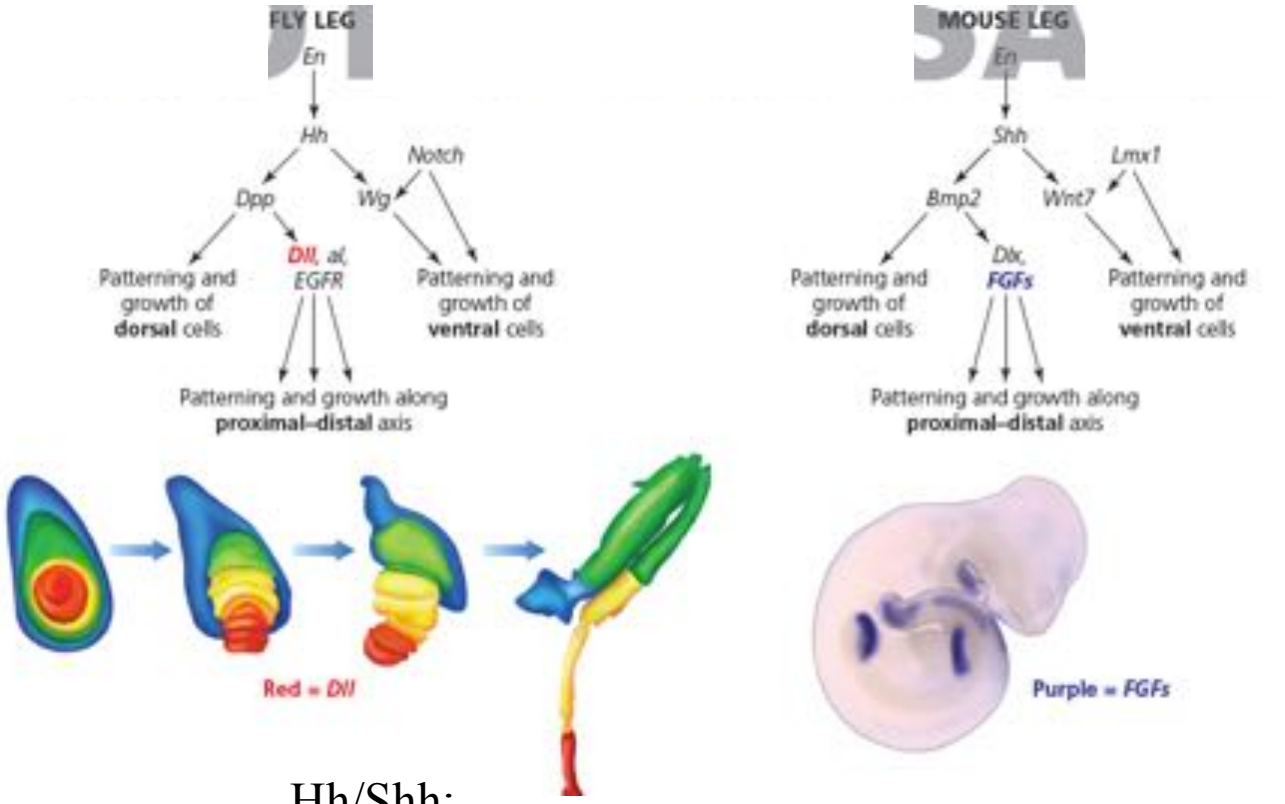
Hox em membros de tetrapodos (co-option and modular evolution)



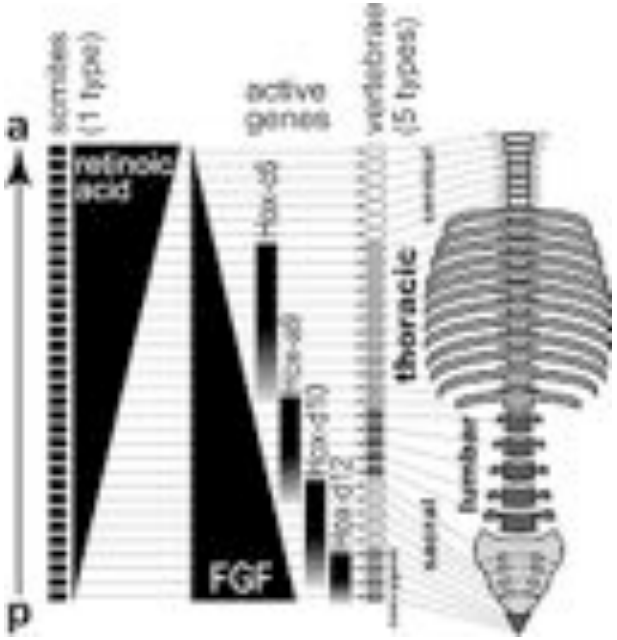
Hh signalling in patterning proximal distal axes

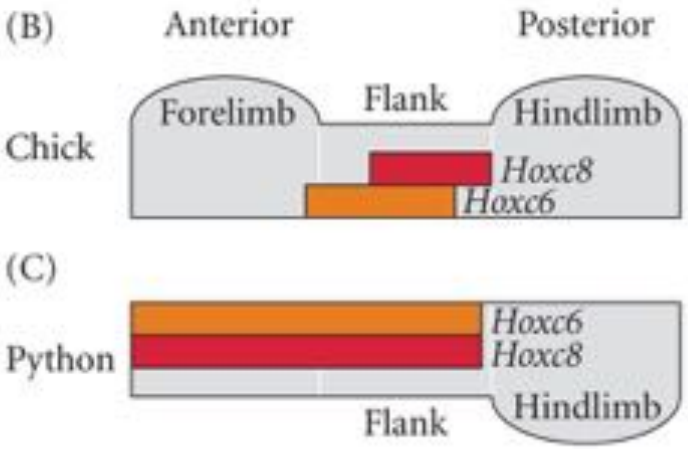


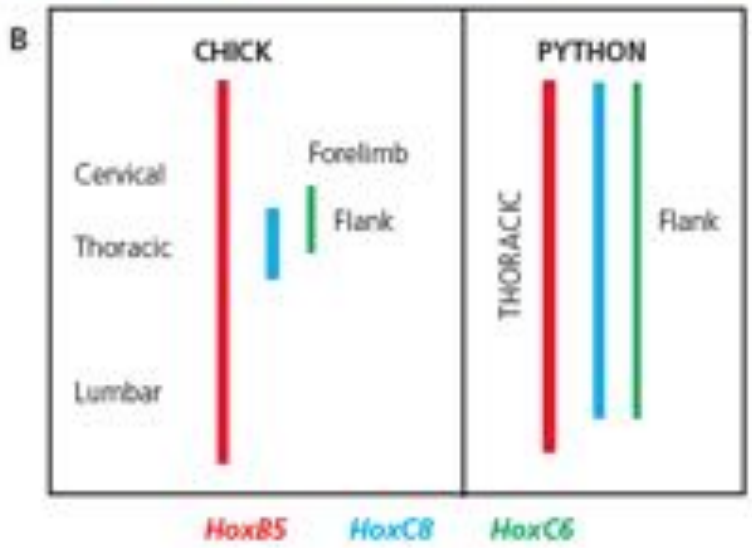
Regulacão do eixo proximal-distal

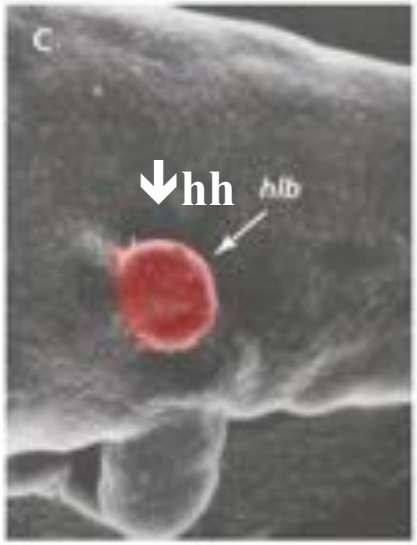
Hh/Shh:

