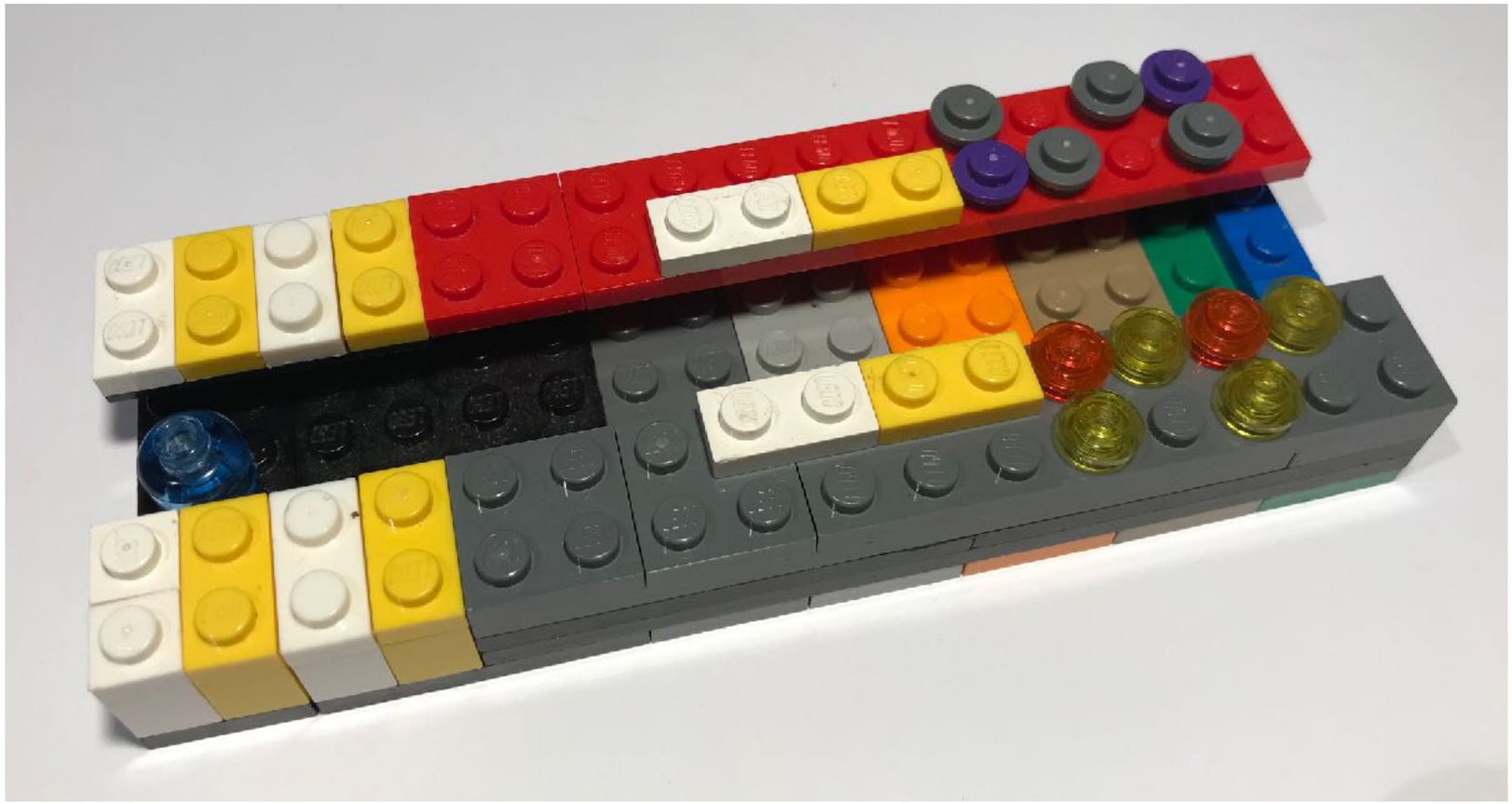
?

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 1

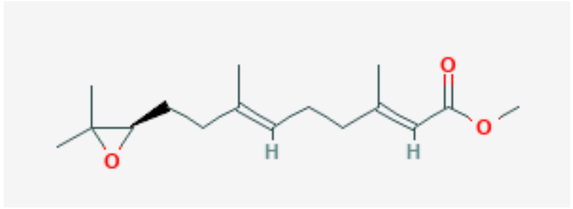
- Male dung beetle horns

Why are these brothers so different?

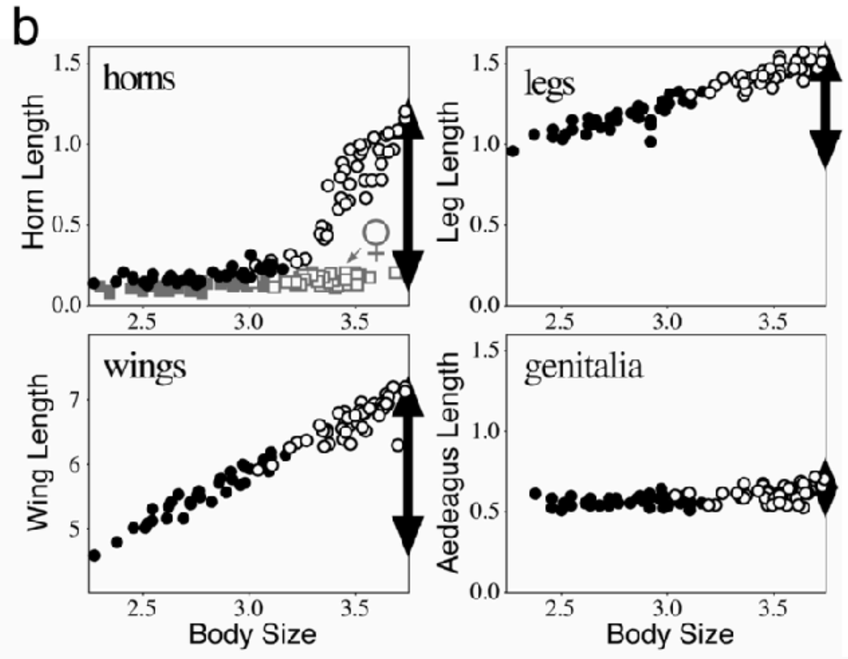
Emlen, PNAS, 2000

Diet-induced polyphenism 1

- Male dung beetle horns



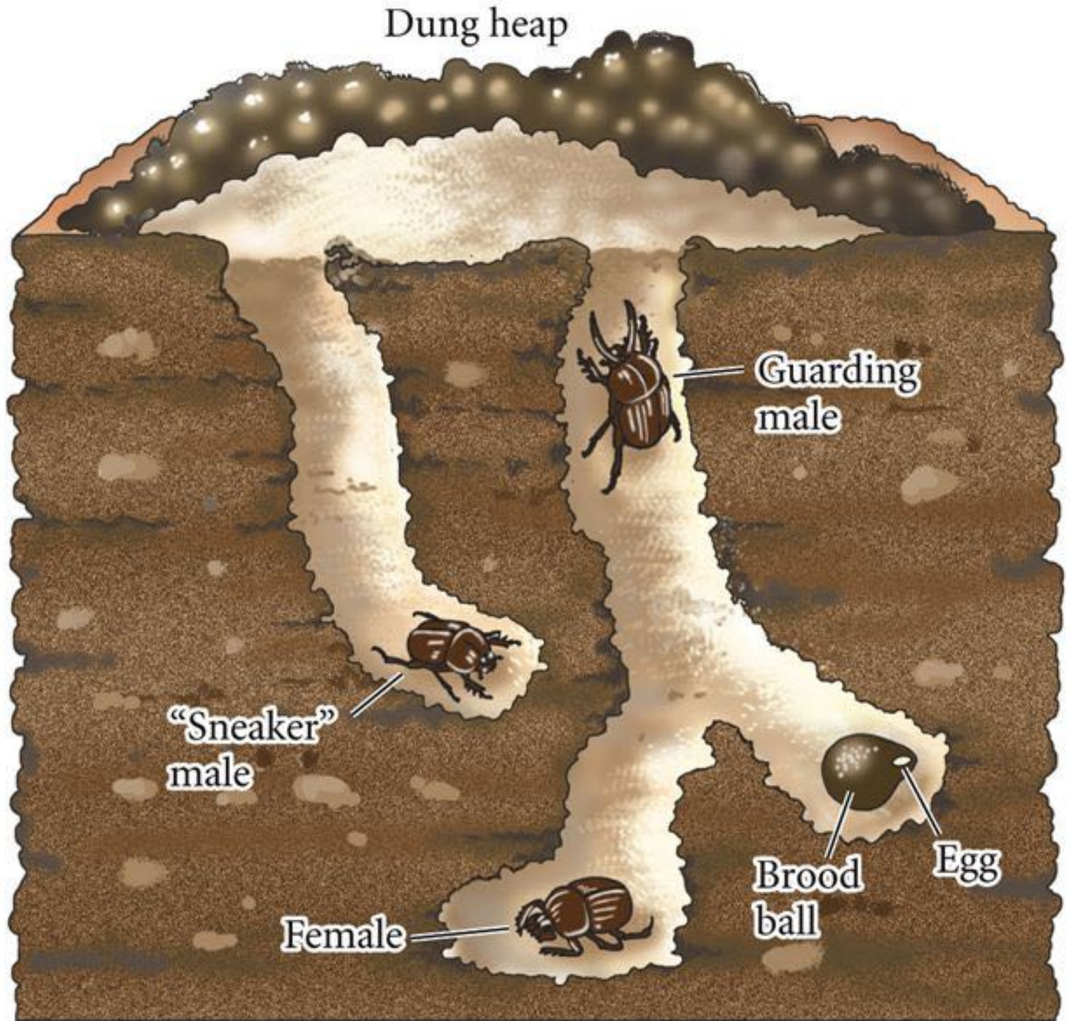
Juvenile hormone
titre depends on
amount of food



