EVOLUTION AND DEVELOPMENT (EVODEVO)

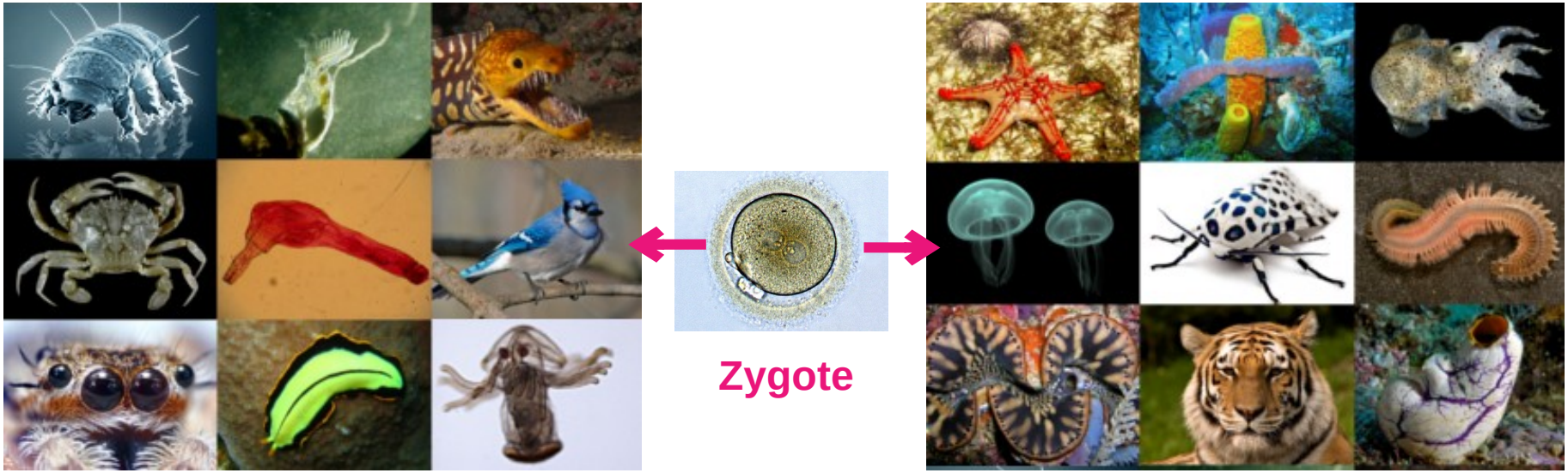
Evolution and the Natural World

Lecture 11

13/10/2021

Vasili Pankratov

Body plans (animal examples)



https://en.wikipedia.org/wiki/Body_plan#
By Nina Sesina - https://commons.wikimedia.org/wiki/File:Zygote.tif, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=67459911

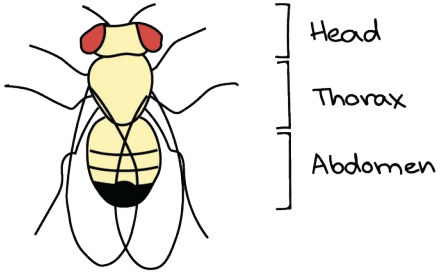
Questions in Developmental Biology

- How is development controlled?
- What is the link between development and evolution? (this is studied by evolutionary developmental biology or EvoDevo)