Expansion of thoracic segments and loss of limbs in snakes

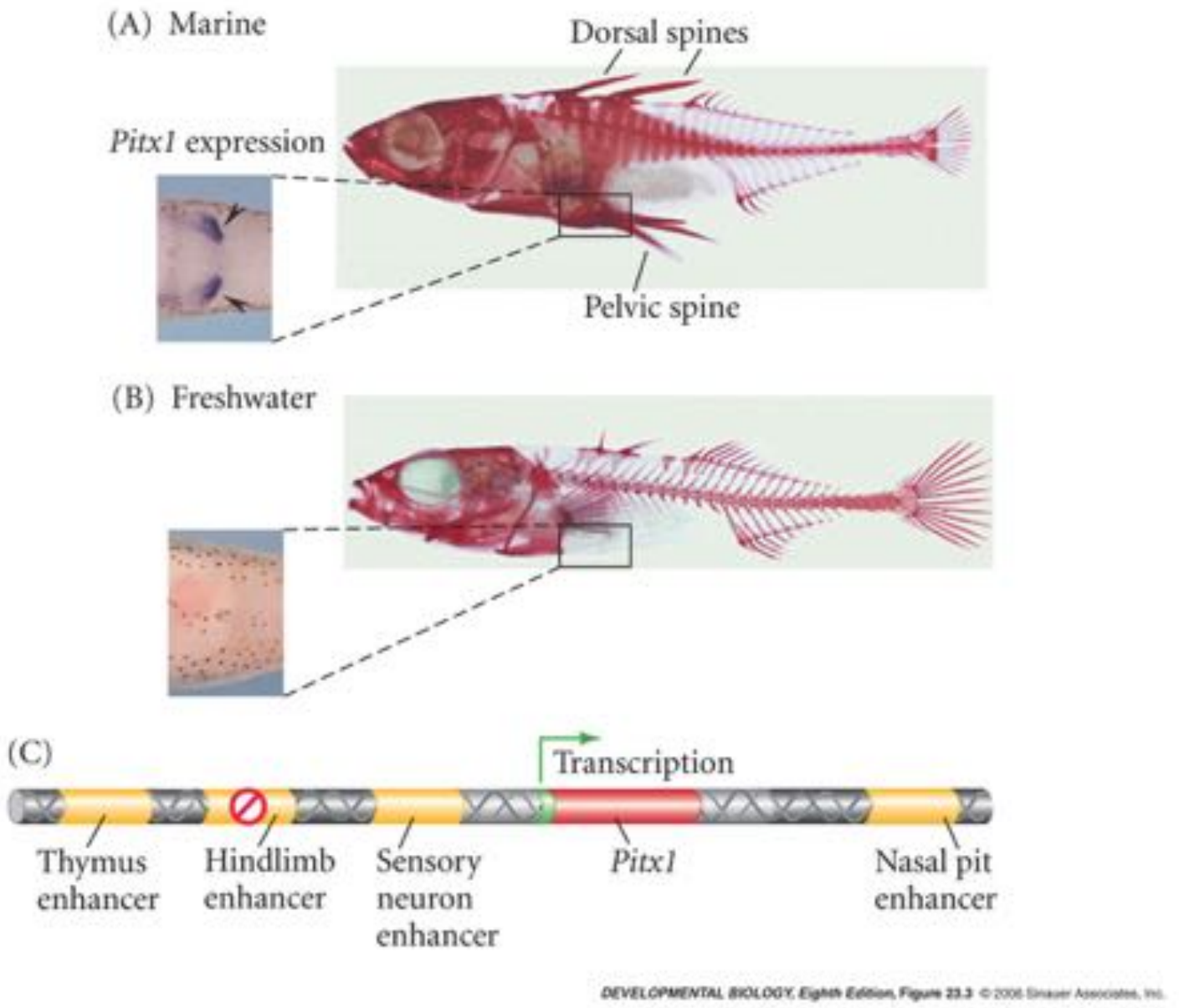








Stickleback evolution and development: Modularity of development of enhancers



D. Kingsley on Pax6 and Pitx1 - 15 min (36-50′): http://media.hhmi.org/hl/05Lect3.html

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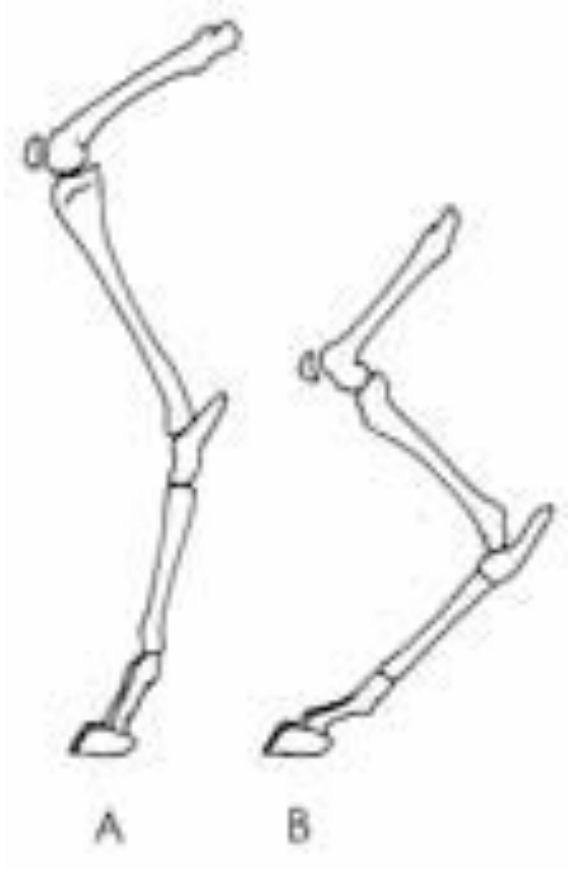
ACOMODACIÓN FENOTÍPICA

http://www.zentastic.com/blog/2009/01/23/amazing-videos-of-two-legged-animals/



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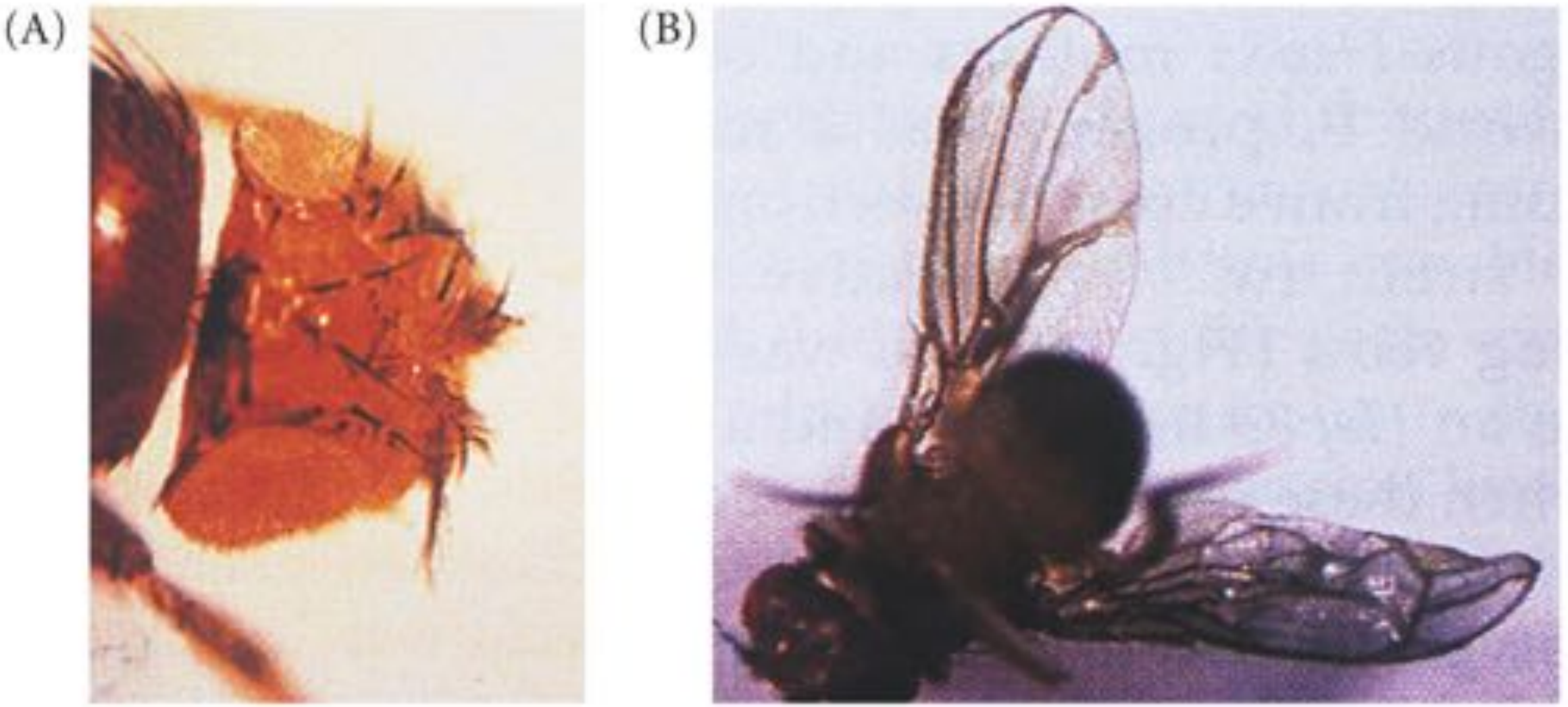
Hsp90 buffers development (Asimilación genética)



Mutaciones o disrupción de Hsp90 permite que se expresen la variabilidad genética normalmente escondida en situaciones de expresión normal de Hsp90

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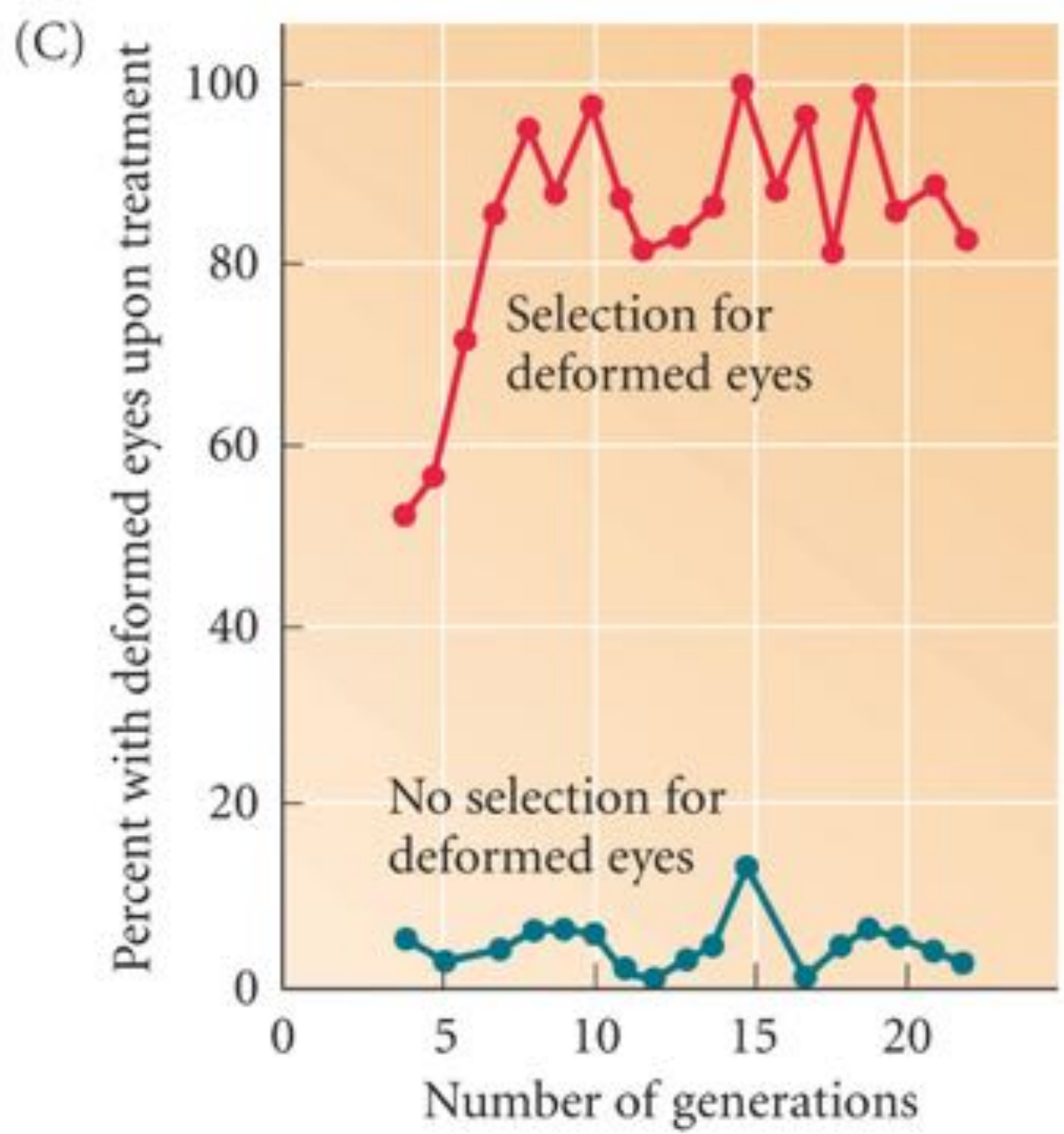
Hsp90 buffers development (Part 2)