Emlen, PNAS, 2000

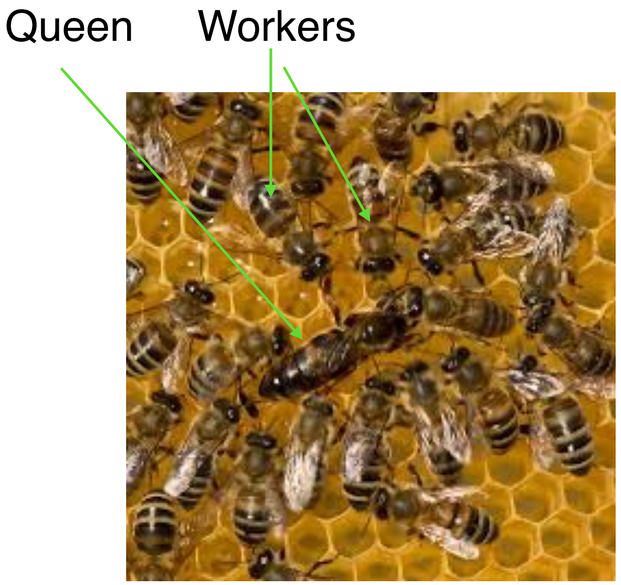
Diet-induced polyphenism 1

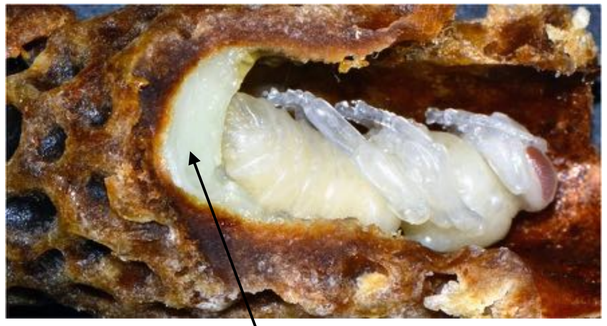
- Male dung beetle horns

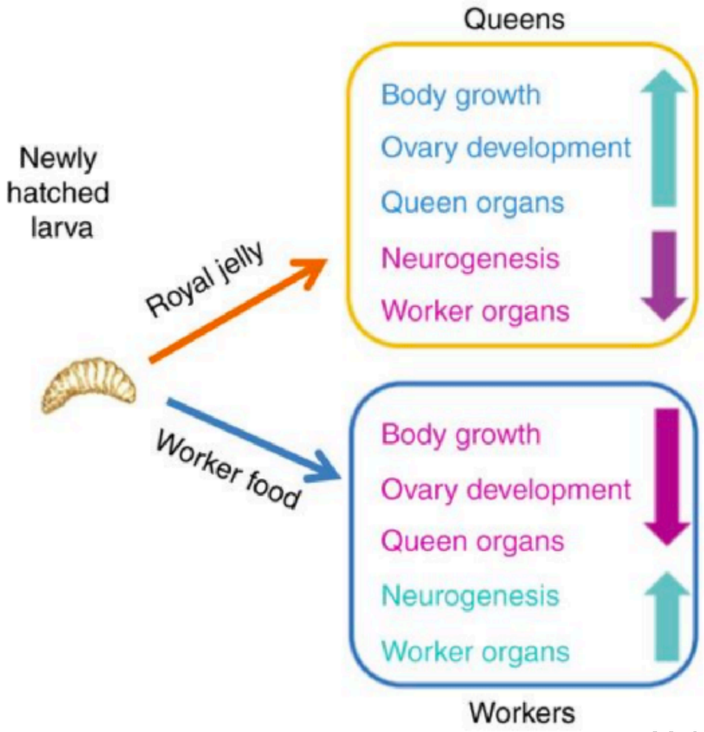


Diet-induced polyphenism 2

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





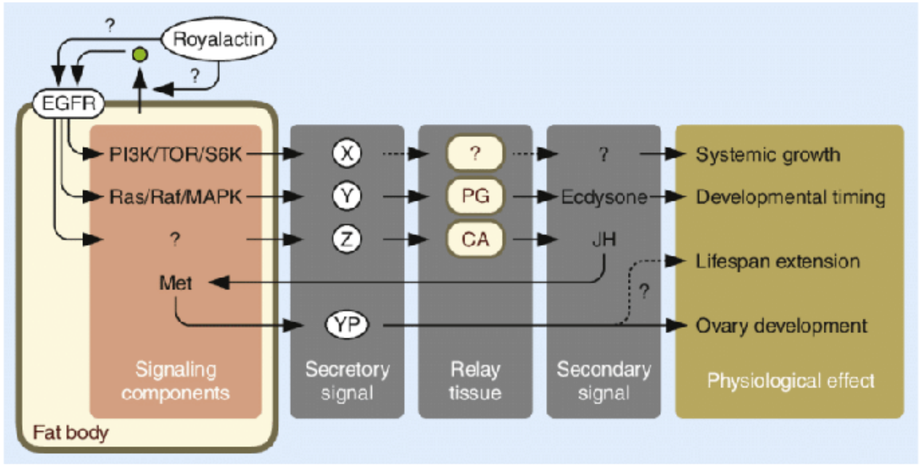


Maleszka, Comm Biol, 2018

Diet-induced polyphenism 2

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

Specfic signals



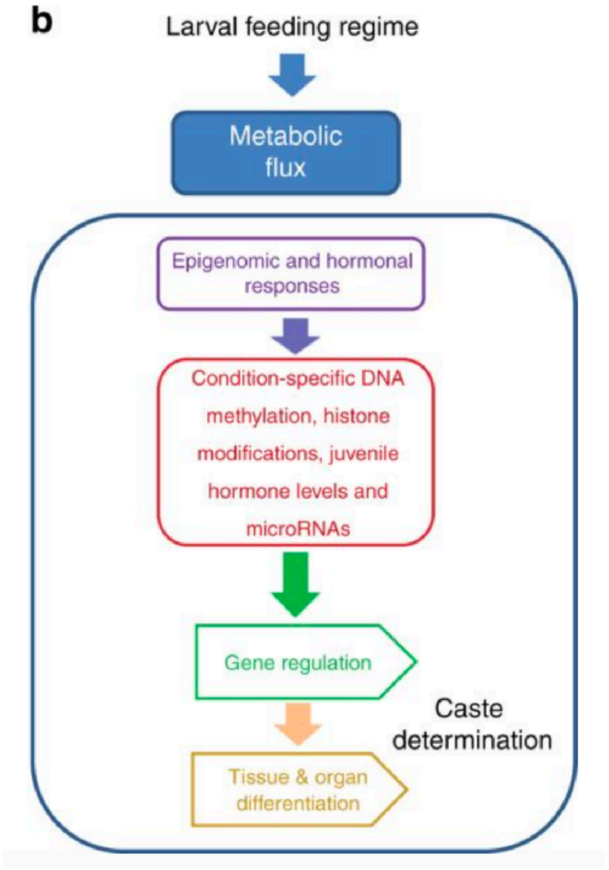
Current Biology

Royalactin (Rol) protein

UAS-Rol *ppl>Rol*

Kamakura, Nature, 2011

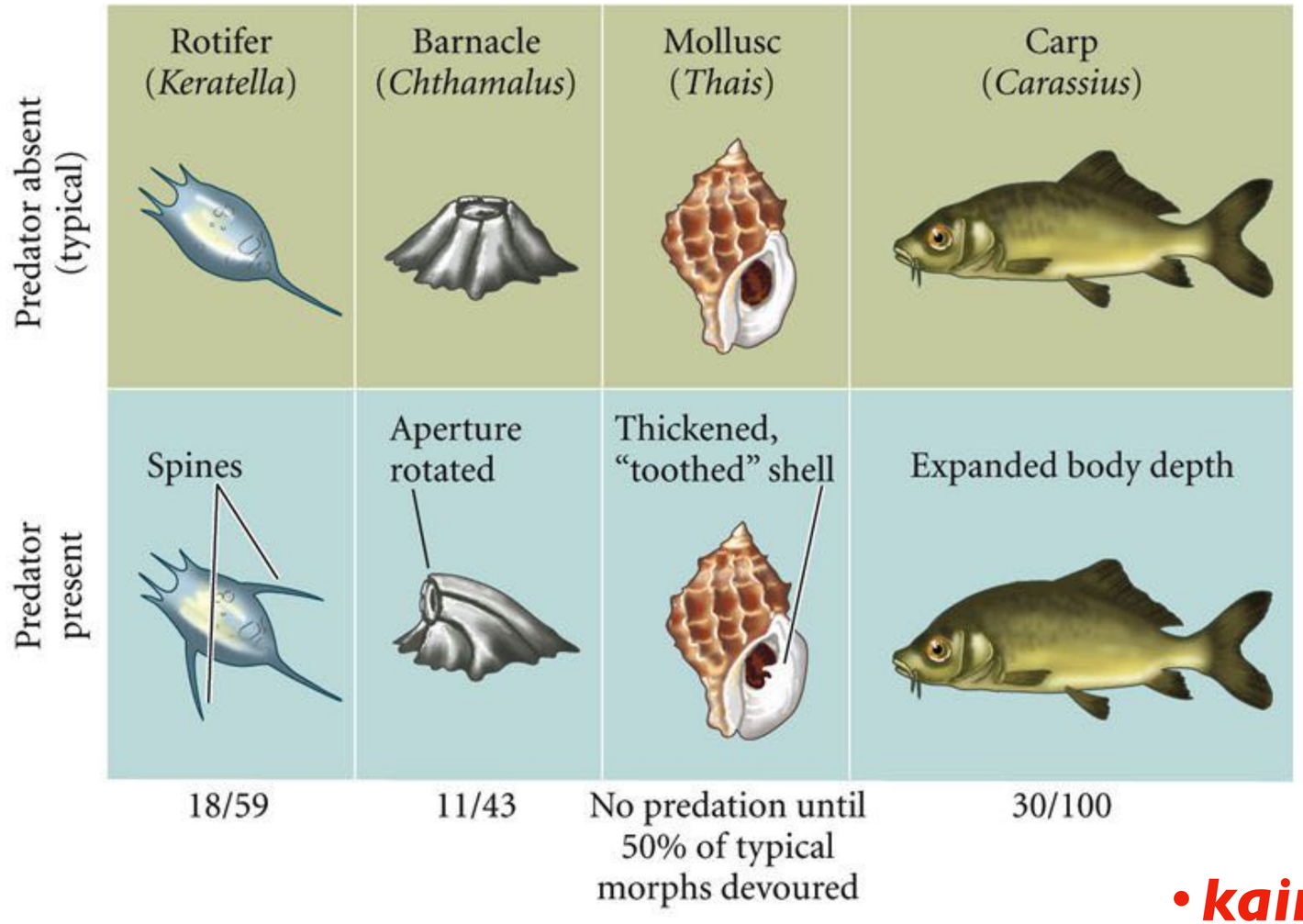
Amount of food



Maleszka, Comm Biol, 2018

Predator-induced polyphenism

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



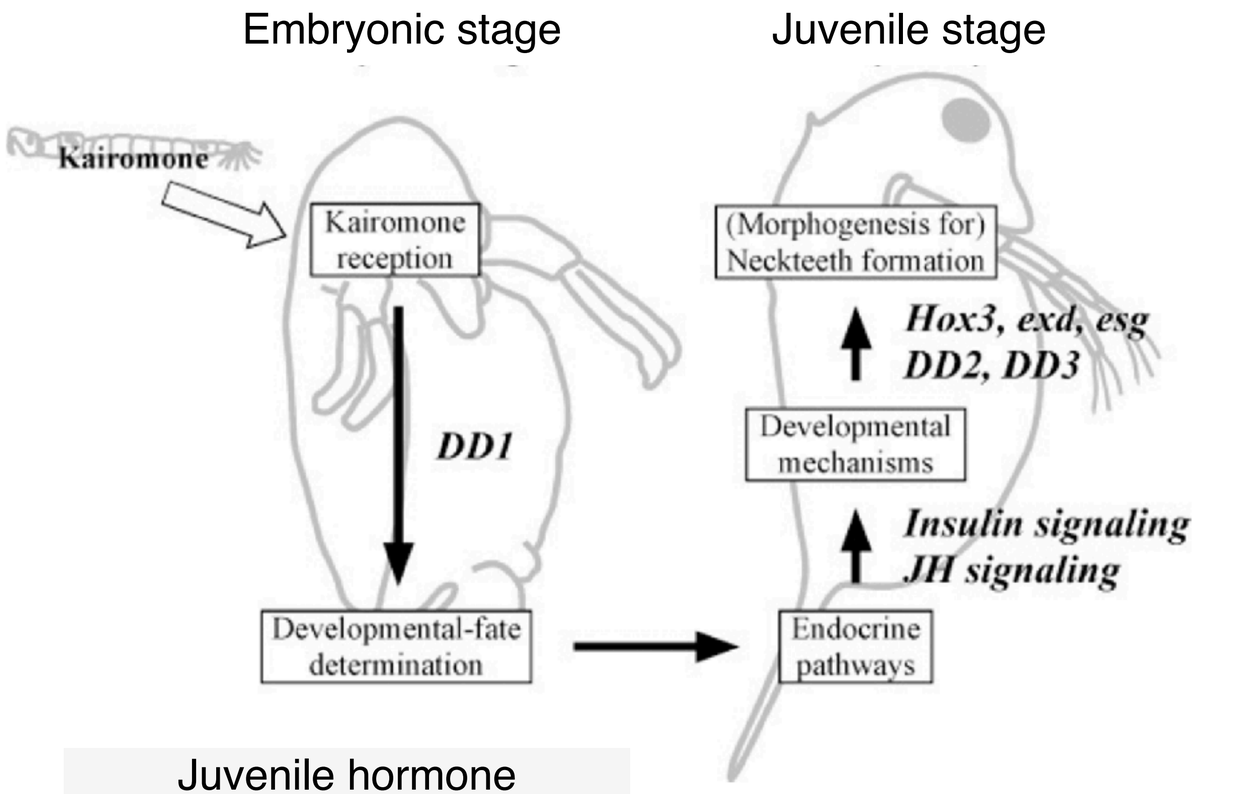
• ***kairomone***

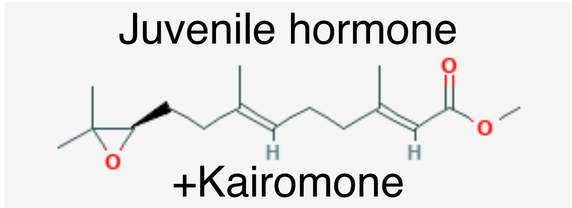
Predator-induced polyphenism

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

Predator present

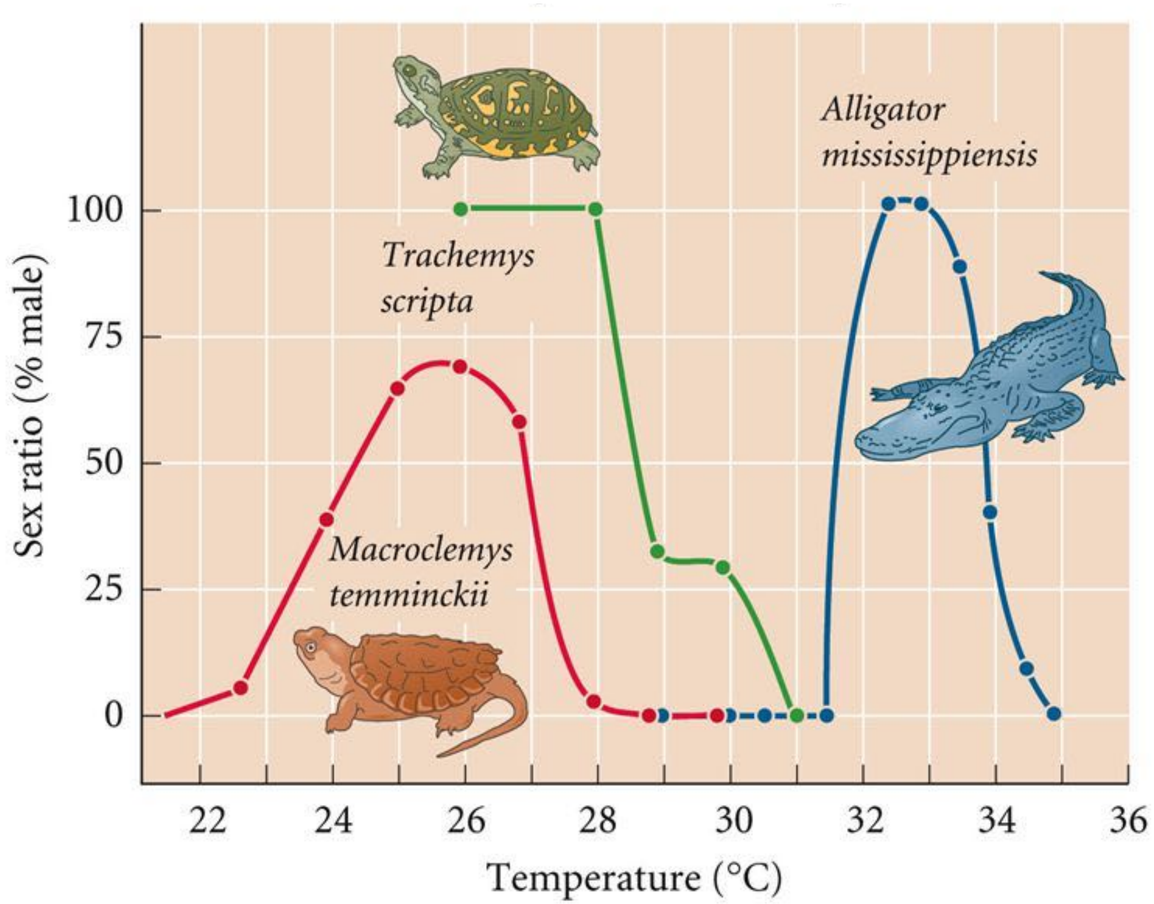
Predator absent





Temperature-induced polyphenism I

- Crocodiles and turtles

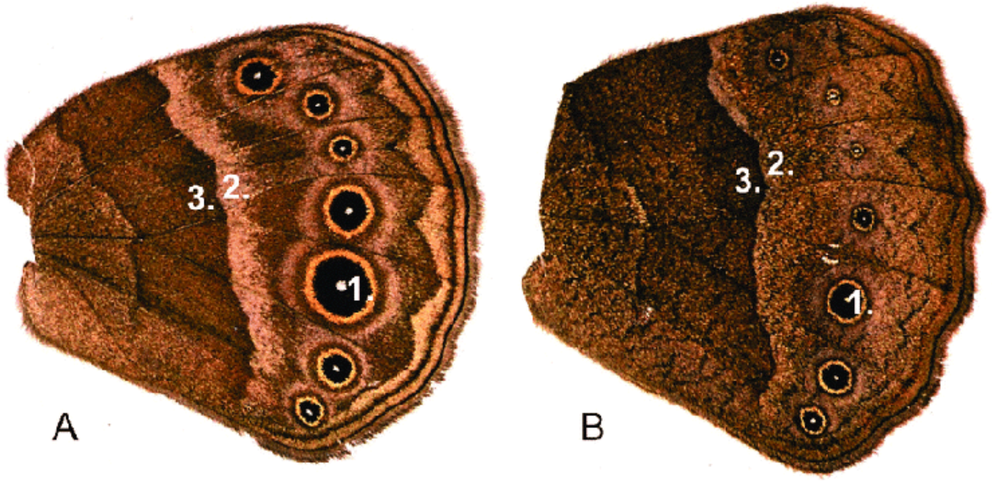


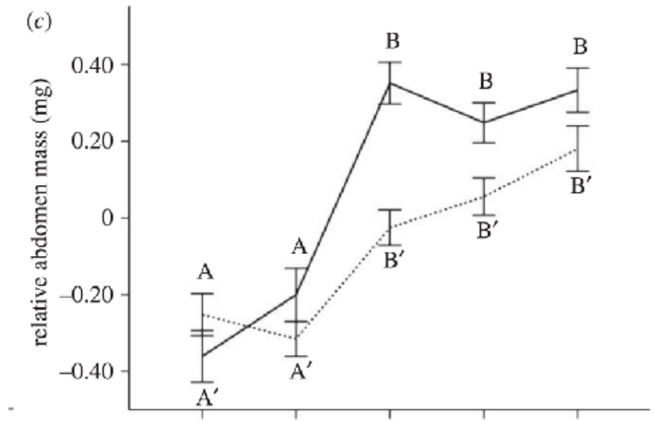
Cold-inducible RNA-binding protein (CIRBP)

