



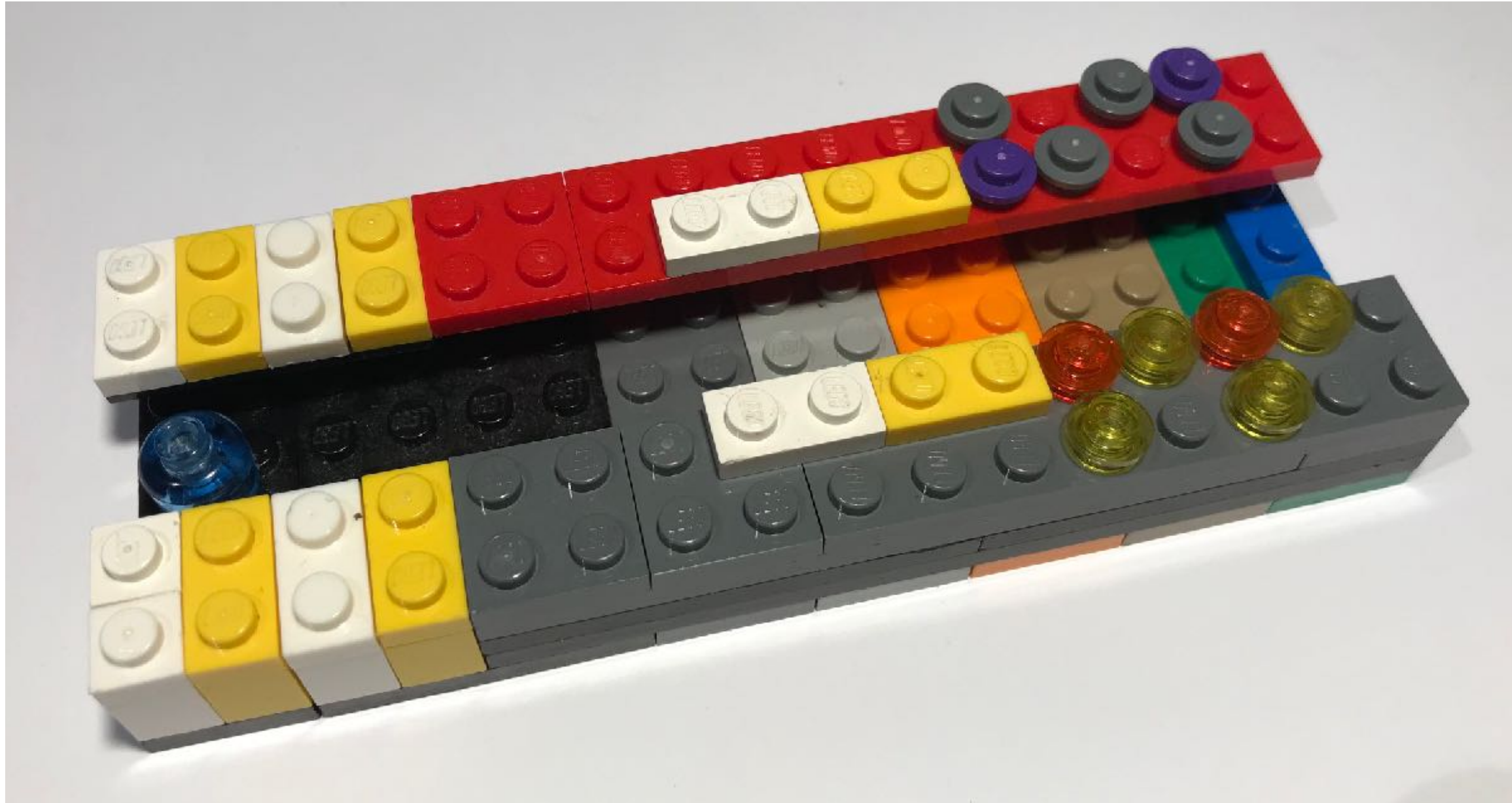
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Big questions



?

LEGO embryo completed!





Today's menu

- **Eco-Devo (ecological developmental biology)**

- *Developmental plasticity*

- Biotic - diet, crowding, predators

- Abiotic - temperature

- Symbiotic - bacteria

- **Evo-Devo (evolutionary developmental biology)**

- *Modularity allows dissociation*

- Changes in morphology come from changes in development

- Regulatory mutations are known drivers of change

- Role for developmental plasticity in evolution

Developmental plasticity

- Reaction norm - a continuous variation in phenotype in response to the environment
- Polyphenism - discrete phenotypes in response to the environment
- Not due to different *genotypes*



Individual puzzle



Diet-induced polyphenism I

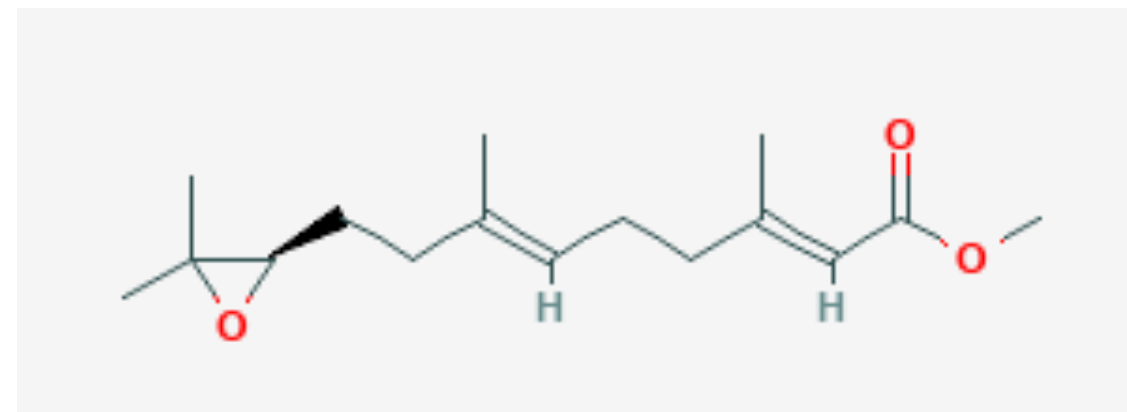
- Male dung beetle horns



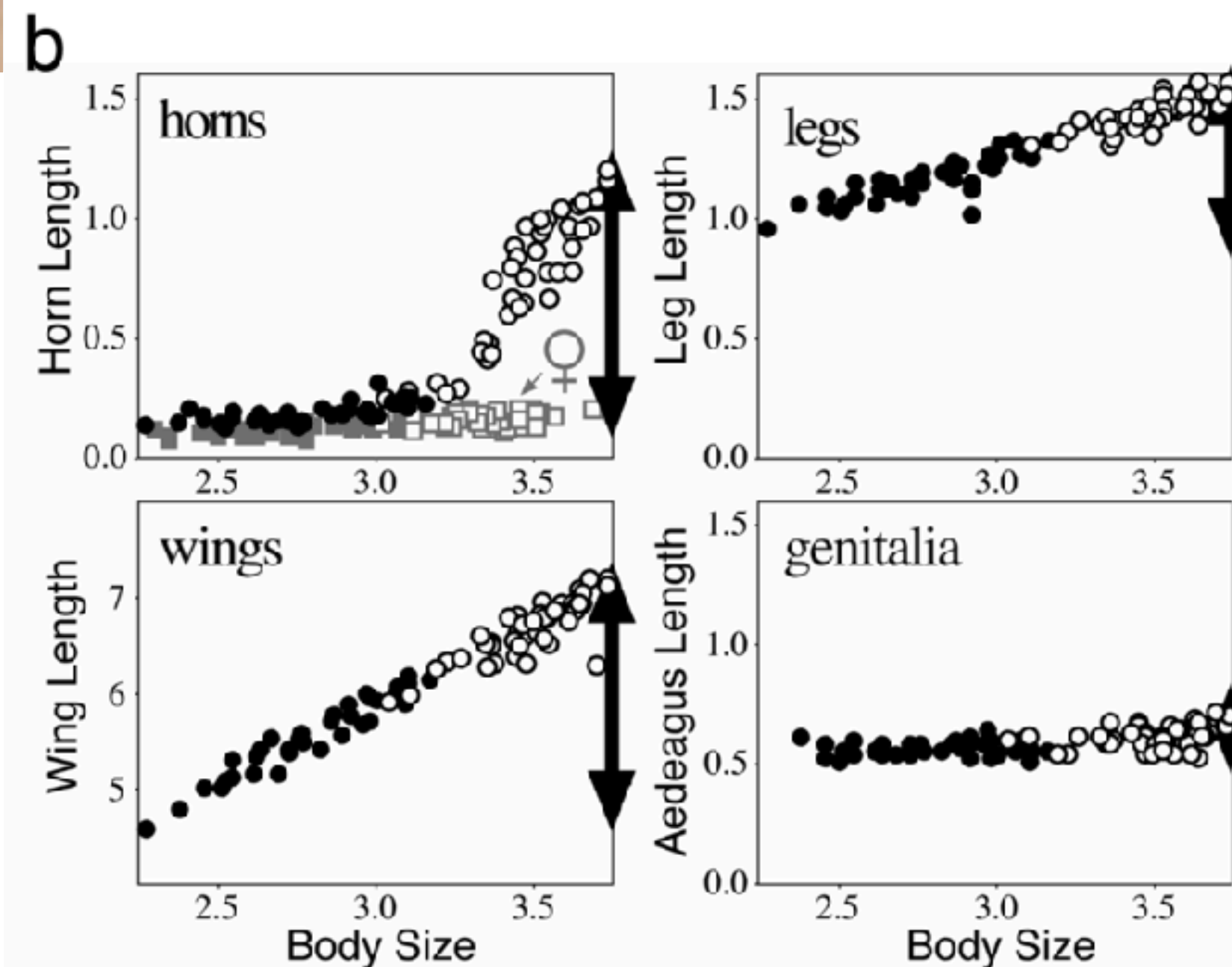
Why are these brothers so different?

Diet-induced polyphenism I

- Male dung beetle horns

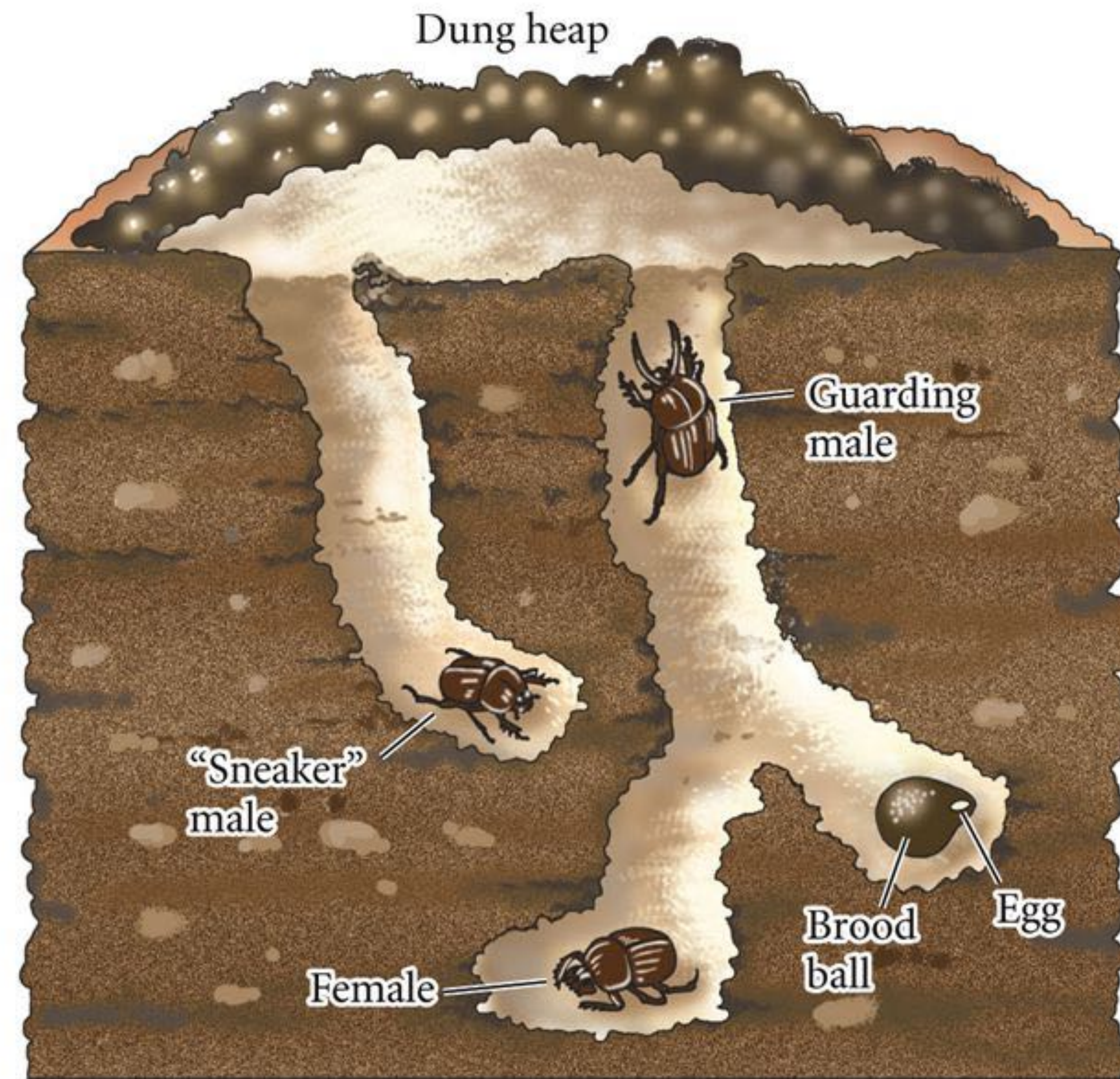


Juvenile hormone titre depends on amount of food



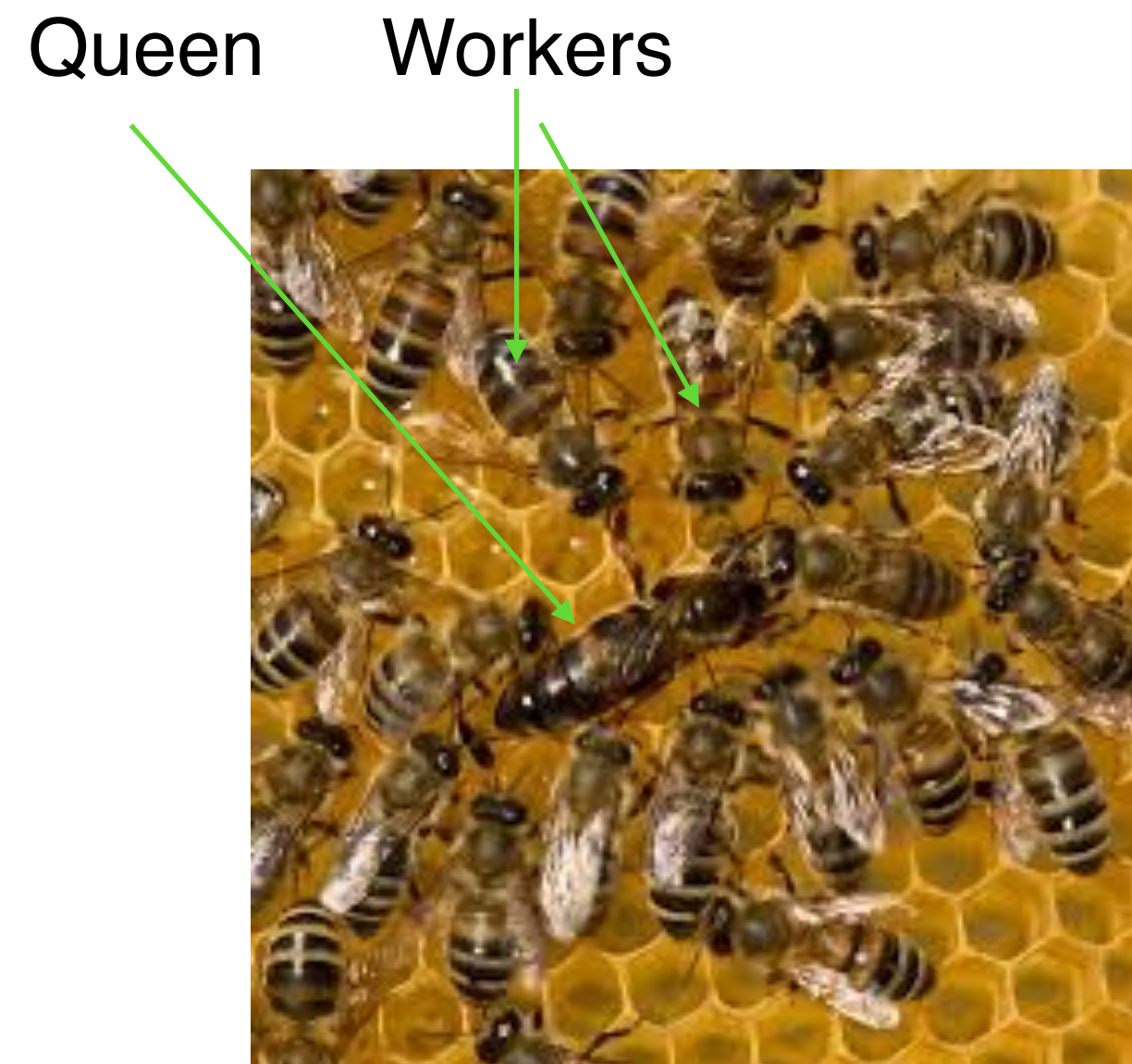
Diet-induced polyphenism I

- Male dung beetle horns

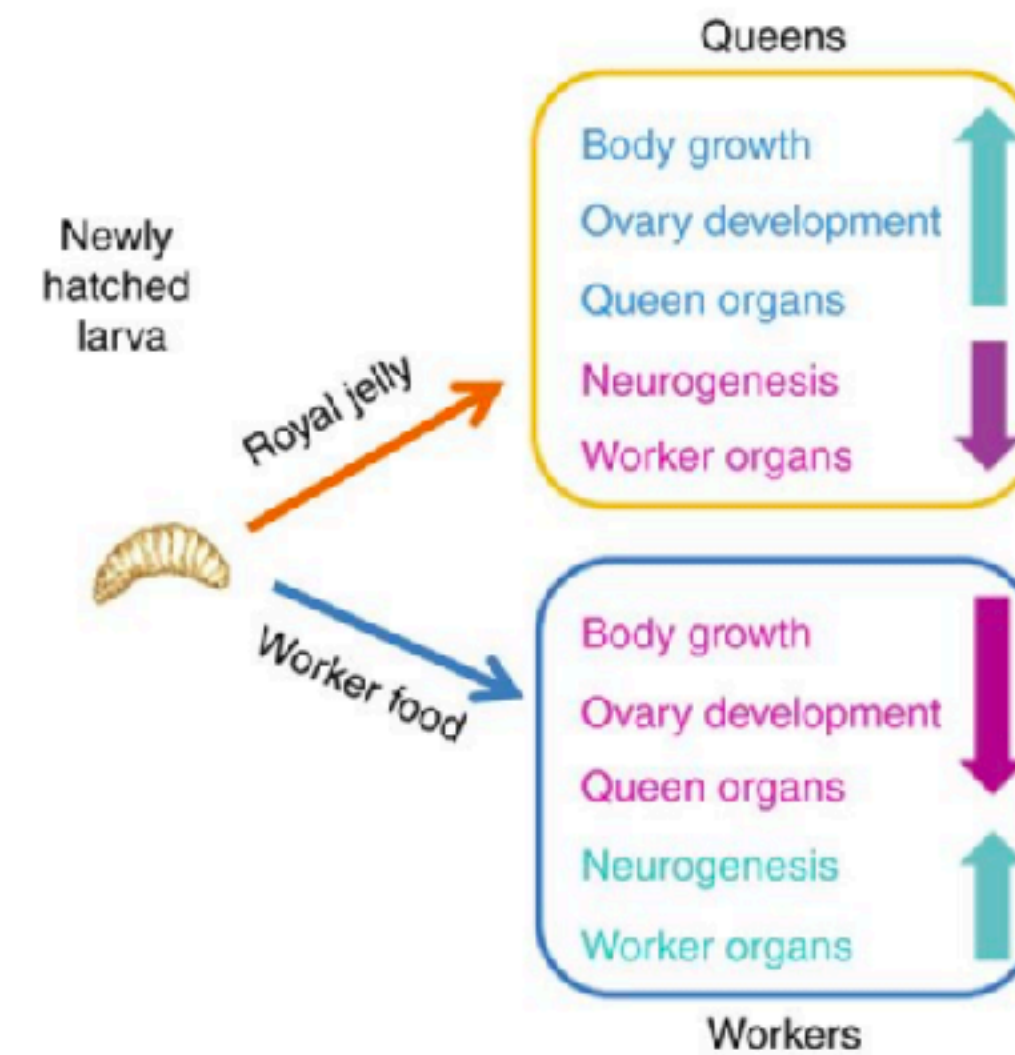


Diet-induced polyphenism 2

- Castes in social insects (bees, ants etc.)



Royal jelly

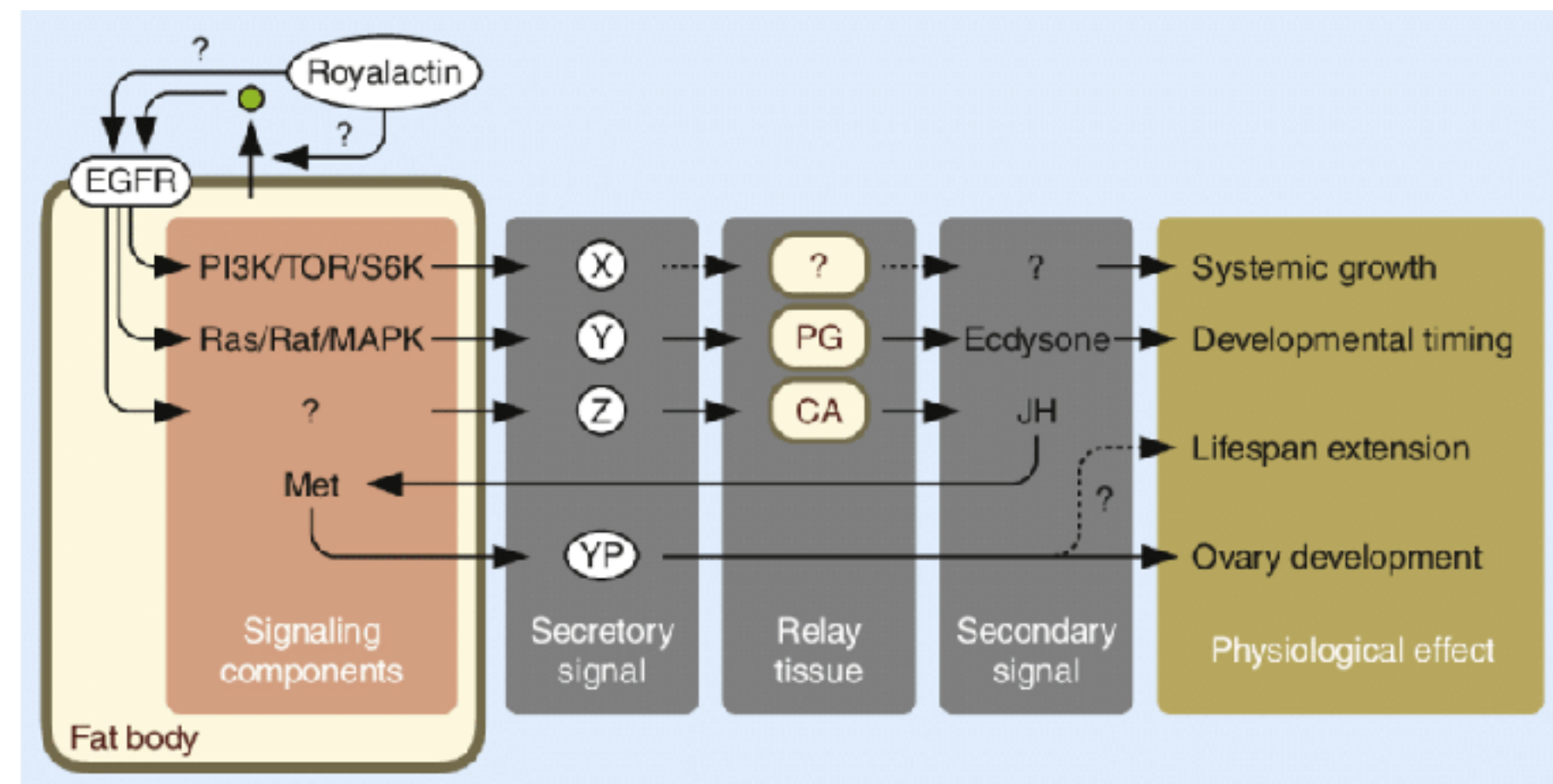


Maleszka, Comm Biol, 2018

Diet-induced polyphenism 2

- Castes in social insects (bees, ants etc.)