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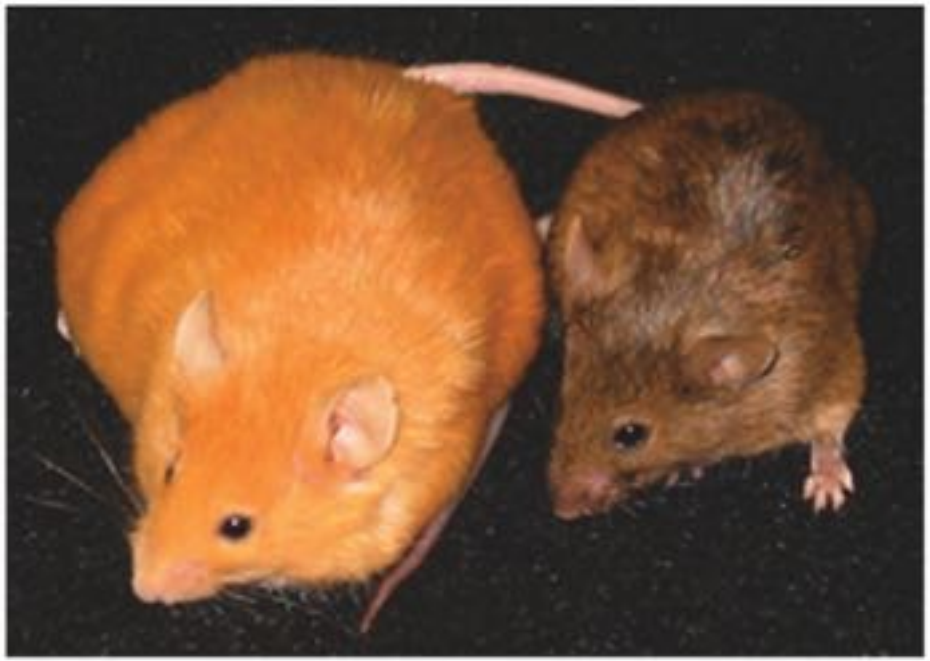
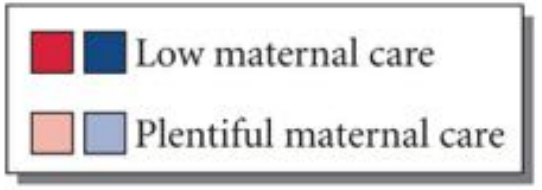
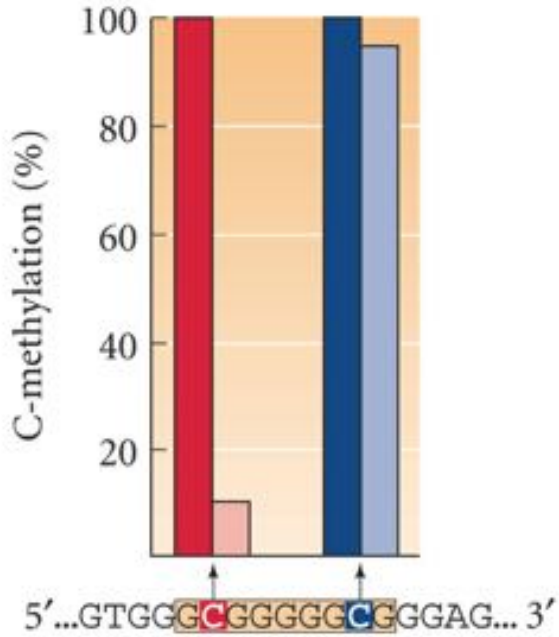
Cambios en la dieta prenatal del feto



ratones identicos geneticamente cuyas madres fueron alimentadas con dietas distintas

Cuidado parental en el recién nacido





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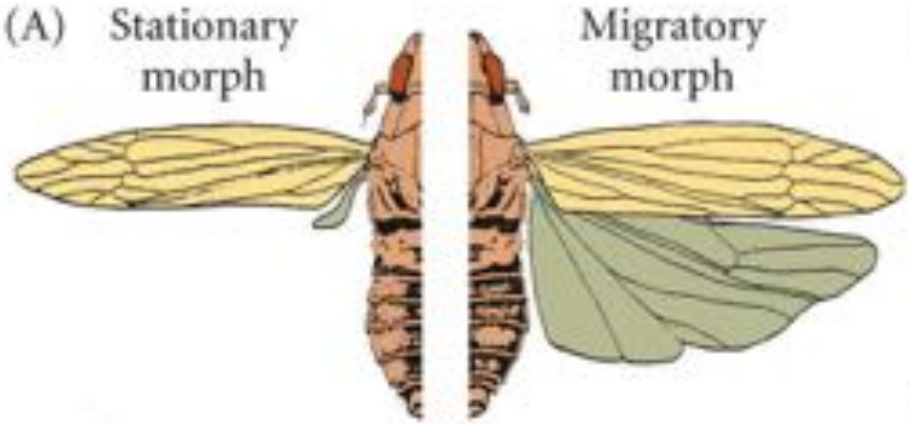
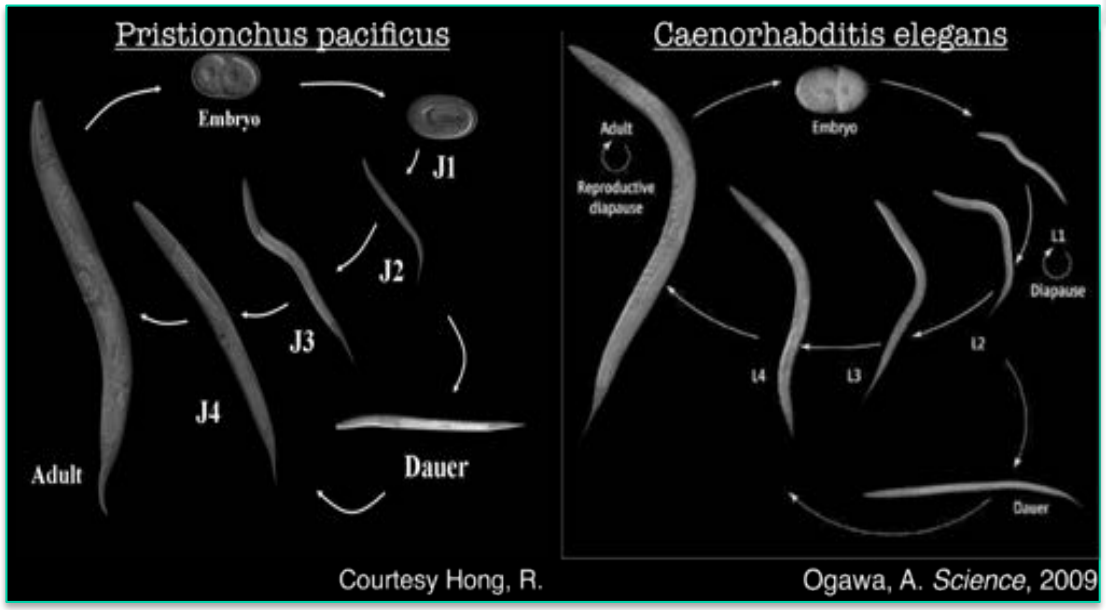
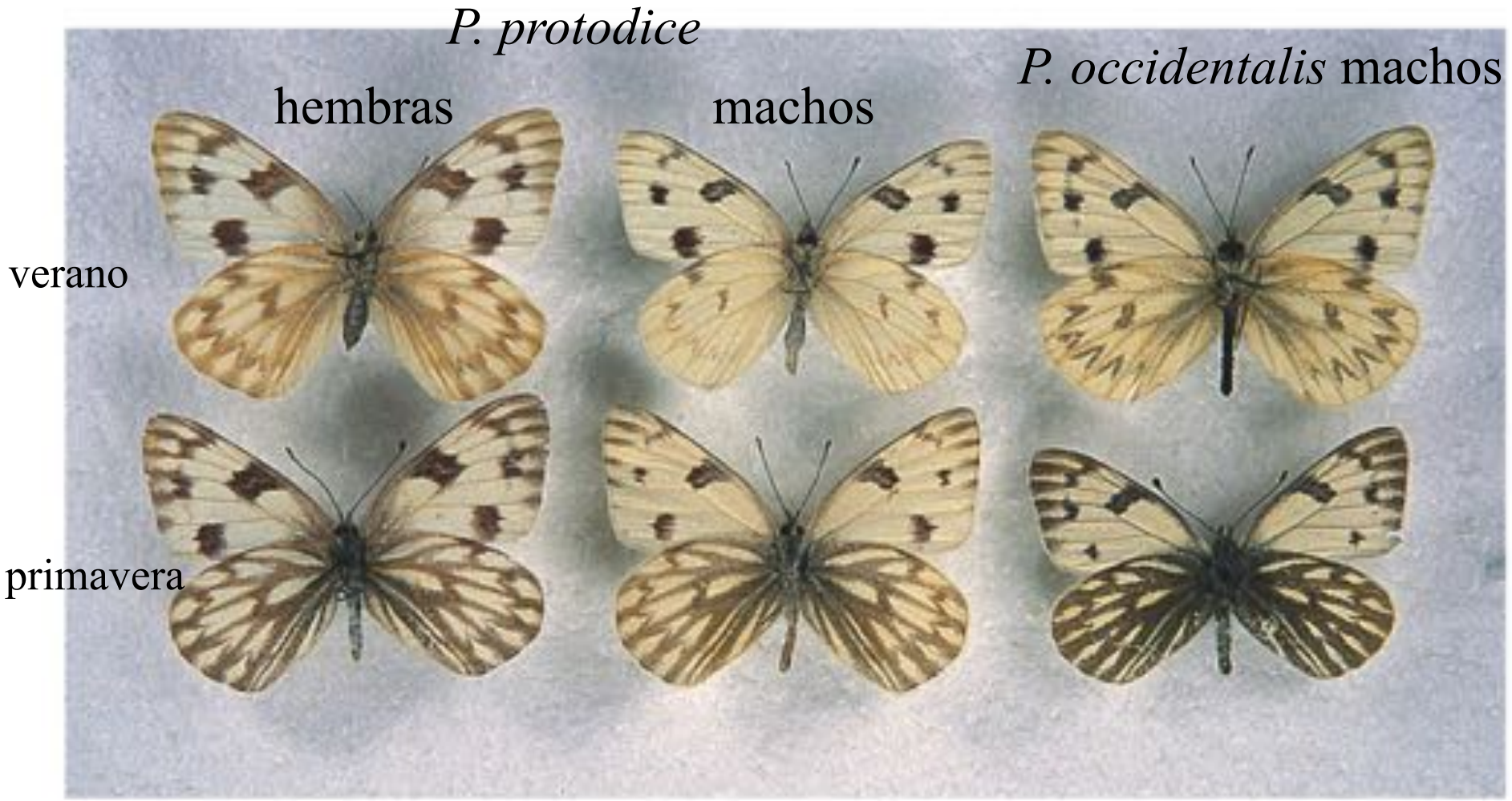
Density-induced polyphenism in planthoppers and grasshoppers



The dauer stage of nematodes:



Polyphenic variation in *Pontia* (Pieridae) butterflies



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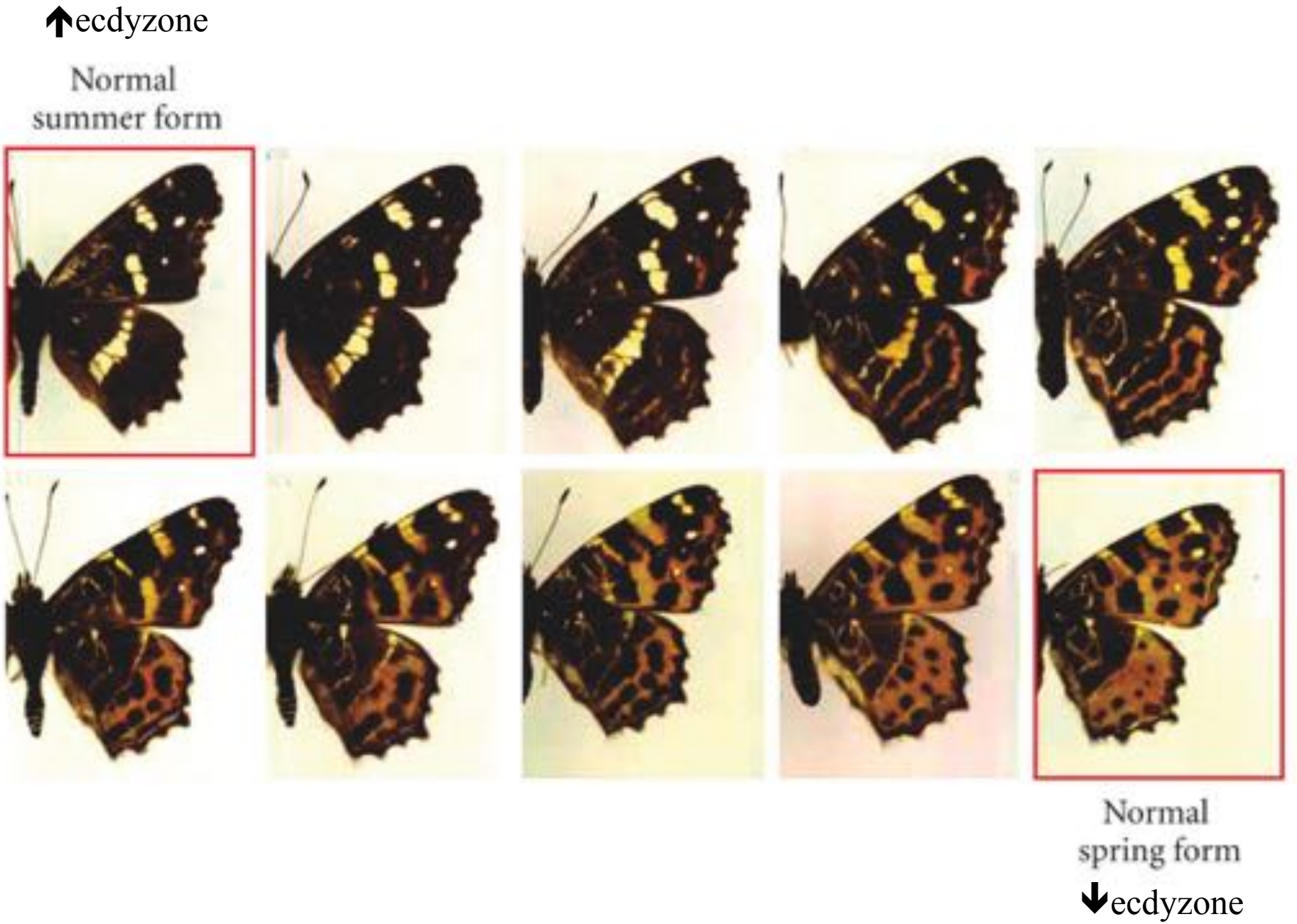
Hormonal regulation mediates the environmentally controlled pigmentation of *Araschnia*



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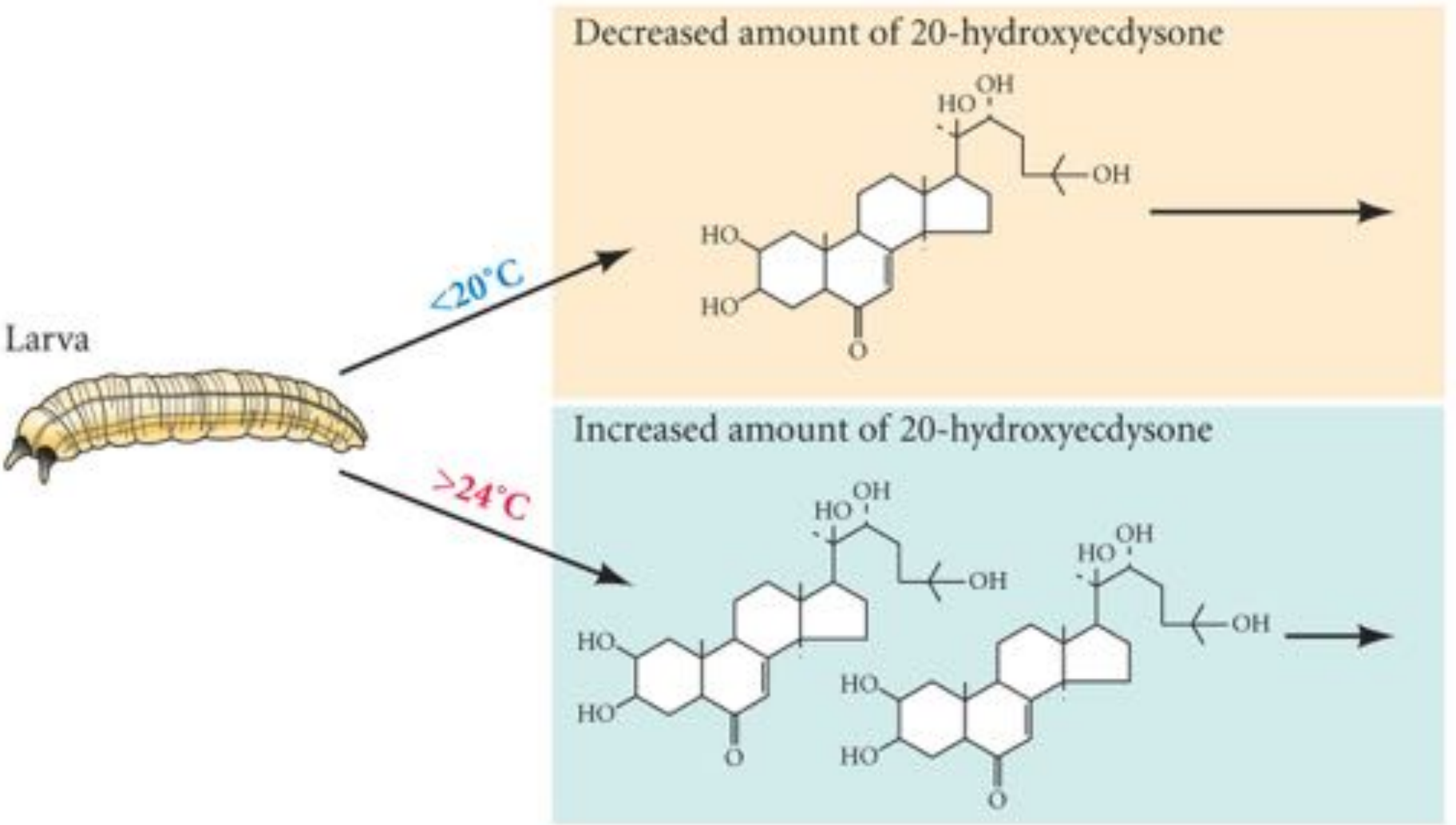
Phenotypic plasticity in *Bicyclus anynana* is regulated by temperature (Part 1)



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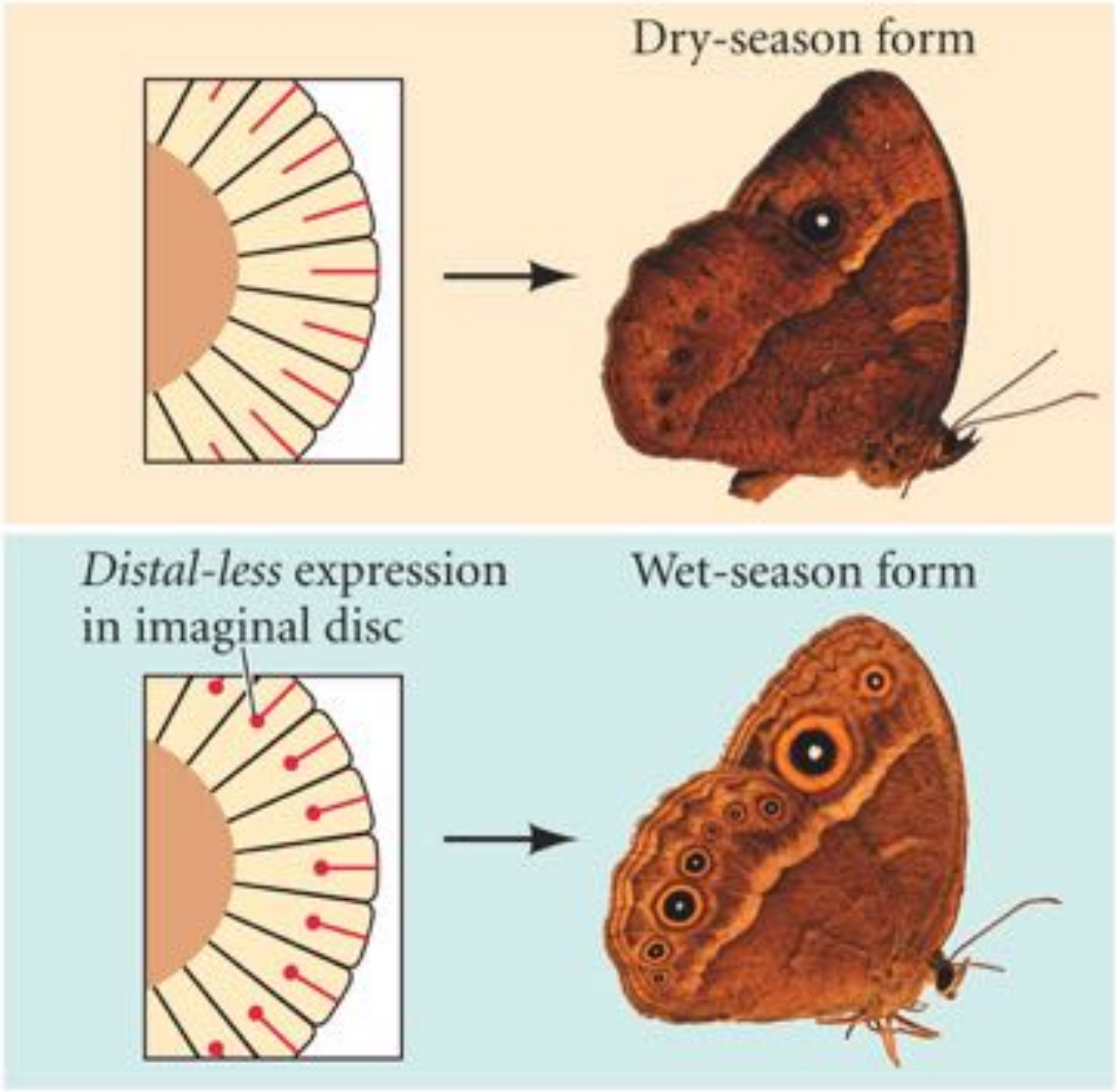
Phenotypic plasticity in *Bicyclus anynana* is regulated by temperature (Part 2)



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Obrera y reina de la hormiga *Pheidologeton*