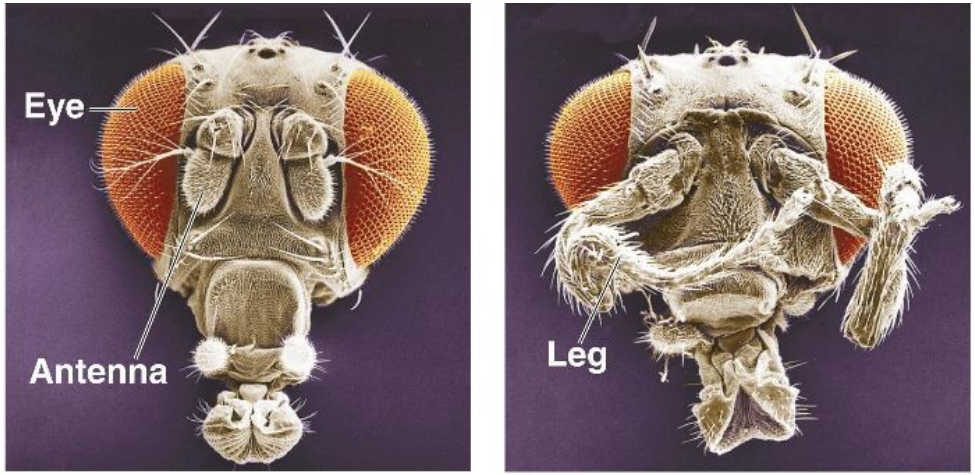
CONTROL OF ORGANISM DEVELOPMENT

Genetics + Environment

Genetics of development

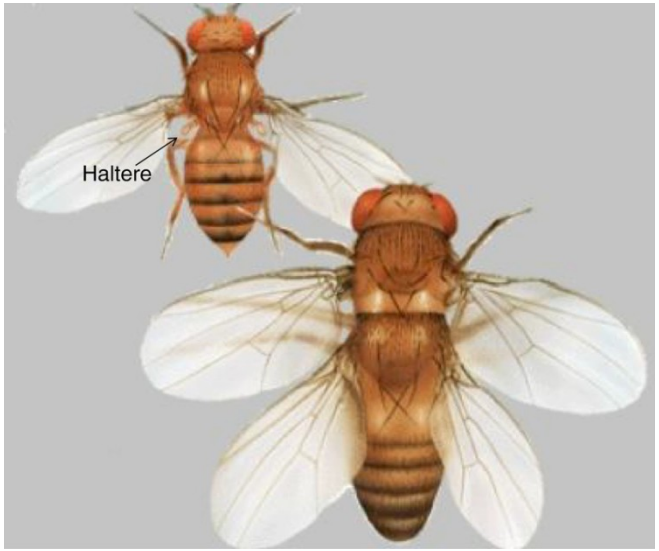


- Search for mutants (mutation screens)
- **Homeotic mutations**



Antennapedia mutation

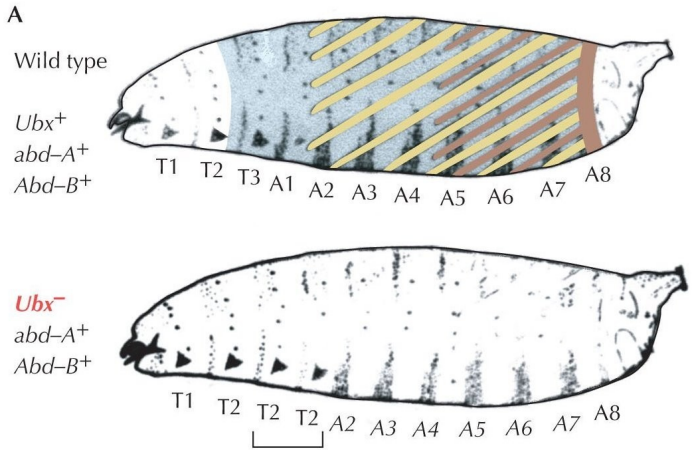
Bithorax mutation



https://infograph.venngage.com/p/219814/homeotic-genes
https://www.researchgate.net/figure/The-four-winged-fruit-fly-In-the-homeotic-mutant-bithorax-the-halteres-which-are-a_fig3_258524737

Genetics of development

- Examples above are due to mutations changing the place of expression of homeotic genes
- Loss-of-function mutations are lethal but studying the embryos shows interesting patterns

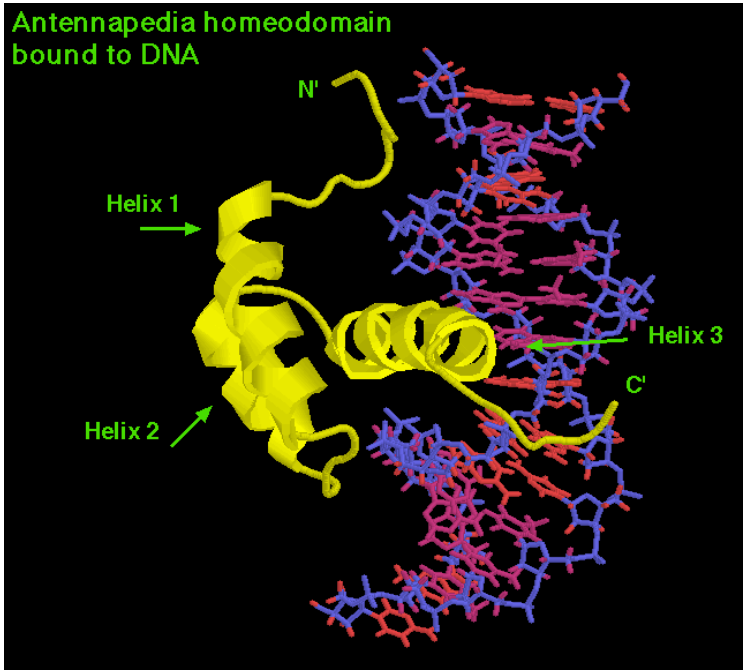


Anterior end

Posterior end

http://evolution-textbook.org

Oh, those names!