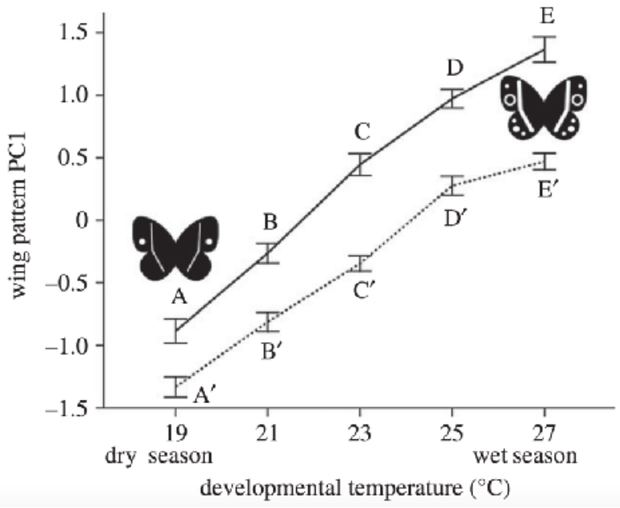
Schroeder, Genetics 2015

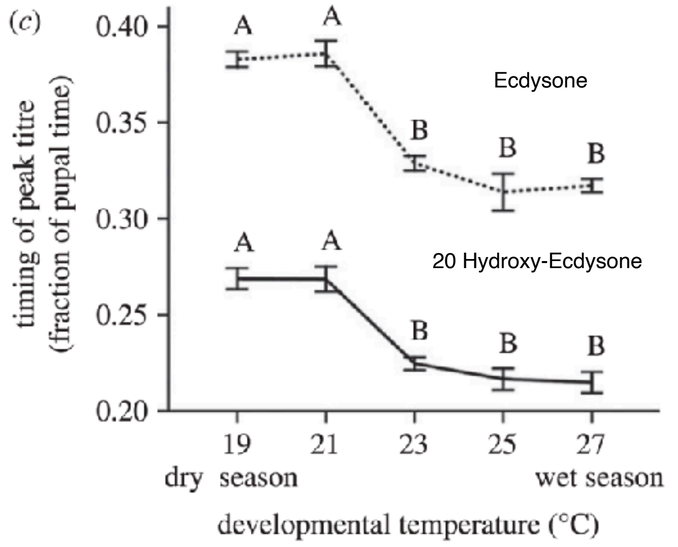
Temperature-induced polyphenism 2

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





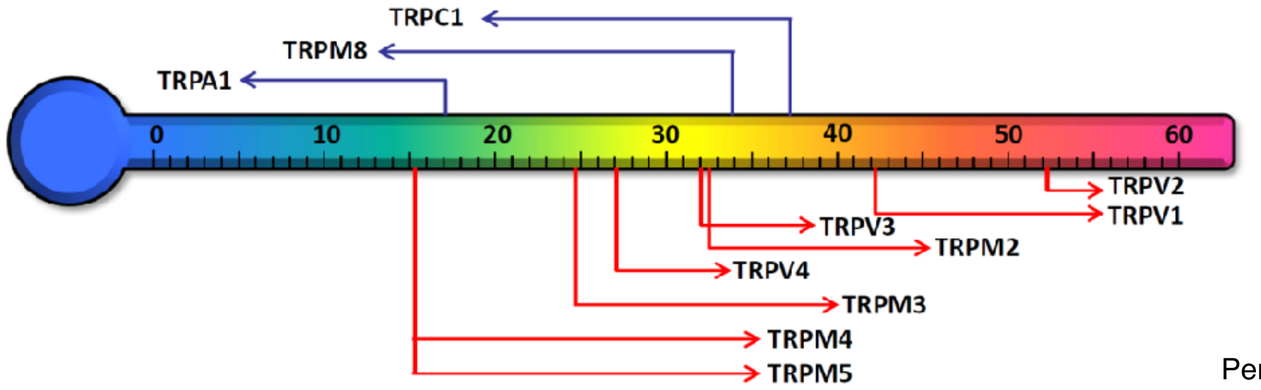




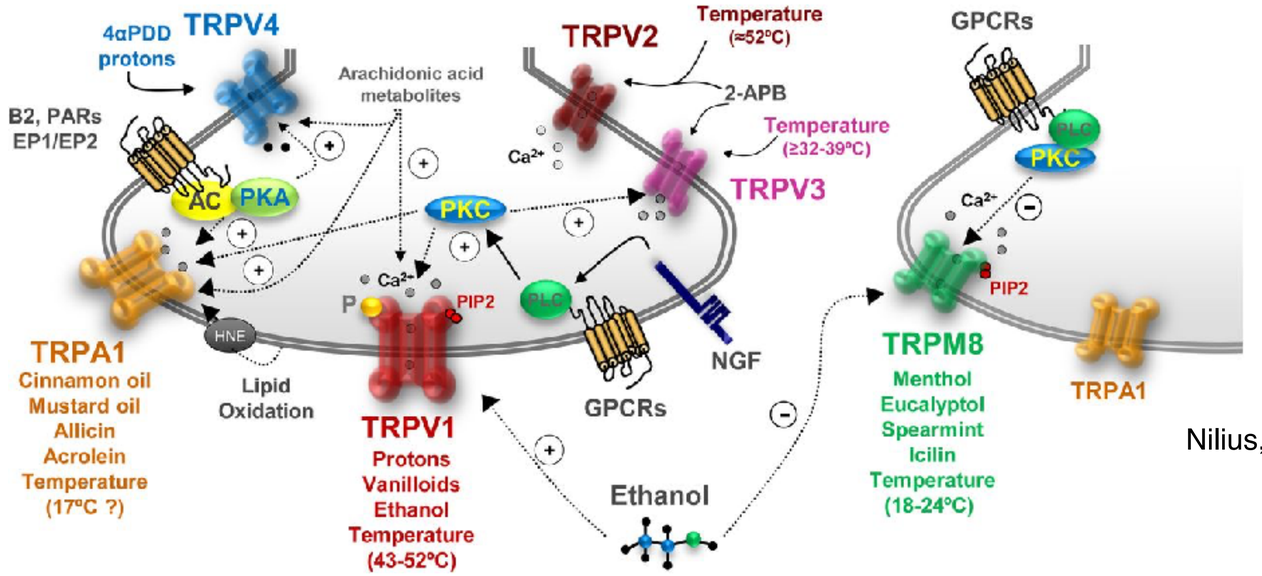
Distal-less expression

Oostra, Proc R Soc B, 2011

Temperature sensing by ion channels?



Pertusa, IntechOpen, 2012



Nilius, Pharm. Rev, 2014

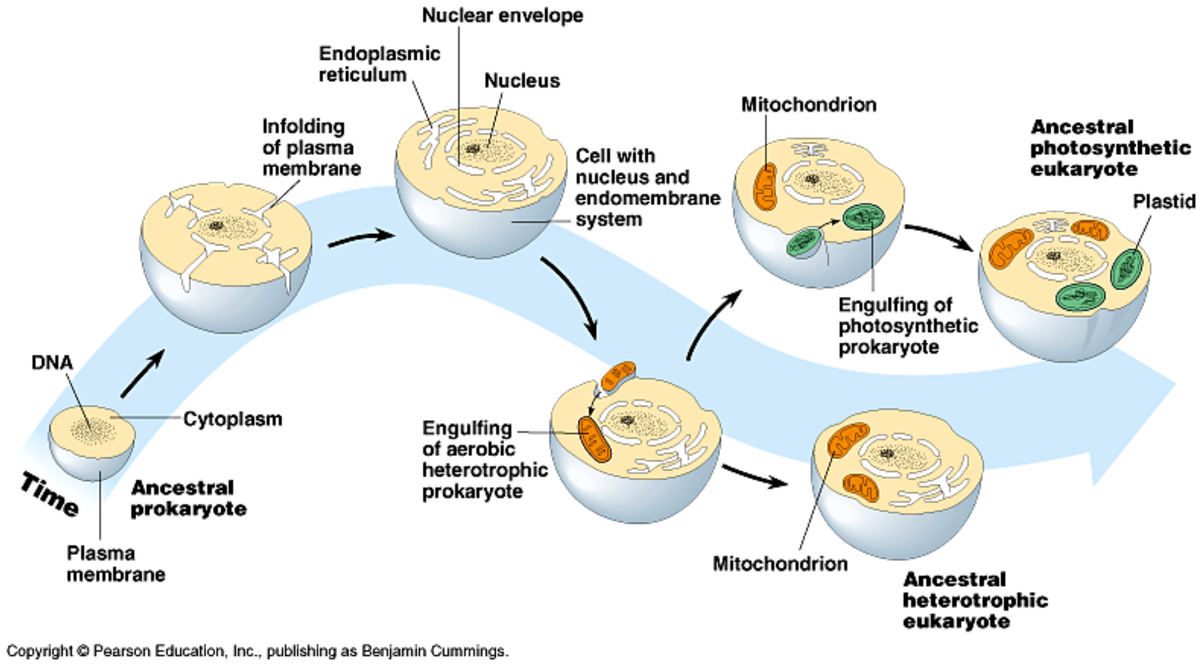
Nobel Prize for Physiology and Medicine, 2021: David Julius and **Ardem Patapoutian**

Monday, January 27, 2025
⏰ 14:15–15:15 (followed by a coffee break)
📍 SV 1717

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)



For an alternative, see Baum and Baum, BMC Biology 2014

Symbiosis-induced polyphenism I

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

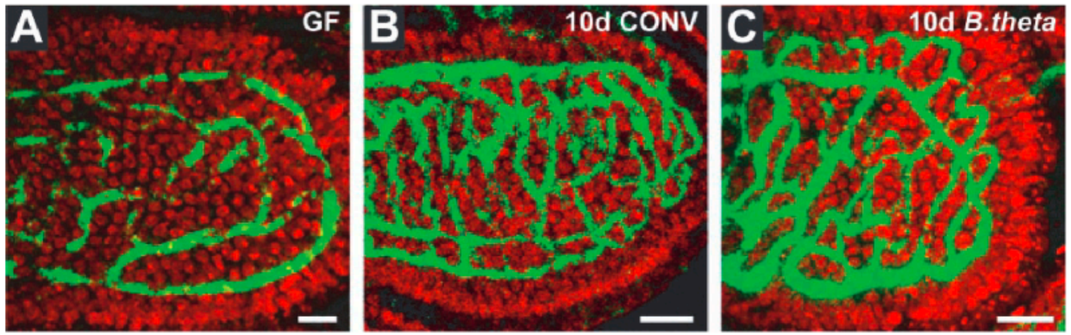
Drosophila ovary
Infected mothers lay 4x eggs
Protected from some viruses

Armadillidium
Infected males develop as females

Culex
Sperm modified to
kill non-infected eggs

Symbiosis-induced polyphenism 2

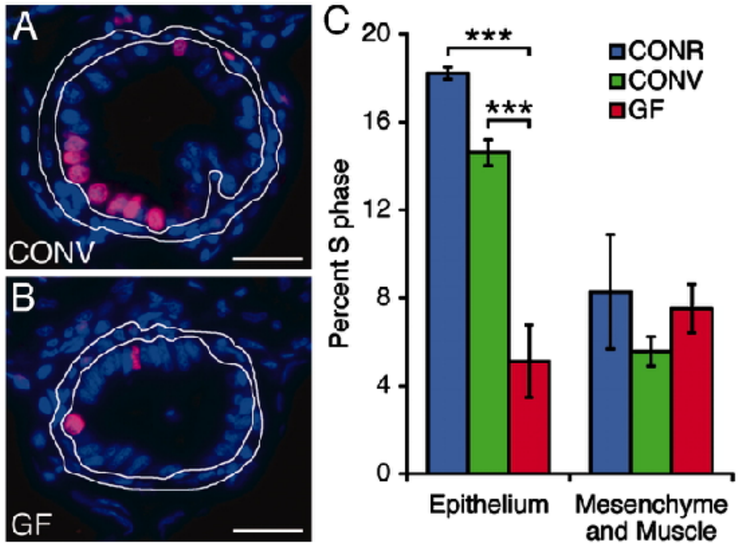
- Gut microbiome in vertebrates
- Hundreds of different species, transferred at birth
- Germ-free mice and zebrafish have developmental defects
- Paneth cells secrete antibacterial peptide to *select* microbes



Intestinal blood vessels

B. thetaiotaomicron

Stappenbeck PNAS, 2002



Intestinal stem cell divisions

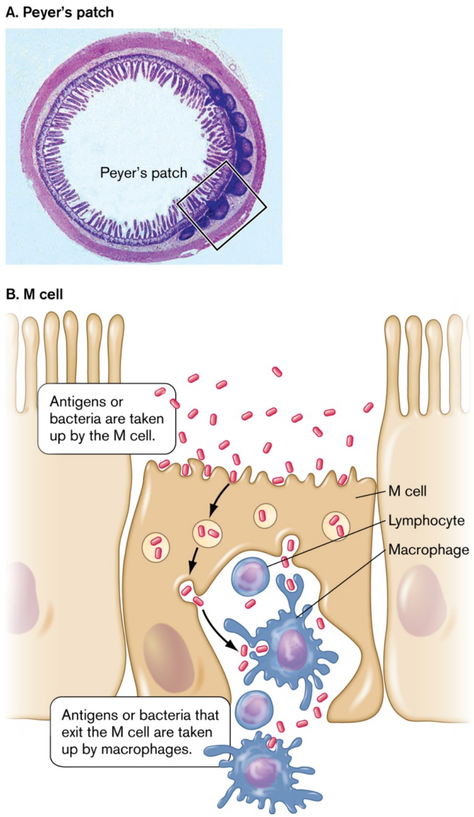
Rawls PNAS, 2004

CONV = Conventionally raised, GF = Germ Free, CONV = conventionalized (bacteria added back)