DEVELOPMENTAL BIOLOGY, Eighth Edition, Figu

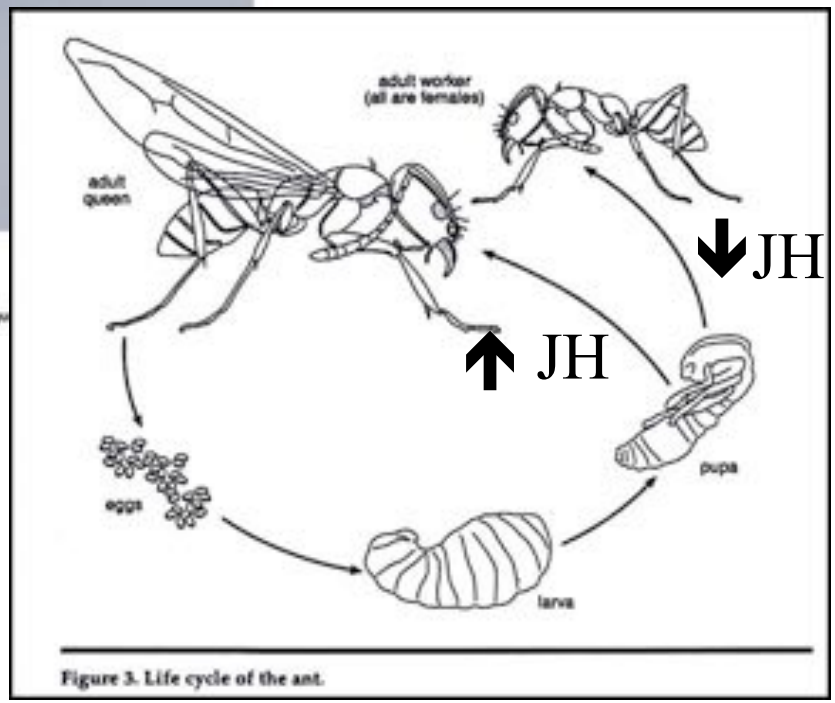


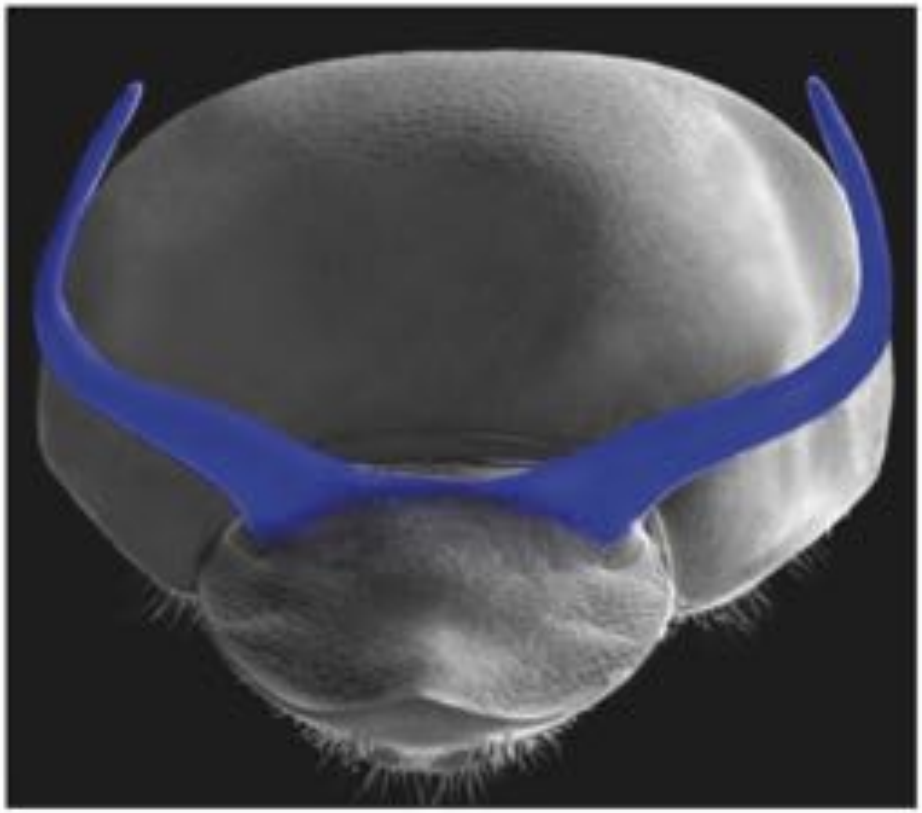
Figure 3. Life cycle of the ant.

PELOTERO CORNUDO

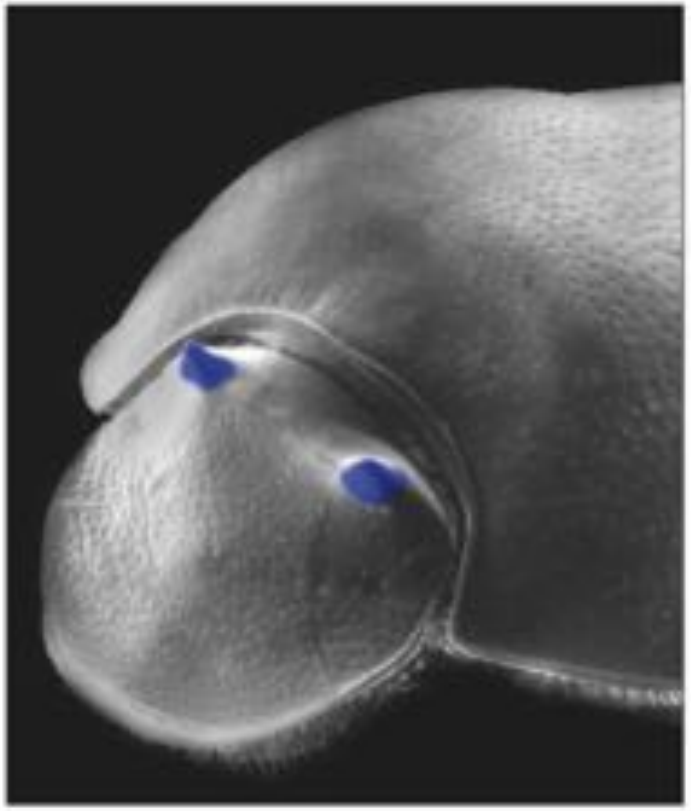
Horned and hornless male dung beetles (Part 1)

(A)

Horned male

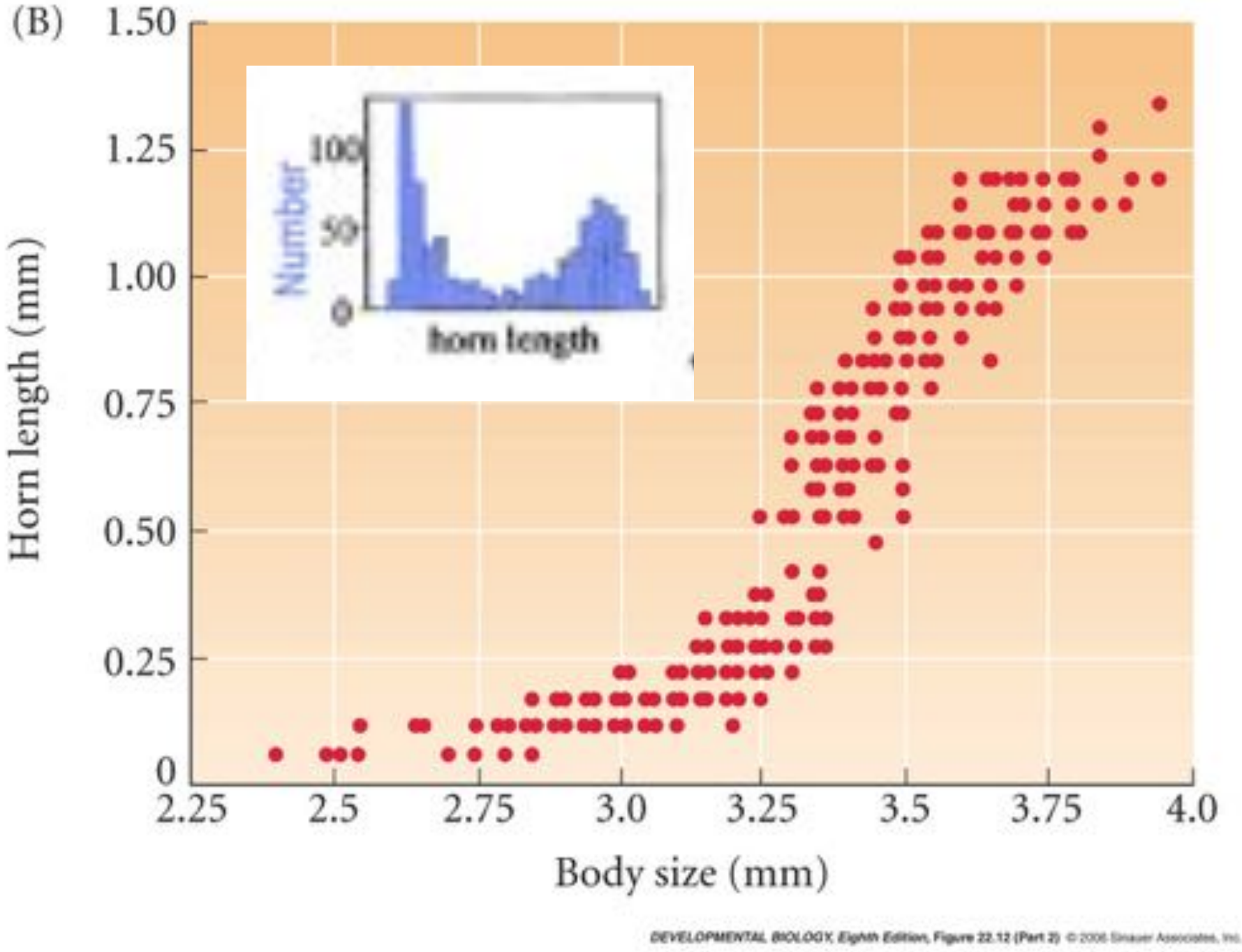


Hornless male



DEVELOPMENTAL BIOLOGY, Eighth Edition, Figure 22.12 (Part 1)

Horned and hornless male dung beetles (Part 2)