Specific signals



Current Biology

Royalactin (Rol) protein

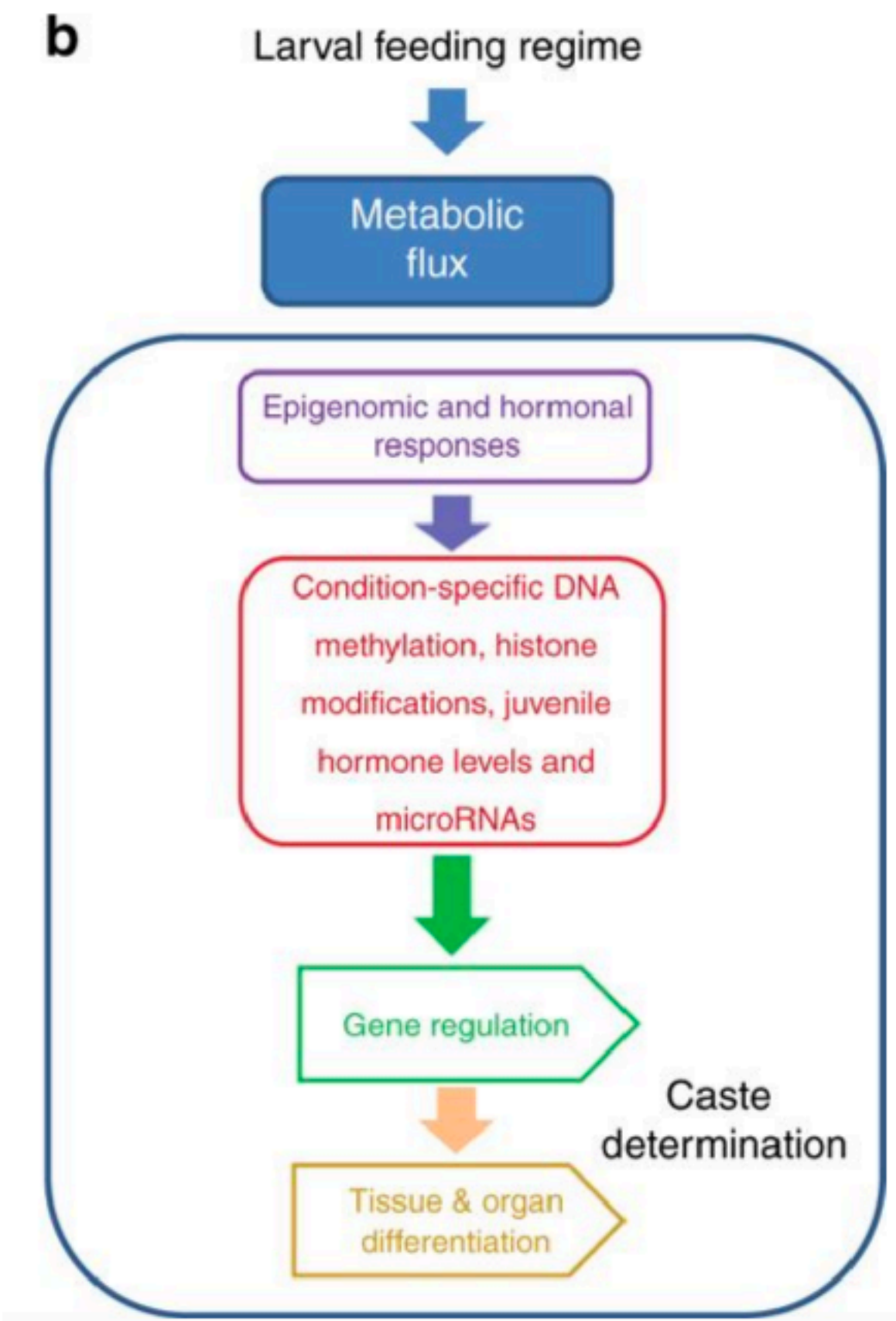


UAS-Rol

ppl>Rol

Kamakura, Nature, 2011

Amount of food



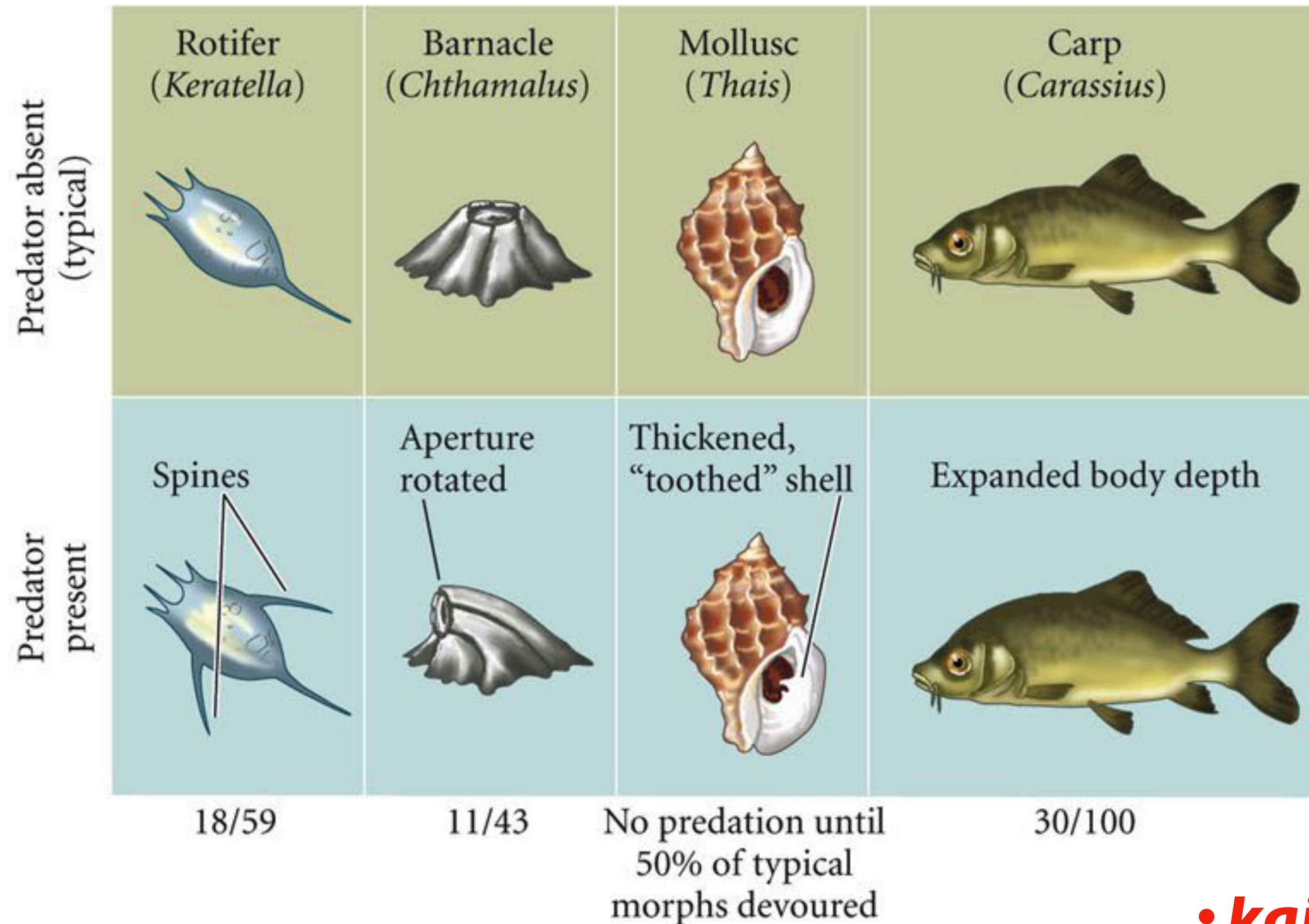
Maleszka, Comm Biol, 2018



Volume 5
Issue 2
Summer/Fall 2011

Predator-induced polyphenism

- Induced morph better able to survive predator
- Soluble filtrate from water around predator sufficient



• **kairomone**

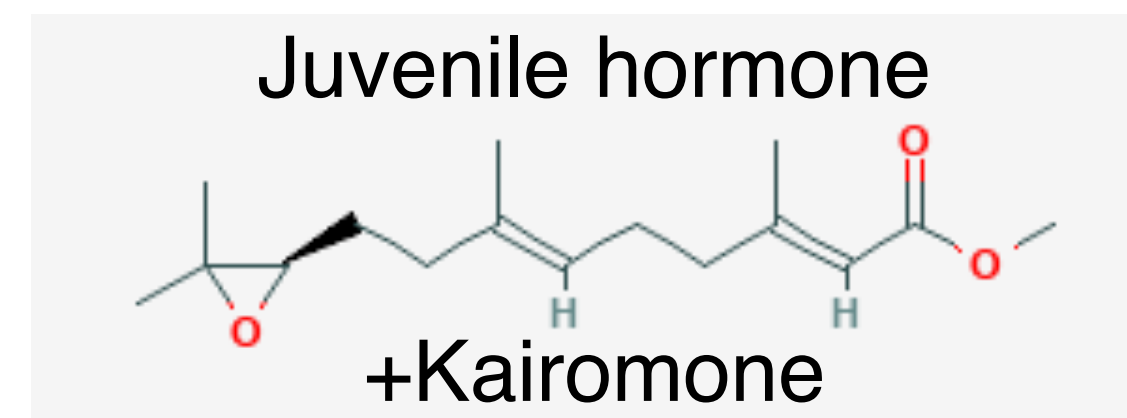
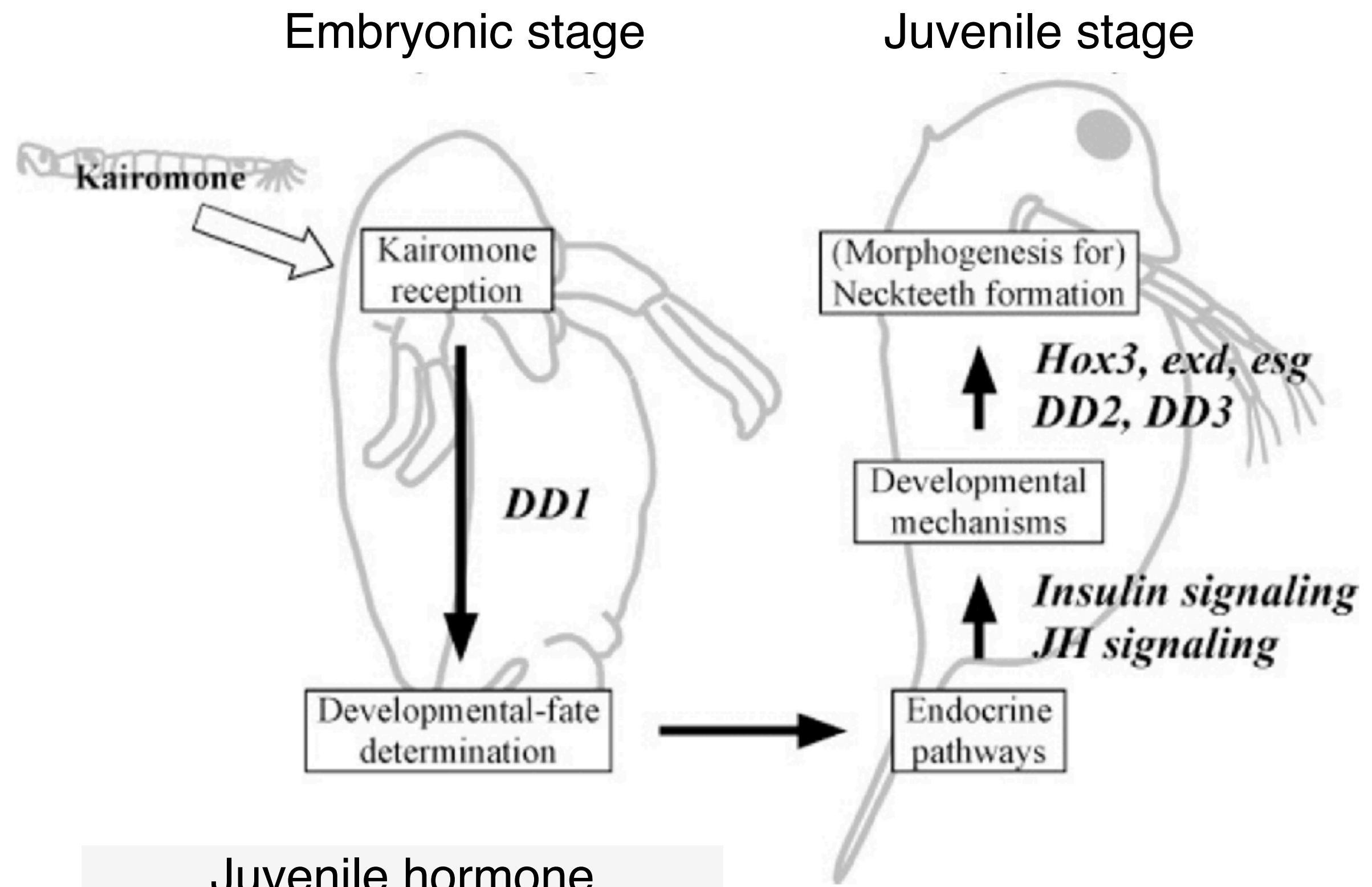
Predator-induced polyphenism

- Helmets or neckteeth in *Daphnia* in response to *Chaoborus* larvae
- Inherited for one generation
- Tradeoff with egg numbers



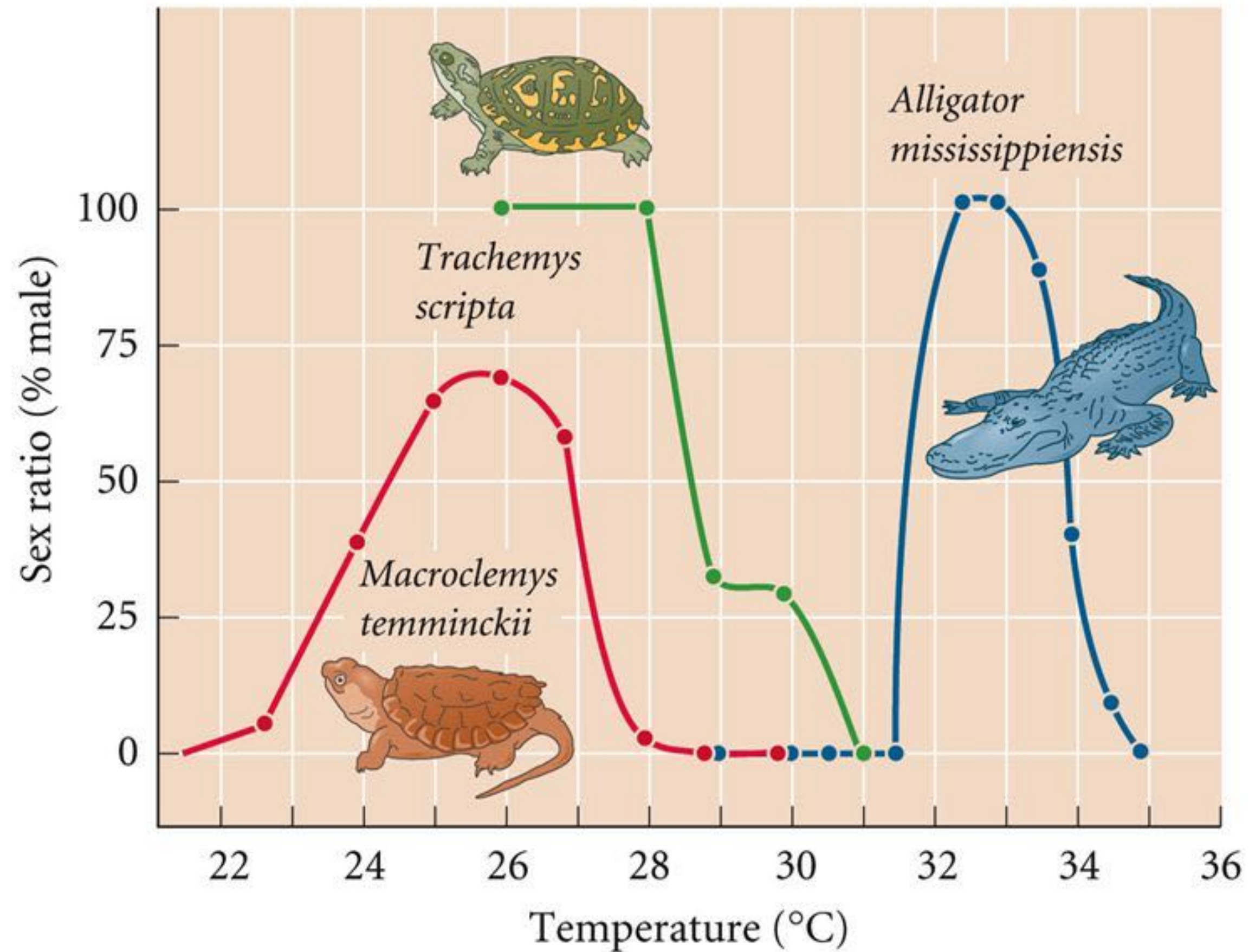
Predator present

Predator absent



Temperature-induced polyphenism I

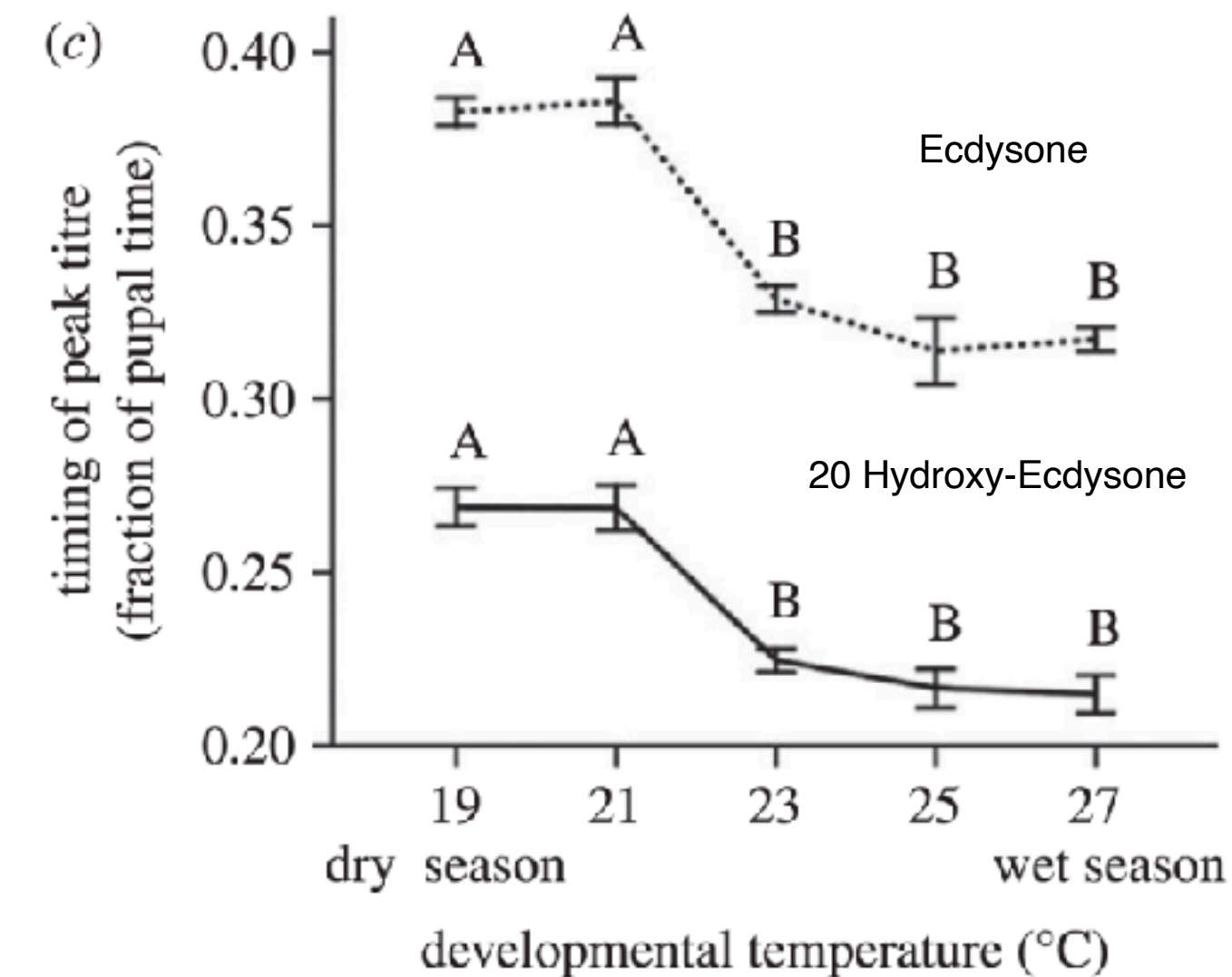
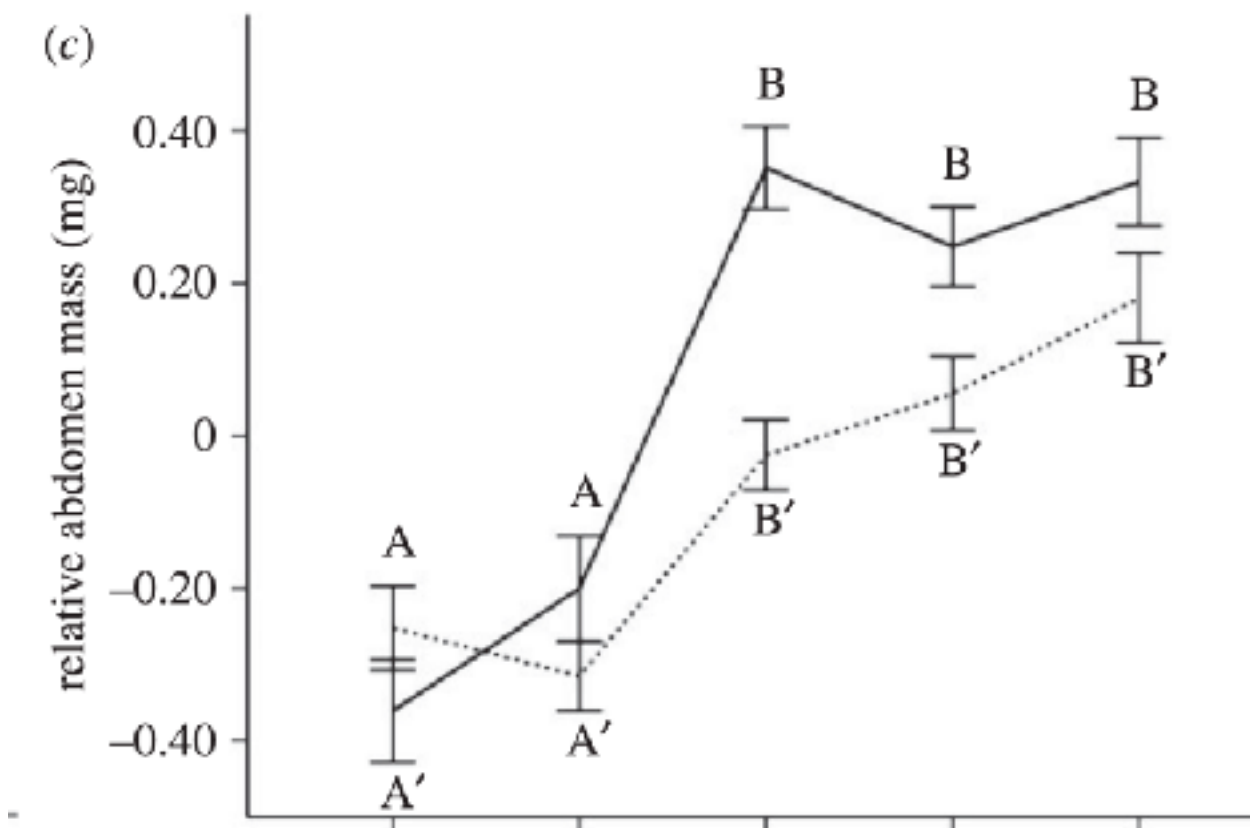
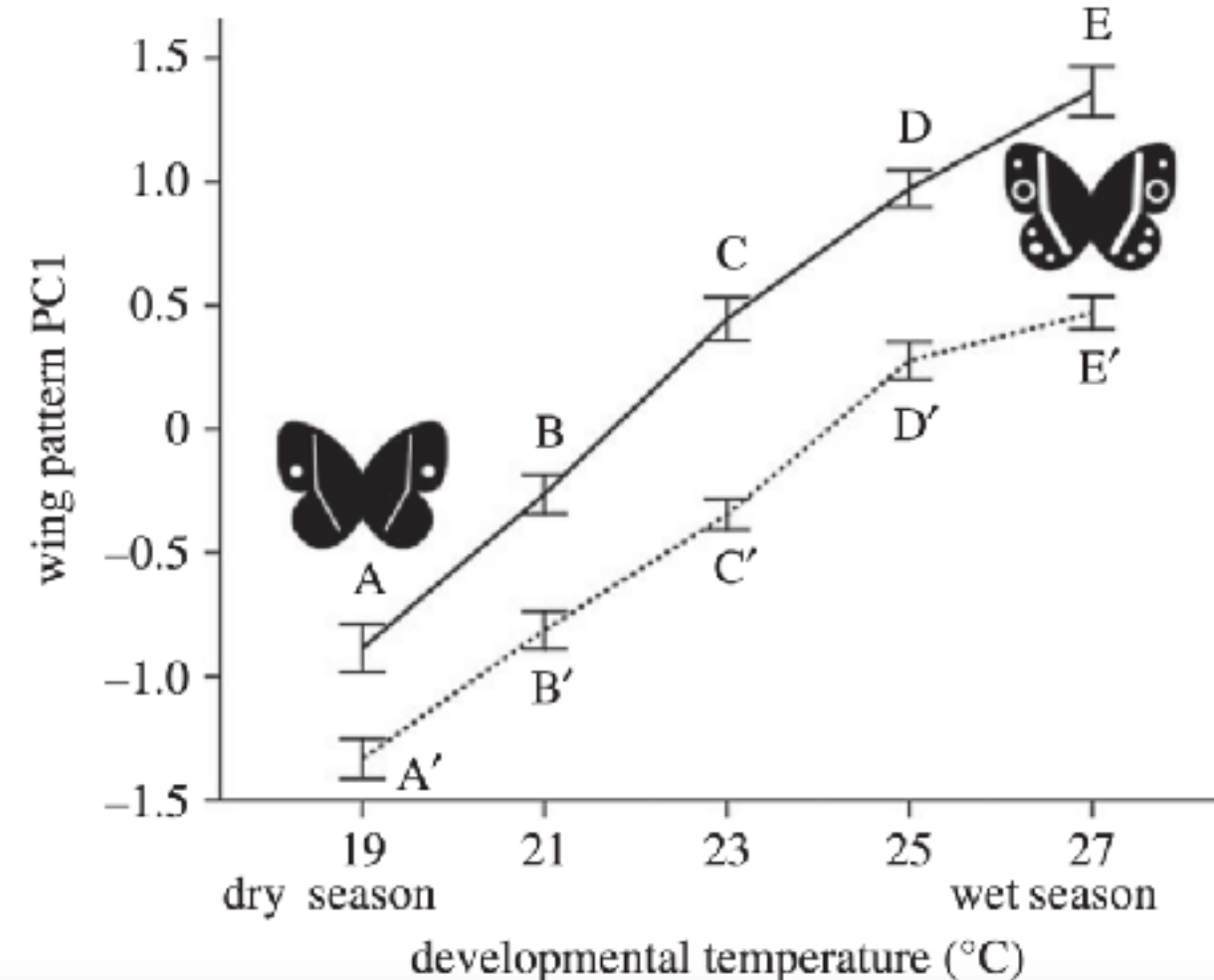
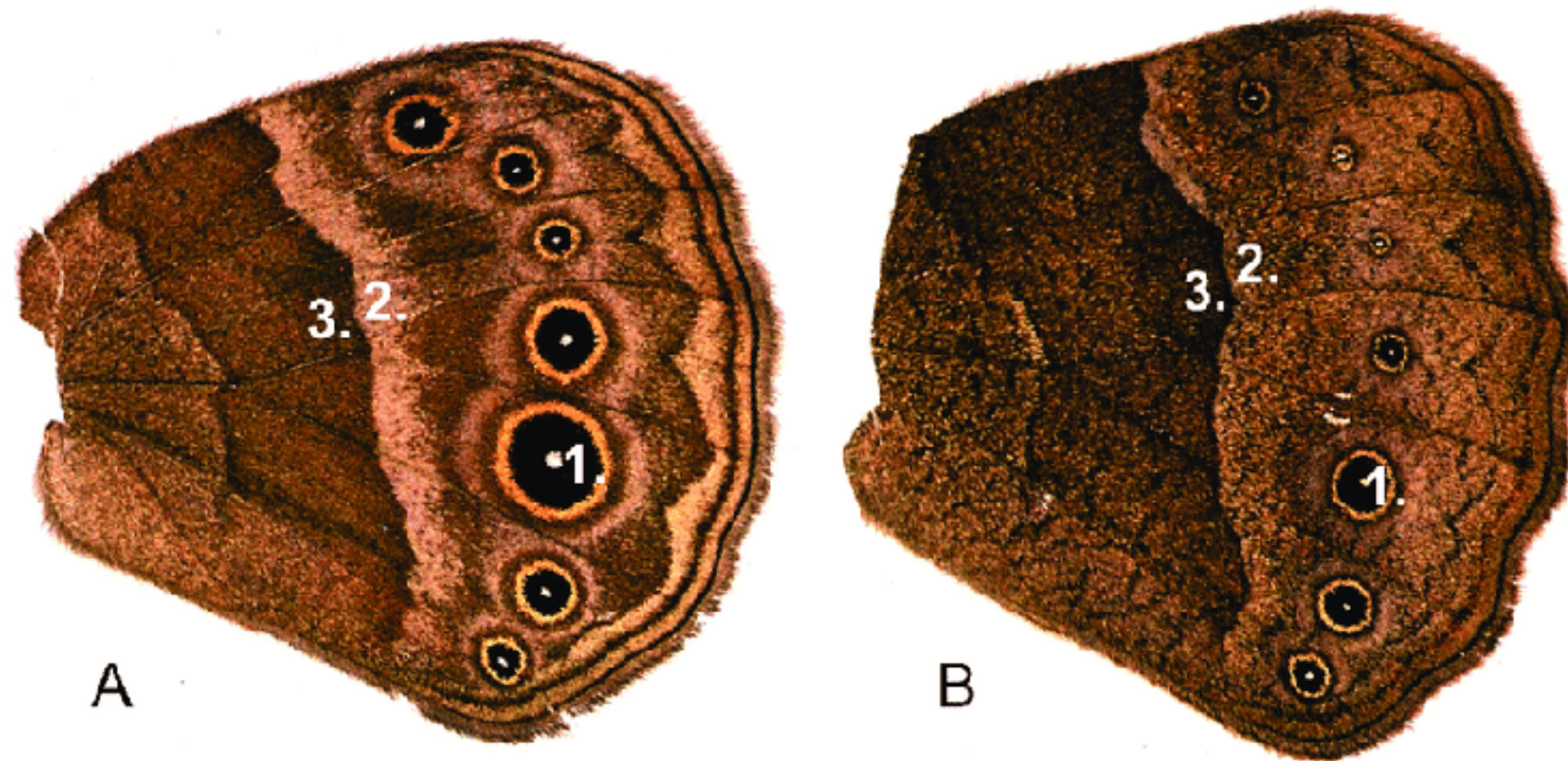
- Crocodiles and turtles