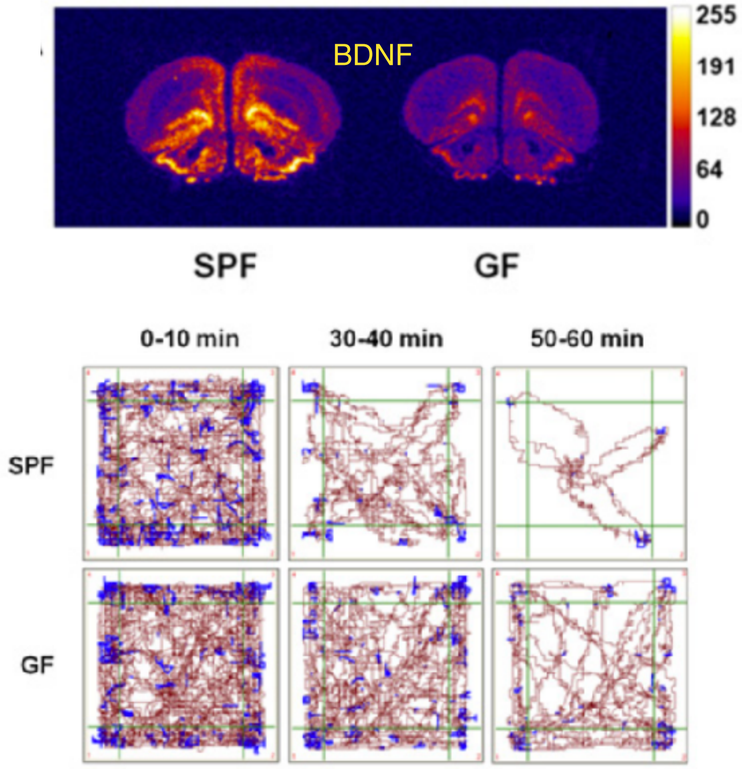
Symbiosis-induced polyphenism 2

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

Gut-associated Lymphoid Tissue
(70% of lymphocytes)



Frontal cortex

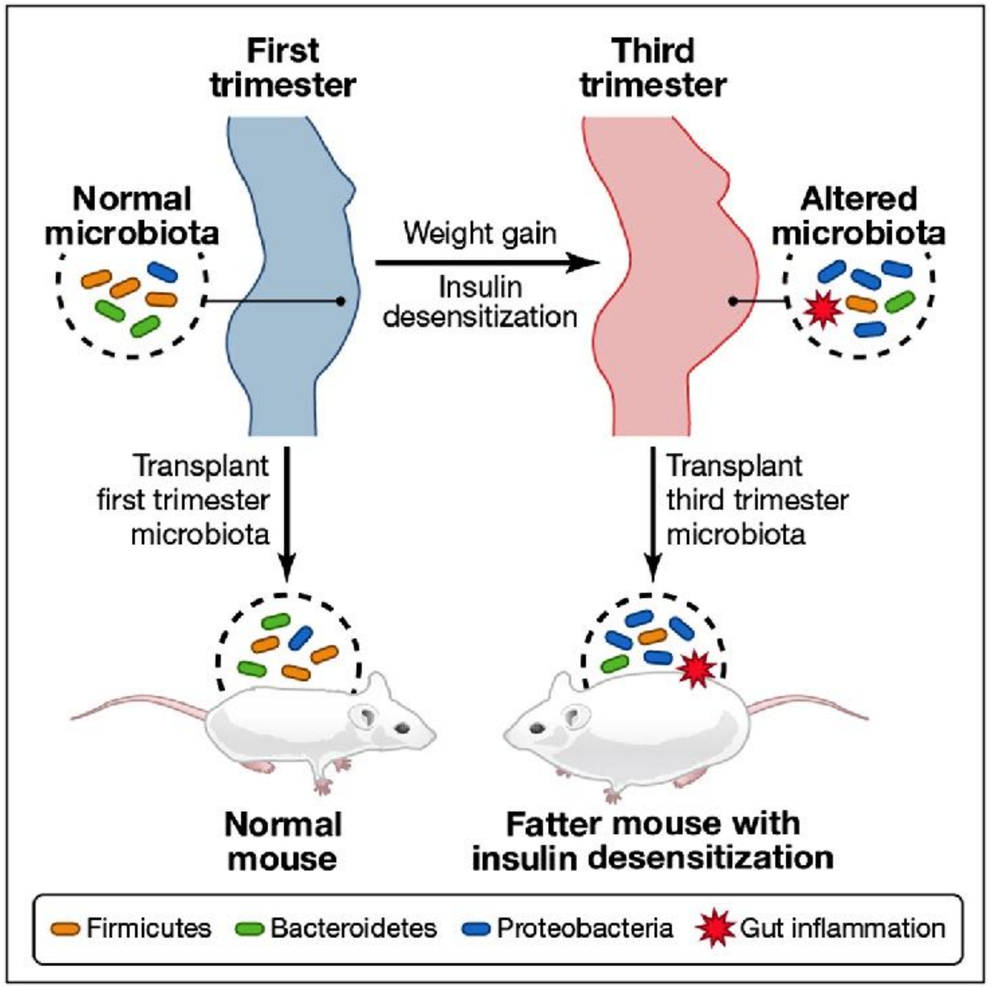


SPF = specific pathogen free, GF = Germ Free

Diaz Heijtz PNAS, 2011

Symbiosis-induced polyphenism 3

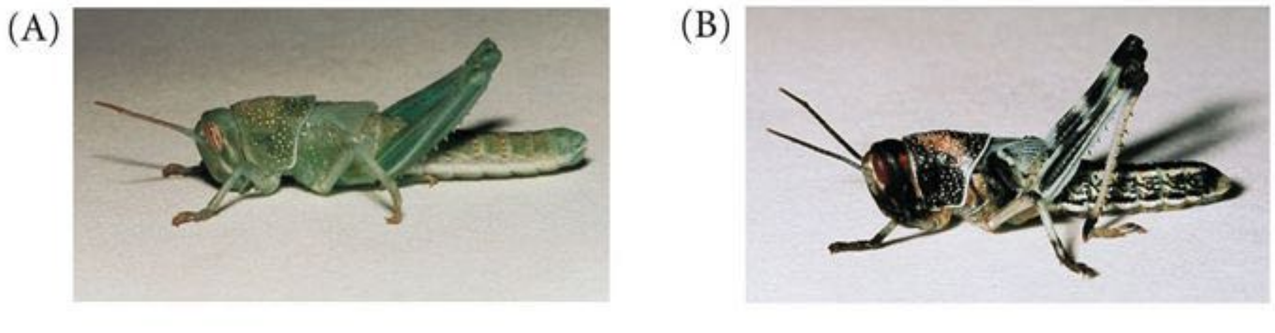
- Gut microbiome changes with pregnancy
- Confer pregnancy-related metabolic changes to mice



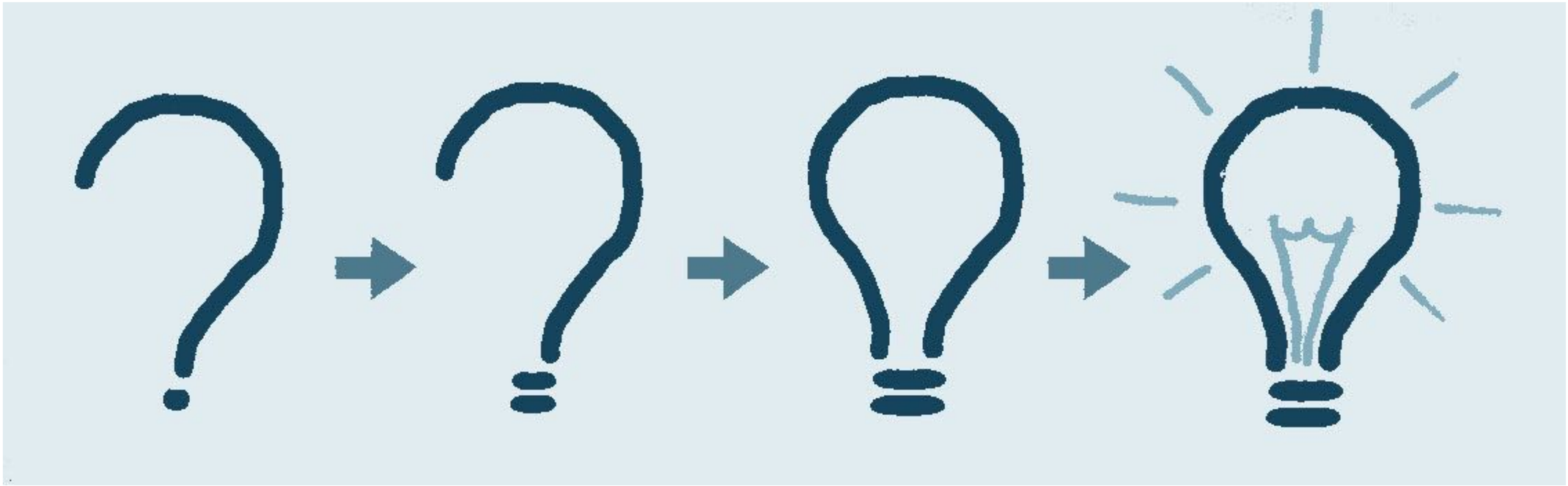
Koren, Cell, 2012

Summary

- The genome in an egg/sperm does not determine the phenotype in isolation
- 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

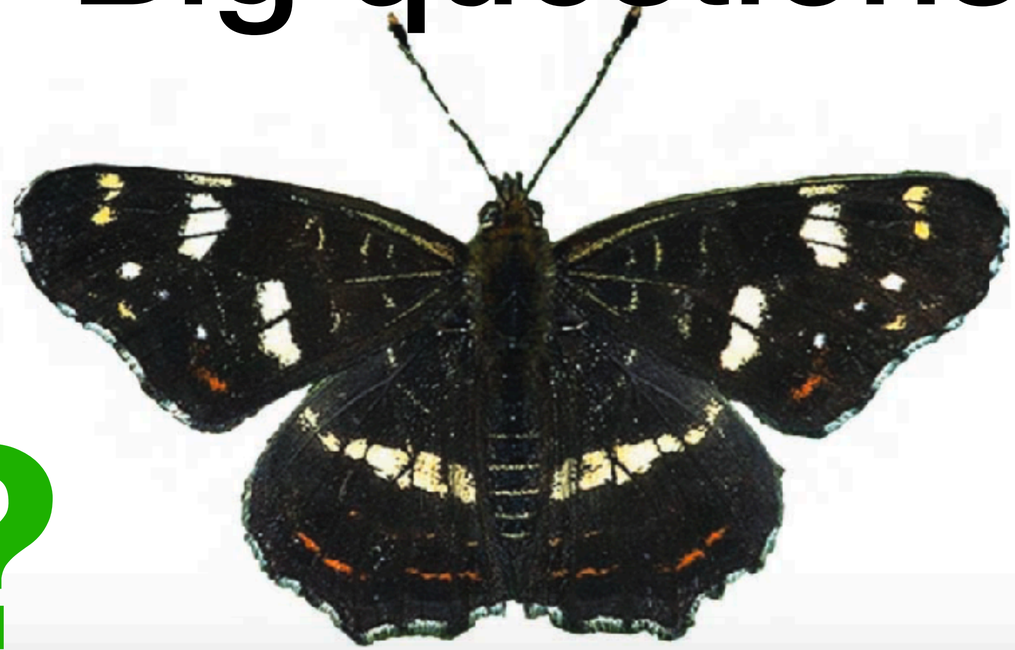


Questions?



Take a break

? Big questions



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Today’s menu

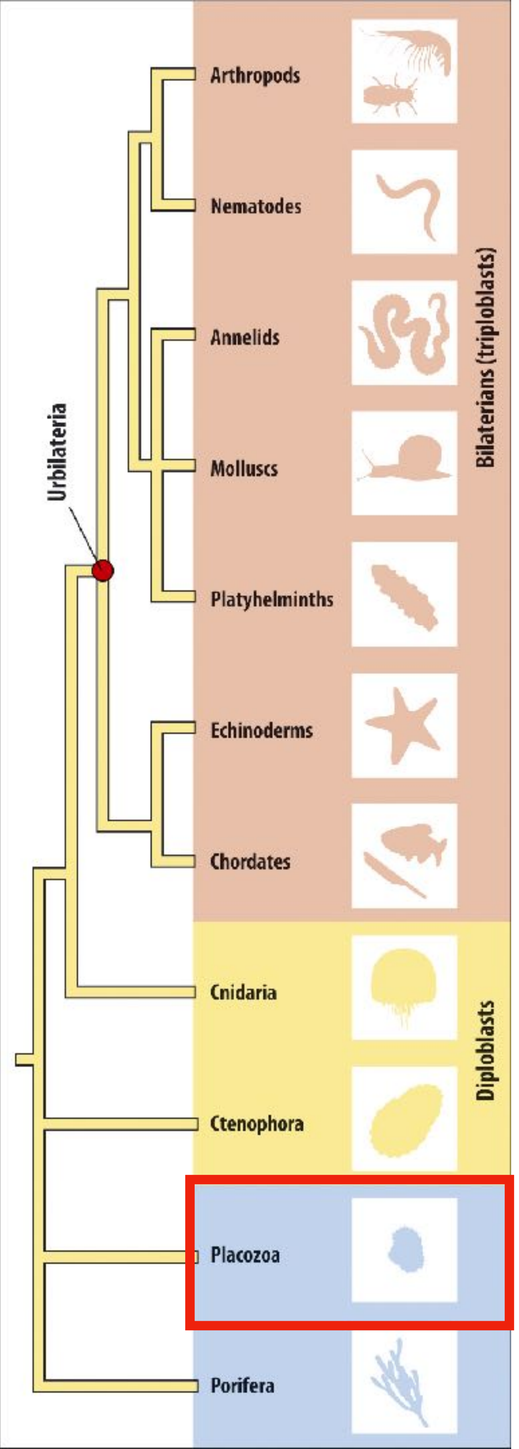
- **Eco-Devo (ecological developmental biology)**
- ***Developmental plasticity***
- Biotic - diet, crowding, predators
- Abiotic - temperature
- Symbiotic - bacteria
- **Evo-Devo (evolutionary developmental biology)**
- ***Modularity allows dissociation***
- Changes in morphology come from changes in development
- Regulatory mutations are known drivers of change
- Role for developmental plasticity in evolution