- **Homeotic genes** – mutations lead to homeosis (one structure develops in place of another)
- **Homeobox genes** – genes with a specific 180 bp long sequence motif coding for the **homeobox domain**. This is the DNA-binding domain of these proteins.
- **Hox-genes** – a special case of Homeobox genes involved in identity along AP axis

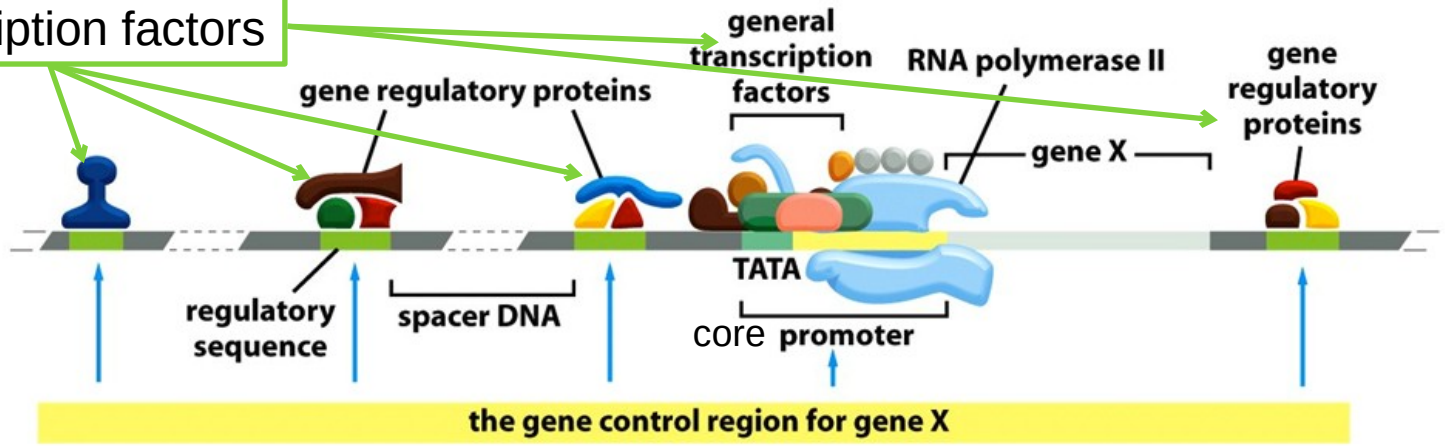
Genetics of development

- **Conclusion:** there are individual genes that regulate certain developmental process (i.e. segment identity in Drosophila regulated by the Hox-genes)

- But how do they work?

Regulation of gene expression

Transcription factors



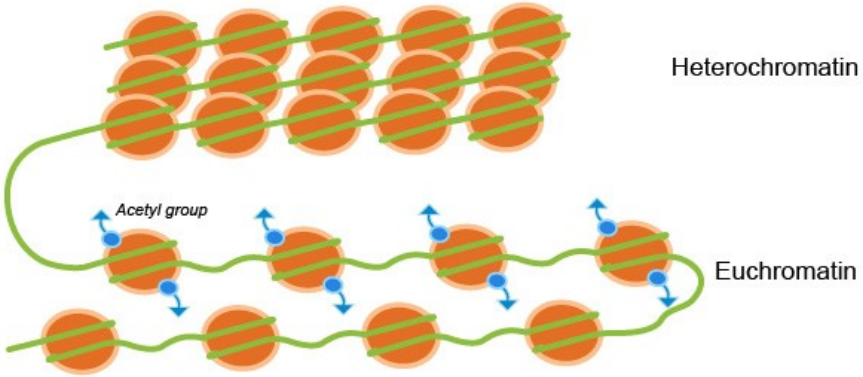
Genes controlling development (like Hox-genes) code for TF

TF regulating transcription of many genes incl other TF are called **Master Regulators**

Figure 7-44 *Molecular Biology of the Cell* (© Garland Science 2008)