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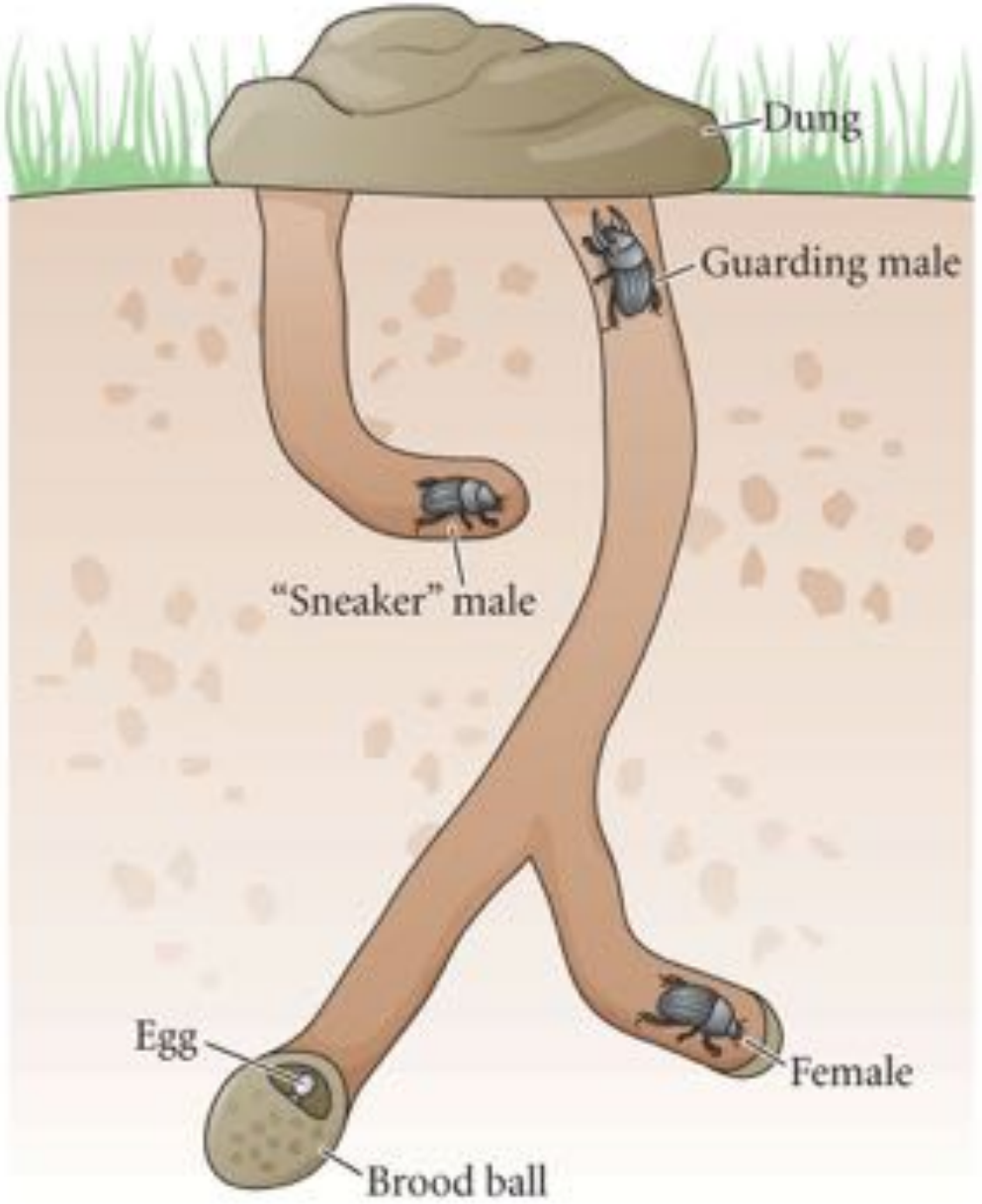
The presence or absence of horns determines the reproductive strategy of the male dung beetle (*Onthophagus*)



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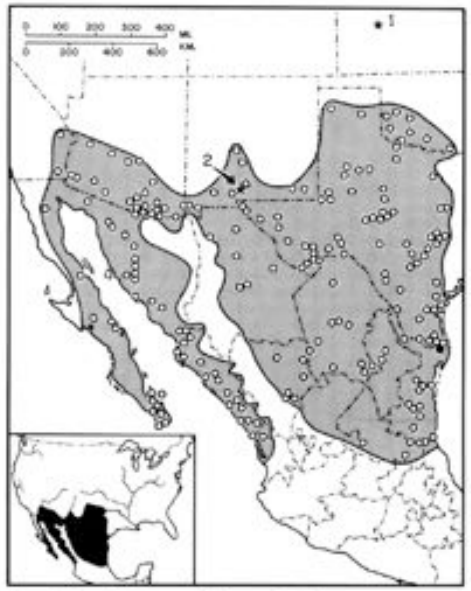
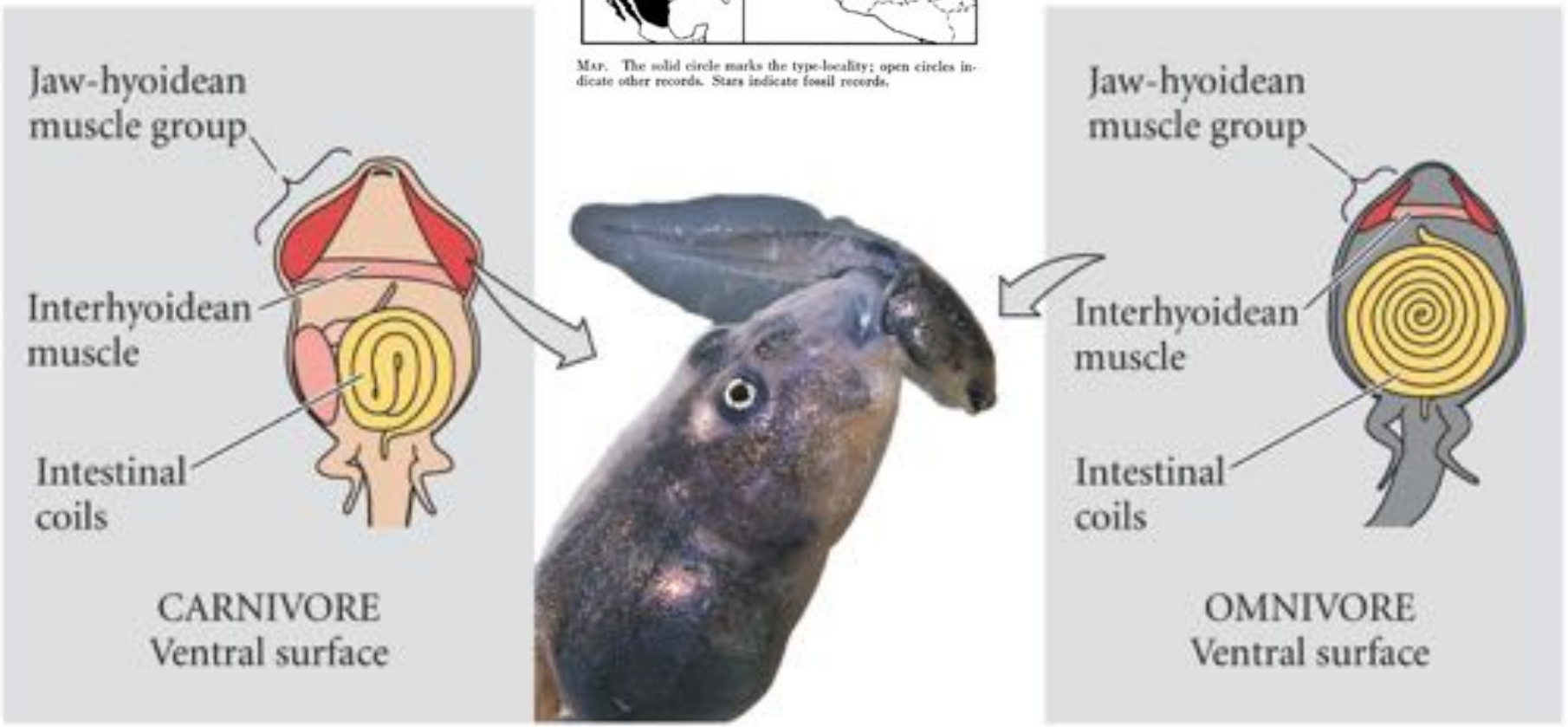
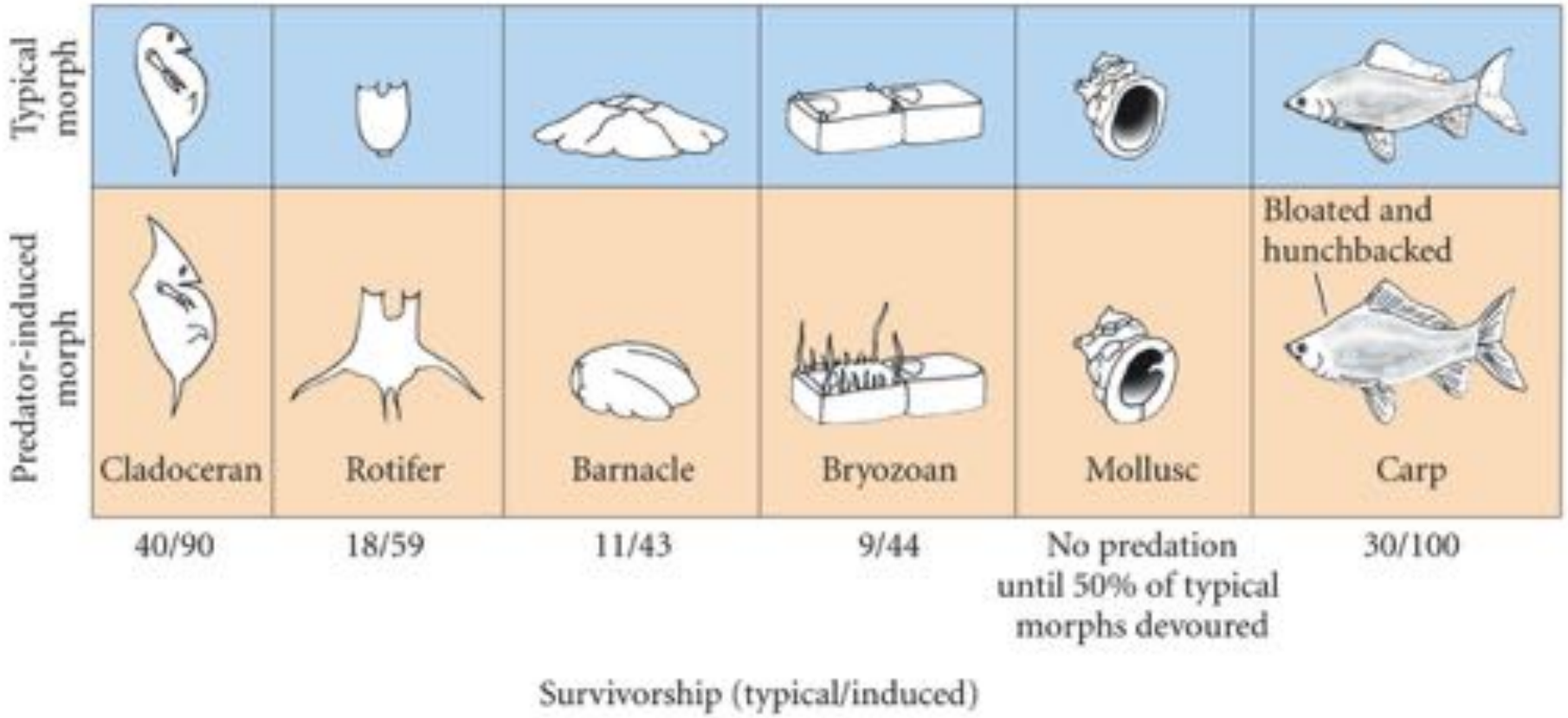
Polyphenism in the tadpoles of the spadefoot toad, *Scaphiopus couchii*