Developmental modules

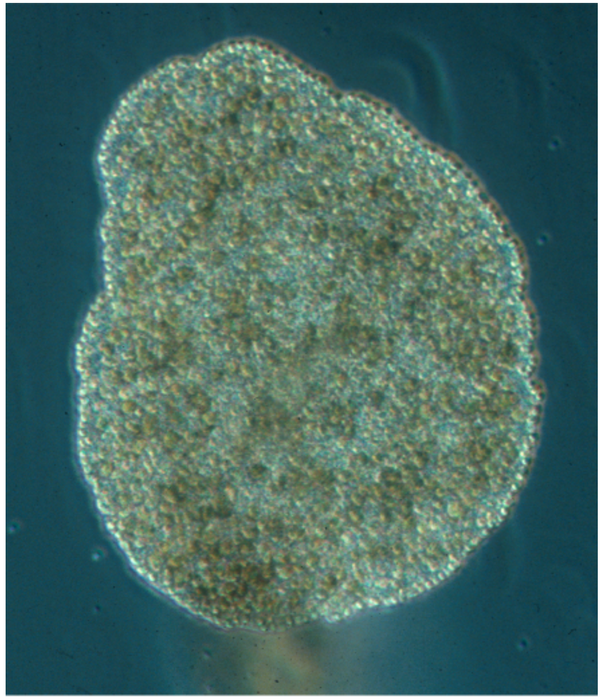
- Morphgenetic fields - organiser…
- Equivalence groups - proneural cluster…
- Signaling pathways - Wnt, Fgf, Notch…
- Cell lineages - muscle …
- Tissue mechanics - epithelial folding…
- Genes - duplicated families
- Regulatory DNA - promoters, enhancers…

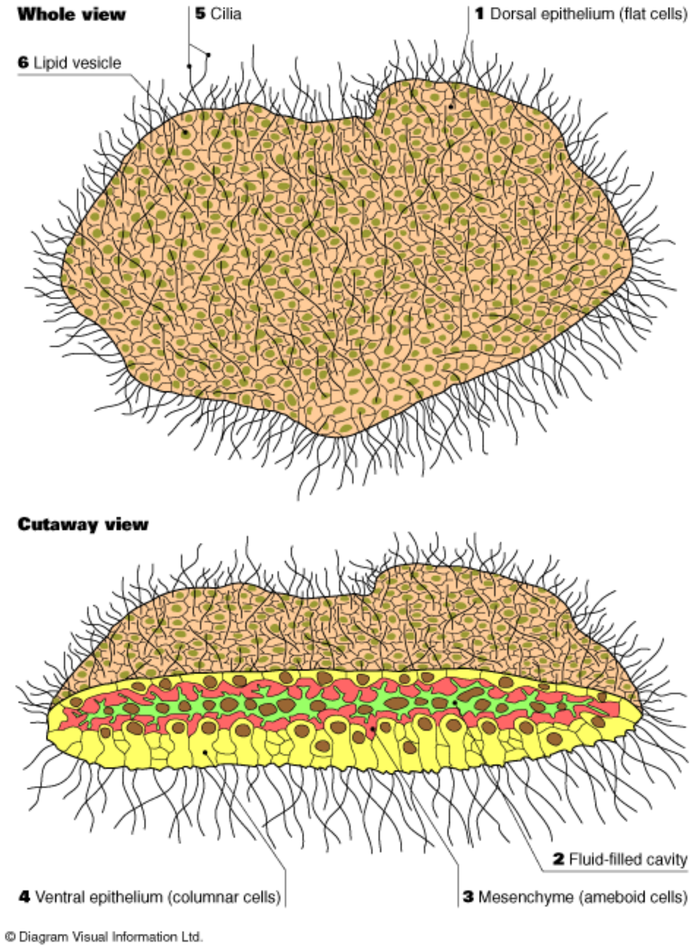
Q. Is evolving development just like shuffling cards?

Origin of animal body plans



Trichoplax adherens

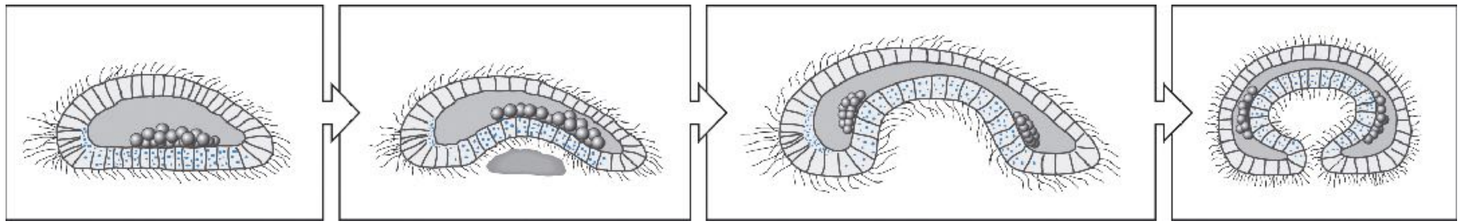


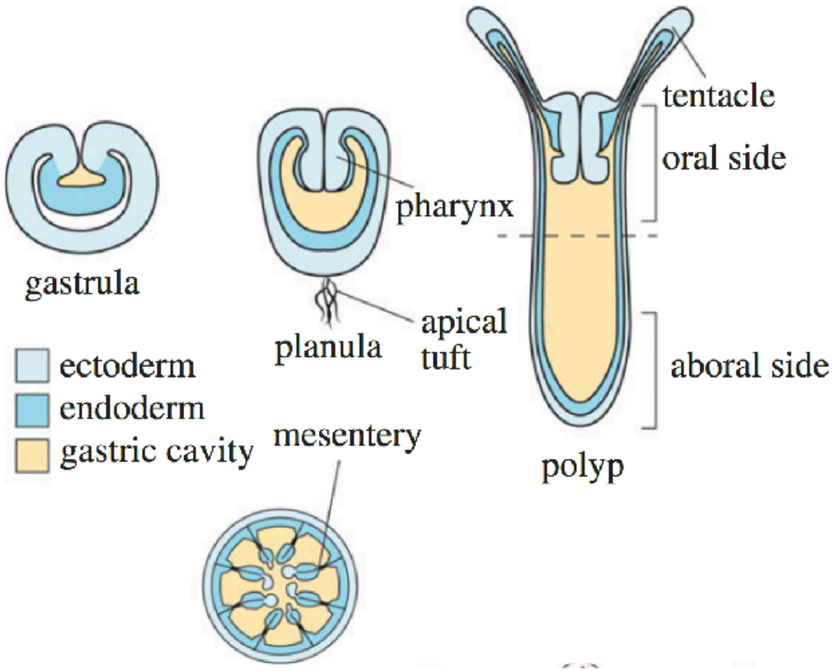


Small genome, 85% of its 11,514 predicted protein-coding genes have homologs in animals

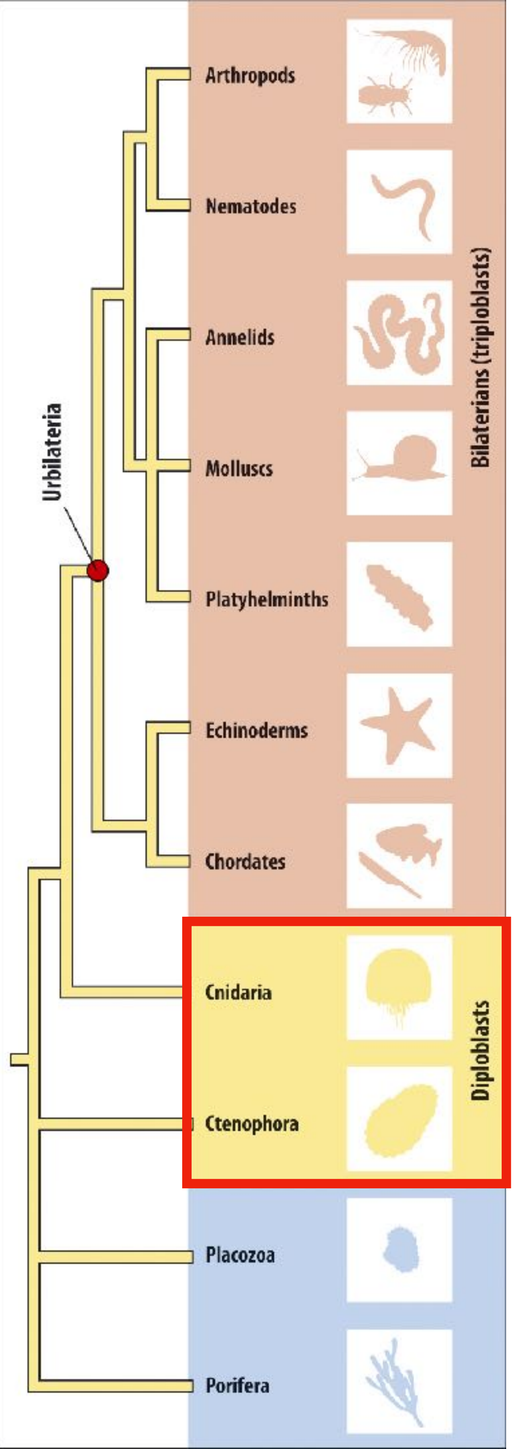
Origin of animal body plans

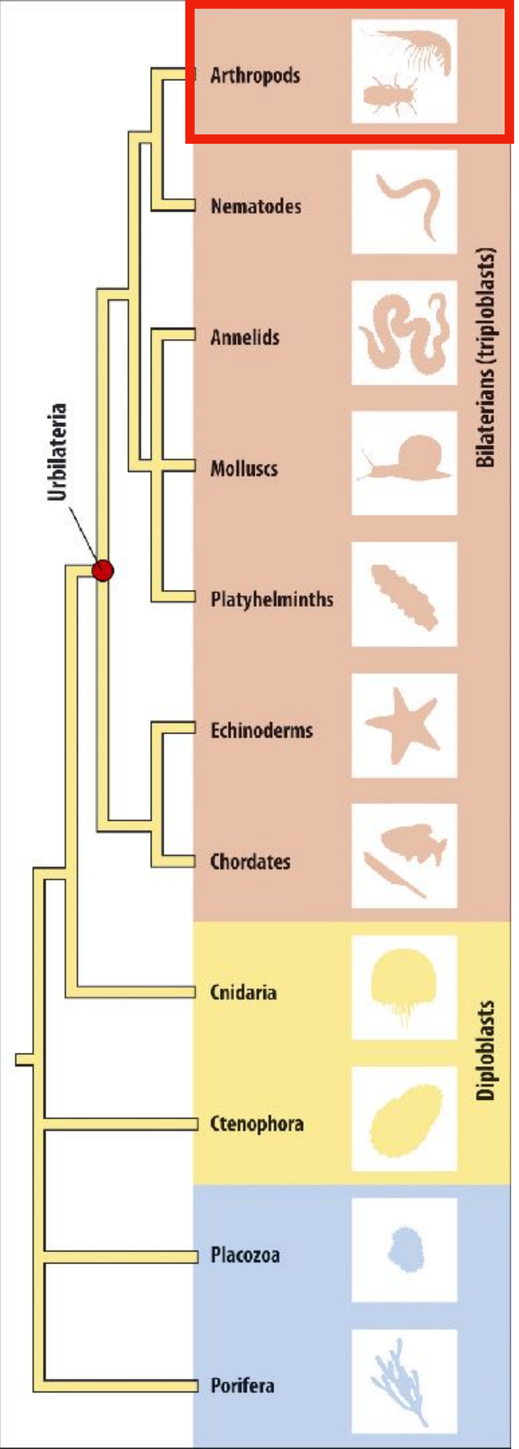
- Gastrula





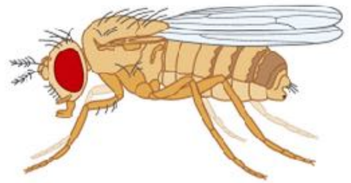
Kaleva, Phil. Trans. R. Soc. B, 2015





Origin of animal body plans

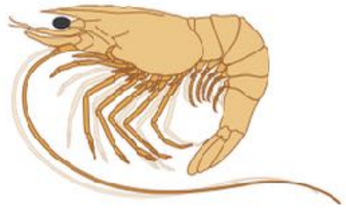
Drosophila



Insecta

Head						Thorax			Abdomen								
Oc	An	In	Mn	Mx	La	T1	T2	T3	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
						leg	leg	leg										
							wing	wing										

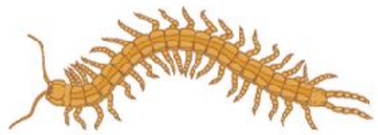
Shrimp



Crustacea (Malacostraca: Decapoda)

Head						Thorax (Pereon)								Abdomen (Pleon)						
Oc	An1	An2	Mn	Mx1	Mx2	T1	T2	T3	T4	T5	T6	T7	T8	A1	A2	A3	A4	A5	A6	A7
						mxp	mxp	mxp	leg	leg	leg	leg	leg	sw	sw	sw	sw	sw		

Centipede

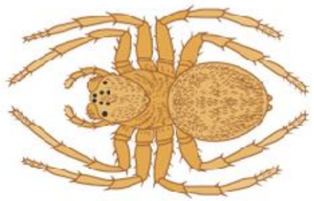


Myriapoda

Head							Trunk											
Oc	An	In	Mn	Mx1	Mx2	Mxp	T1	T2	T3	T4	T5	T6	T7	T8	T9			
						mxp	leg	leg	leg	leg	leg	leg	leg	leg	leg			

more posterior segments added with growth (all with legs)