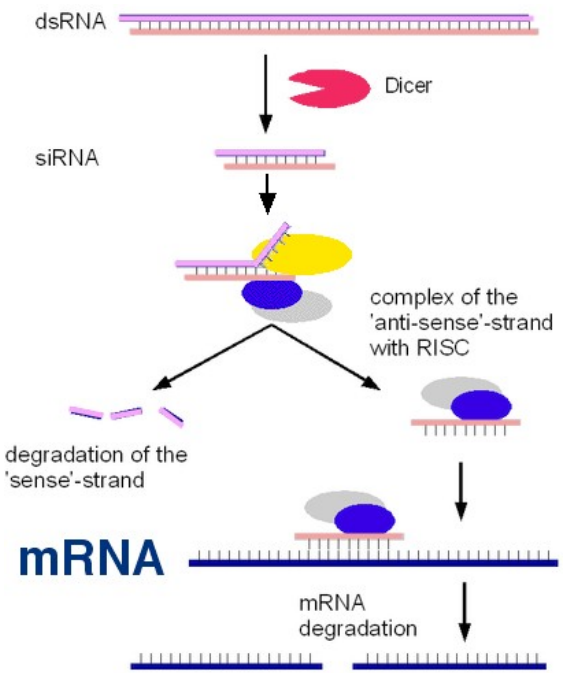
More mechanisms

Chromatin remodeling

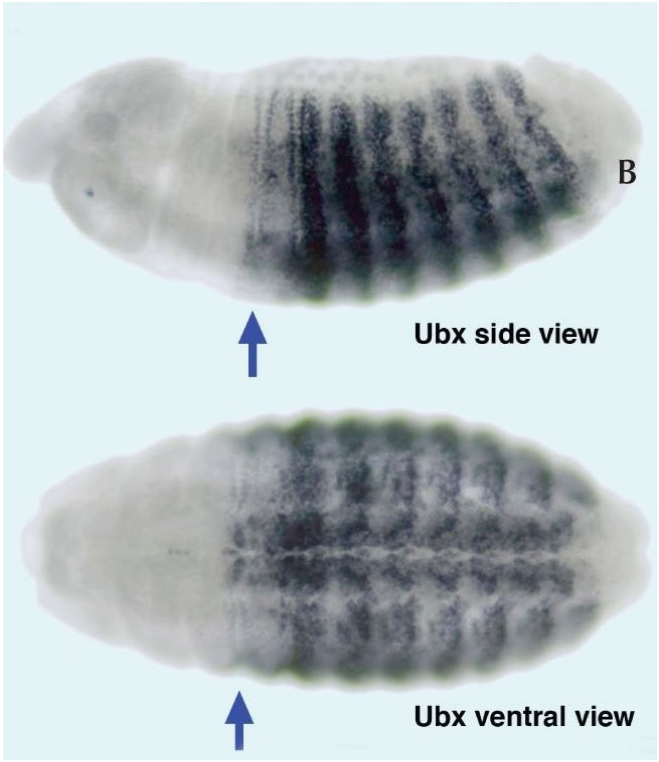


https://www.whatisepigenetics.com/chromatin-remodeling/

RNA decay



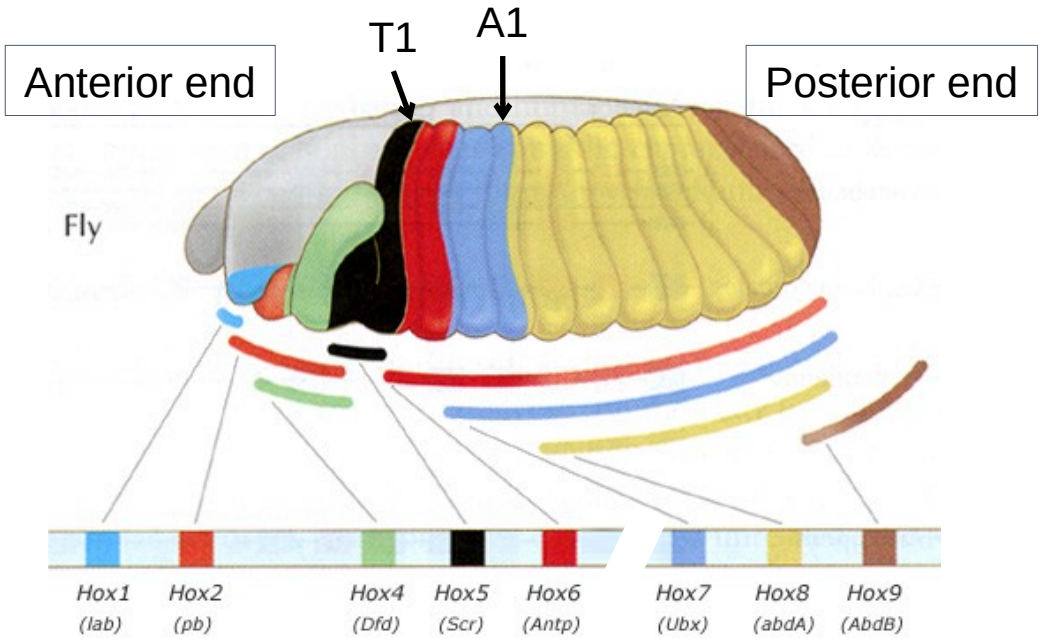
Hox-proteins distribution



- Each Hox-protein has its' specific localization in the fly's embryo (and hence activates corresponding genes only in those body parts)
- Changes in this pattern lead to homeotic mutations