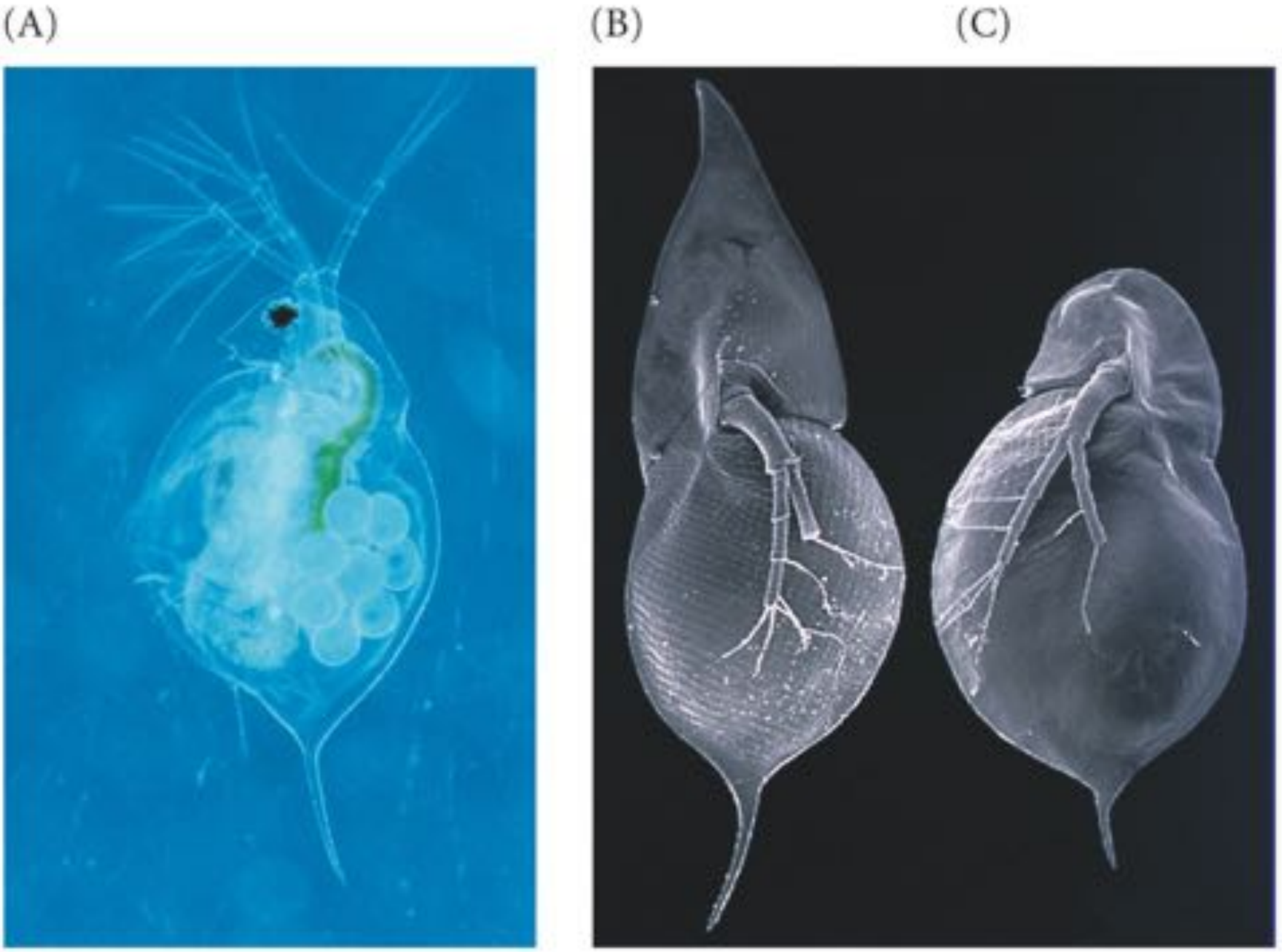
MAP. The solid circle marks the type-locality; open circles indicate other records. Stars indicate fossil records.



Predator-induced defenses



Predator-induced polyphenism in *Daphnia*



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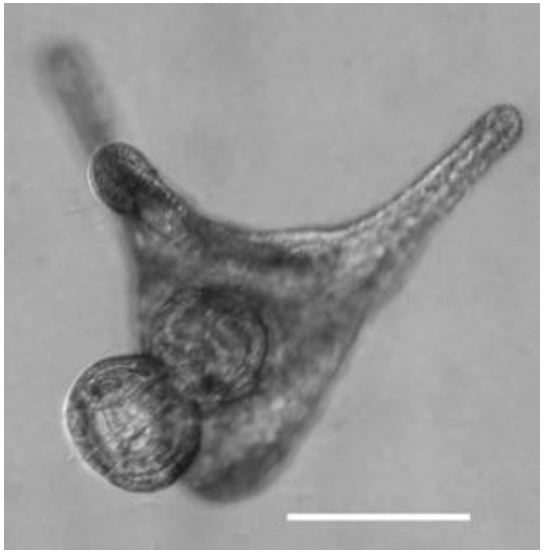
Predator induced larval cloning

Whole body regeneration,

Larval cloning in the sand dollar:



Dawn Vaughn (2008)

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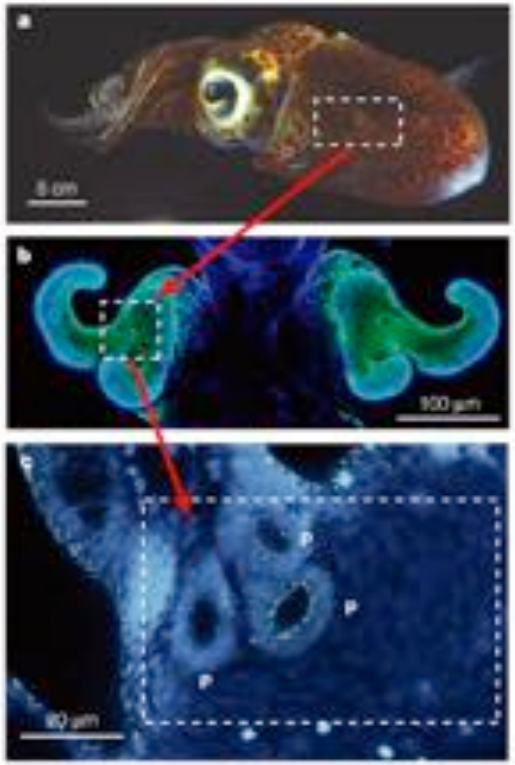
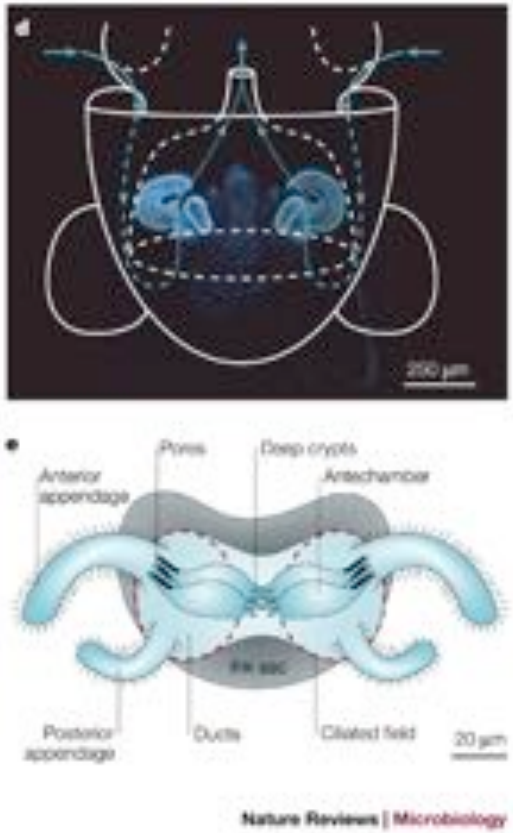
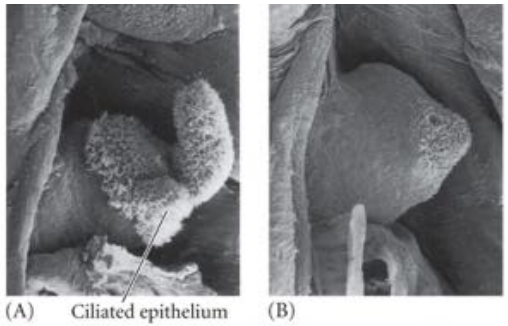
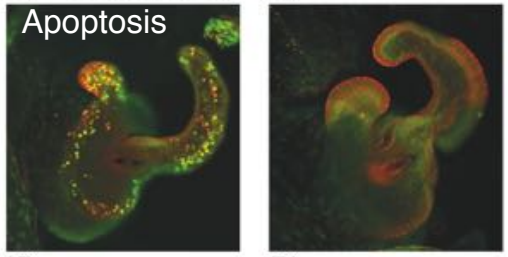
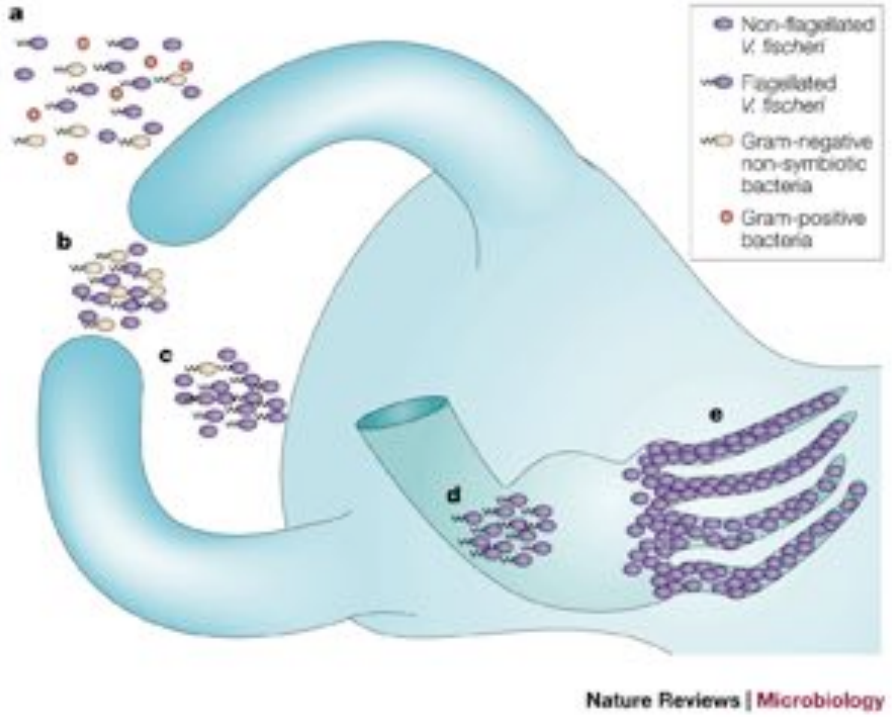
Symbiosis in the squid *Euprymna*