Cold-inducible RNA-binding protein (CIRBP)

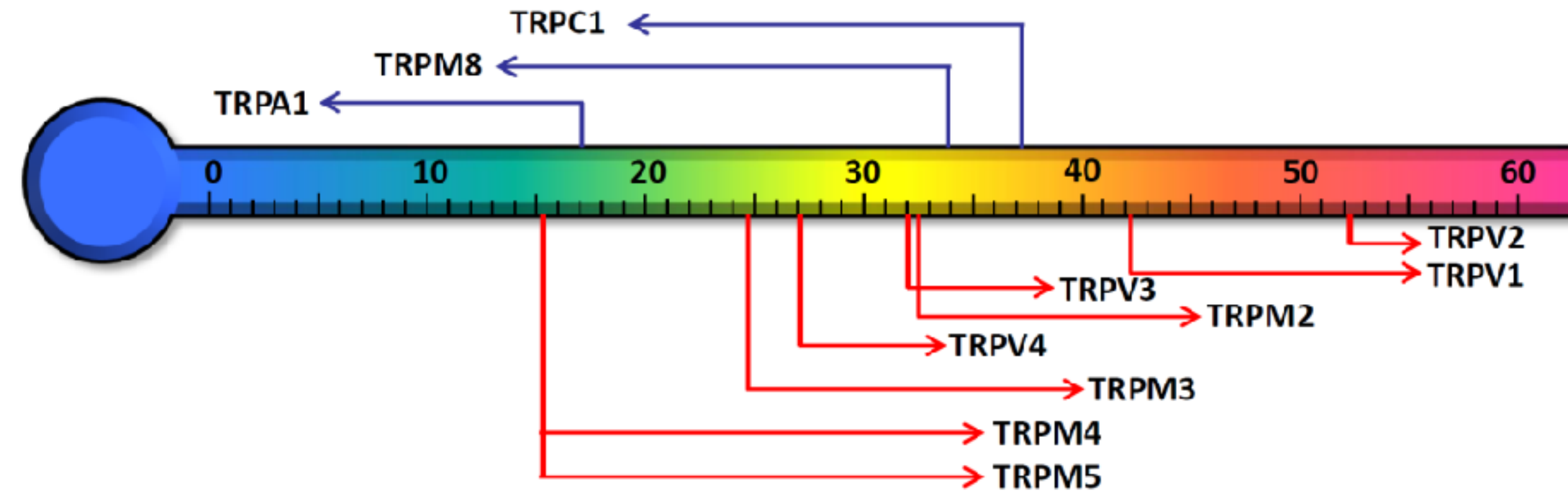
Temperature-induced polyphenism 2

- Butterfly wing pattern smooth
- Abdomen size bimodal
- Ecdysone response bimodal

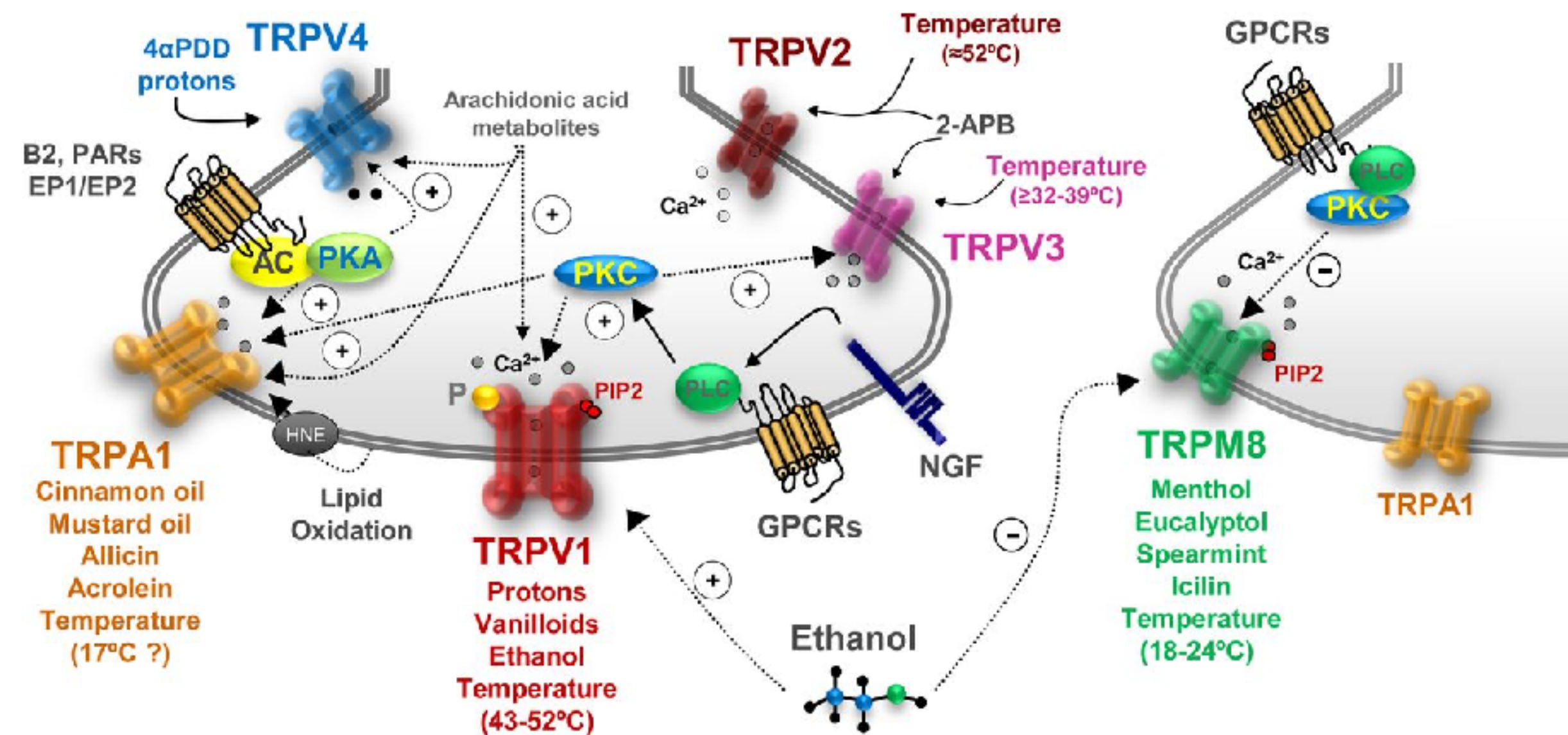


Distal-less expression

Temperature sensing by ion channels?



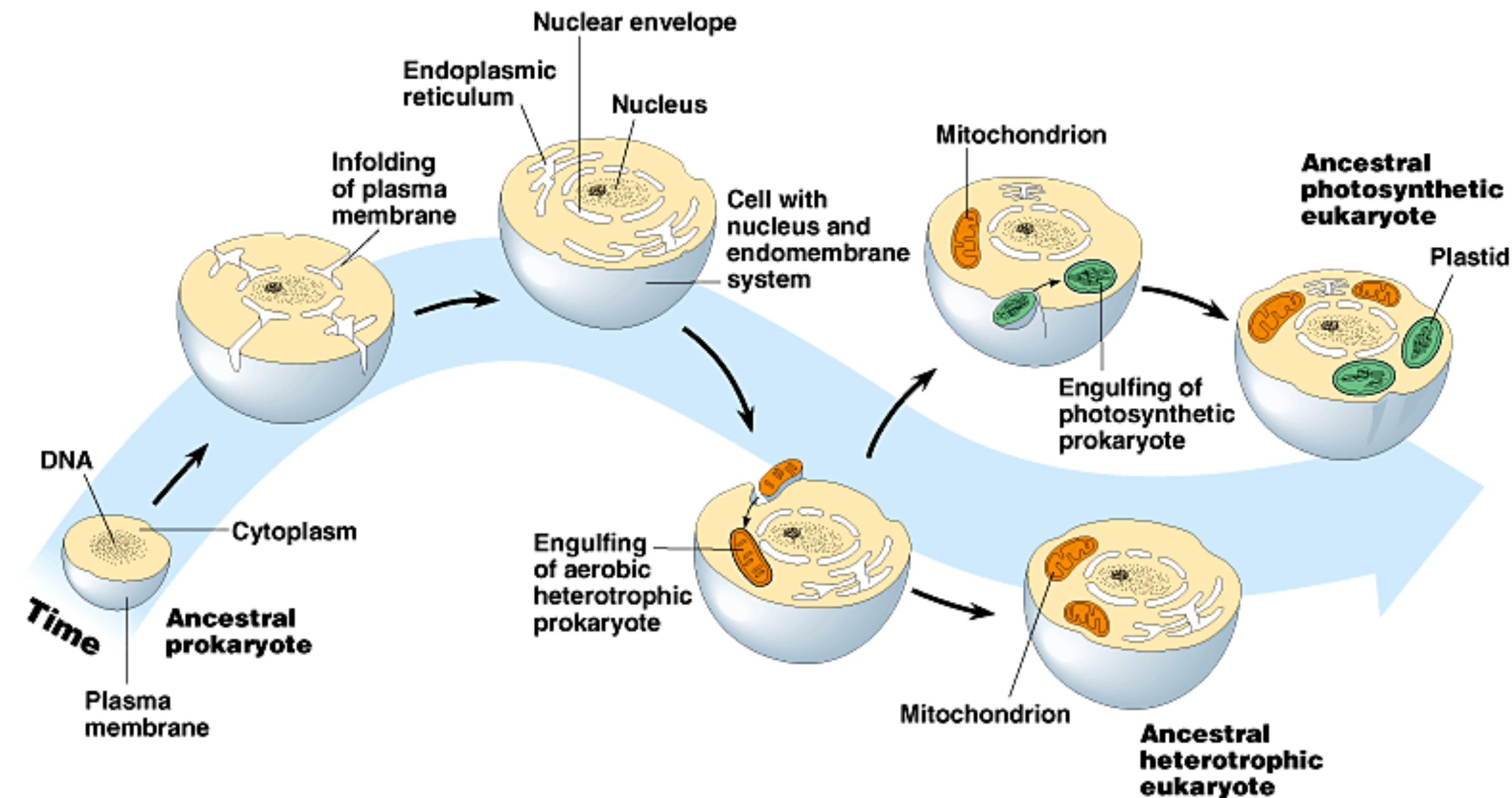
Pertusa, IntechOpen, 2012



Symbiosis-induced polyphenism

“A vital part of an organism’s environment is the presence of other organisms.”

- Host and symbiont (= holobiont)
- Parasitism versus mutualism
- Endosymbiosis, e.g. the eukaryotic cell (bacteria+archaea)



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Symbiosis-induced polyphenism I

- *Wolbachia* intracellular bacteria infects insects
- Vertical transmission through the egg
- Horizontal transmission
- Cytoplasmic incompatibility, parthenogenesis, feminisation, male killing...

Drosophila ovary

Infected mothers lay 4x eggs
Protected from some viruses



Armadillidium

Infected males develop as females



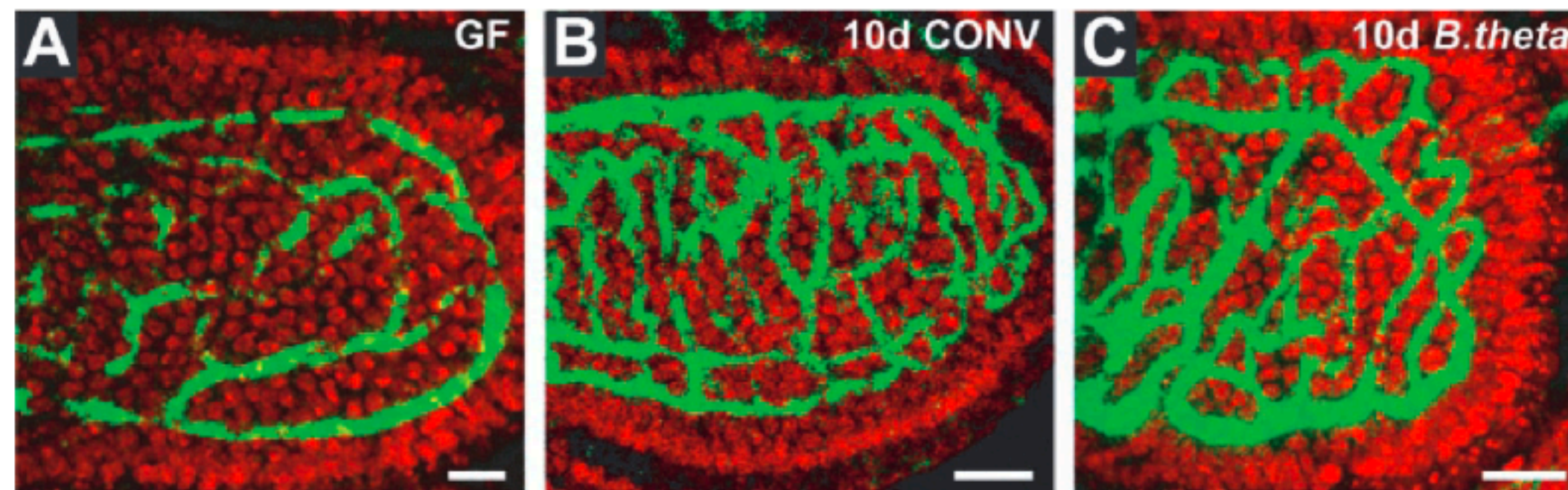
Culex

Sperm modified to
kill non-infected eggs



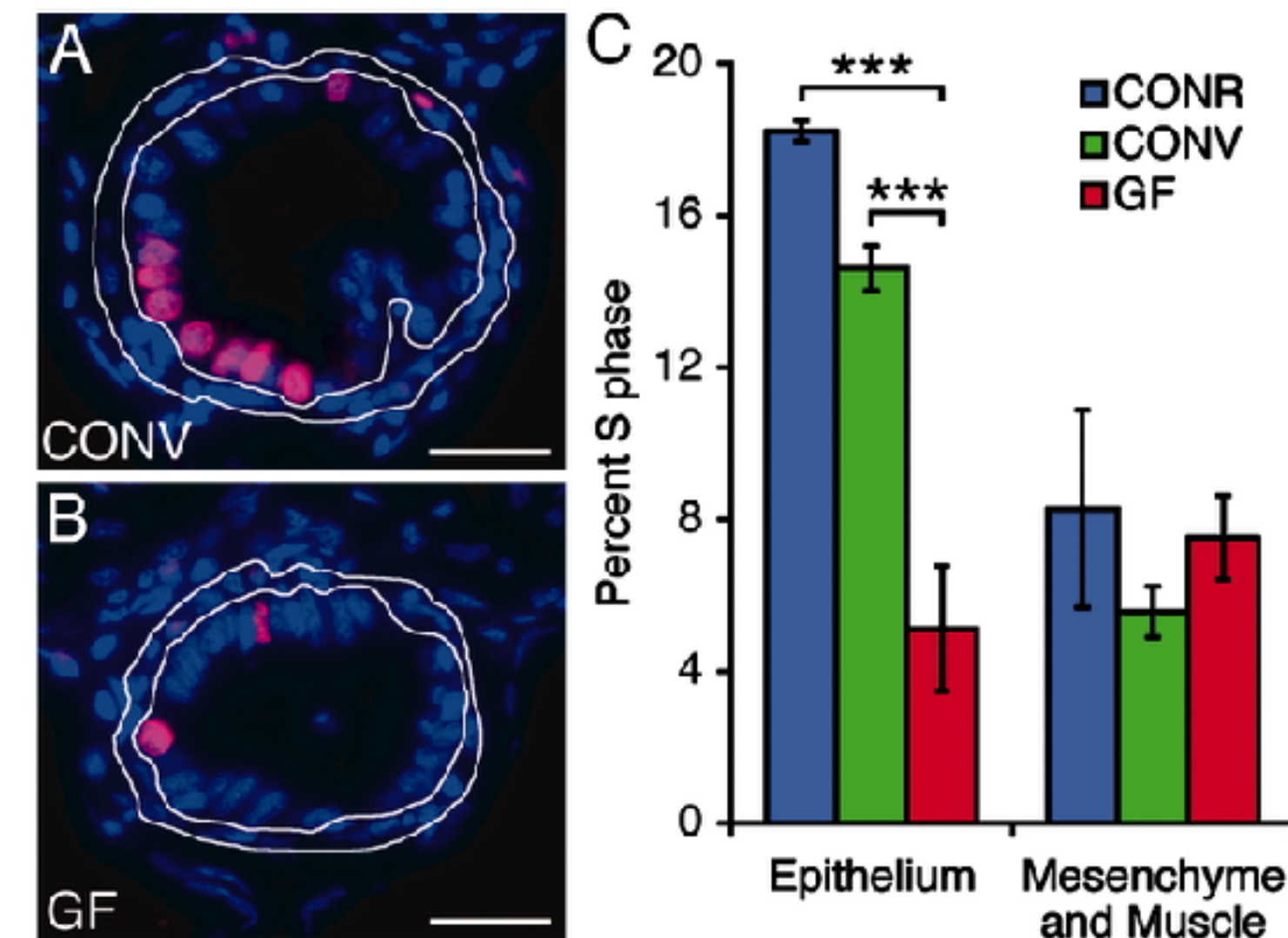
Symbiosis-induced polyphenism 2

- Gut microbiome in vertebrates
- Hundreds of different species, transferred at birth
- Germ-free mice and zebrafish have developmental defects
- Paneth cells secrete antibacterial peptide to *select* microbes