http://evolution-textbook.org

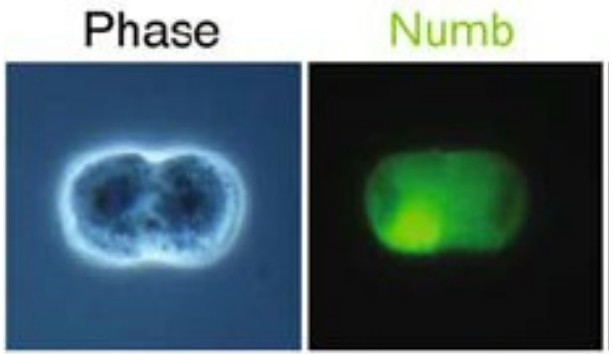
Hox-proteins distribution



https://www.pbs.org/wgbh/nova/genes/fate-03.html

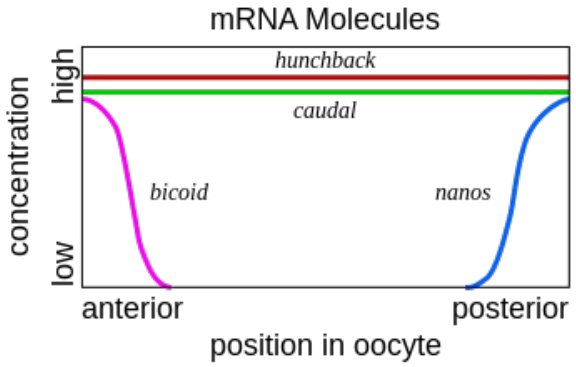
- Segment's fate is determined by local concentrations of different Hox-proteins
- There is a AP gradient of each of the Hox-proteins in the embryo
- BTW, the order of Hox-genes on the chromosome corresponds to their expression along the AP axis

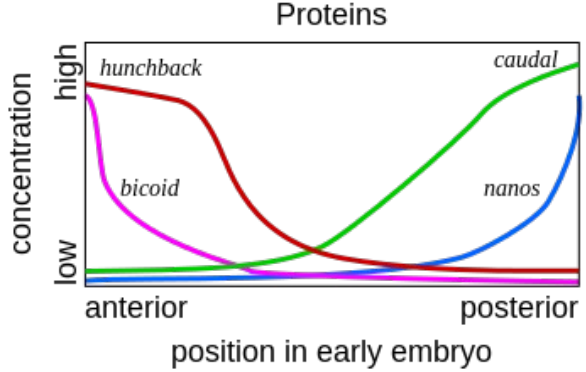
But how is the gradient established?



https://www.researchgate.net/figure/Asymmetric-segregation-of-Numb-in-non-differentiating-satellite-cell-derived-myoblasts_fig3_23670250

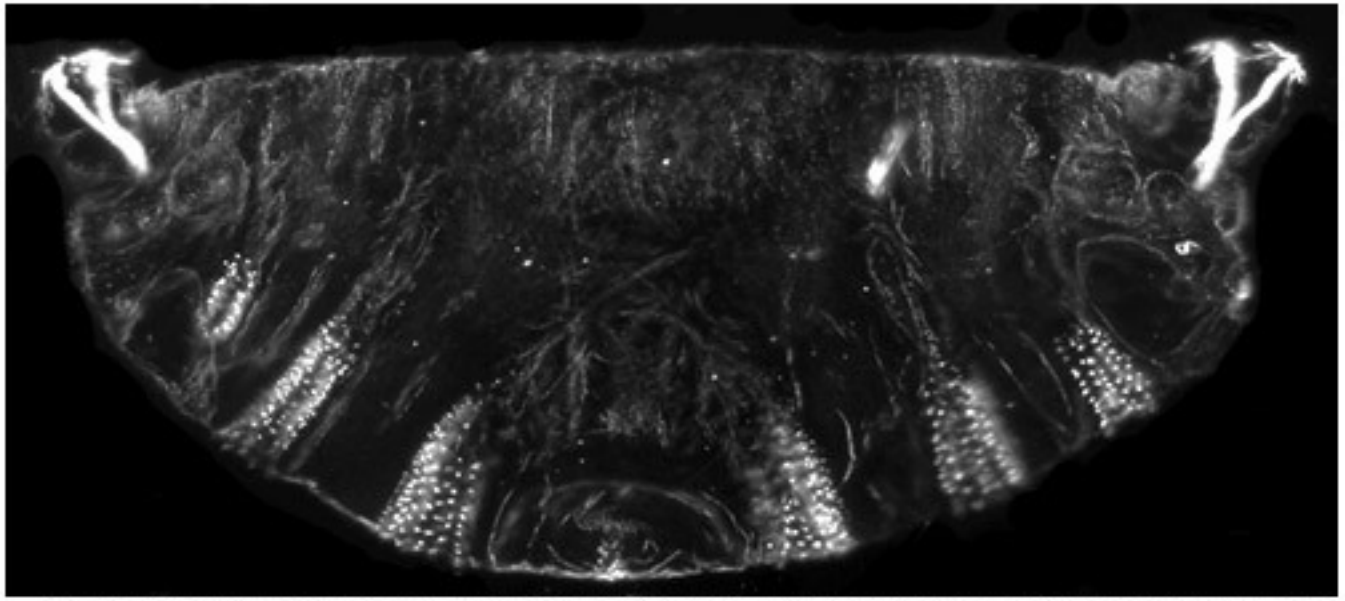
- Asymmetric transfer of mRNA into the egg cell from surrounding cells
- Asymmetric distribution of proteins and mRNA during cell division