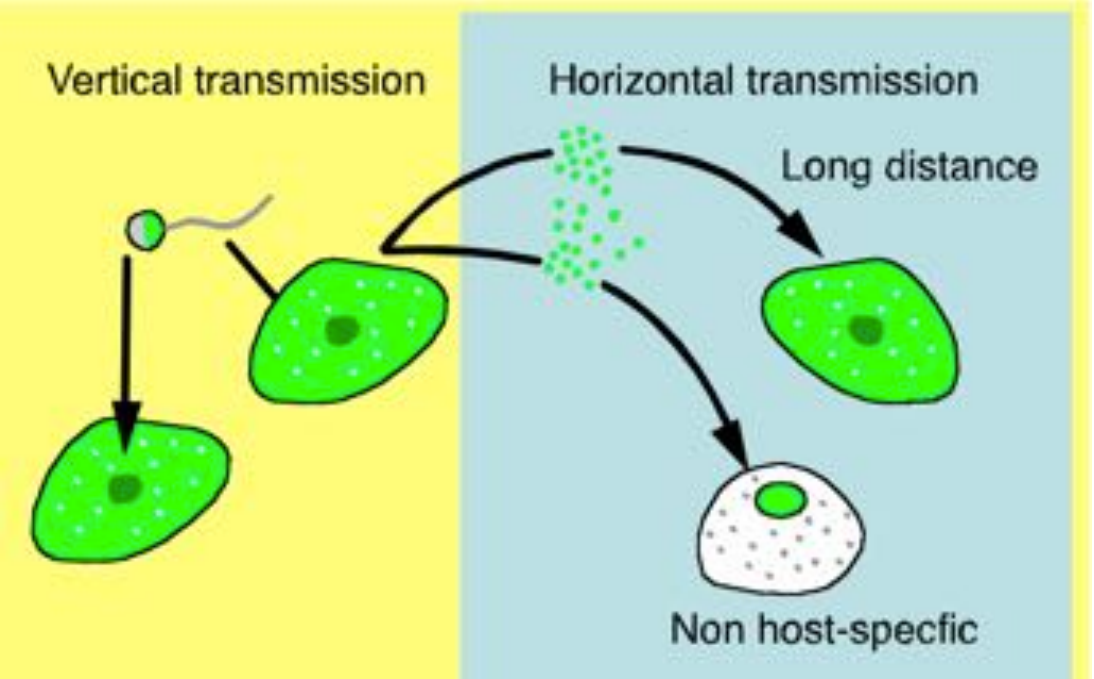




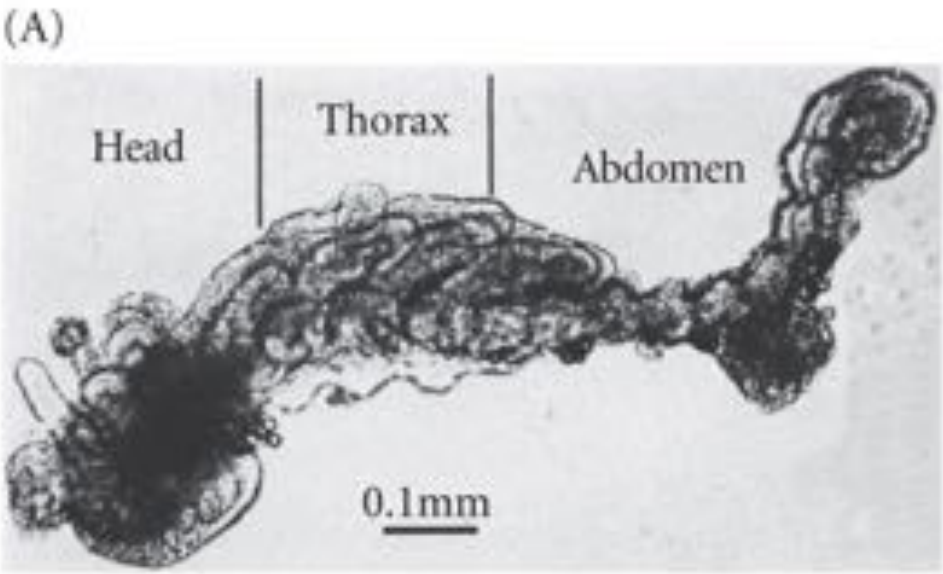


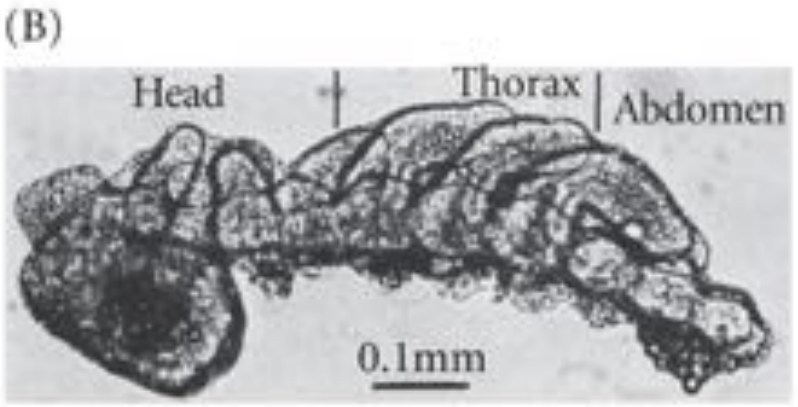
Fotosimbiosis en ascidias (cortesía de L. Hirose)

Único ejemplo de fotosimbiosis obligatoria en los cordados



Microbial symbionts are necessary for gut formation in the leafhopper *Euscelis incisus*



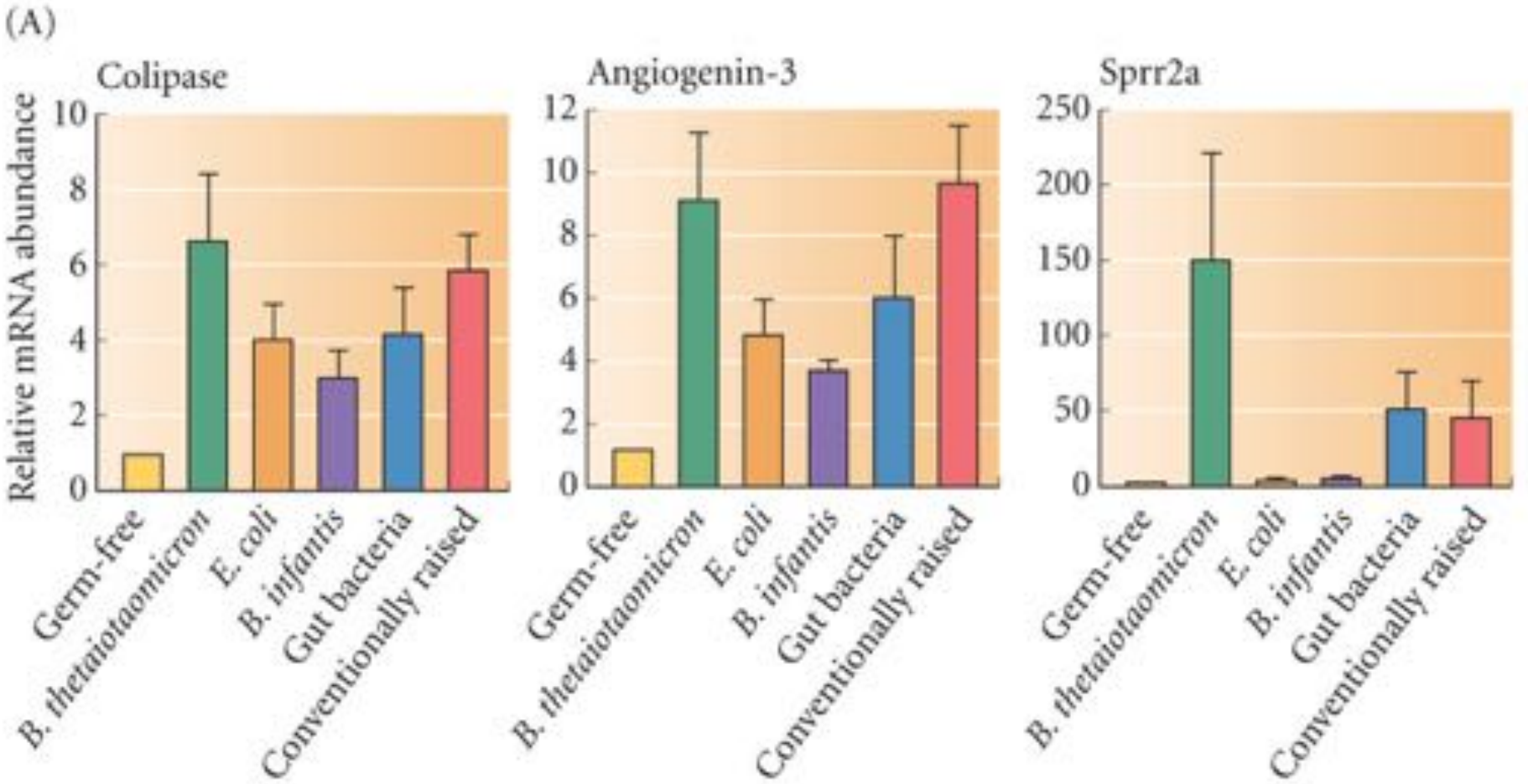


Specificity of host genome responses to different bacteria (Part 1)

nutrient absorption

blood vessel formation

fortifies matrices that line the intestine



DEVELOPMENTAL BIOLOGY, Eighth Edition, Figure 22.5 (Part 1) © 2006 Sinauer Associates, Inc.

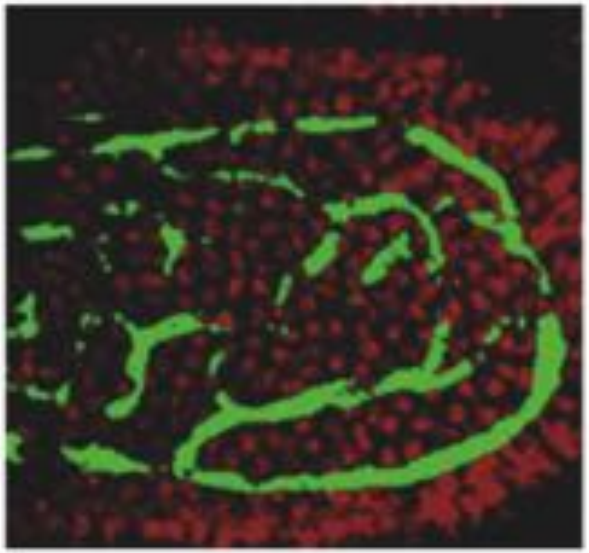
Specificity of host genome responses to different bacteria (Part 2)

Intestinal folds:

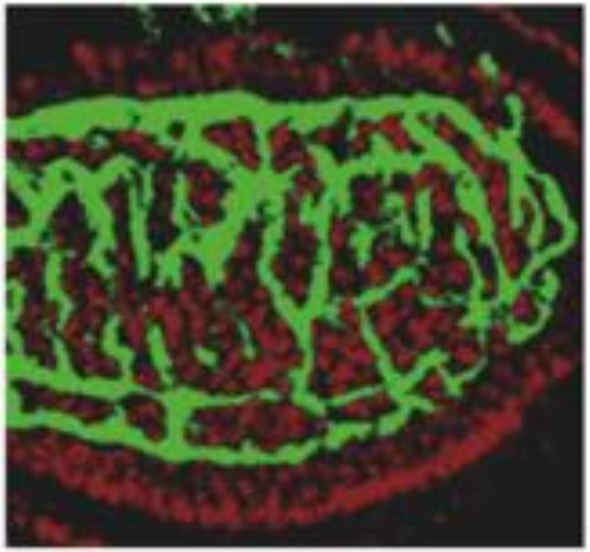
when grown in sterile medium

when grown with conventional bacteria

(B)



(C)



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FORMAS EN LA NATURALEZA: COMO SE *GENERAN, MANTIENEN* O *PIERDEN*?

TEMAS A TRATAR:

- ORIGEN DE LAS NOVEDADES EVOLUTIVAS
  - Restricciones en el desarrollo (planos corporales y reconstrucción de estados ancestrales)
  - Alometría y campos morfogenéticos

- "TOOLKIT GENICO" Y MODULARIDAD
  - Eye evolution and development (Pax6)
  - Hox genes
  - Modularity of animal form

- ACOMODACIÓN VS. ASIMILACIÓN
  - Acomodación fenotipica (cuadrupedos en dos patas)
  - Asimilación genética (mosca HSP90)

- AMBIENTE Y NOVEDADES EVOLUTIVAS
  - Polifenismos
  - Simbiosis

New directions: An emerging evolutionary synthesis