Intestinal blood vessels

B. theta



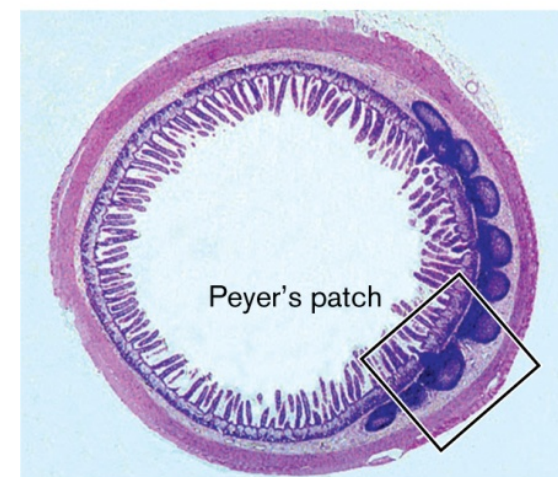
Intestinal stem cell divisions

Symbiosis-induced polyphenism 2

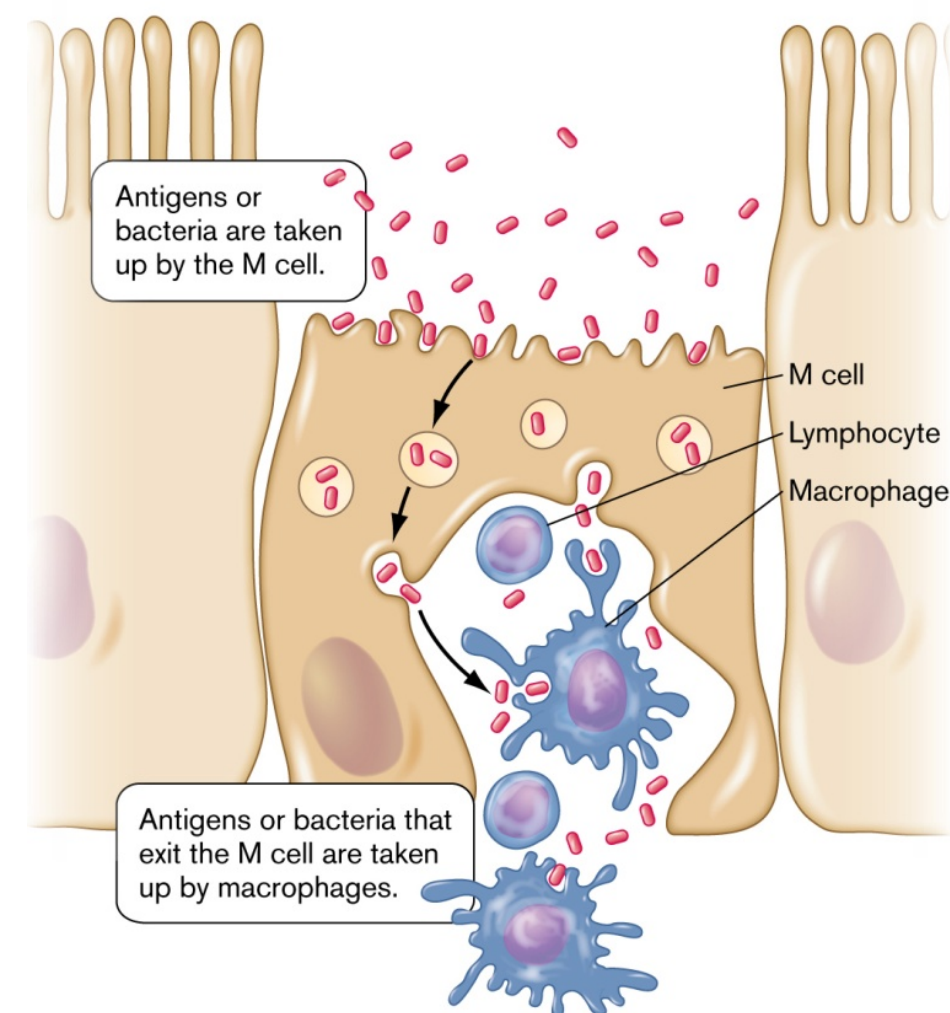
- Gut microbiome in vertebrates
- Affect immune system, brain development and behaviour

Gut-associated Lymphoid Tissue
(70% of lymphocytes)

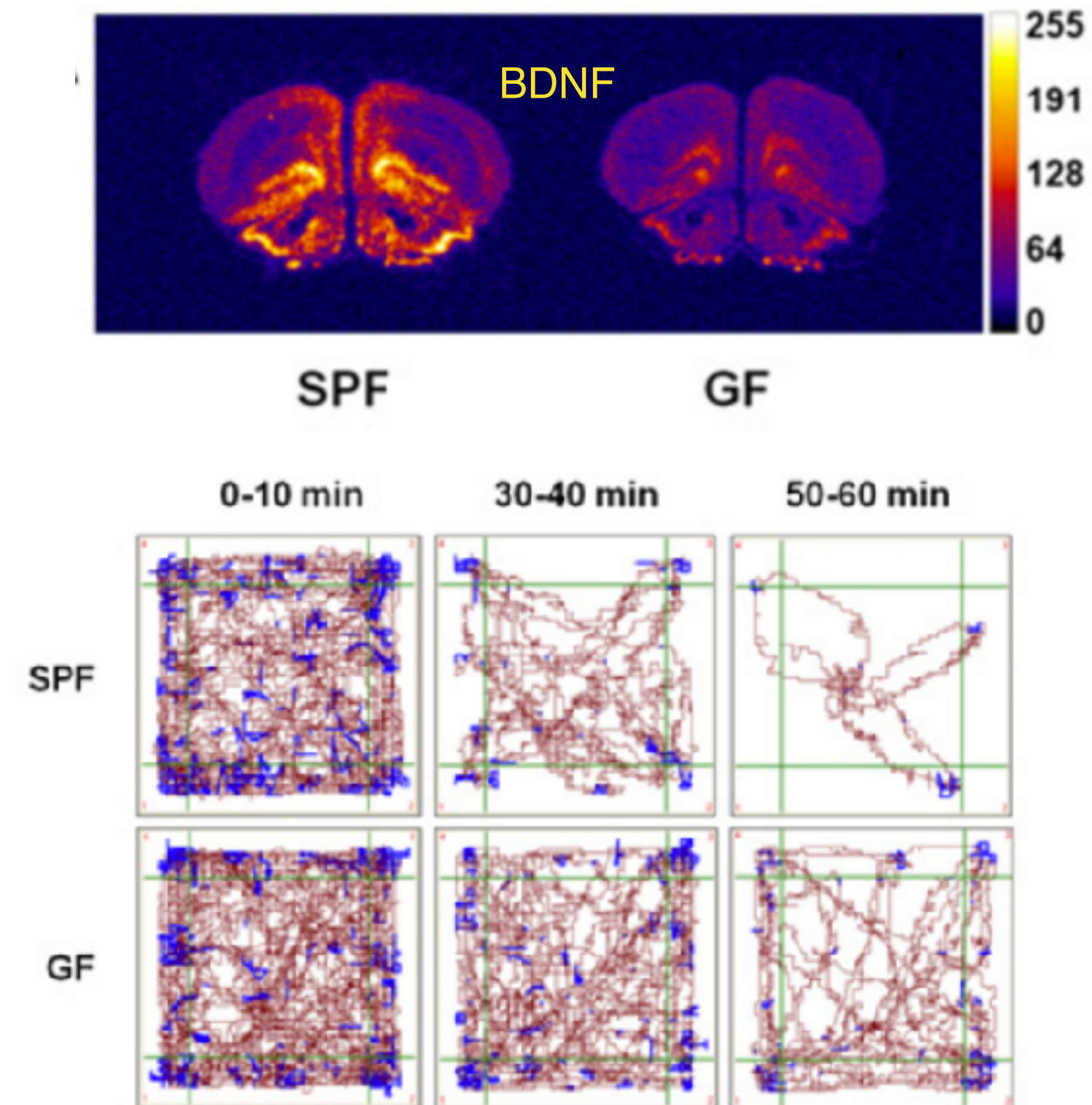
A. Peyer's patch



B. M cell

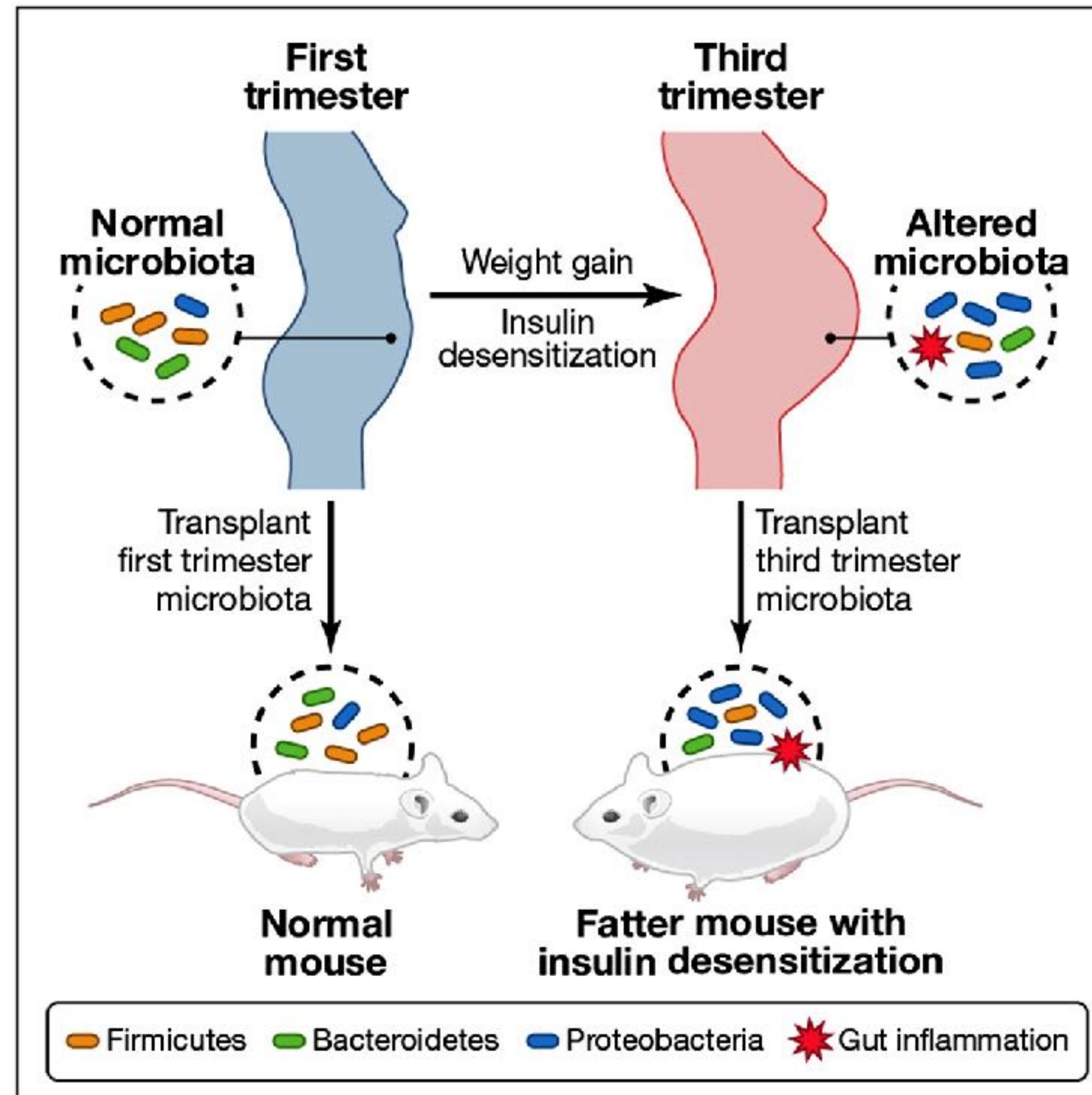


Frontal cortex



Symbiosis-induced polyphenism 3

- Gut microbiome changes with pregnancy
- Confer pregnancy-related metabolic changes to mice

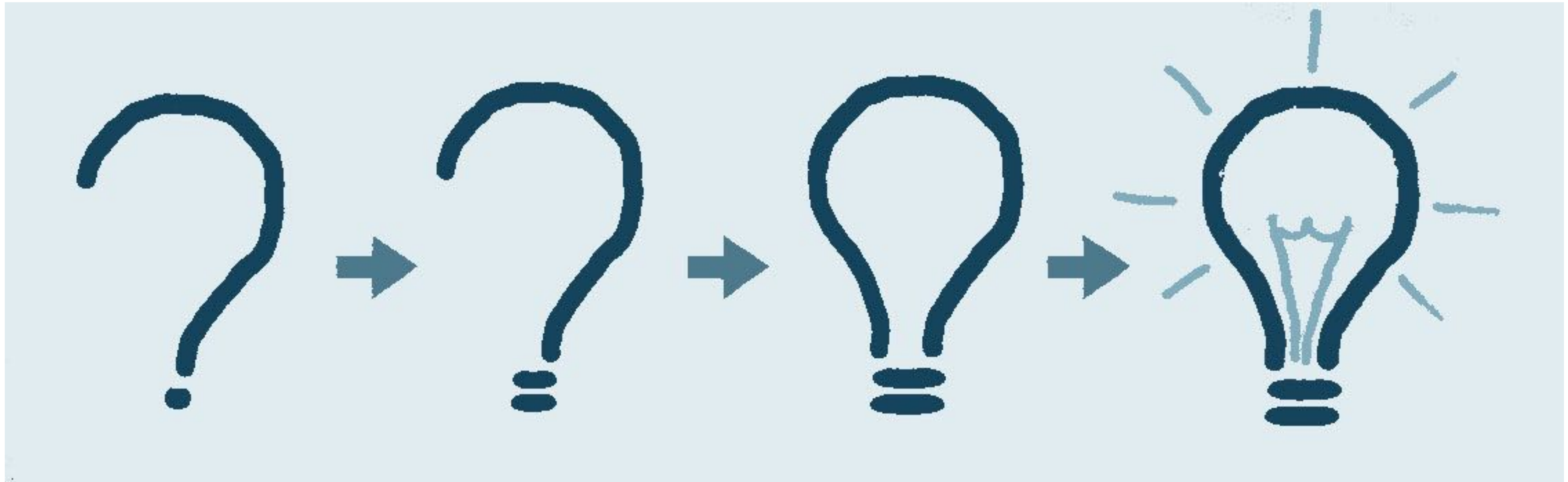


Summary

- The genome in an egg/sperm does not entirely determine the phenotype
- Environment plays role in perhaps almost *every* species
- Other genomes play a role, also perhaps in every species
- The selectable unit is the Holobiont
- Model organisms were chosen because they *don't* have strong developmental plasticity



Questions?



Take a break



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Big questions



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Today's menu

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- *Developmental plasticity*

- Biotic - diet, crowding, predators

- Abiotic - temperature

- Symbiotic - bacteria

- **Evo-Devo (evolutionary developmental biology)**

- *Modularity allows dissociation*

- Changes in morphology come from changes in development

- Regulatory mutations are known drivers of change

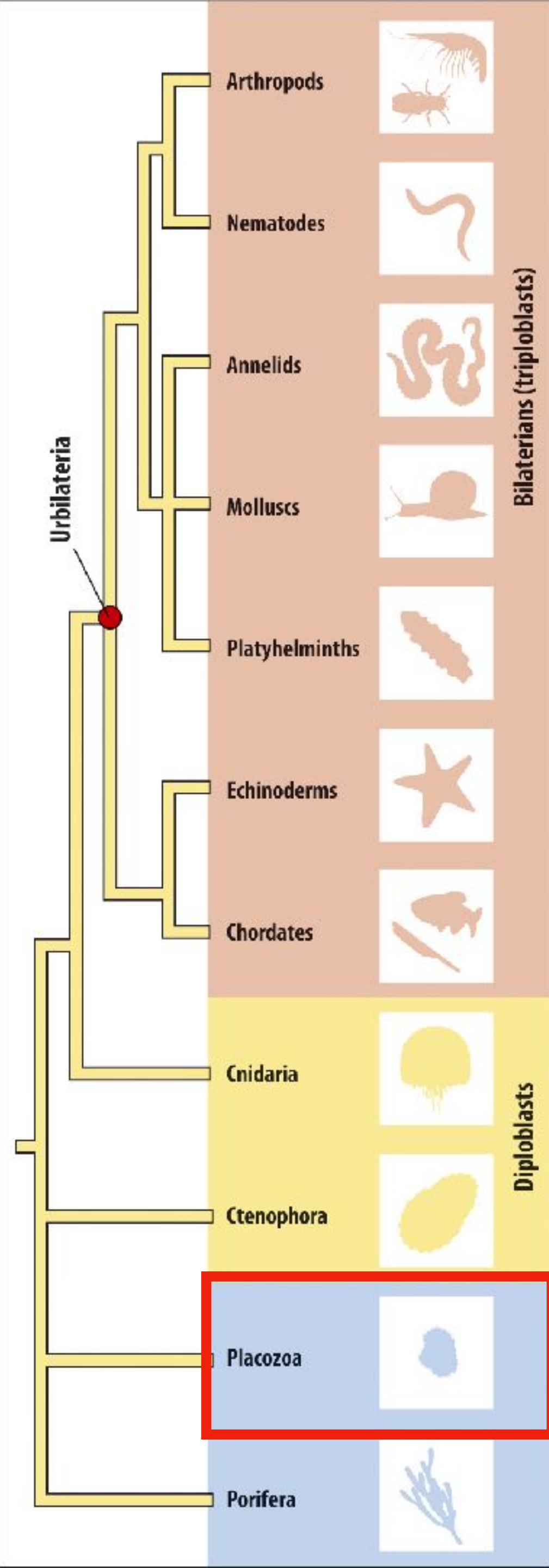
- Role for developmental plasticity in evolution

Developmental modules

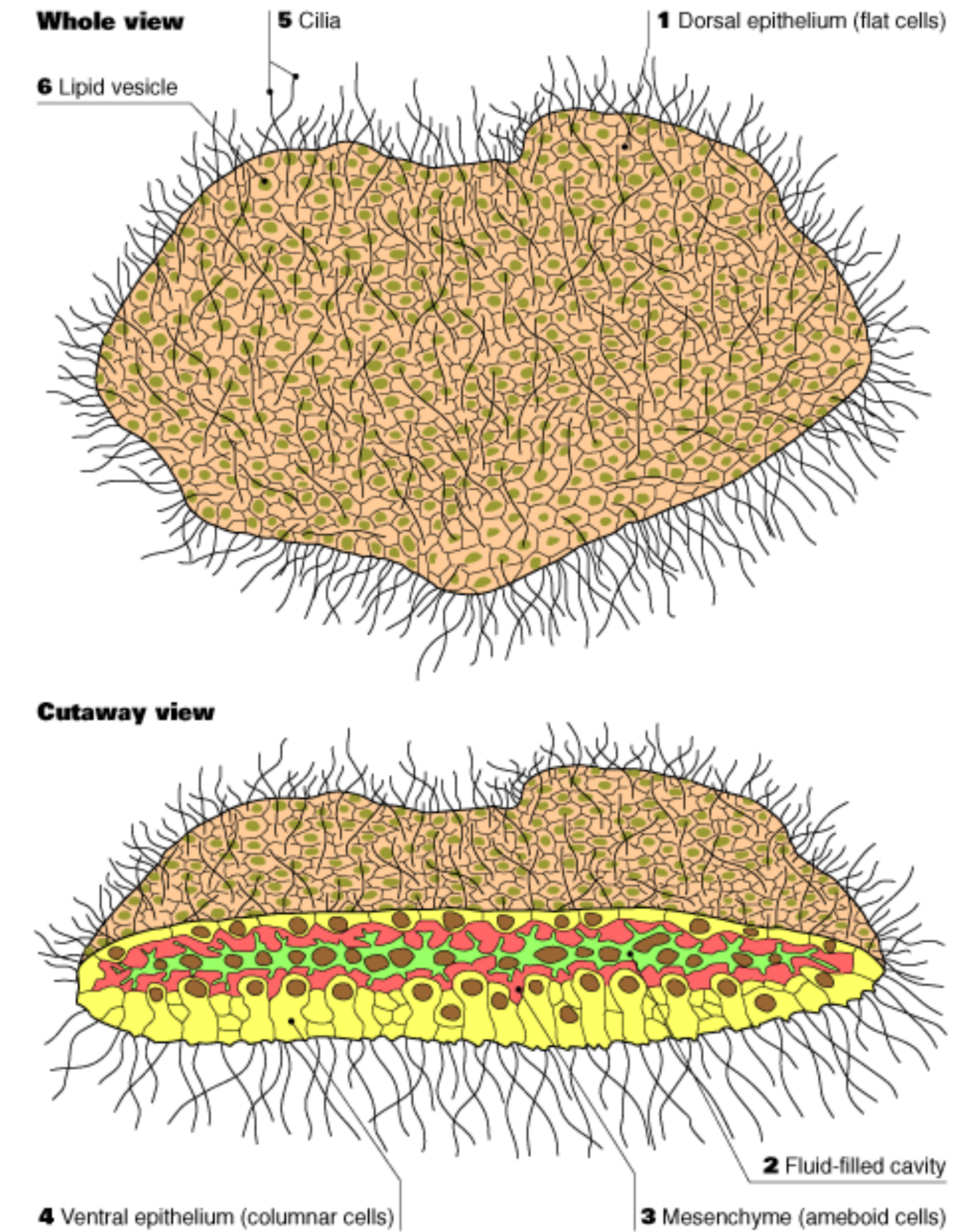
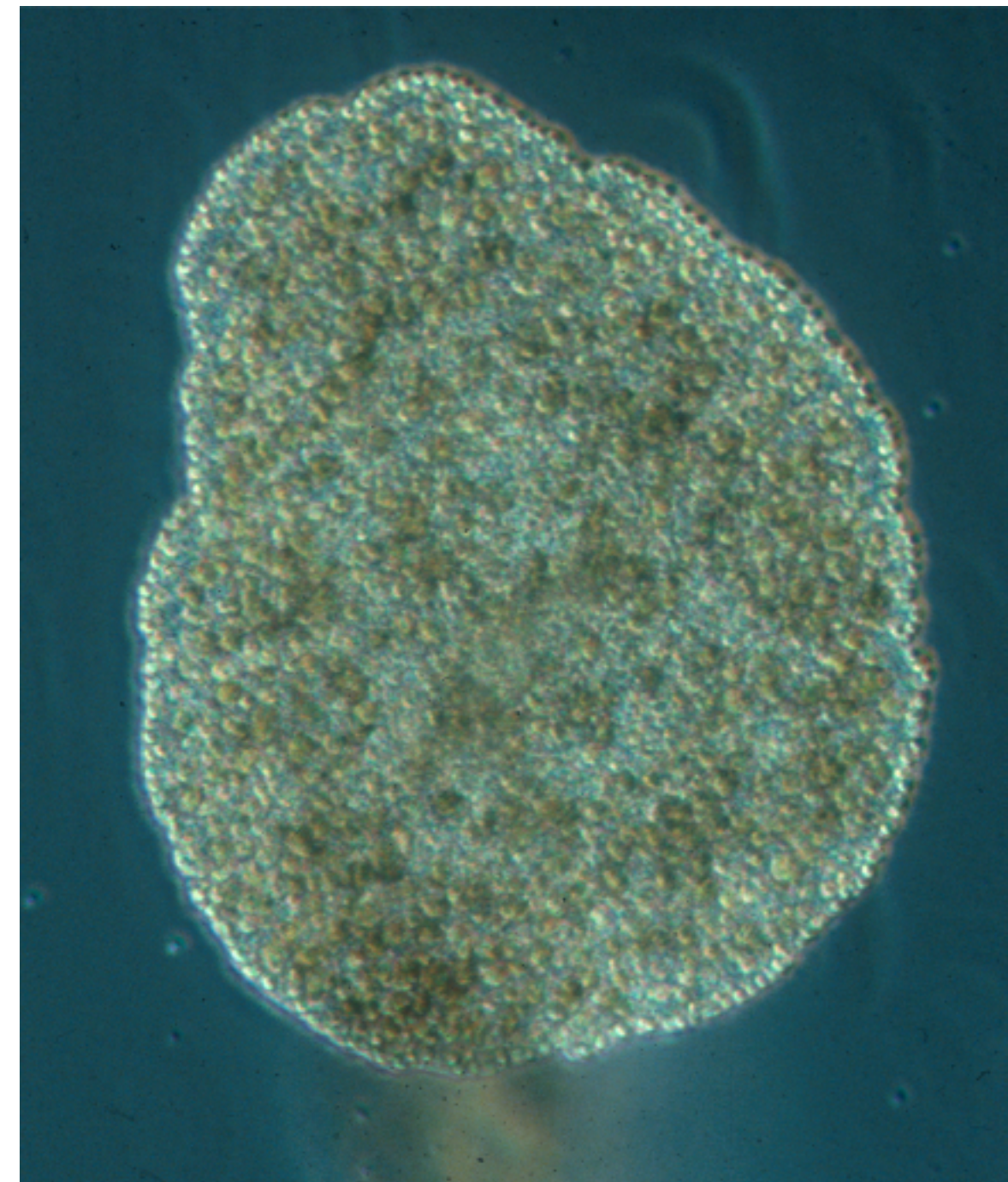
- Morphogenetic fields - organiser...
- Equivalence groups - proneural cluster...
- Signaling pathways - Wnt, Fgf, Notch...
- Cell lineages - muscle ...
- Tissue mechanics - epithelial folding...
- Genes - duplicated families
- Regulatory DNA - promoters, enhancers...