https://en.wikipedia.org/wiki/Drosophila_embryogenesis

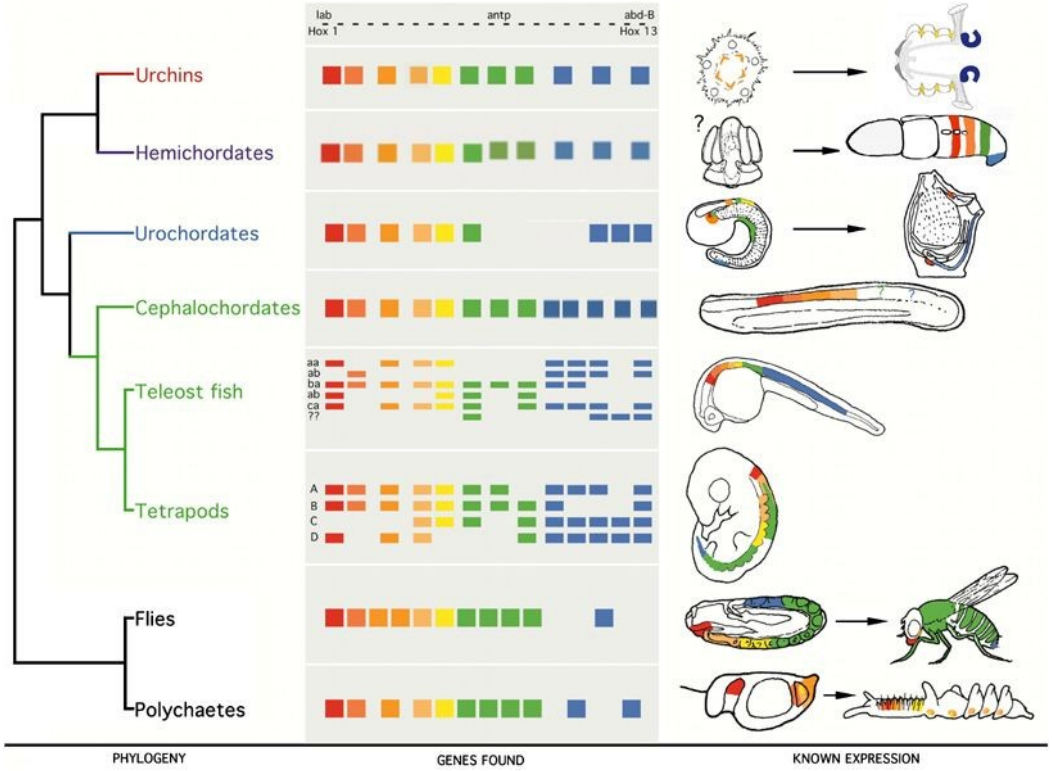
Bicoid mutant (homozygote)



Courtesy of S. Luschnig and F. Schnorrer, Max-Planck-Institut for Developmental Biology, Tübingen. Noncommercial, educational use only.