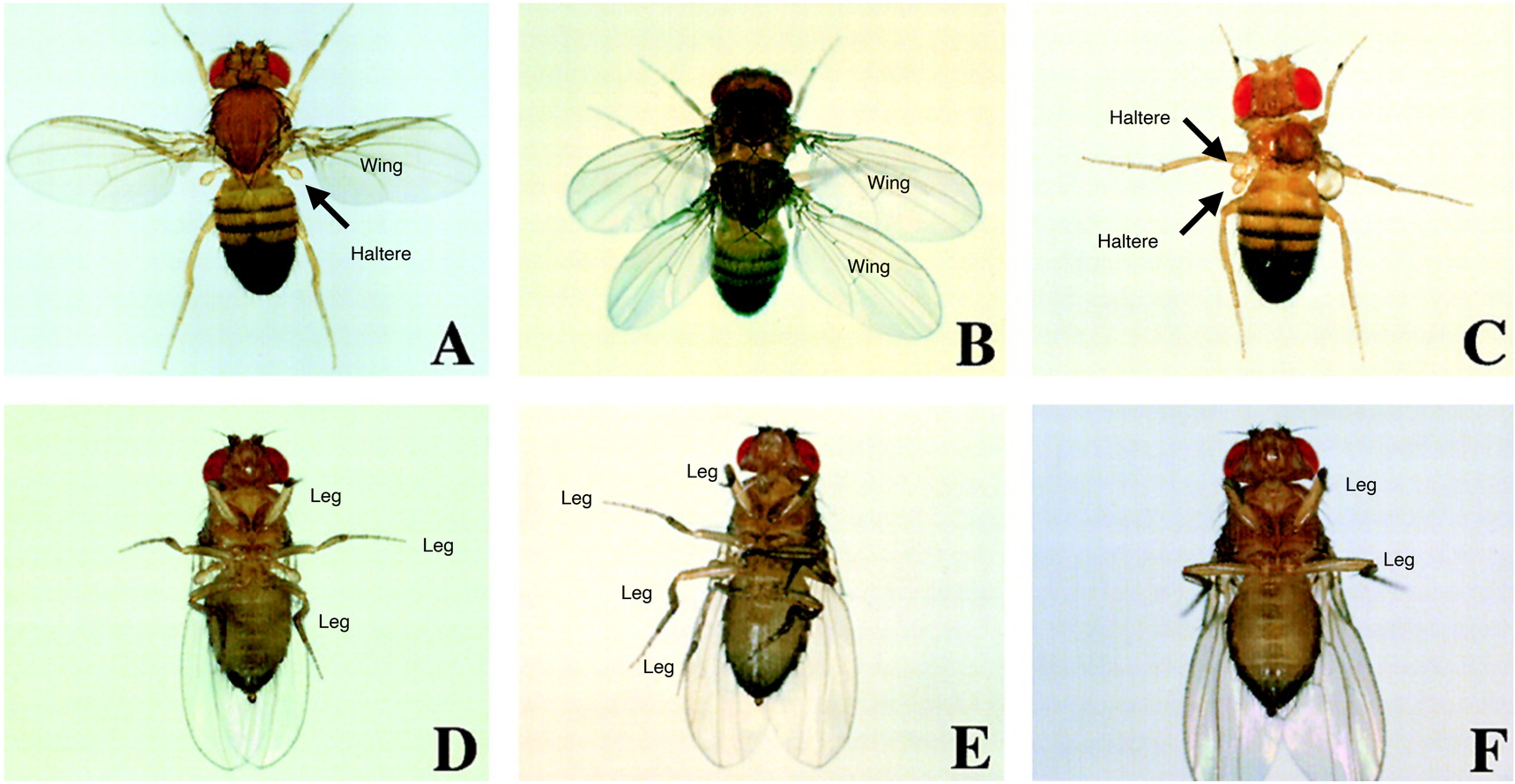
Spider



Chelicerata

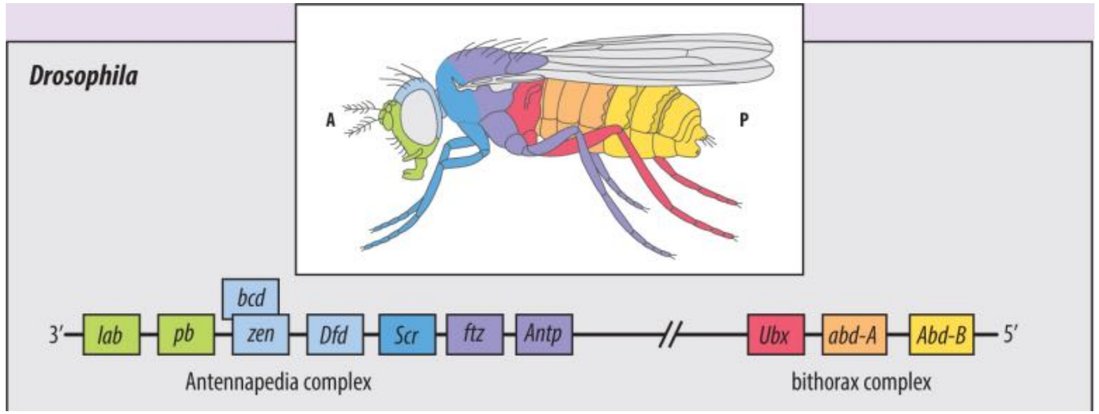
Prosoma							Opisthosoma								
Oc	Ch	Pp	L1	L2	L3	L4	01	02	03	04	05	06	07	08	09
			leg	leg	leg	leg									

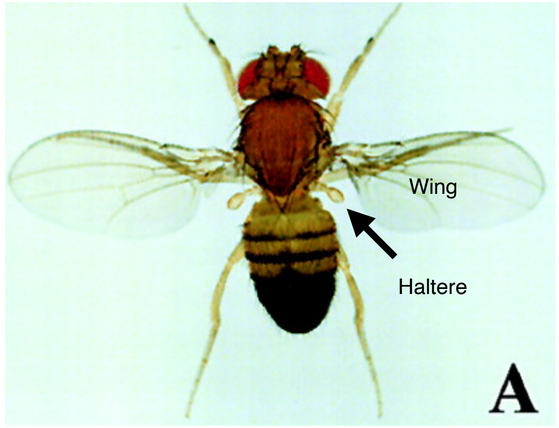
Homeotic mutations change identity of segments

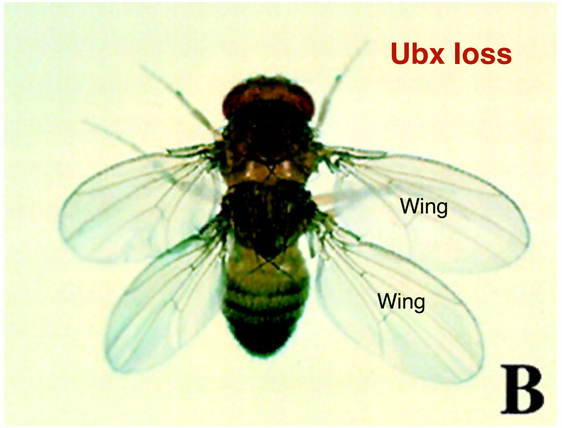


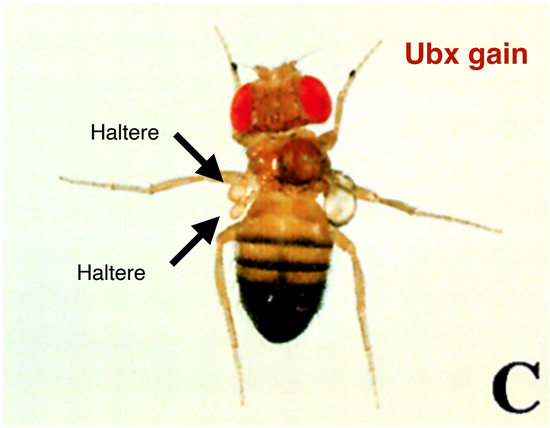
Ed Lewis, Nobel Prize 1995

Hox gene organisation and expression

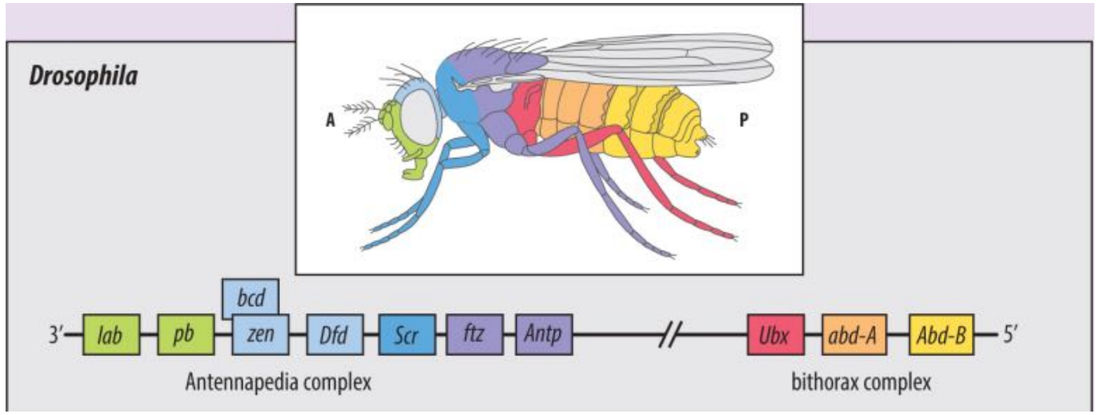


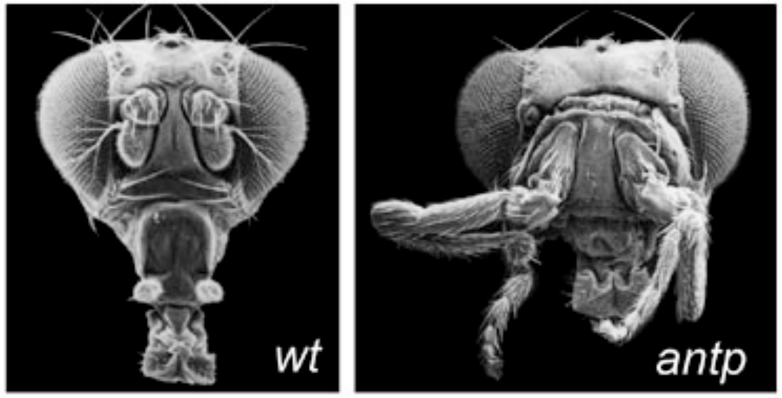






Hox gene organisation, expression and "Master genes"

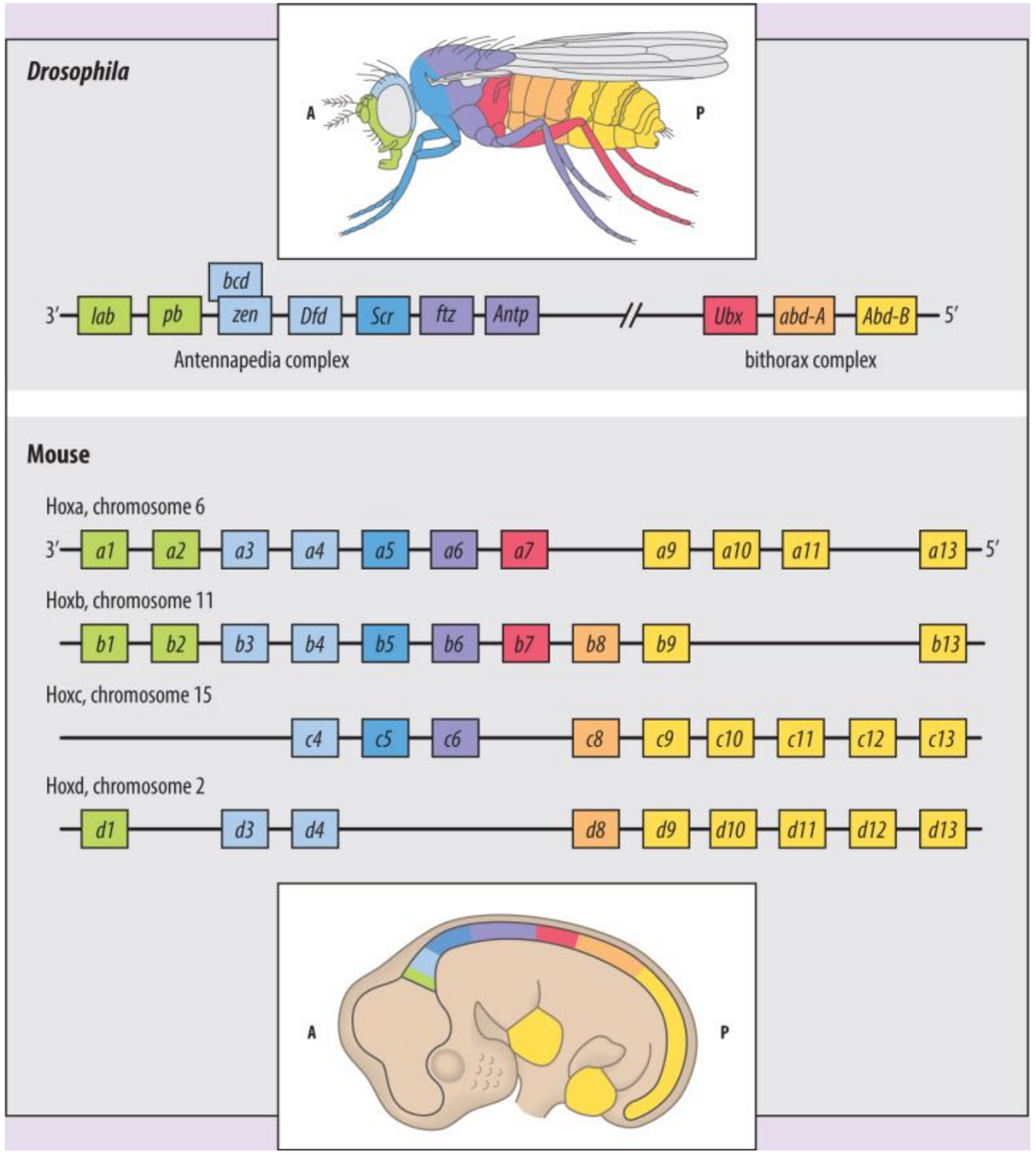


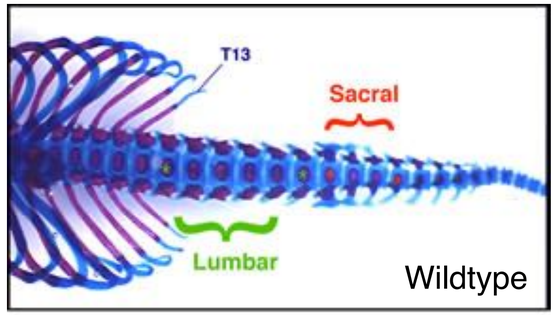


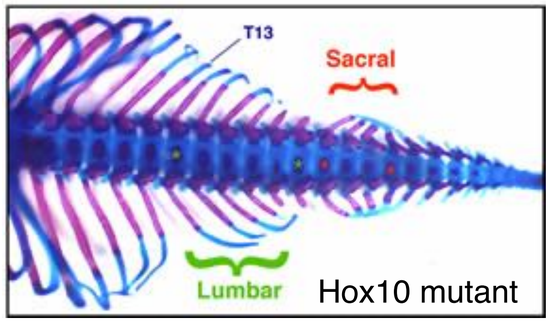
Pax6 (eyeless) expressed by *pb* enhancer