Q. Is evolving development just like shuffling cards?

Origin of animal body plans



Trichoplax adherens

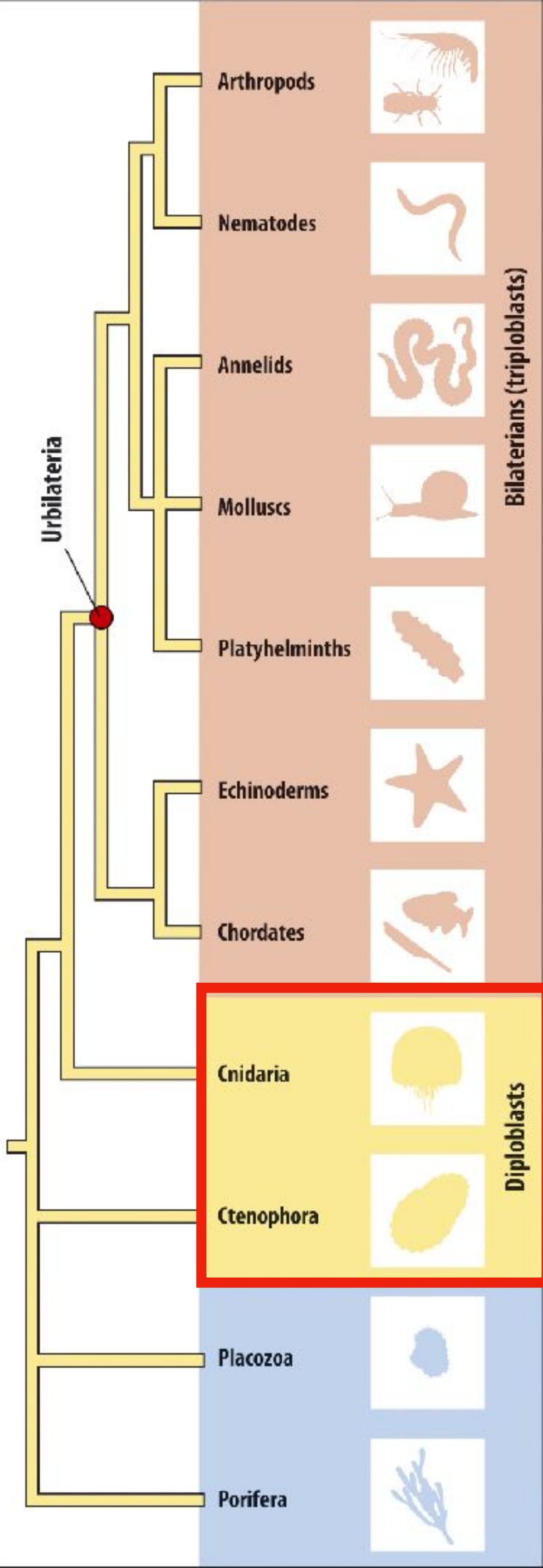
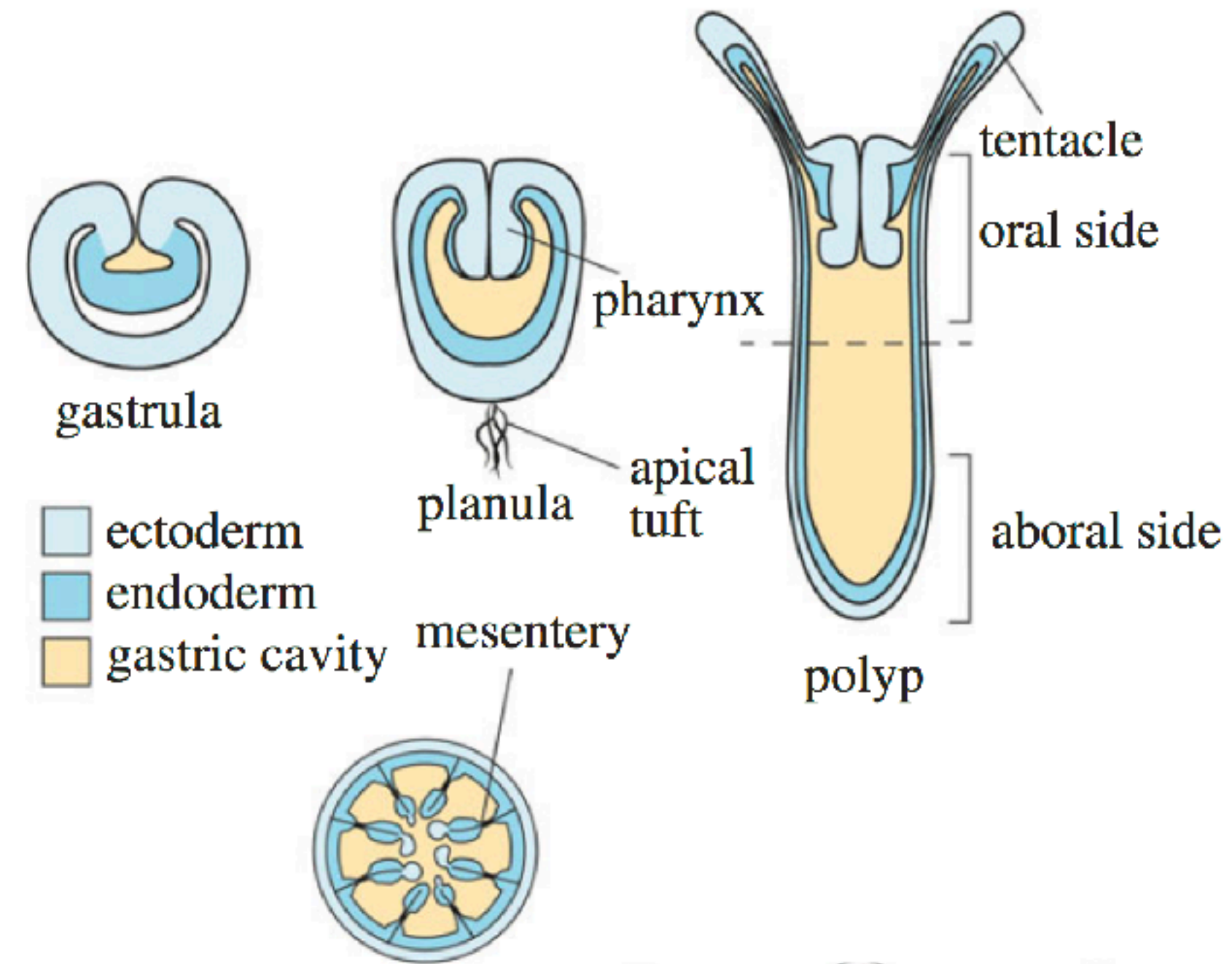
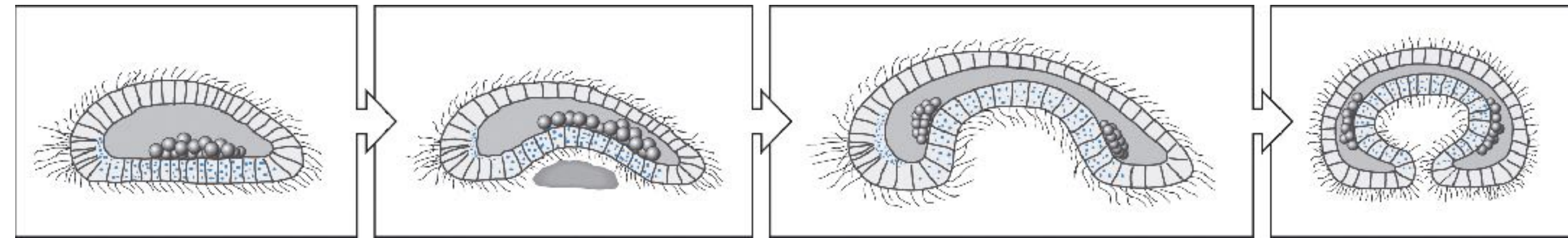


© Diagram Visual Information Ltd.

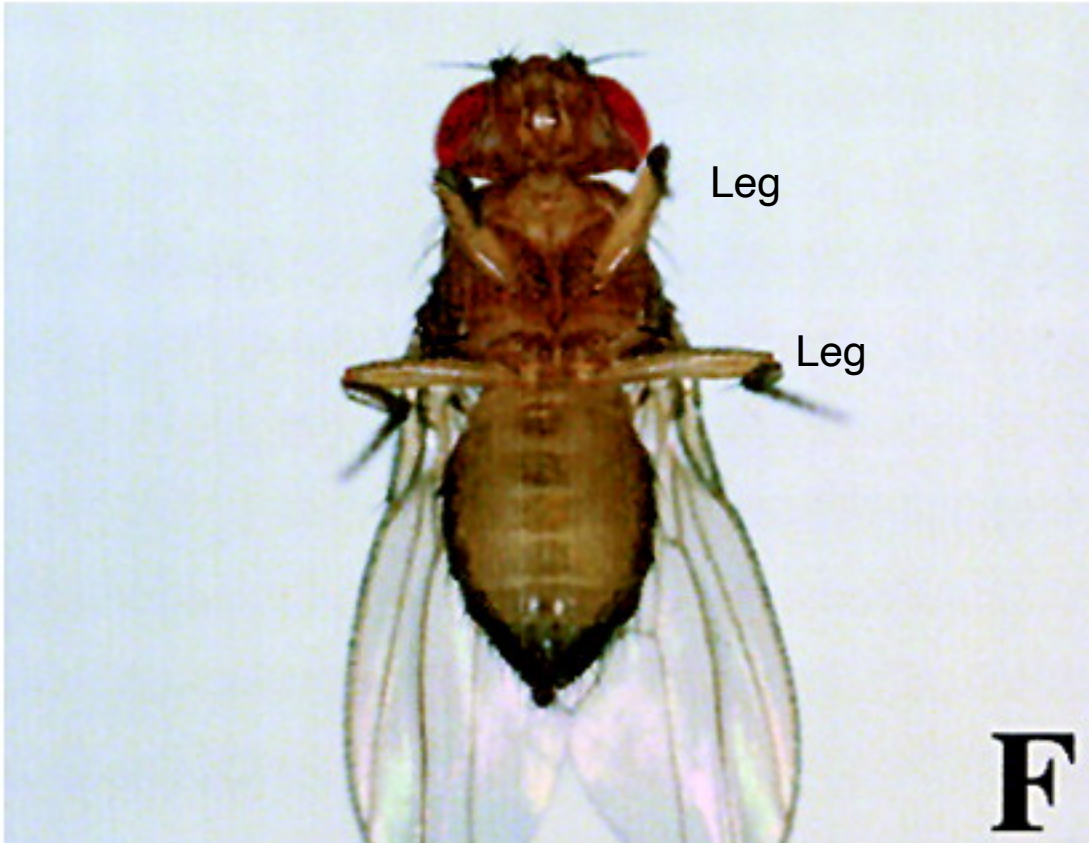
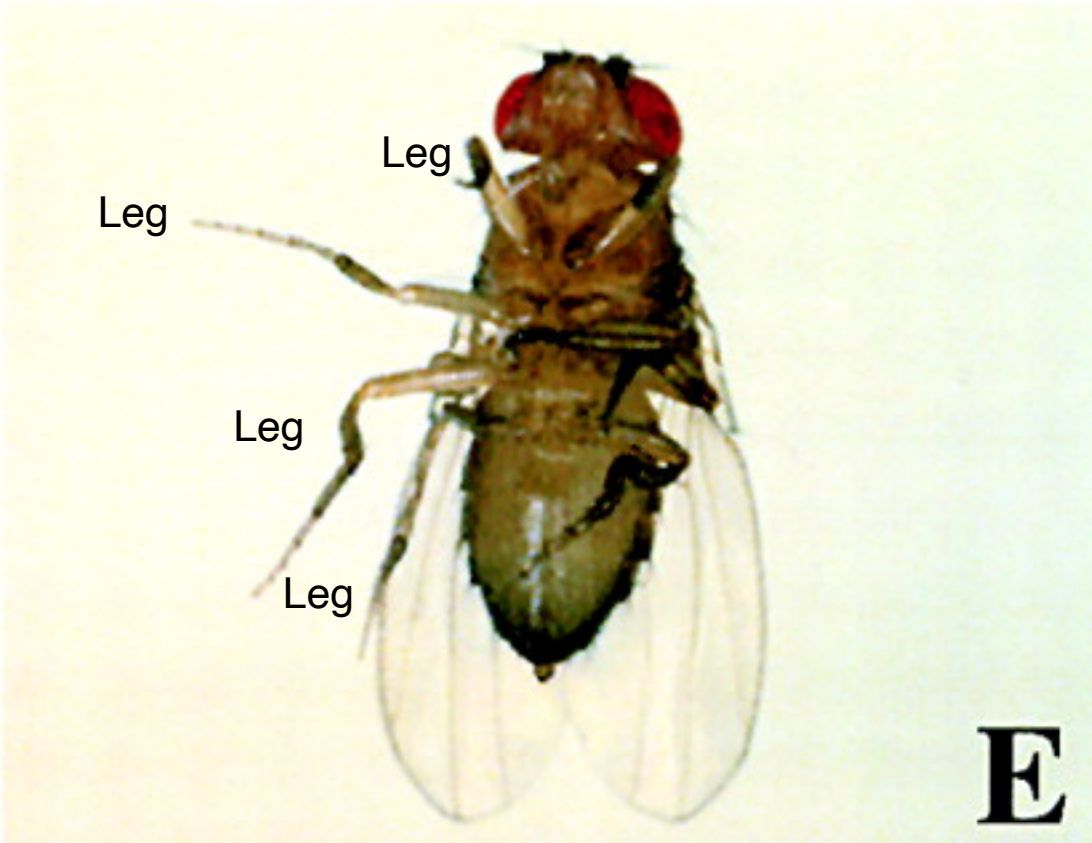
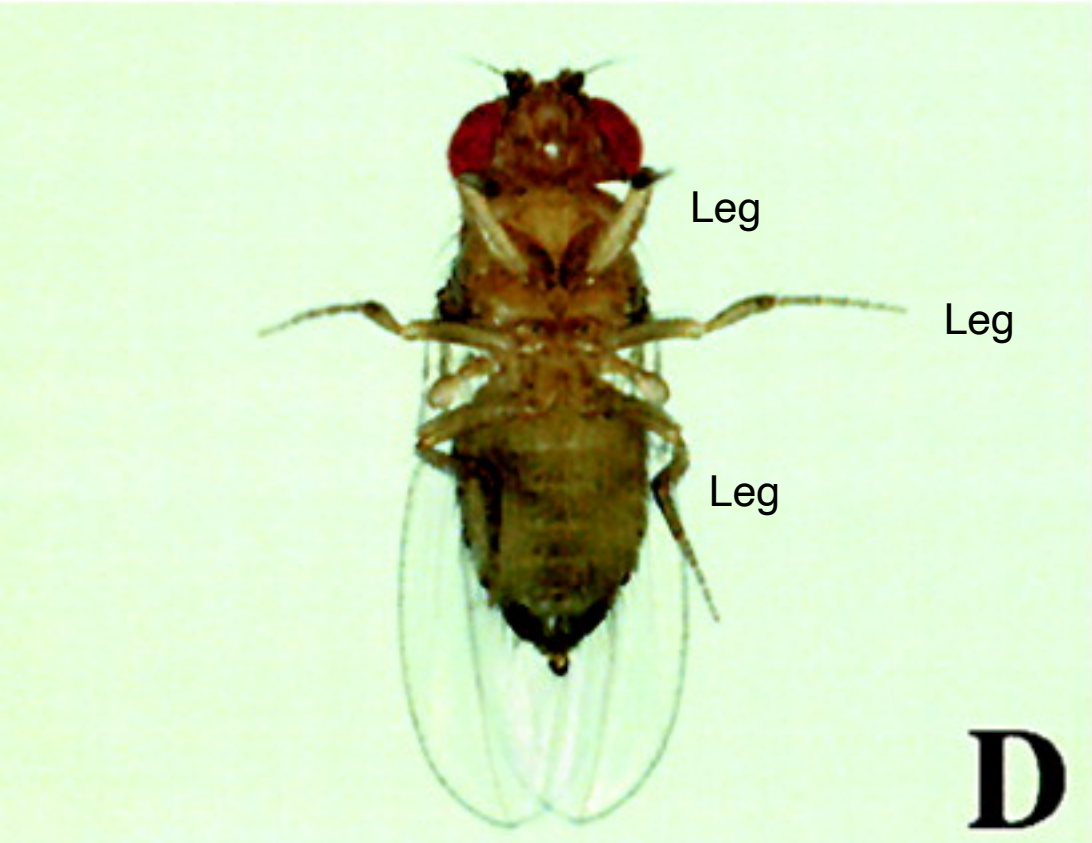
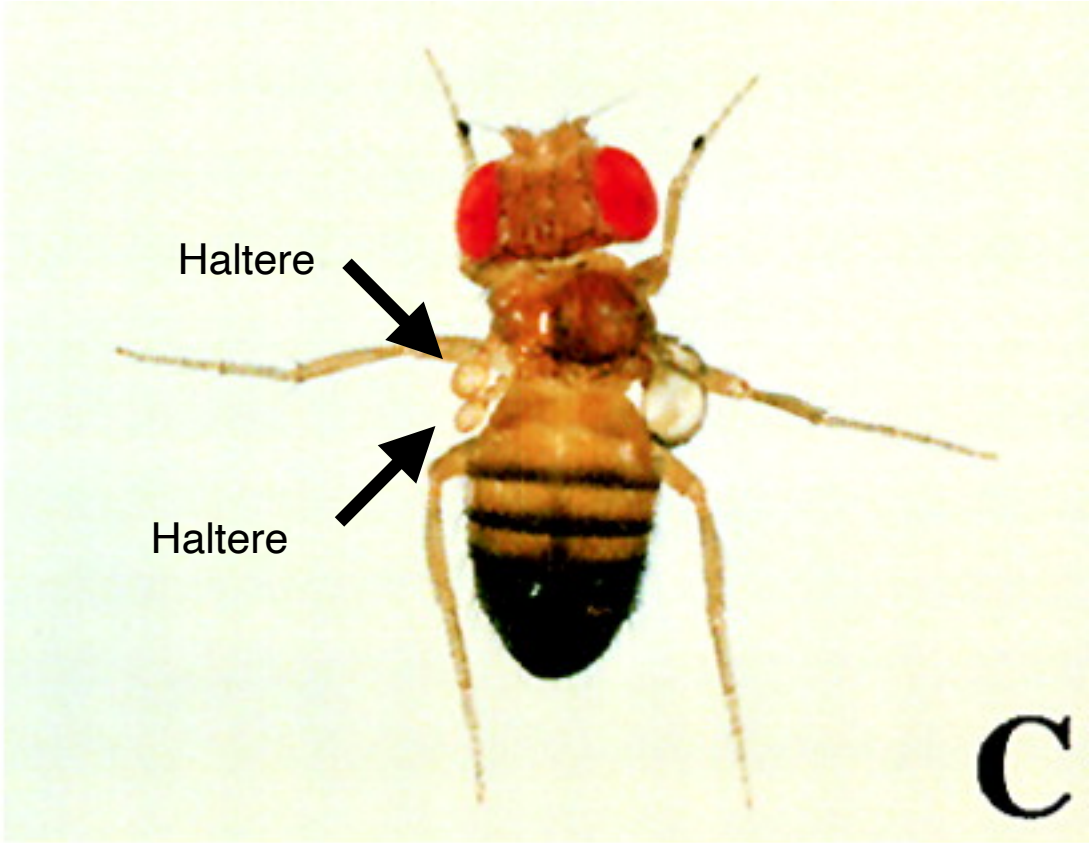
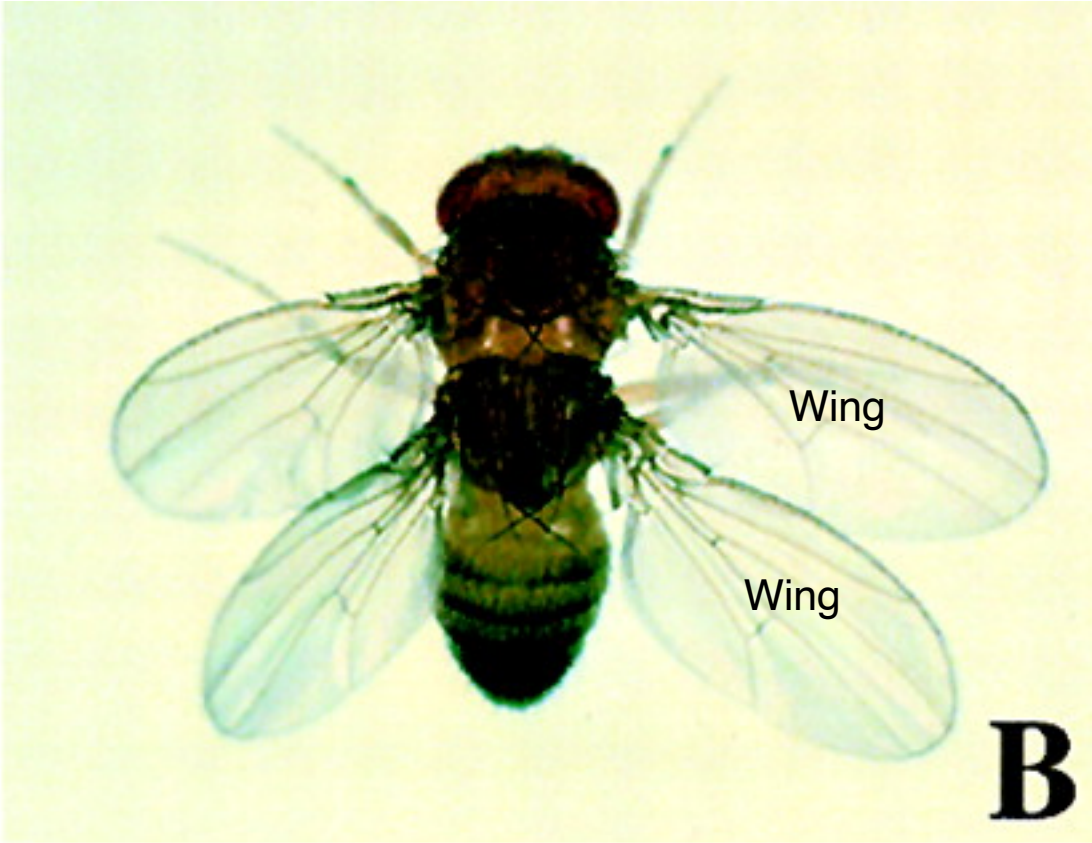
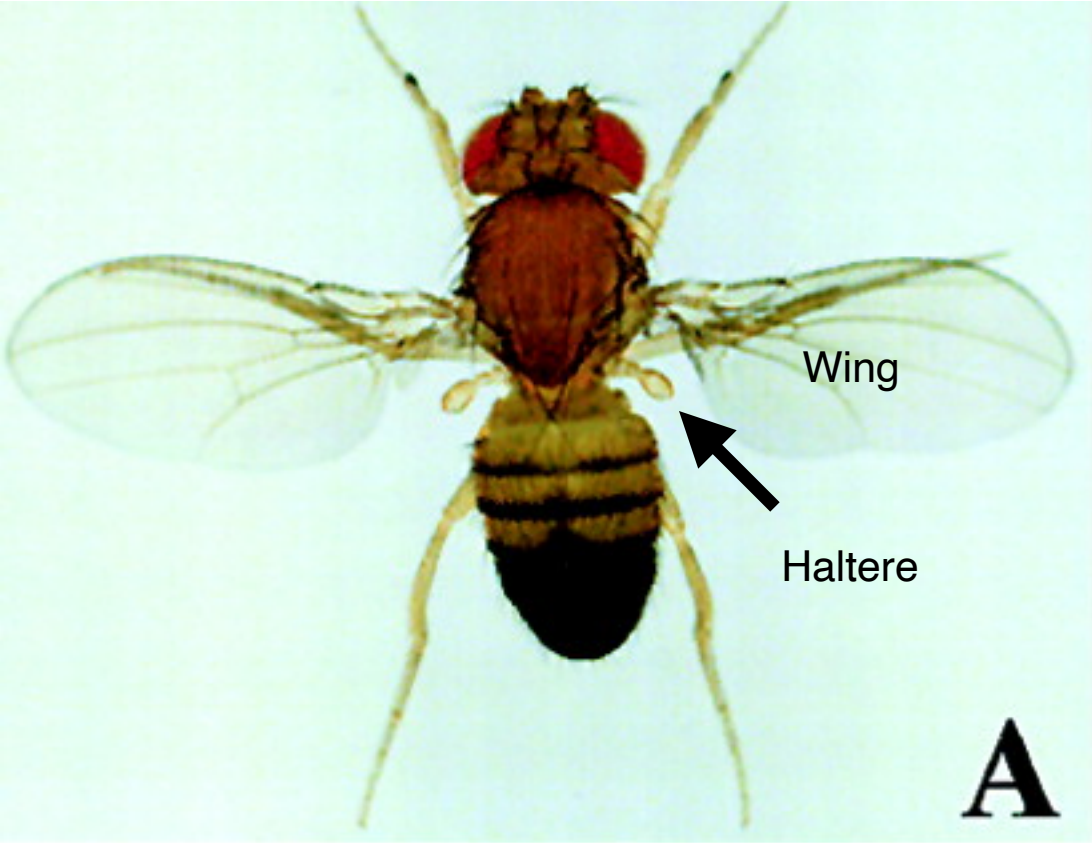
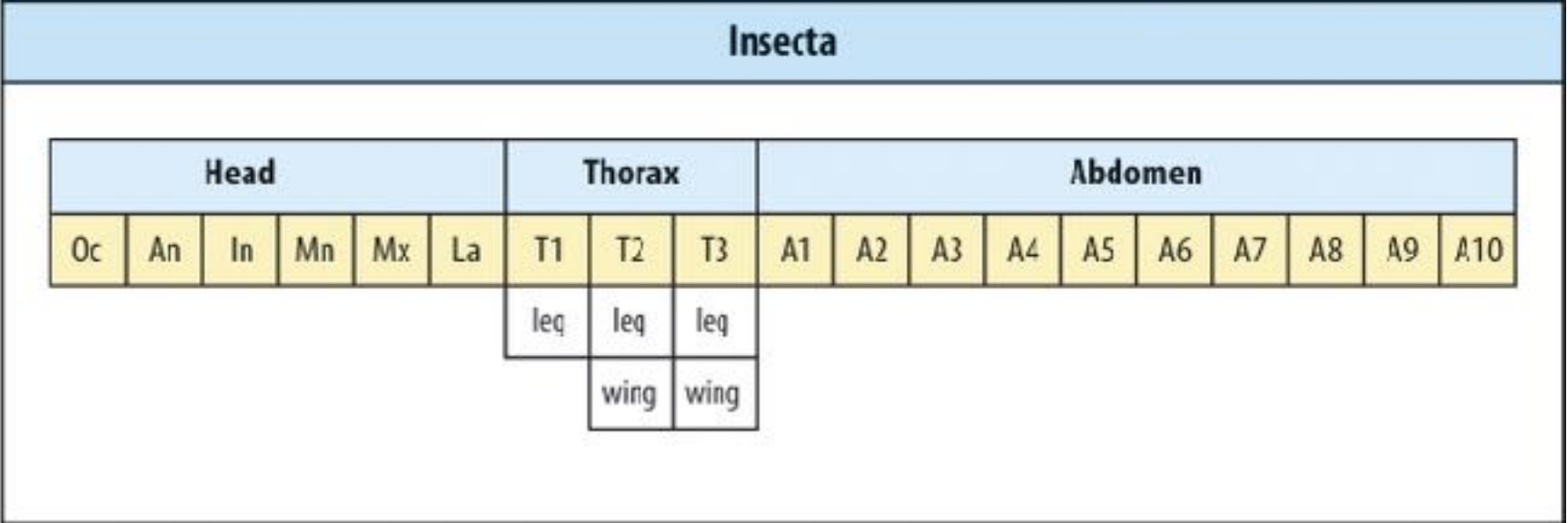
Small genome, 85% of its 11,514 predicted protein-coding genes have homologs in animals