https://dnalc.cshl.edu/view/16771-Gallery-37-Drosophila-null-bicoid-mutant

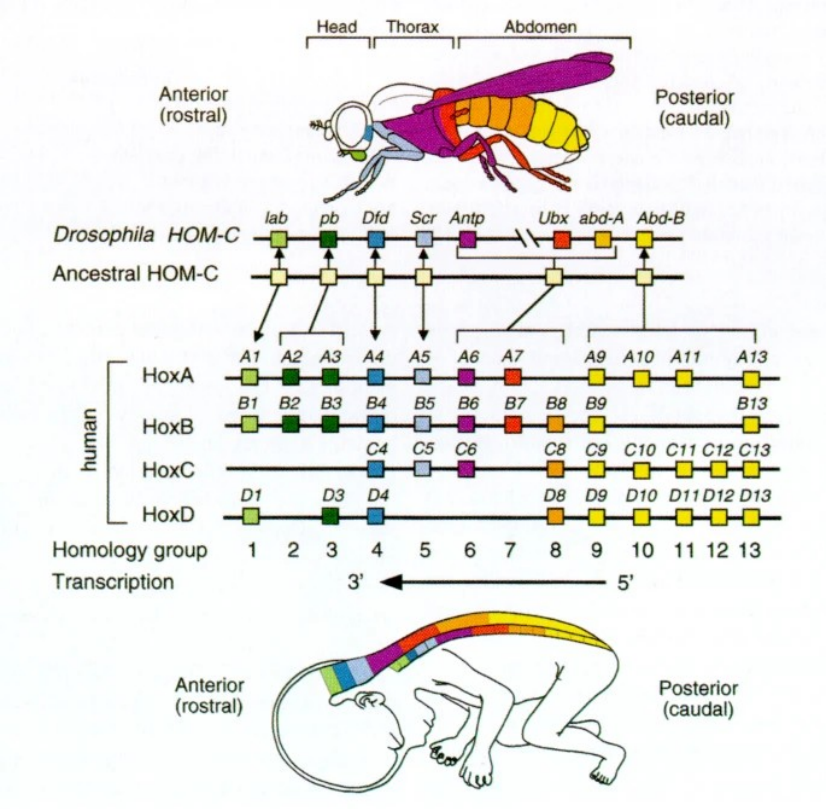
Why care about the fly?



- Genes, homologous to Drosophila Hox-genes are found in all Metazoa
- In all cases they play a role in providing local identity along the AP axis
- Pathways of animal development are highly conserved

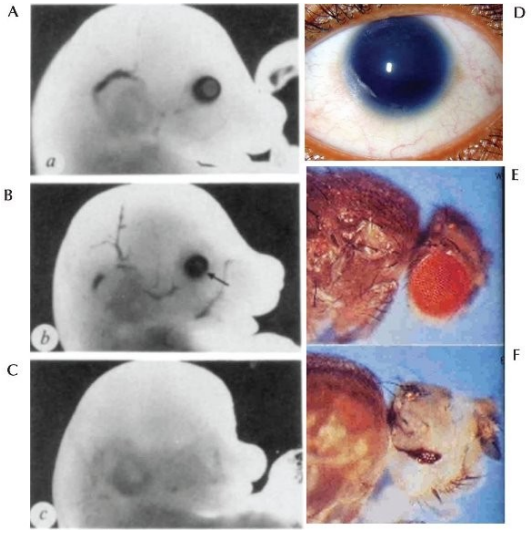
https://www.nature.com/articles/6800872?WT.mc_id=PIN_NPG