Pax6 (eyeless) expressed in all segments

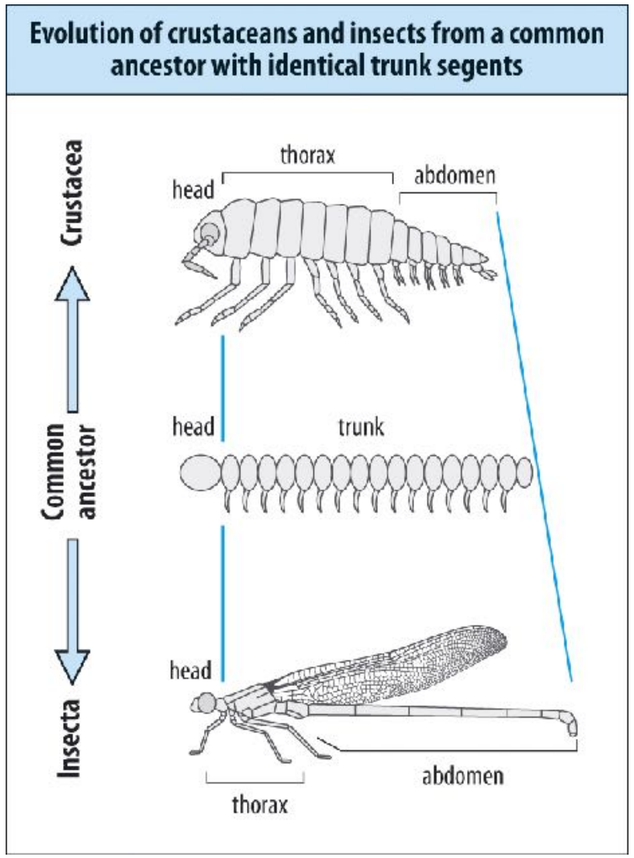
Hox gene organisation and expression



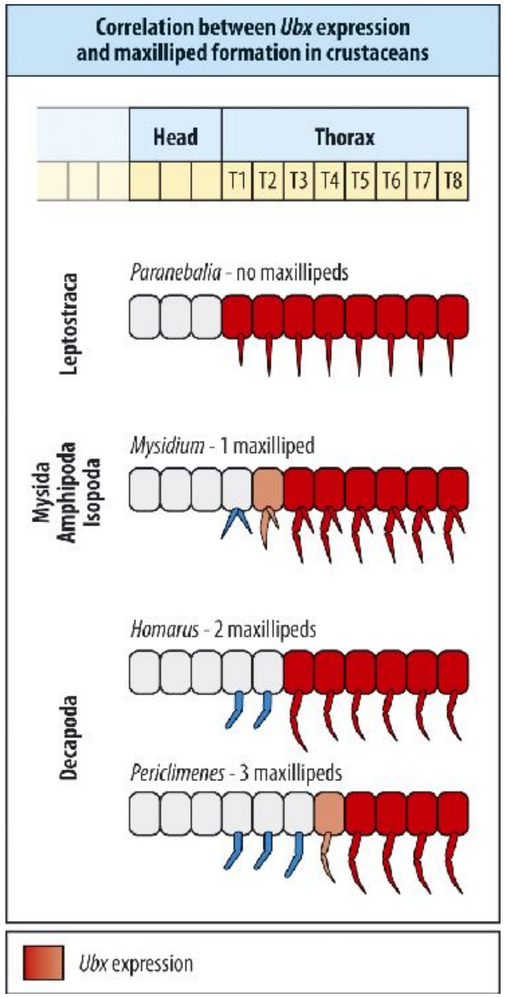




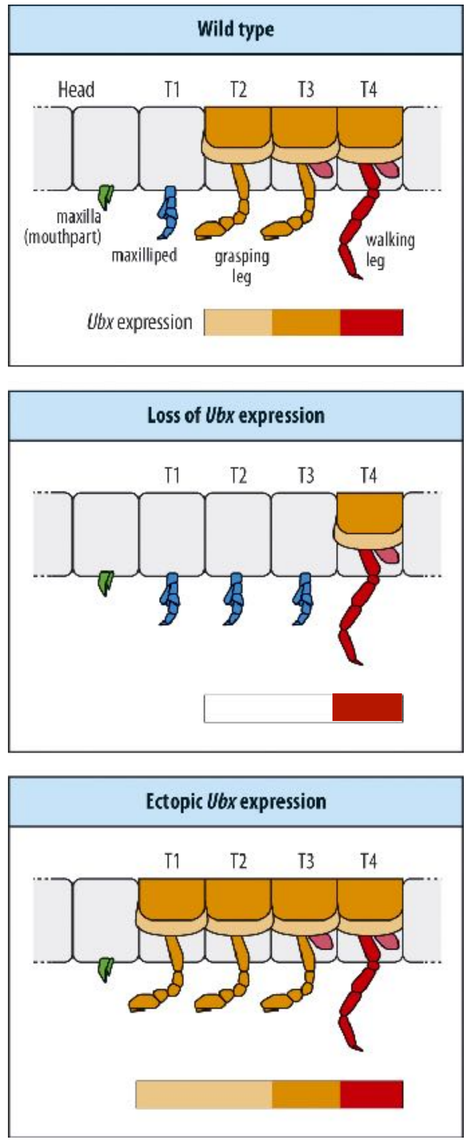
Hox genes and arthropod body plans



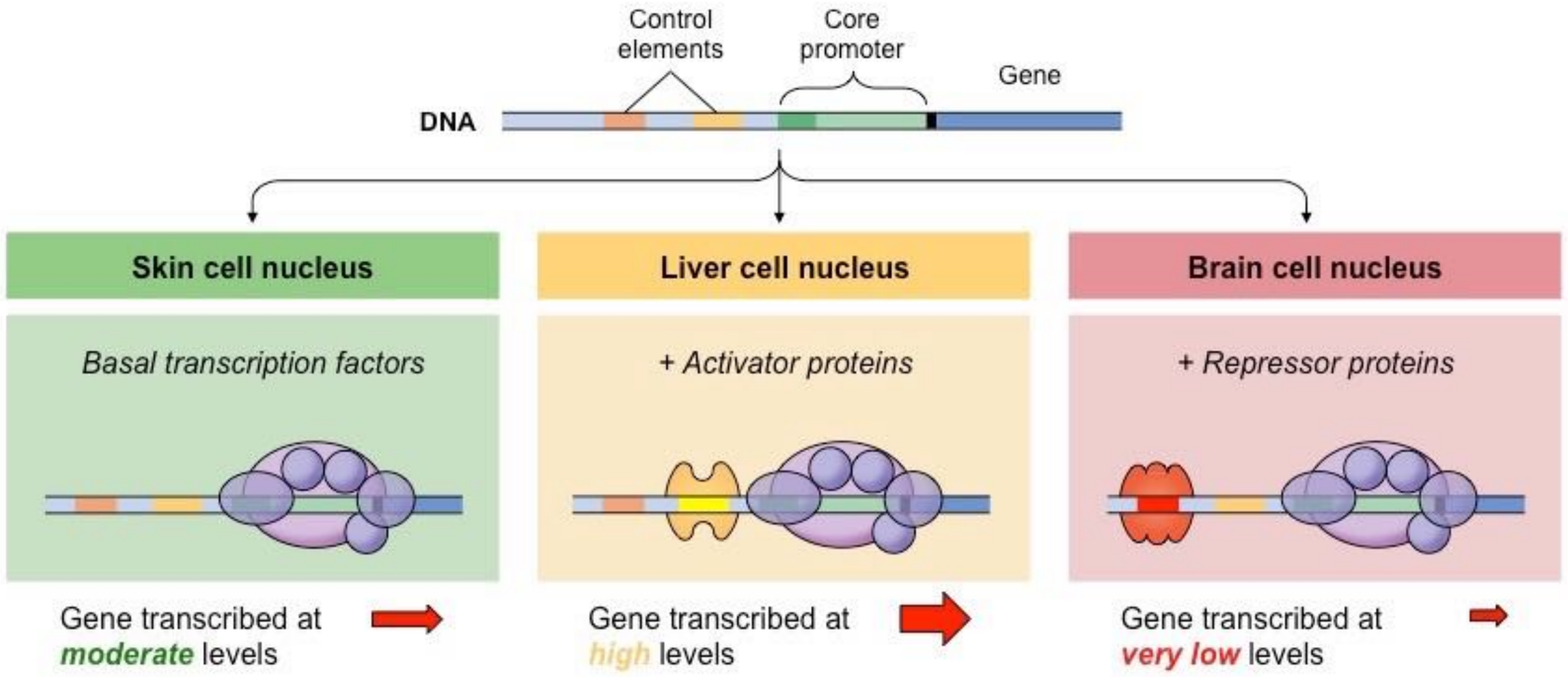
Evolution



Experiment

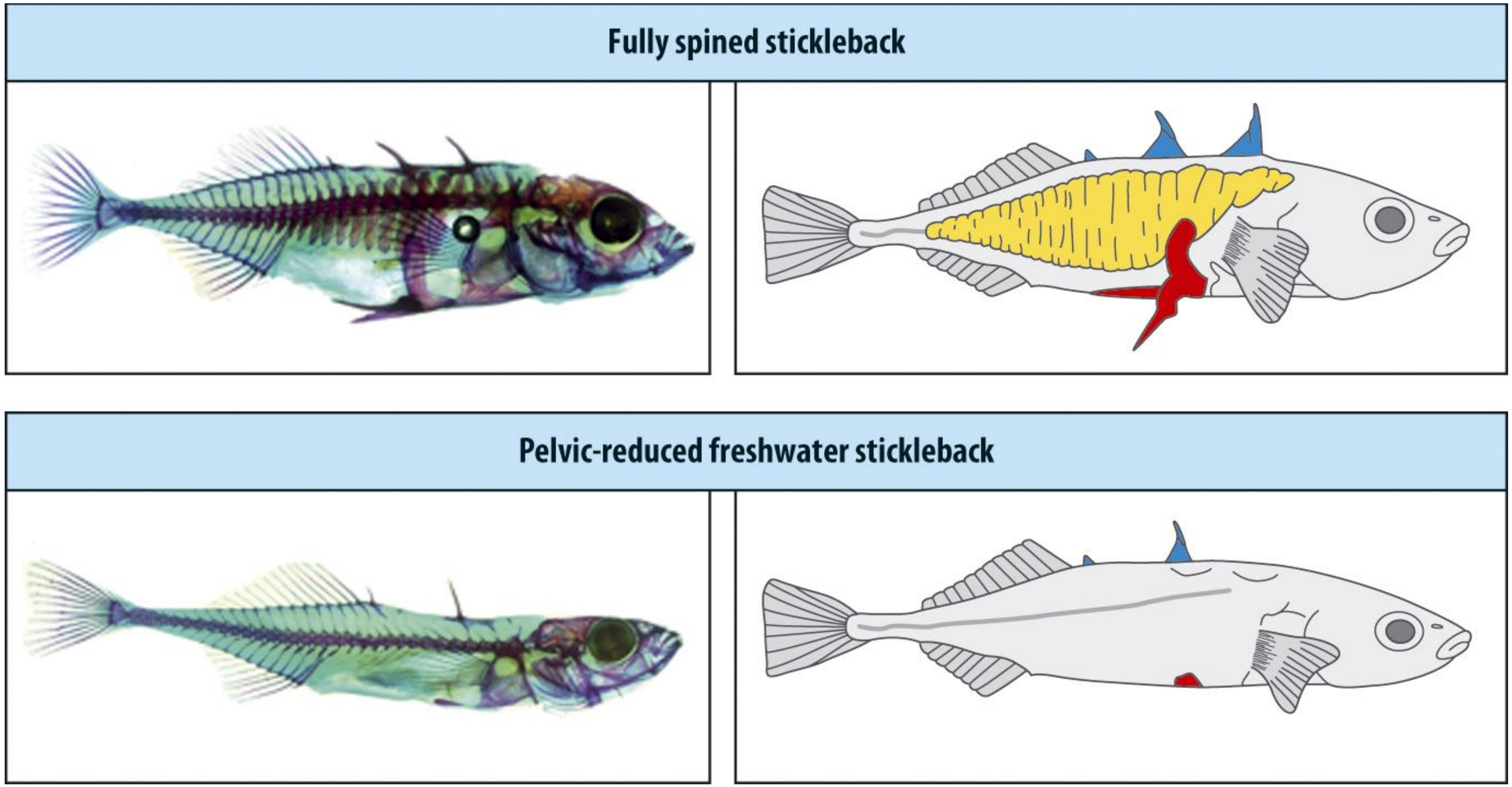


Differential gene expression



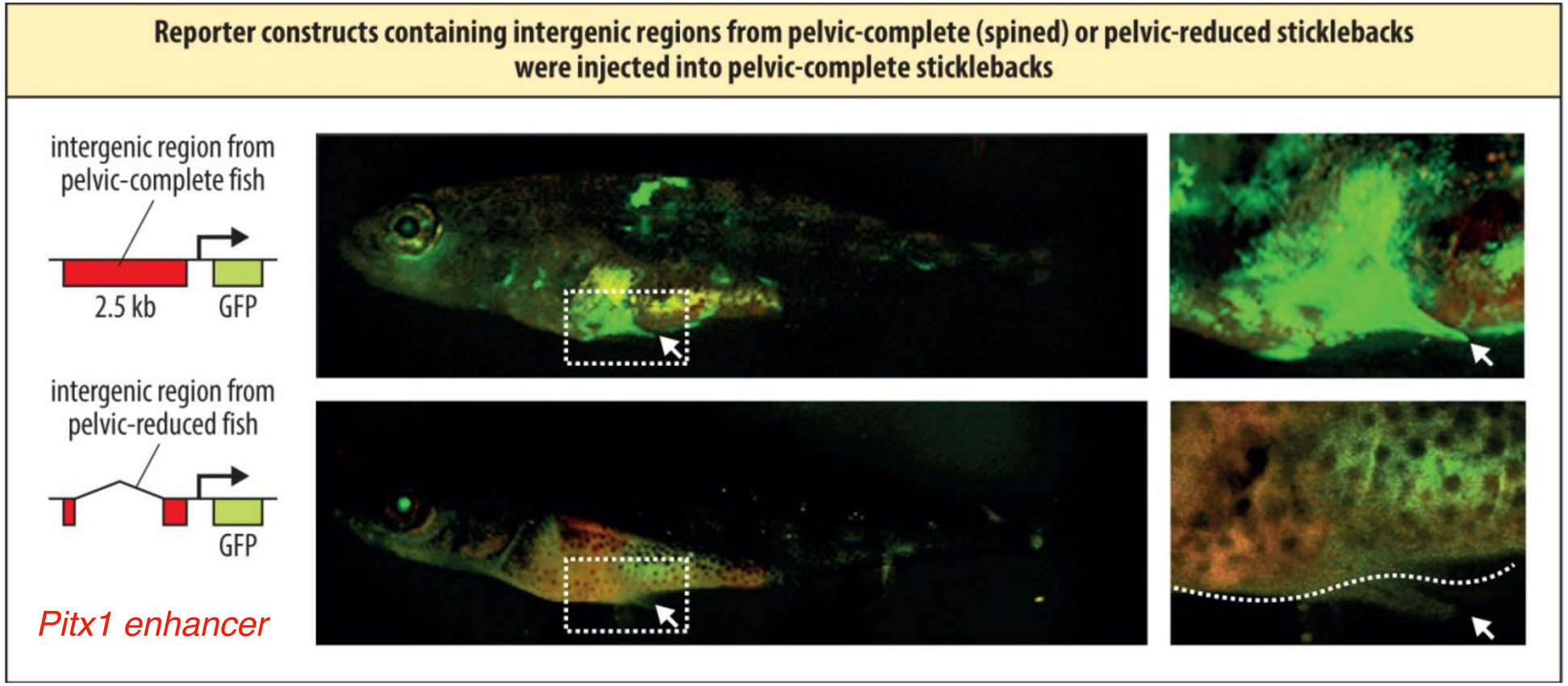
Which *part* of the gene is involved in evolutionary transitions?