Origin of animal body plans

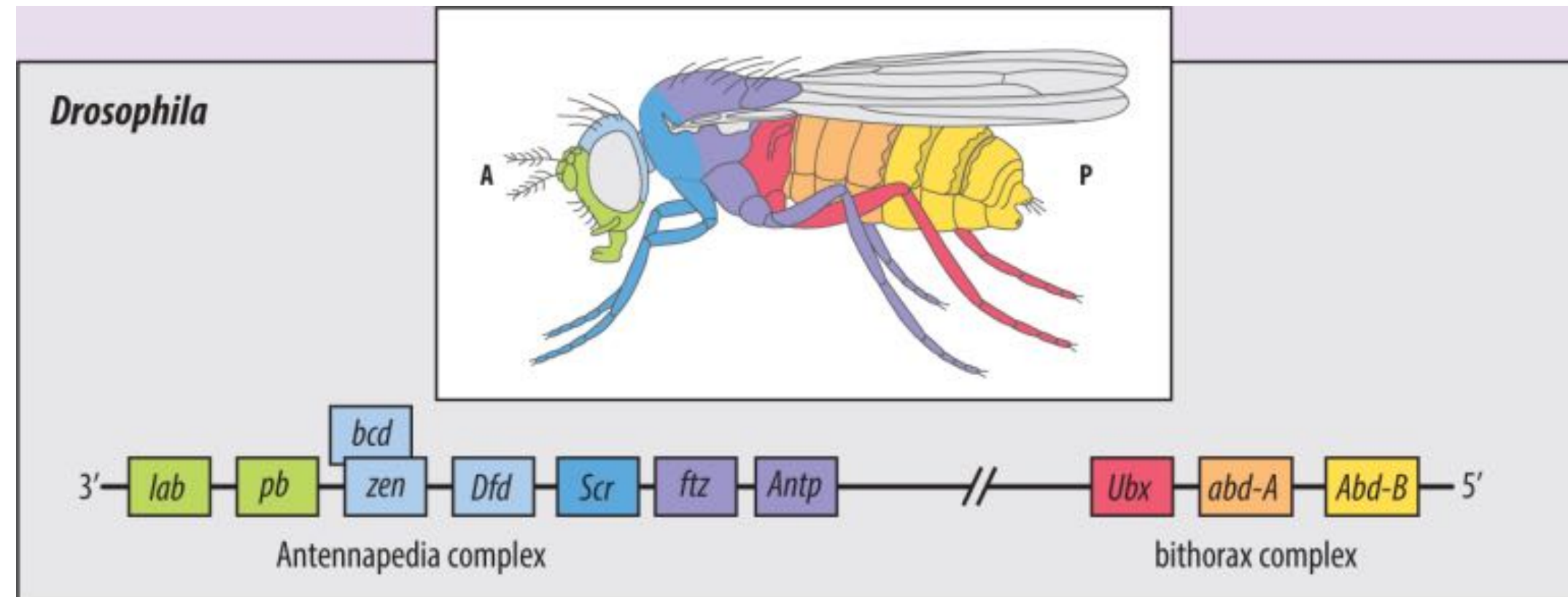
- Gastrula



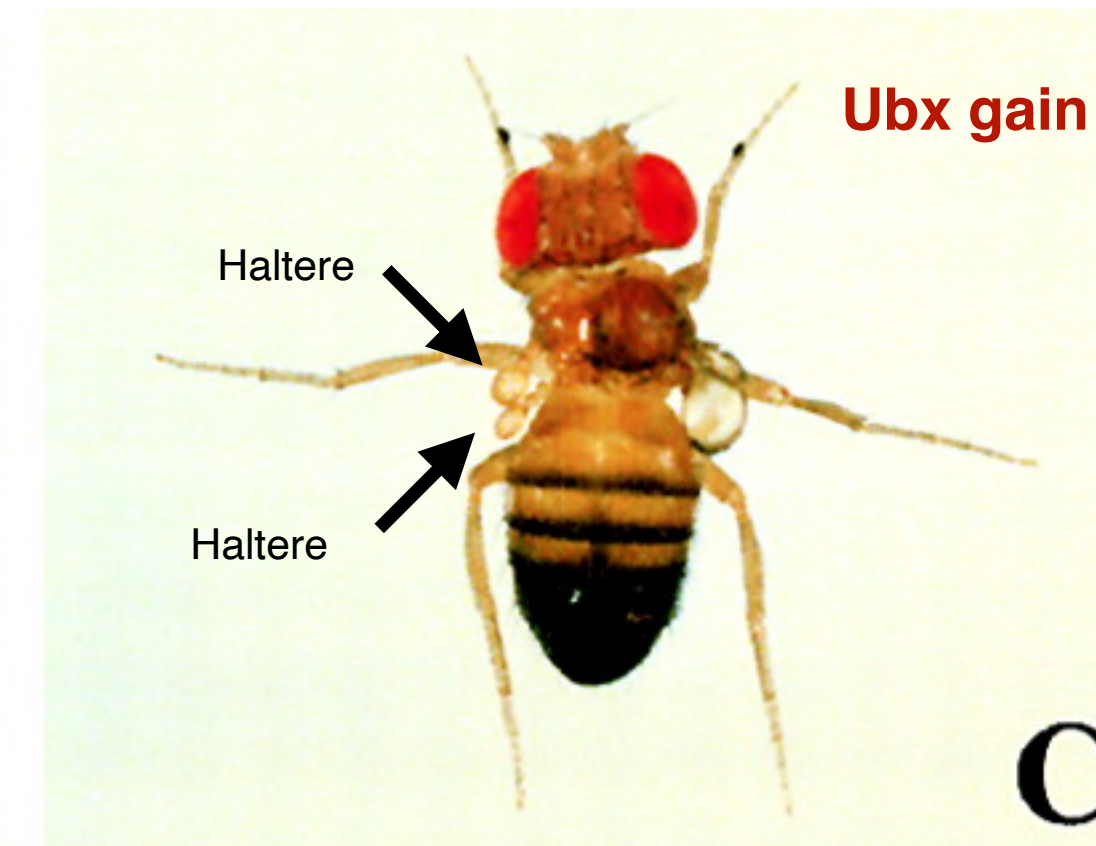
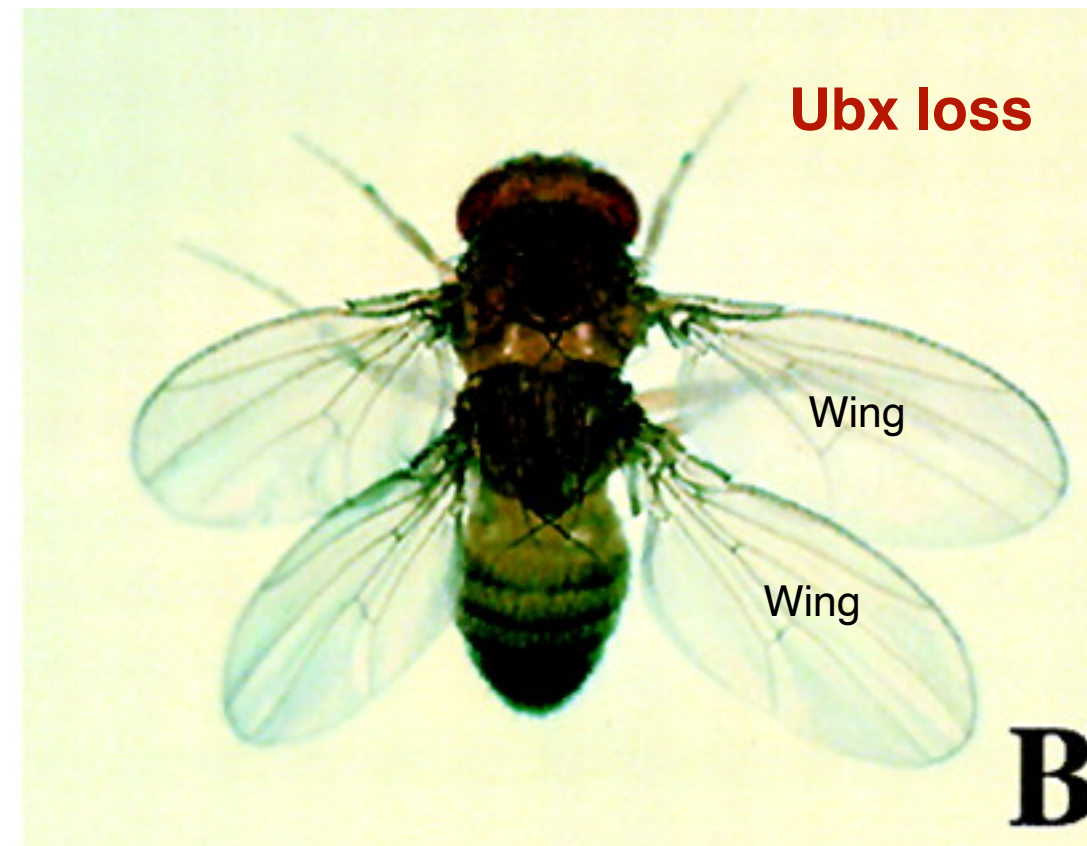
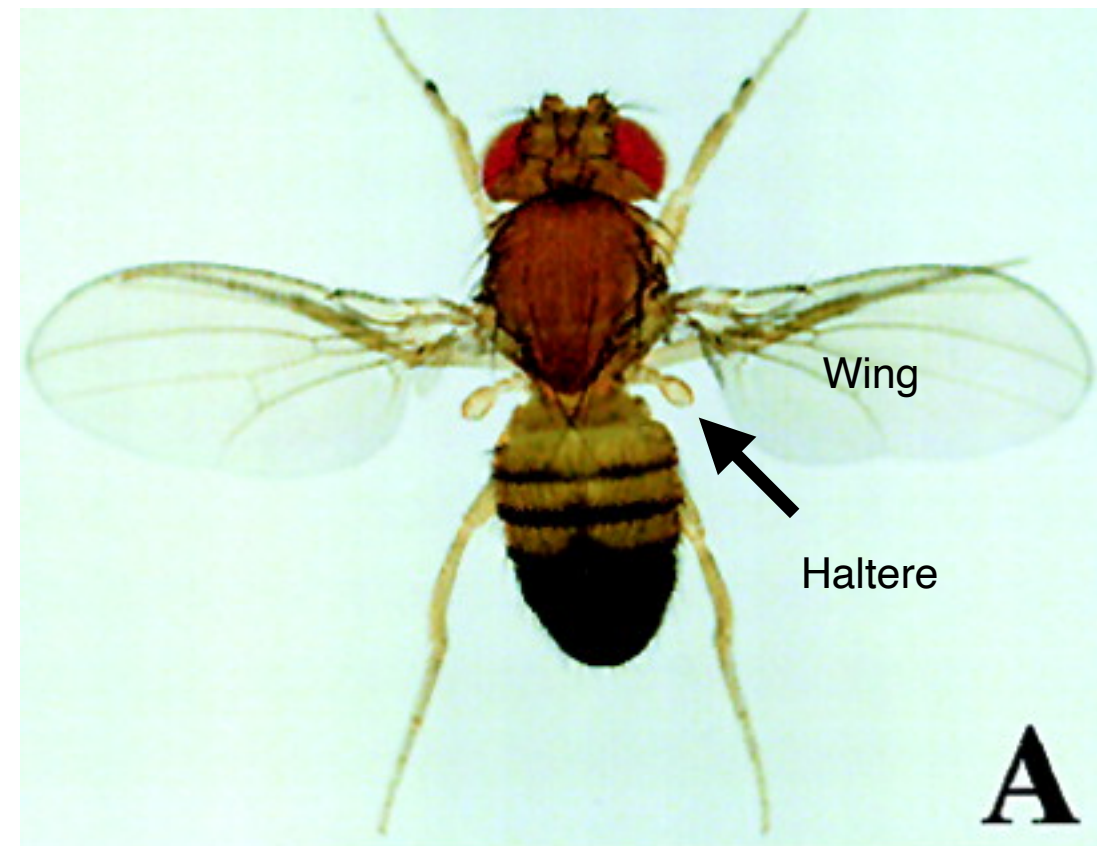
Homeotic mutations change identity of segments



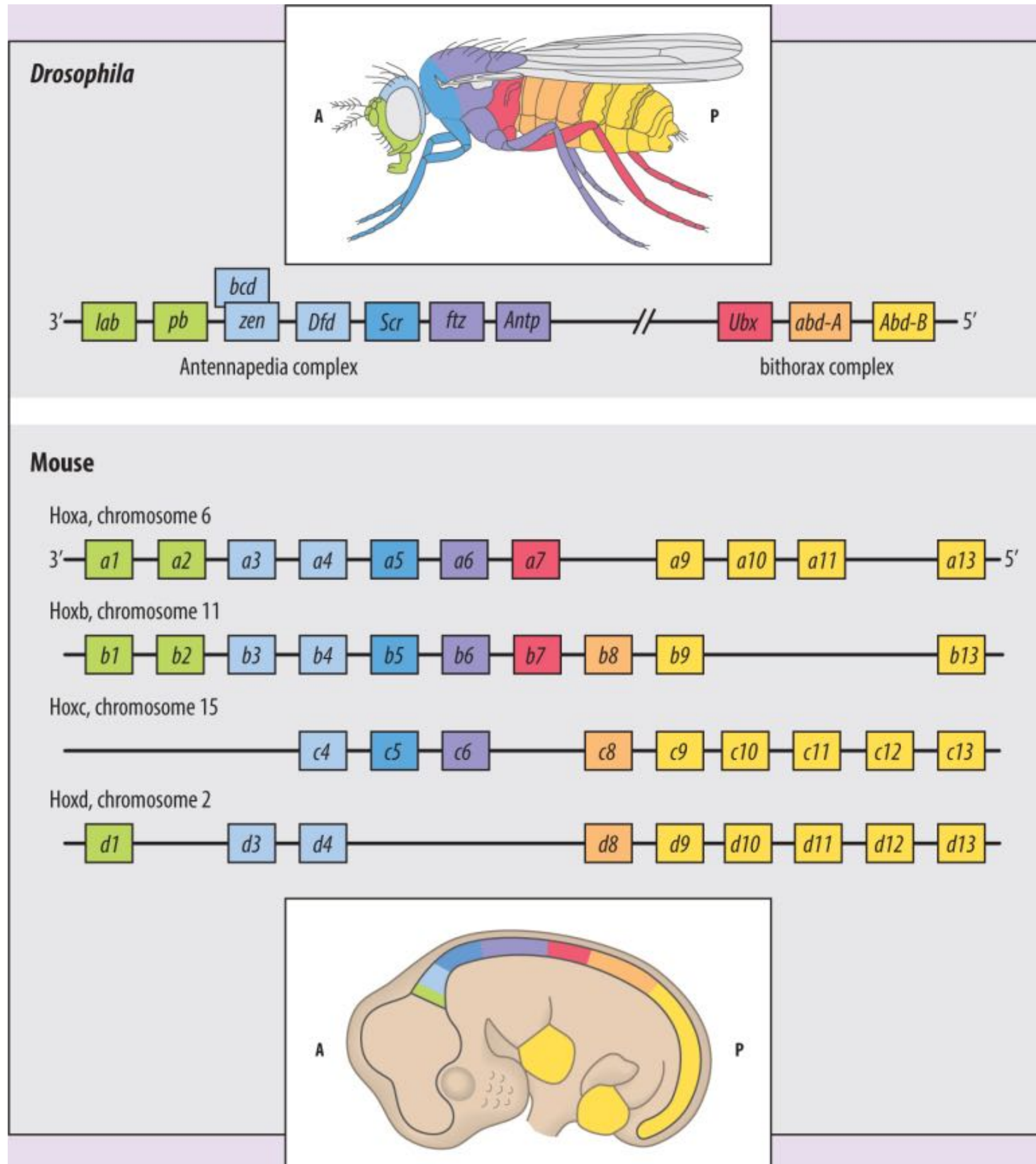
Hox gene organisation and expression



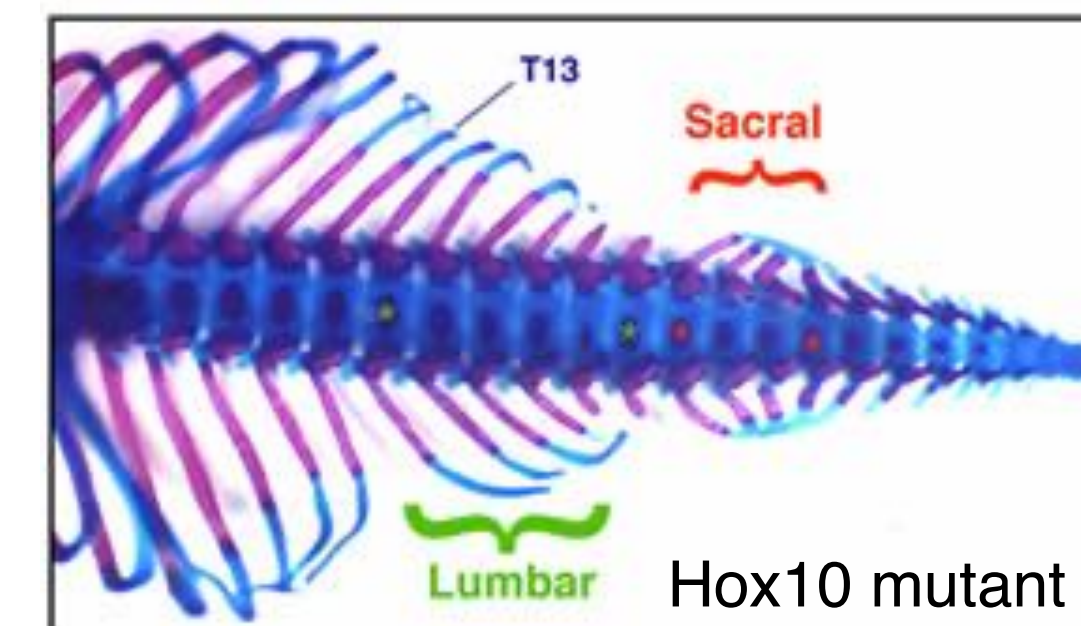
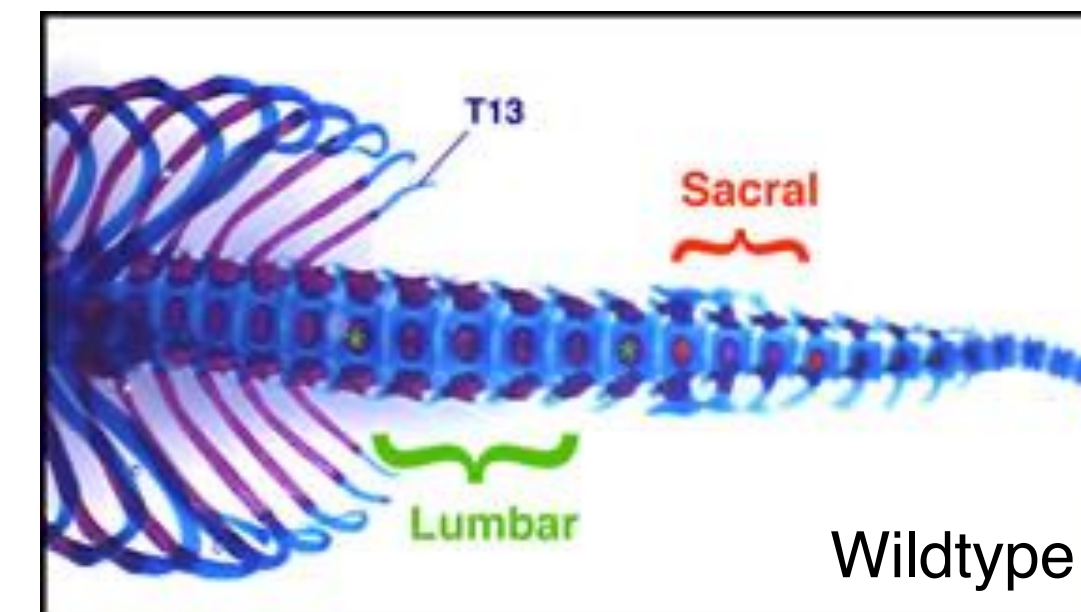
Spatial colinearity:
same order on chromosome
and in body



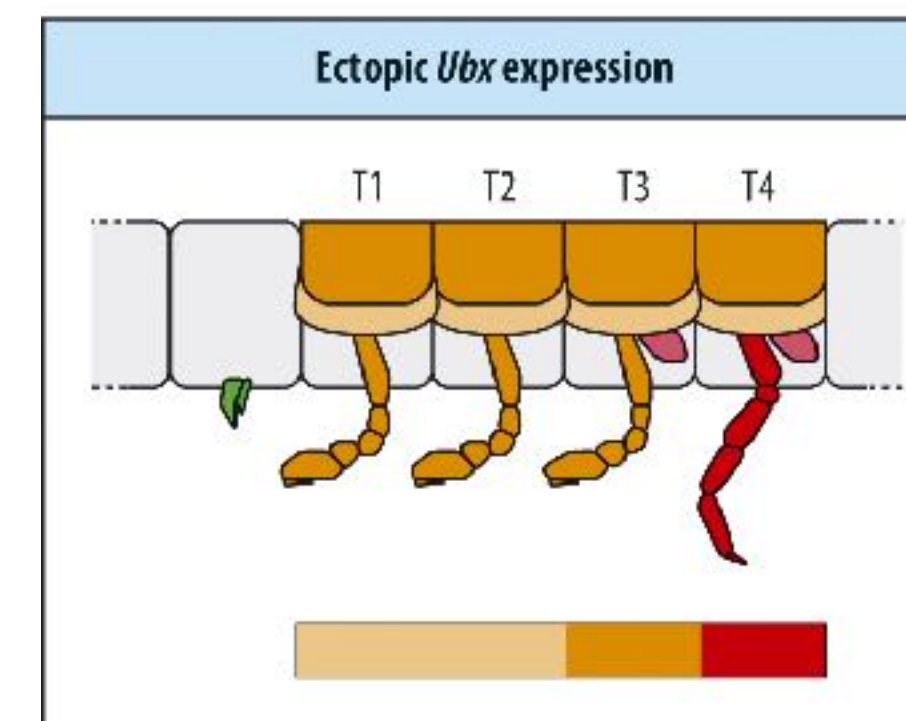
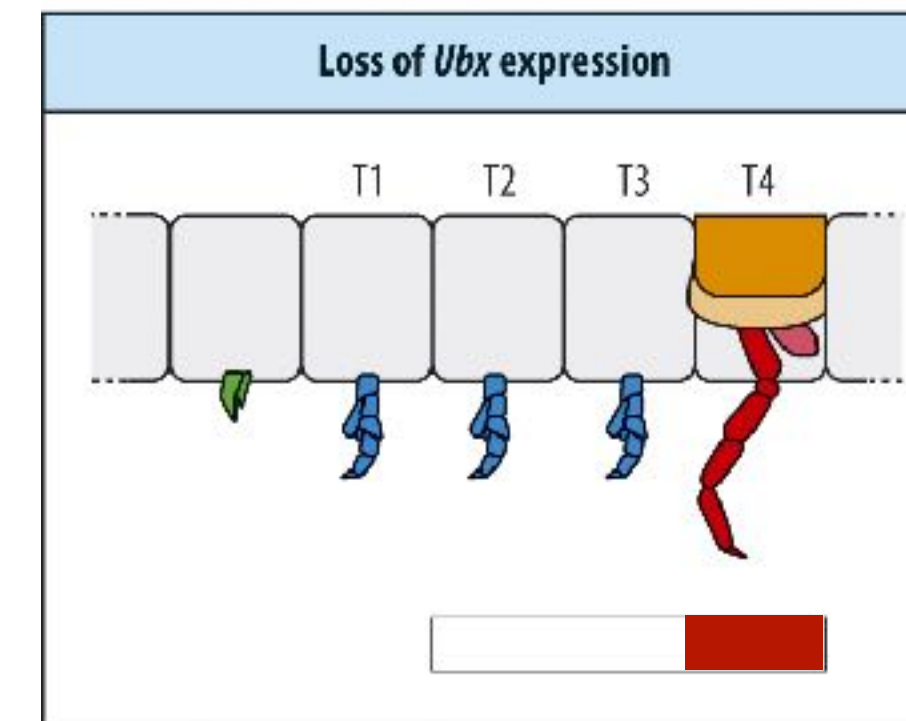
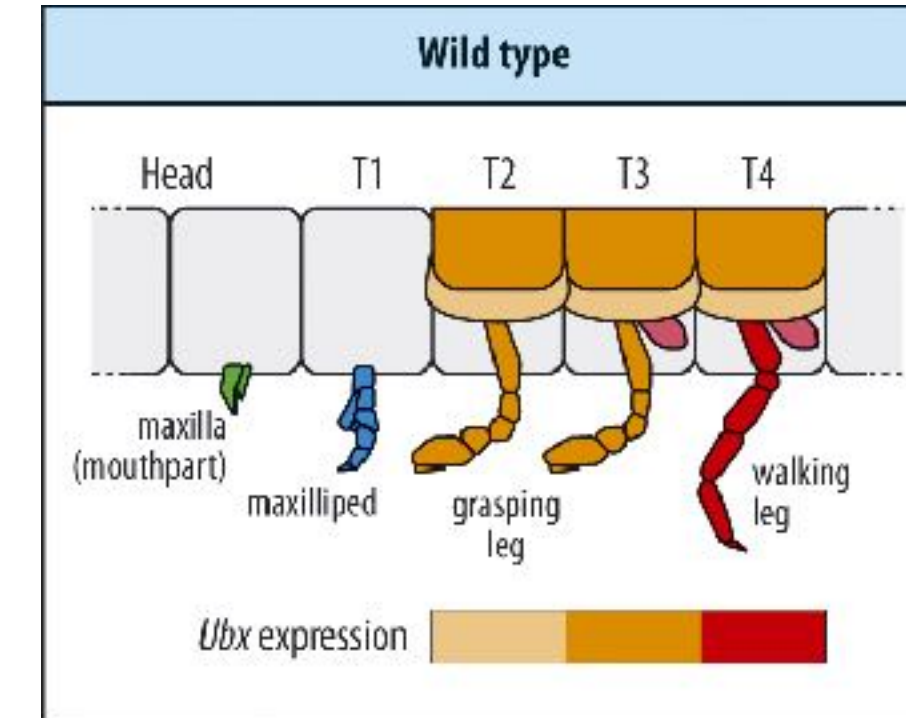
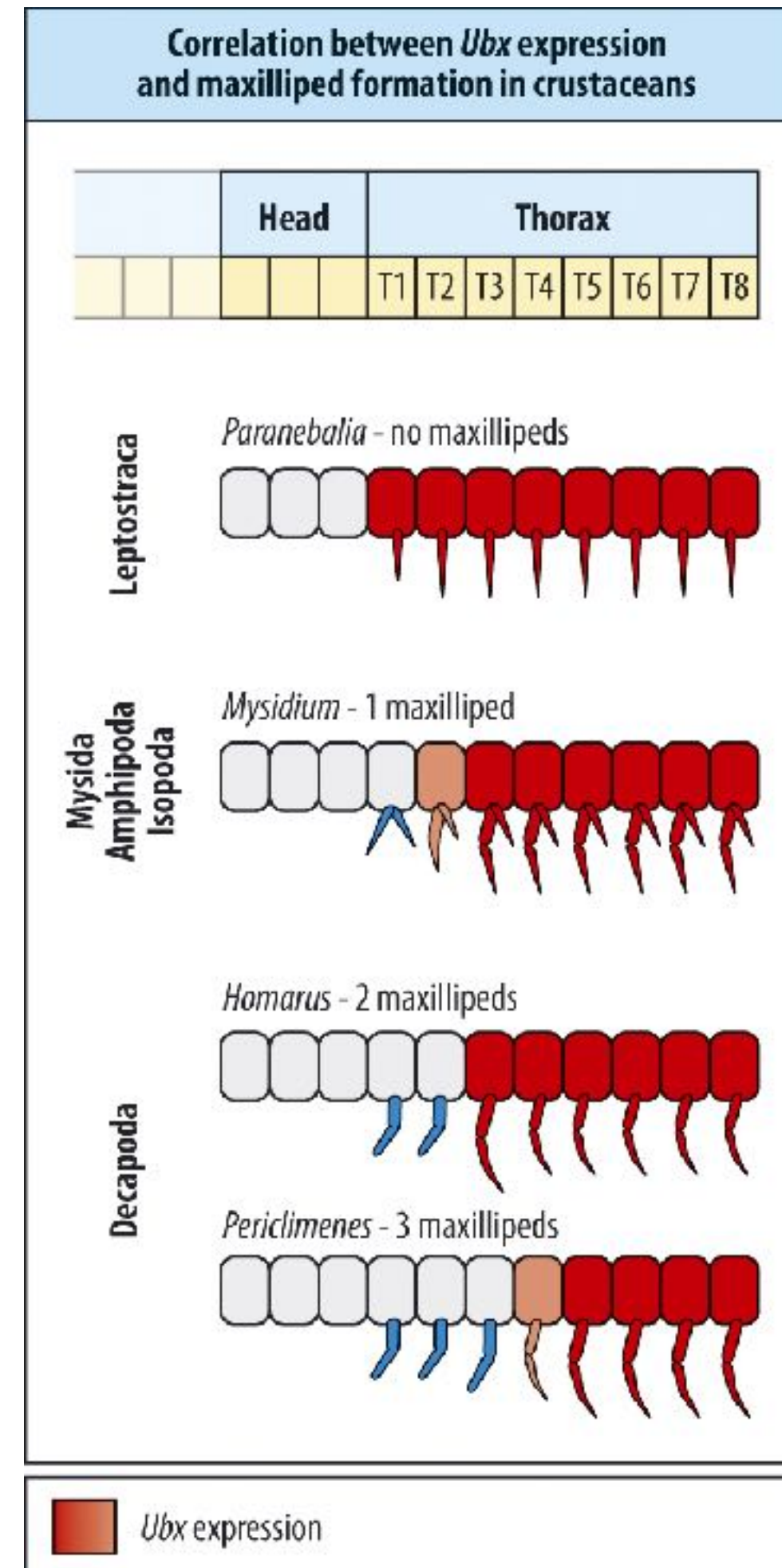
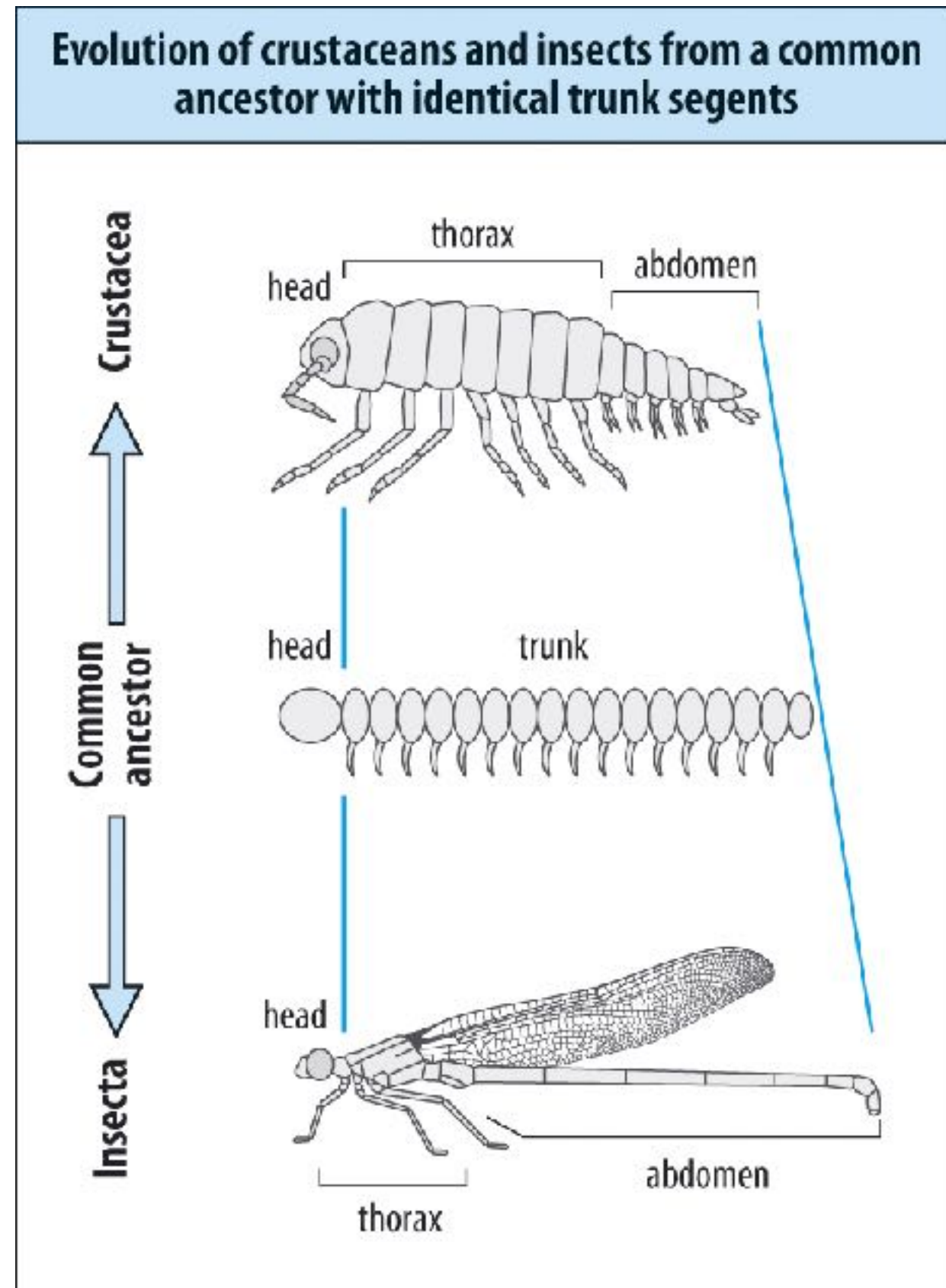
Hox gene organisation and expression



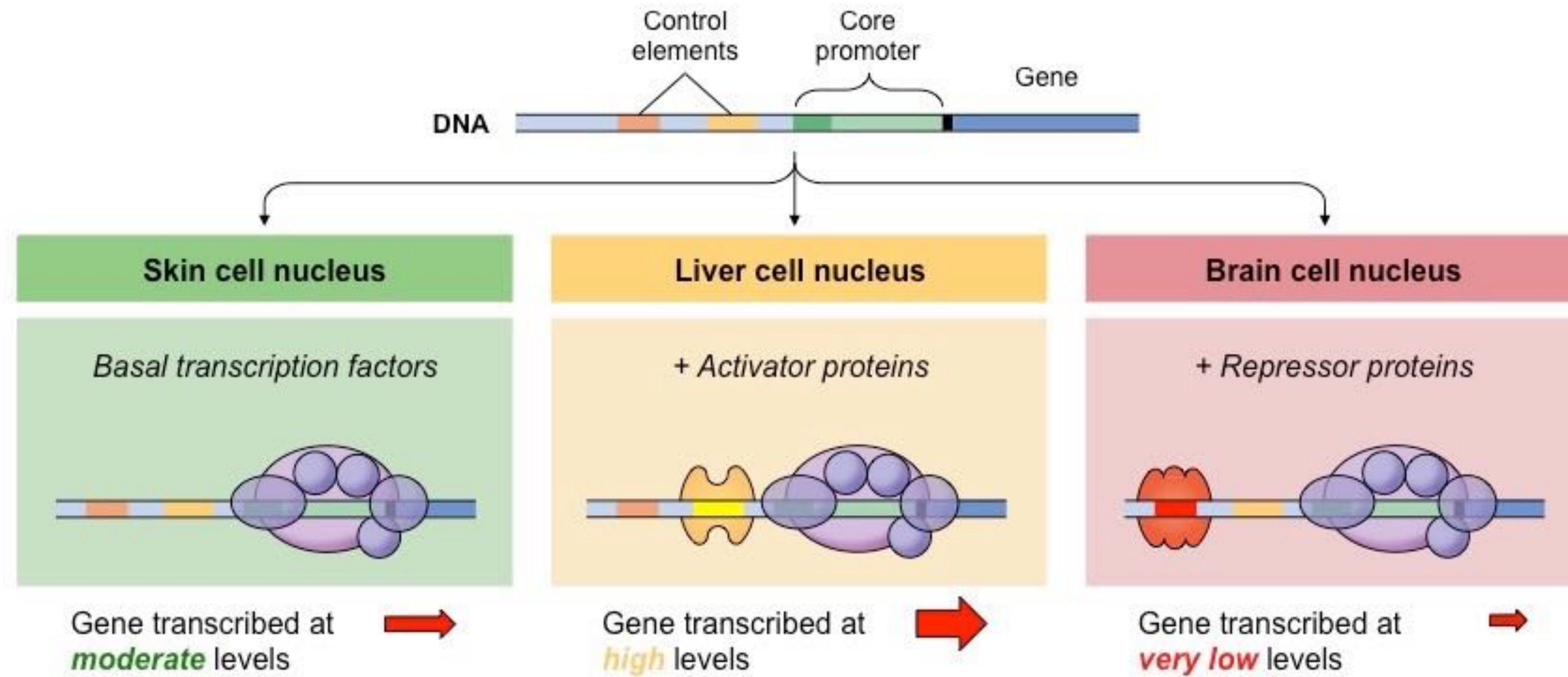
Spatial and temporal colinearity:
same order on chromosome
and timing in body



Hox gene expression and evolution of arthropod body plans



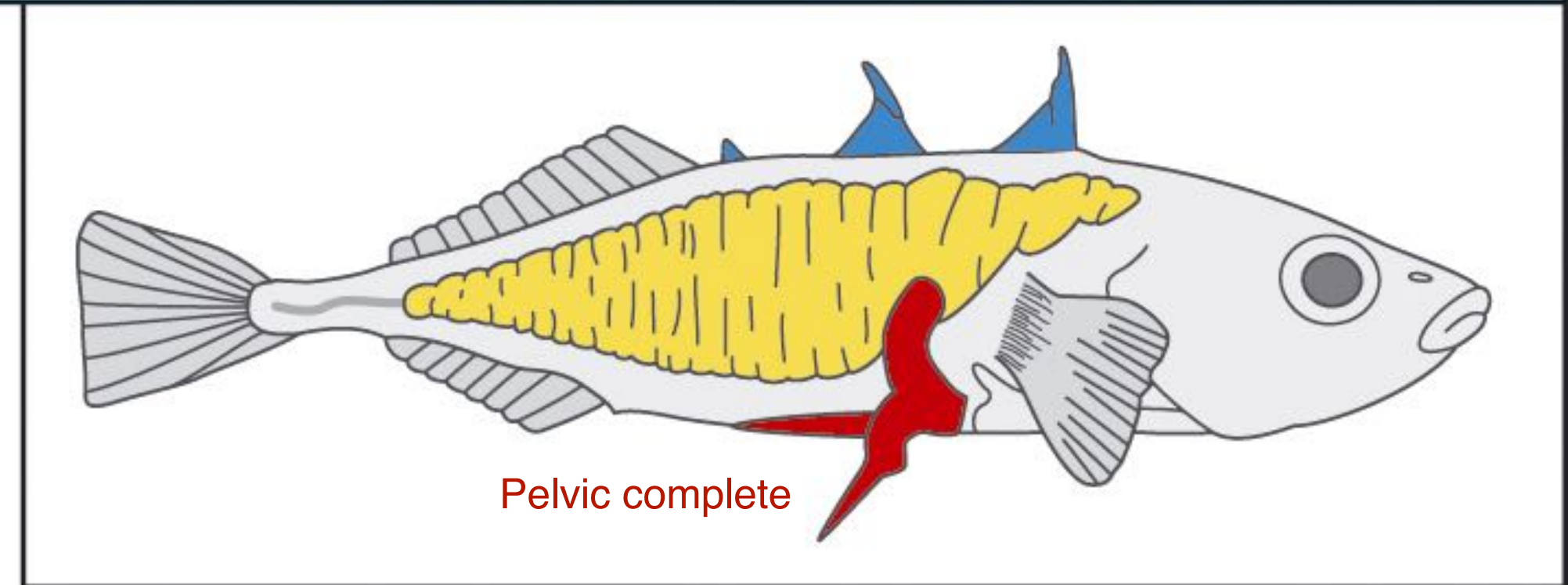
Which *part* of the gene is involved in evolutionary transitions?



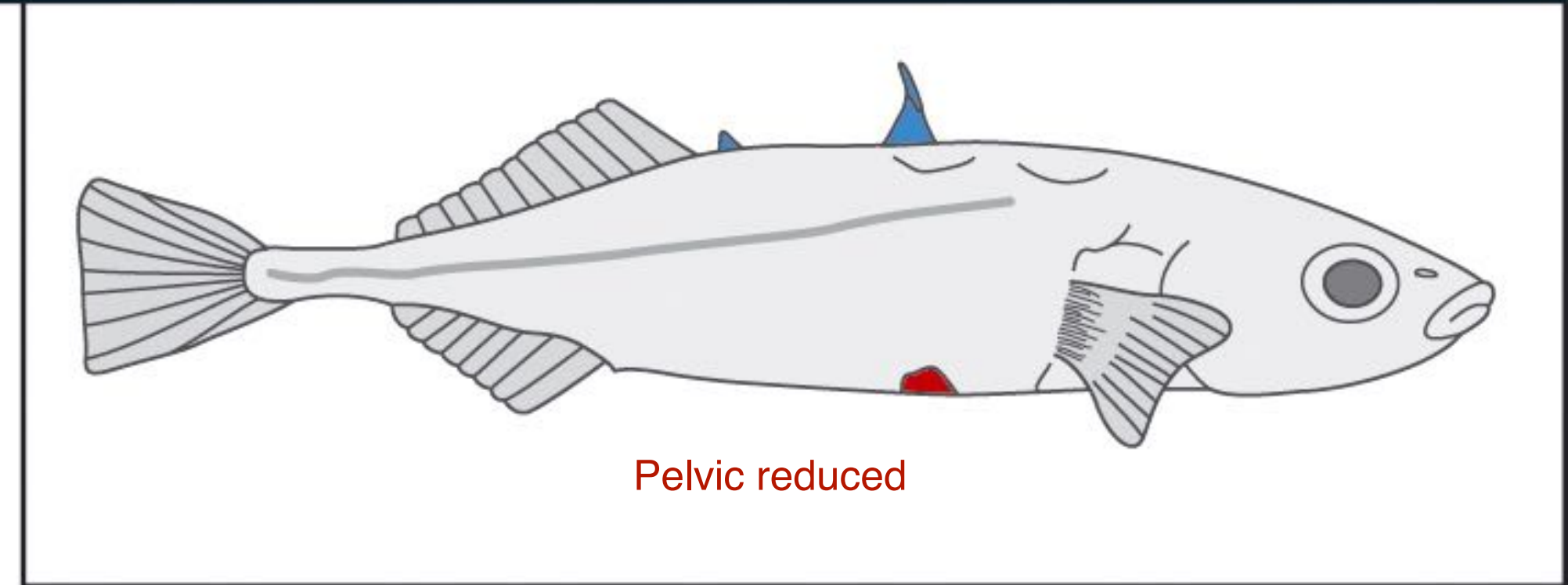
Differential gene expression

Modular enhancers I

Fully spined stickleback



Pelvic-reduced freshwater stickleback

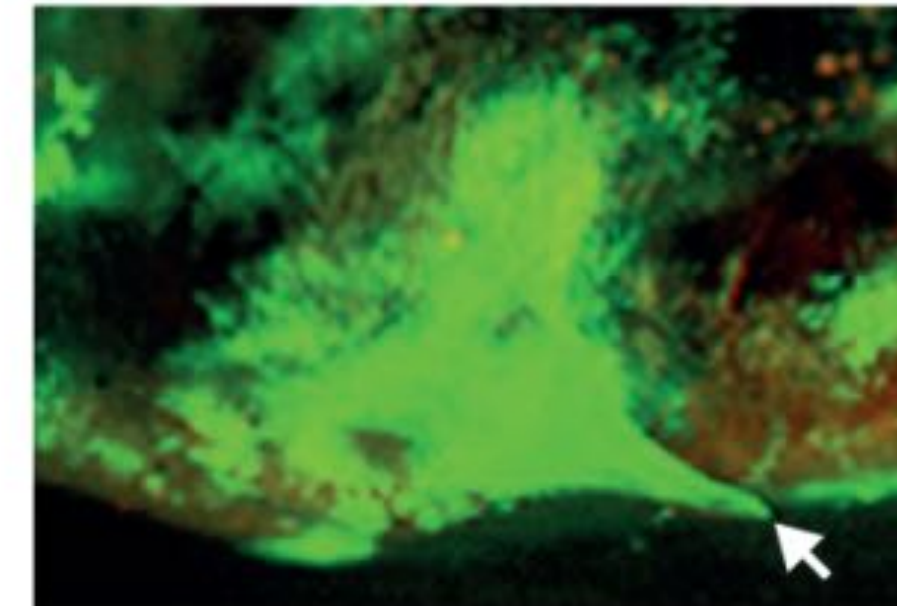
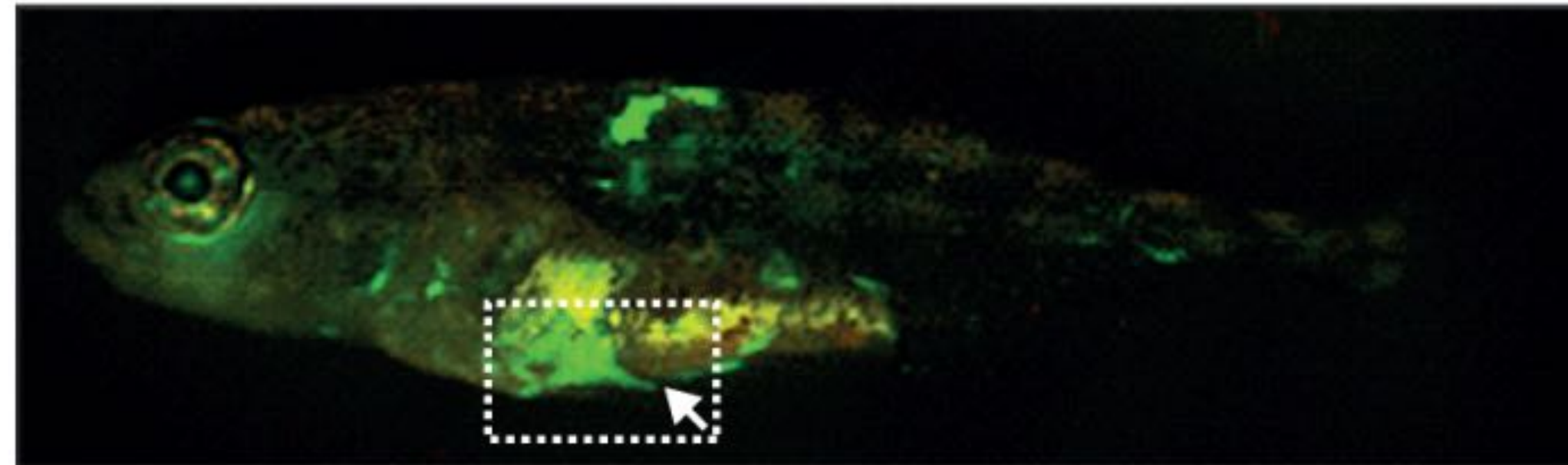
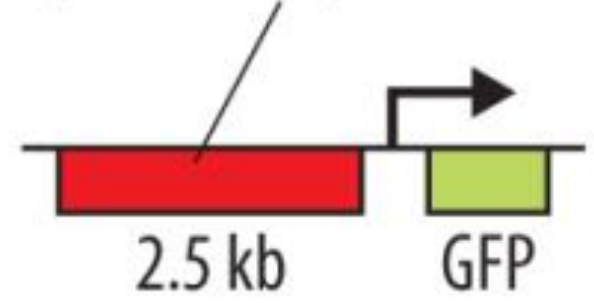