Modular enhancers I

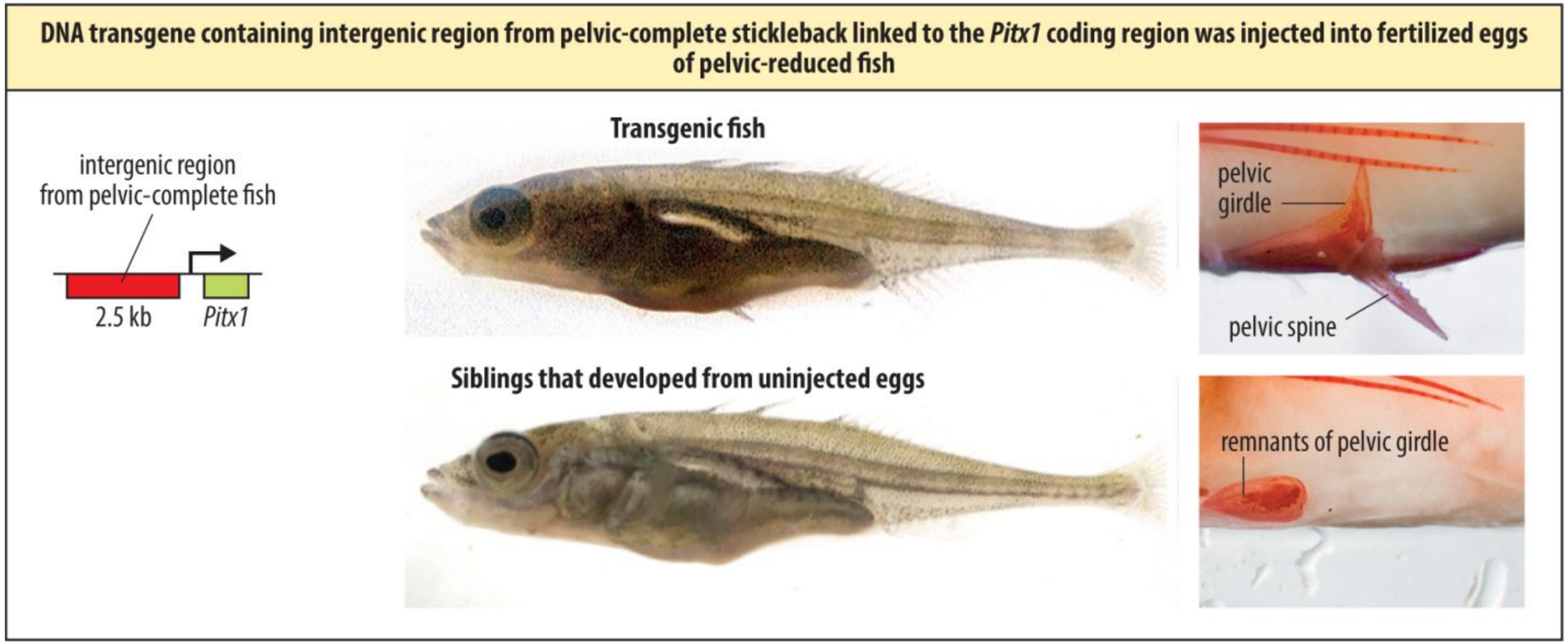


Pitx1 is expressed in the pelvic anlage of vertebrates - mouse KO reduces hind-legs

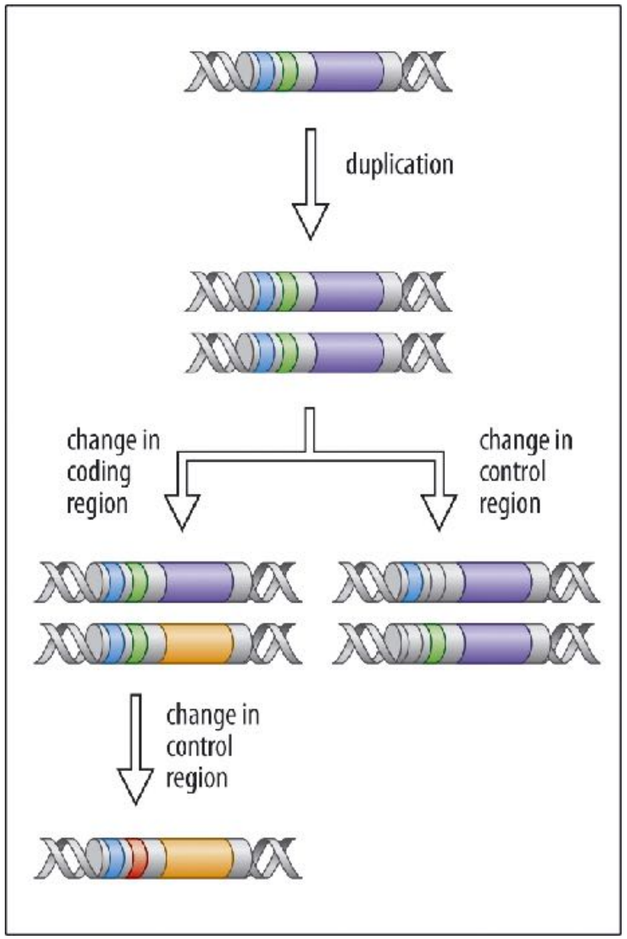
Modular enhancers 2

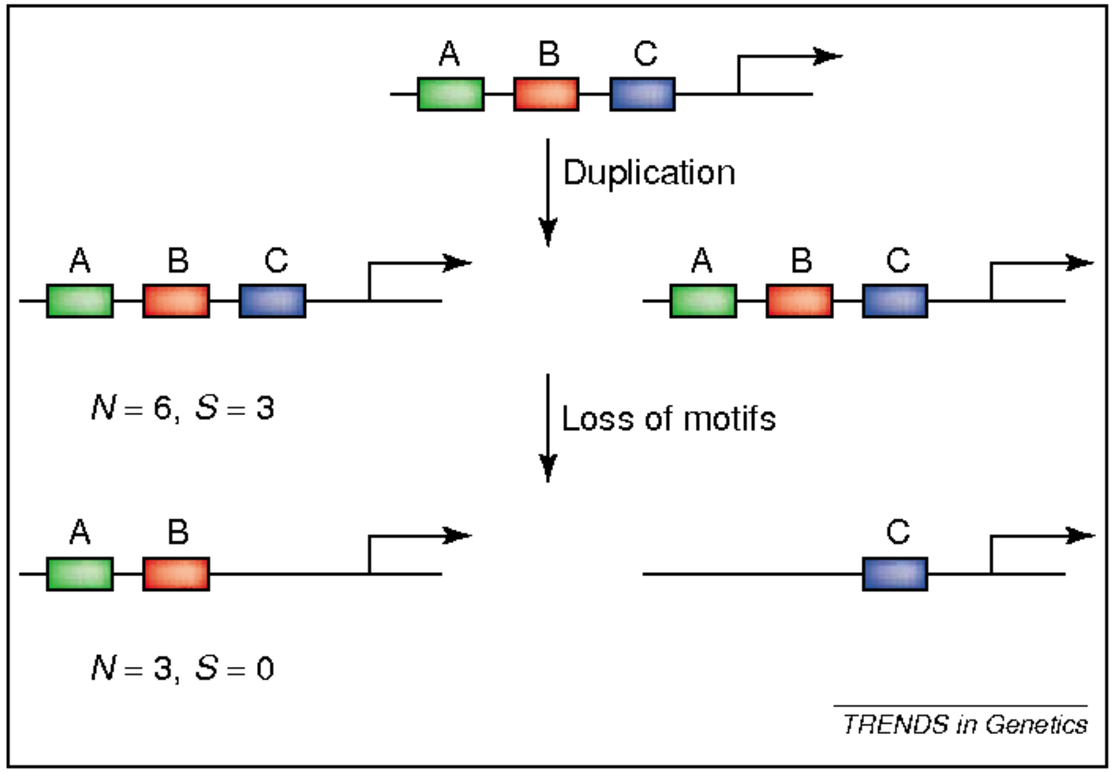


Modular enhancers 3

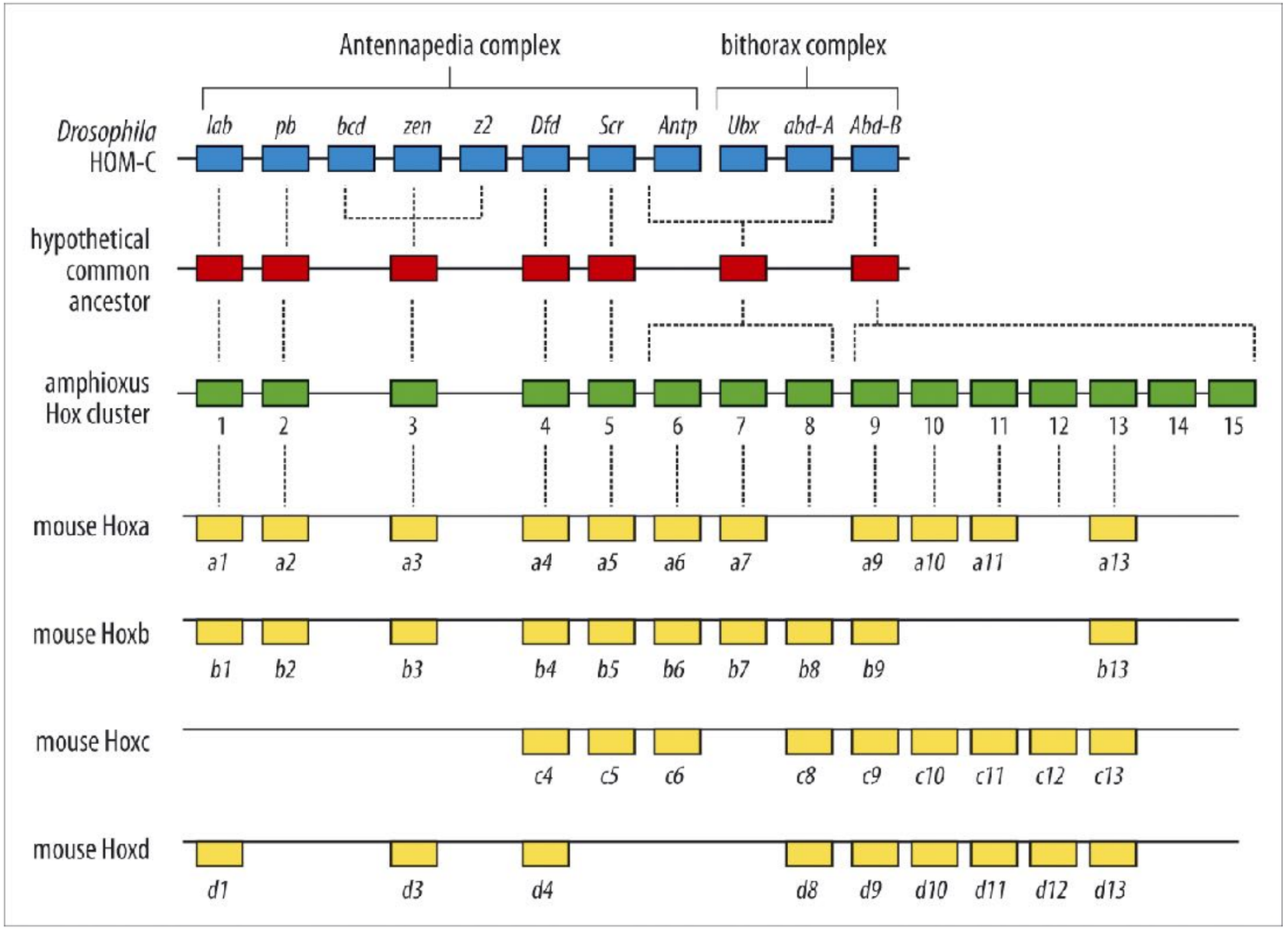


Duplication, Divergence, Complementation





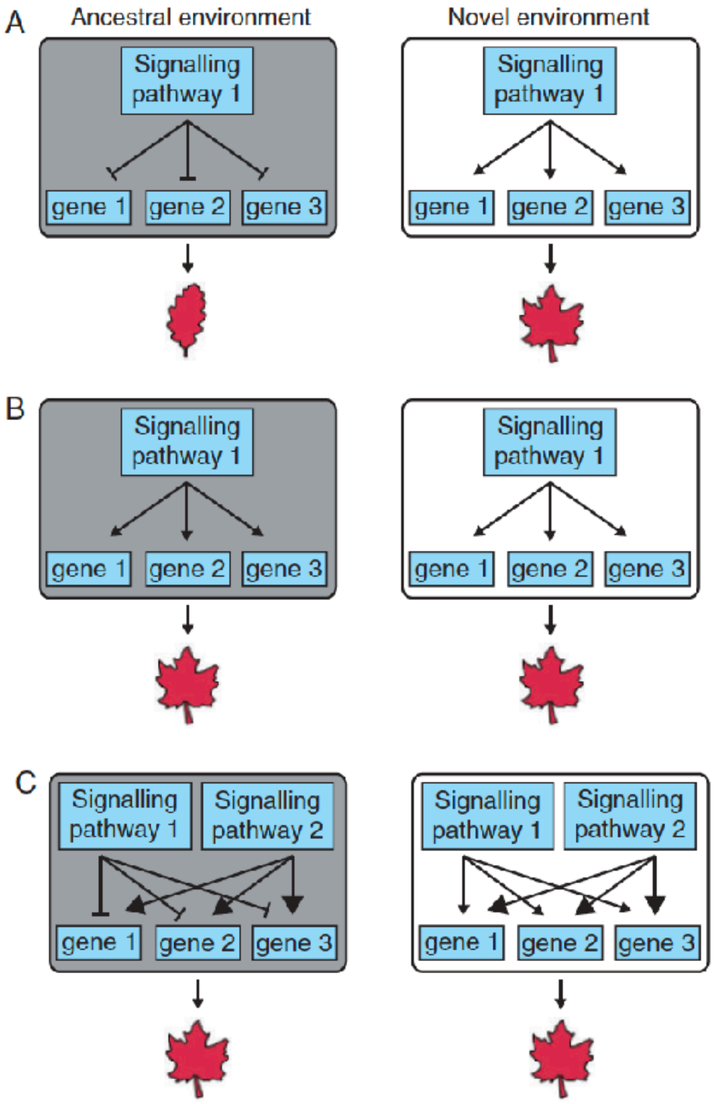
Hox gene clusters



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

Summary

- **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

Questions?