Pitx1 is expressed in the pelvic anlage of vertebrates - mouse KO reduces hind-legs

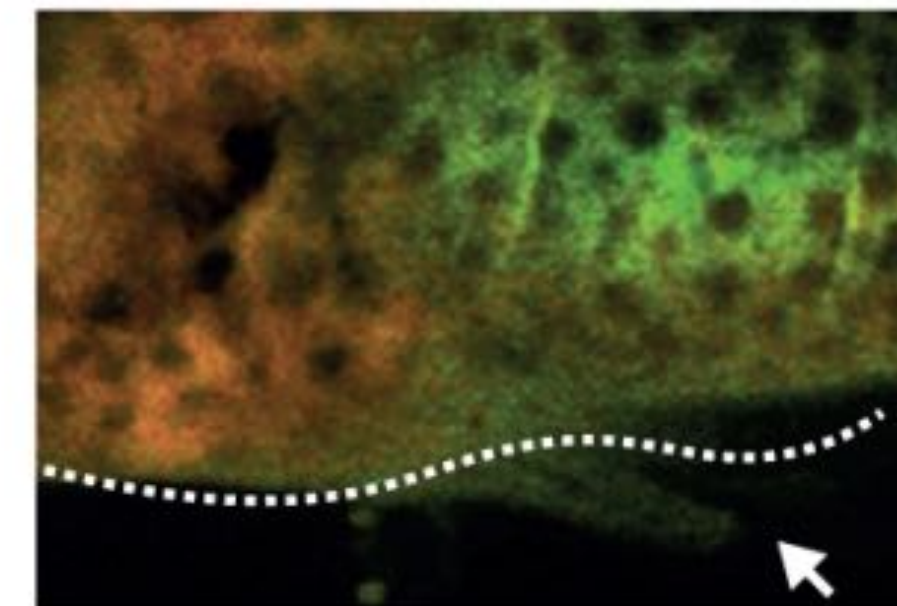
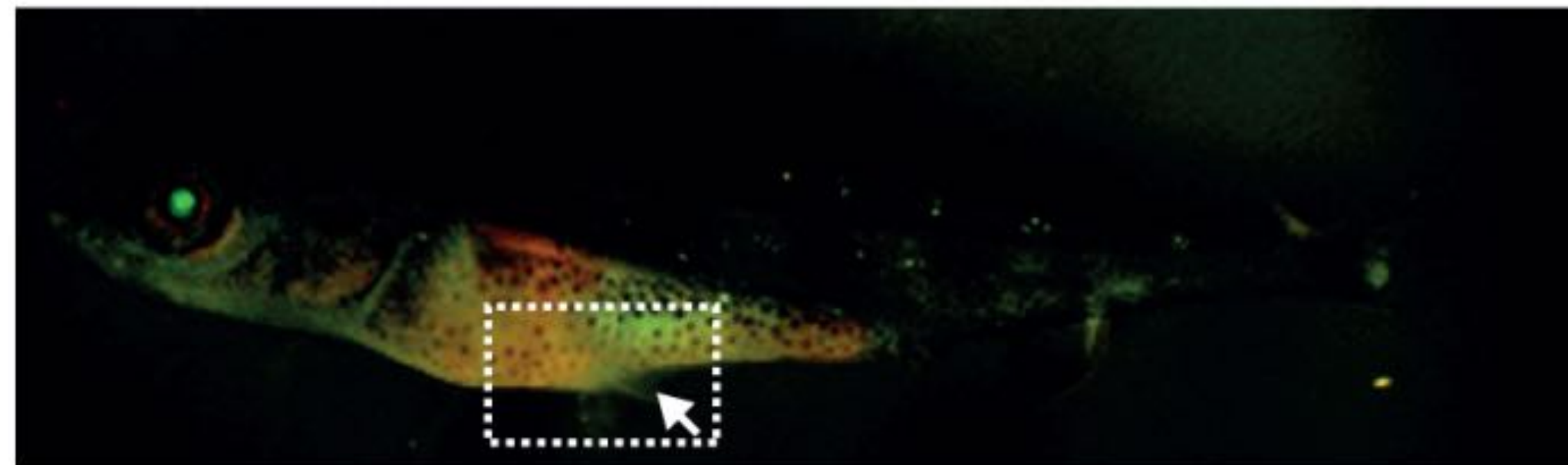
Modular enhancers 2

Reporter constructs containing intergenic regions from pelvic-complete (spined) or pelvic-reduced sticklebacks were injected into pelvic-complete sticklebacks

intergenic region from pelvic-complete fish



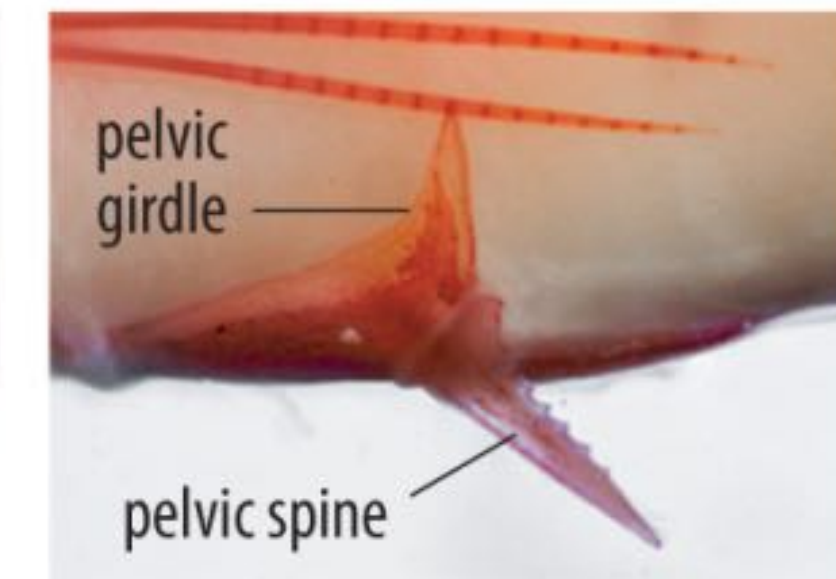
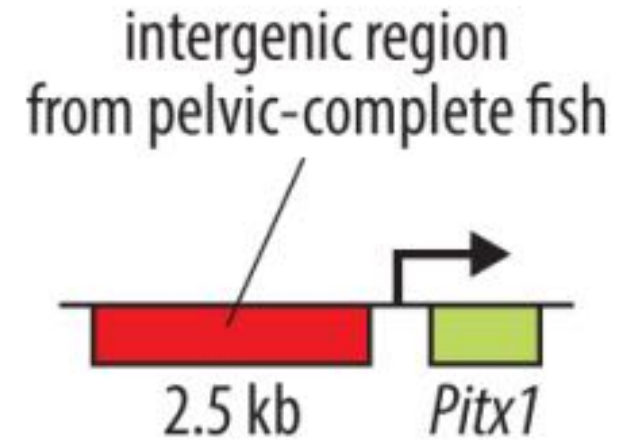
intergenic region from pelvic-reduced fish



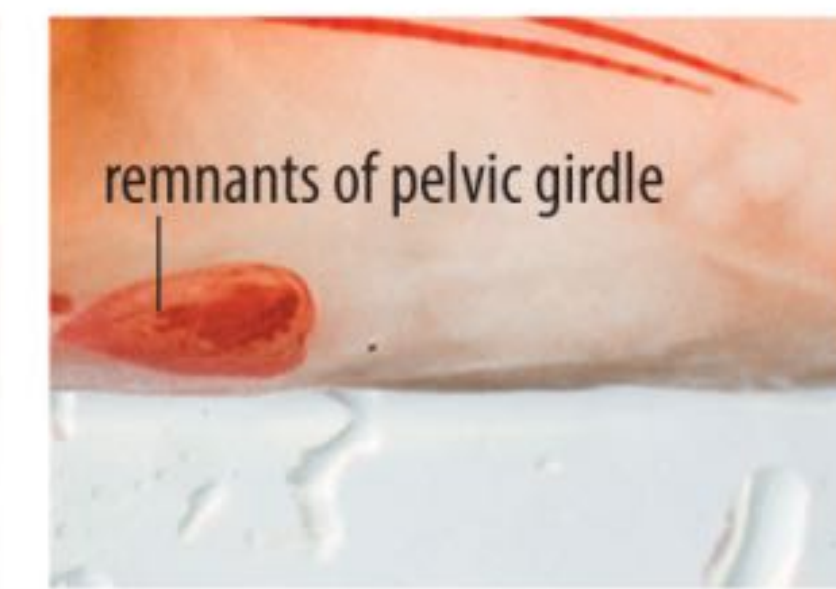
Pitx1 enhancer

Modular enhancers 3

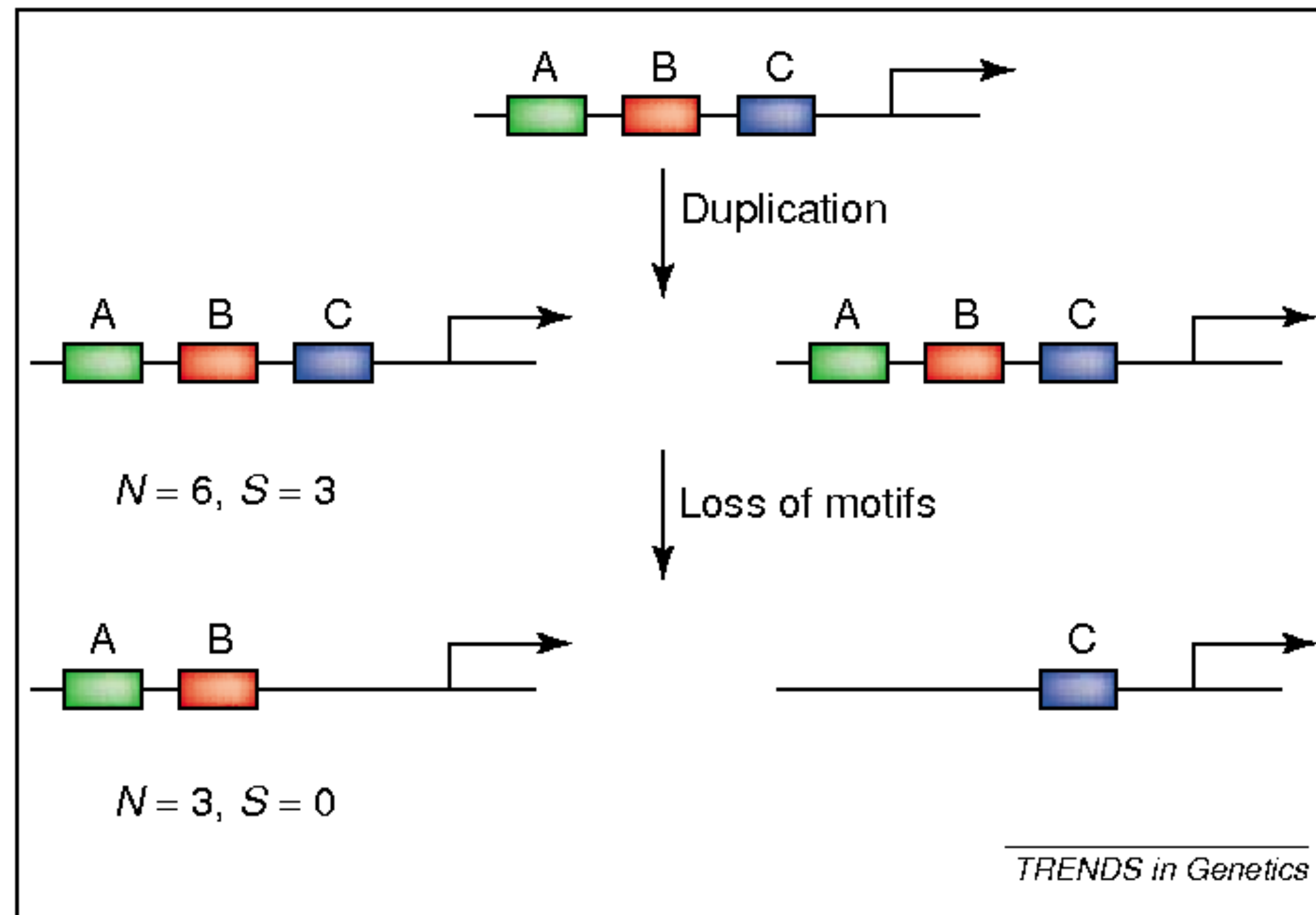
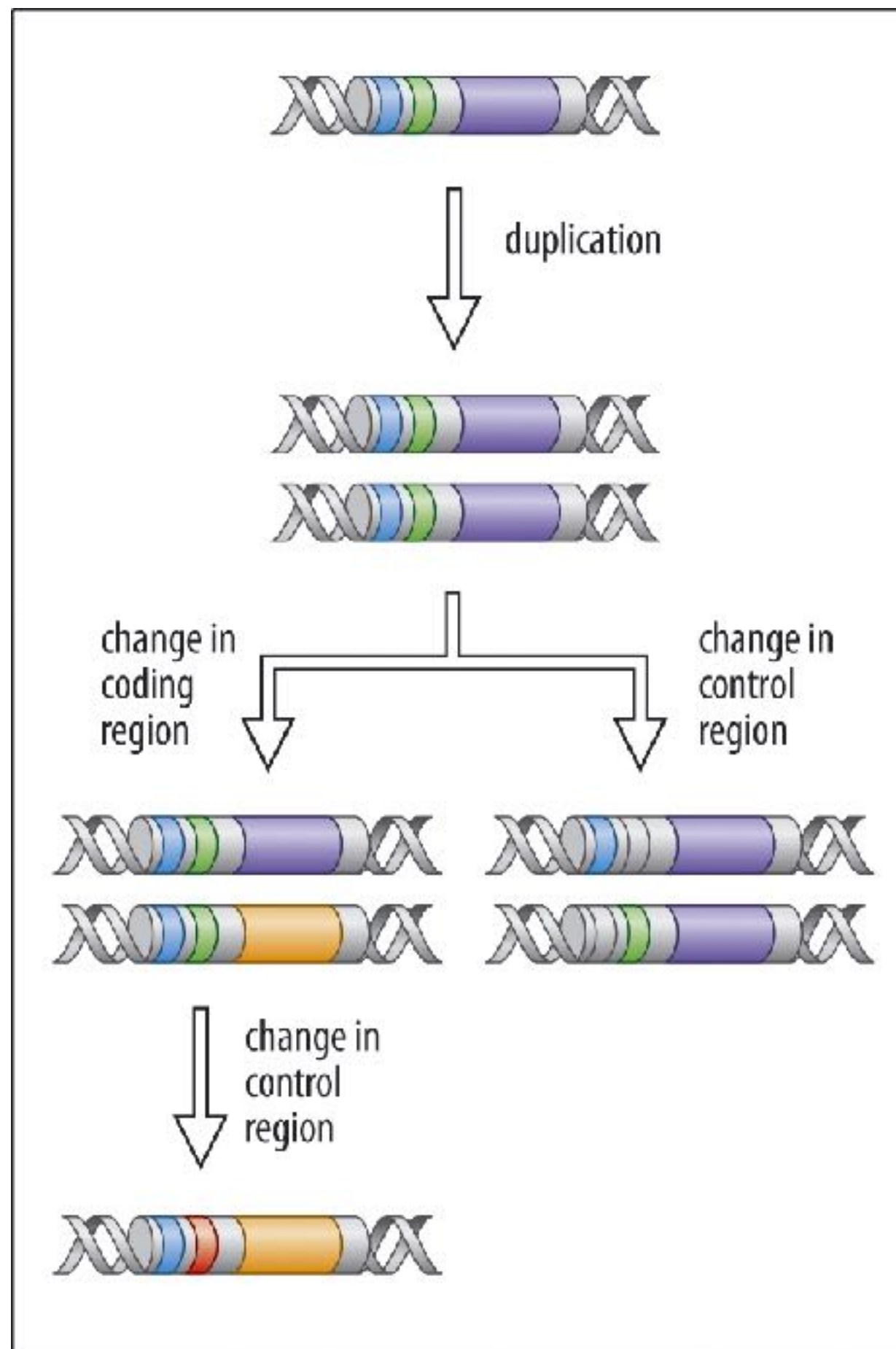
DNA transgene containing intergenic region from pelvic-complete stickleback linked to the *Pitx1* coding region was injected into fertilized eggs of pelvic-reduced fish



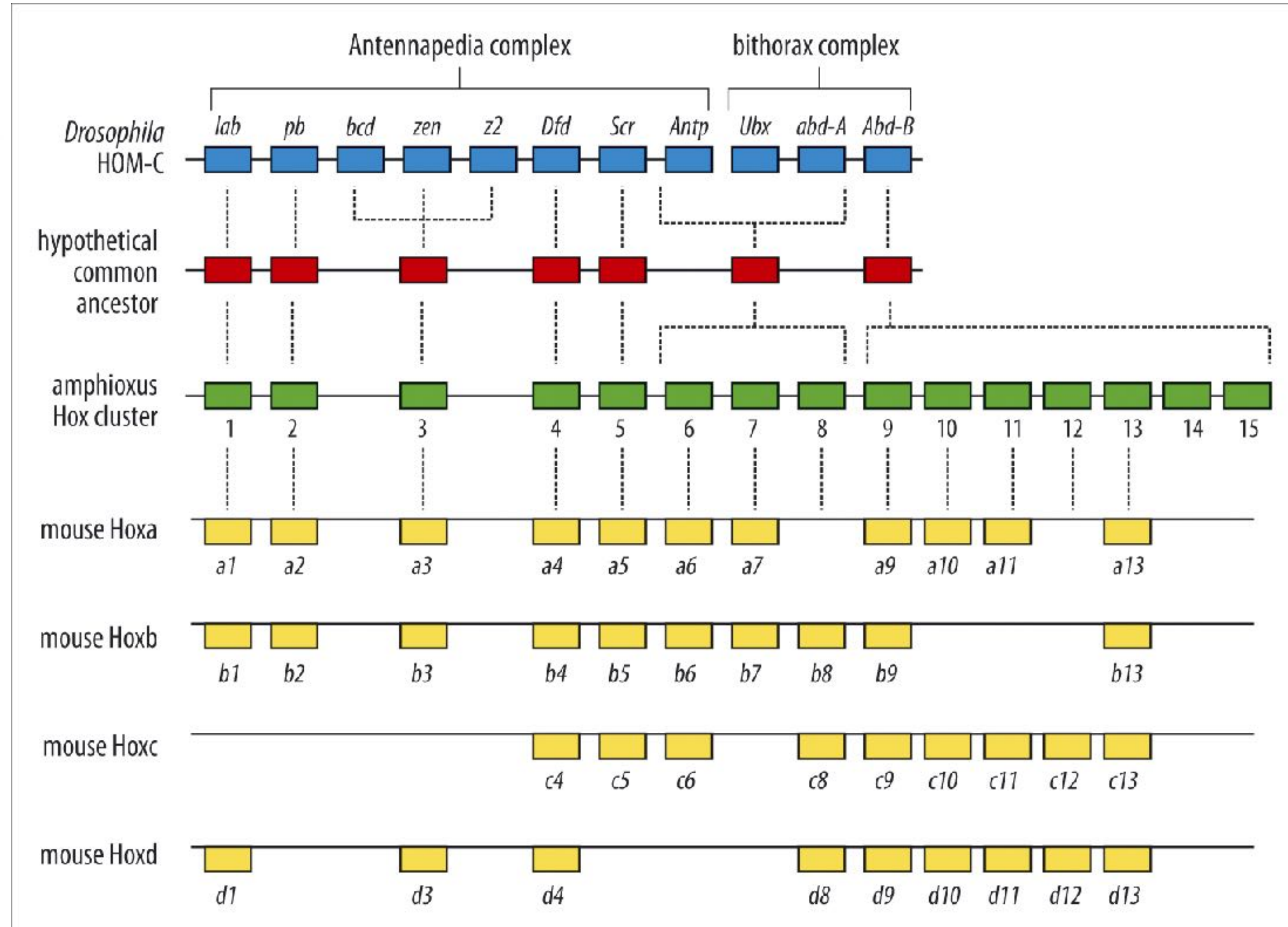
Siblings that developed from uninjected eggs (Control)



Duplication, Divergence, Complementation



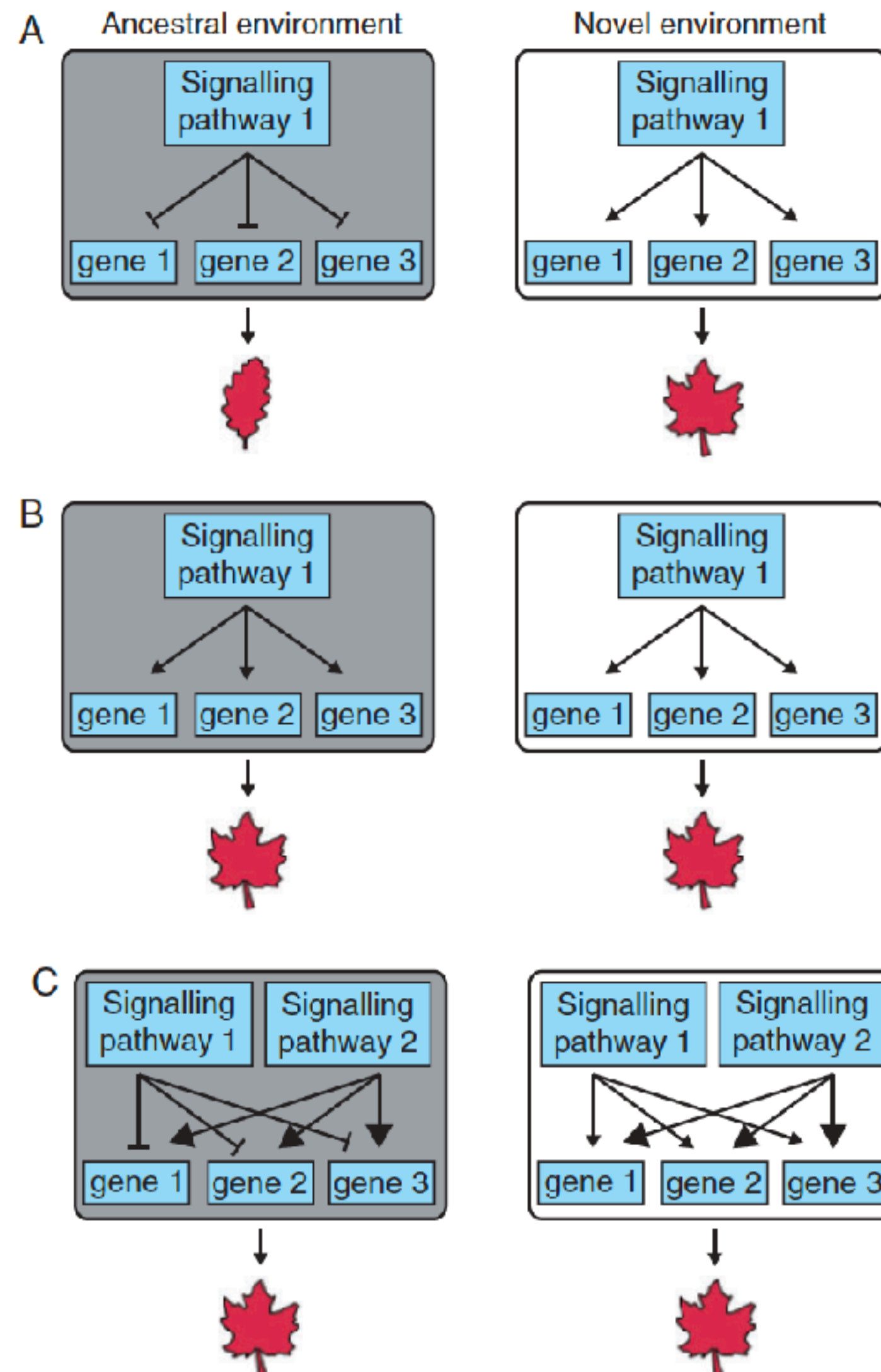
Hox gene clusters



Genetic assimilation

- Developmental plasticity over evolutionary time
- In general, acquired traits can't be passed on, with exceptions:
 - Epialleles - chromatin marks
 - Symbionts
- But phenotypes due to plasticity can be selected and stabilised...
 - *Drosophila* ether shocks, *Manduca* cold shocks, Tiger snakes...

Genetic assimilation



Developmental Plasticity

Developmental Plasticity is lost after repeated selection in *novel* environment
Trait has become “canalised”

Rewiring of development
- recruitment of a second pathway
- modifier genes in pop.

Evolutionary advantages:

1. Non-random phenotype
2. Phenotype in large fraction of population

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- *Developmental plasticity*
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- **Evo-Devo (evolutionary developmental biology)**
- *Modularity allows dissociation*
- Changes in morphology come from changes in development
- Regulatory mutations are known drivers of change
- Role for developmental plasticity in evolution

Questions?