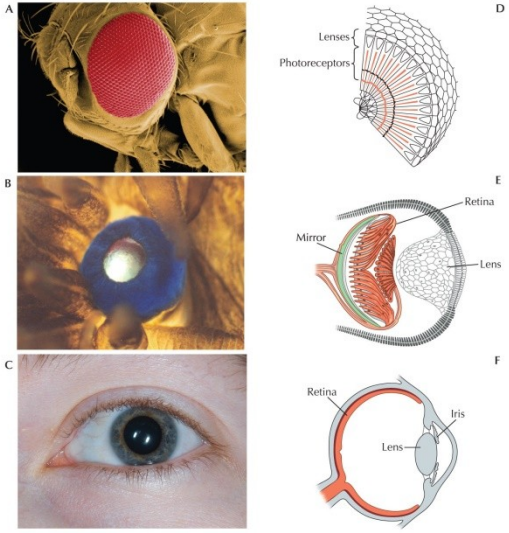
Hox genes in mammals



https://www.nature.com/articles/pr19972506

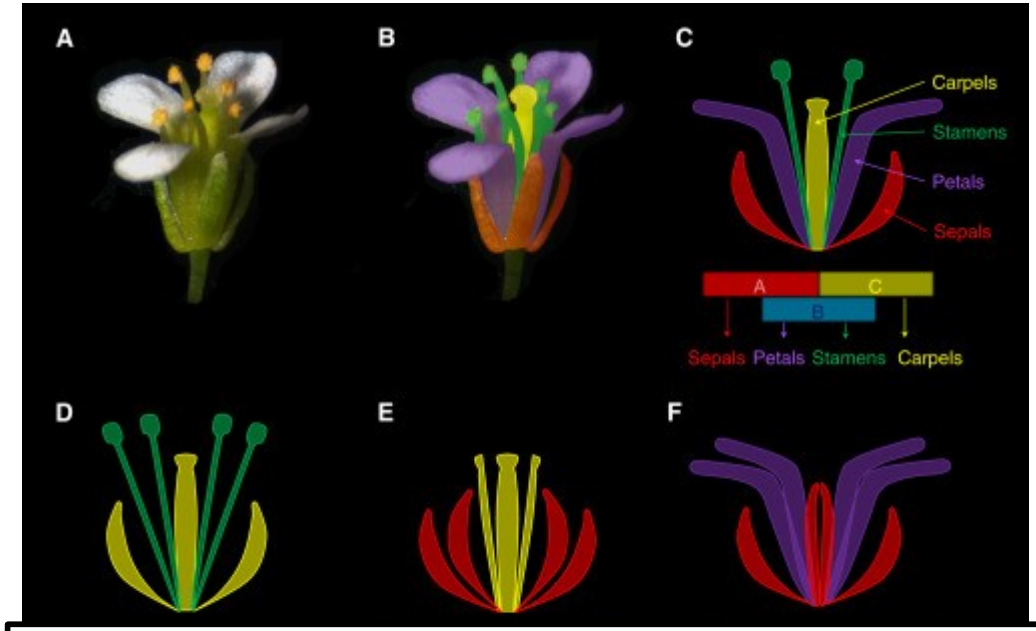
One more example of high conservation: *Pax6* gene





http://evolution-textbook.org

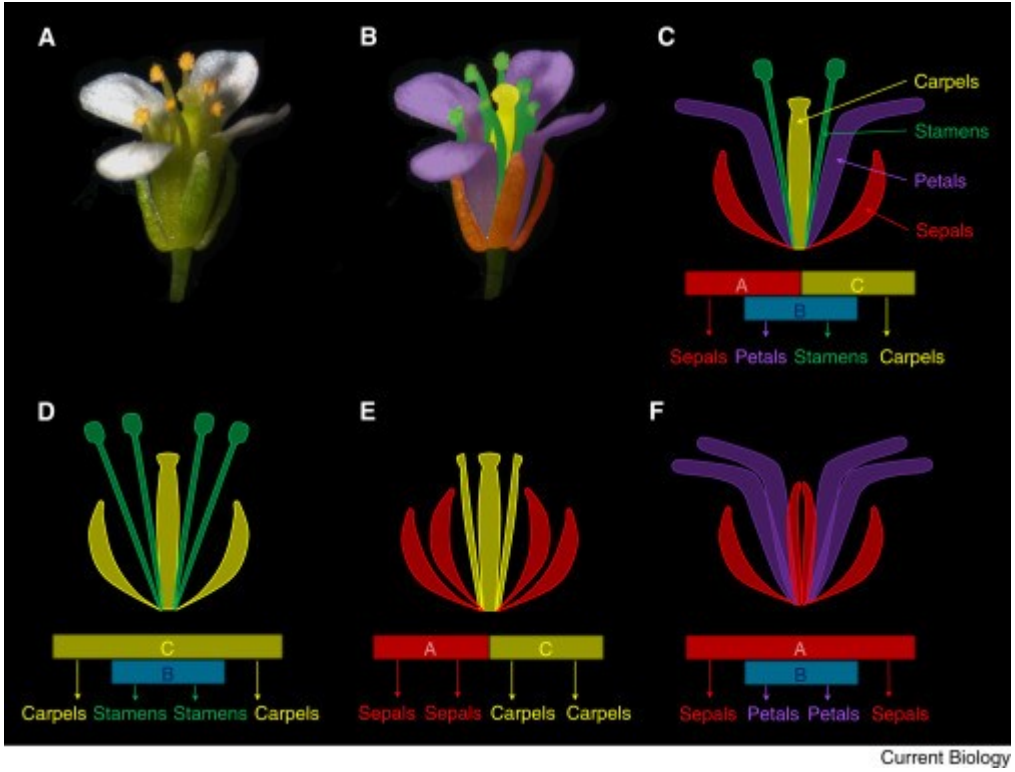
The principle is universal



- Homeotic mutations affecting flower parts were observed
- ABC model of flower development (A, B and C are groups of genes)

https://www.cell.com/current-biology/fulltext/S0960-9822(17)30343-3

The principle is universal



Current Biology

https://www.cell.com/current-biology/fulltext/S0960-9822(17)30343-3

- Homeotic mutations affecting flower parts were observed
- ABC model of flower development (A, B and C are groups of genes)

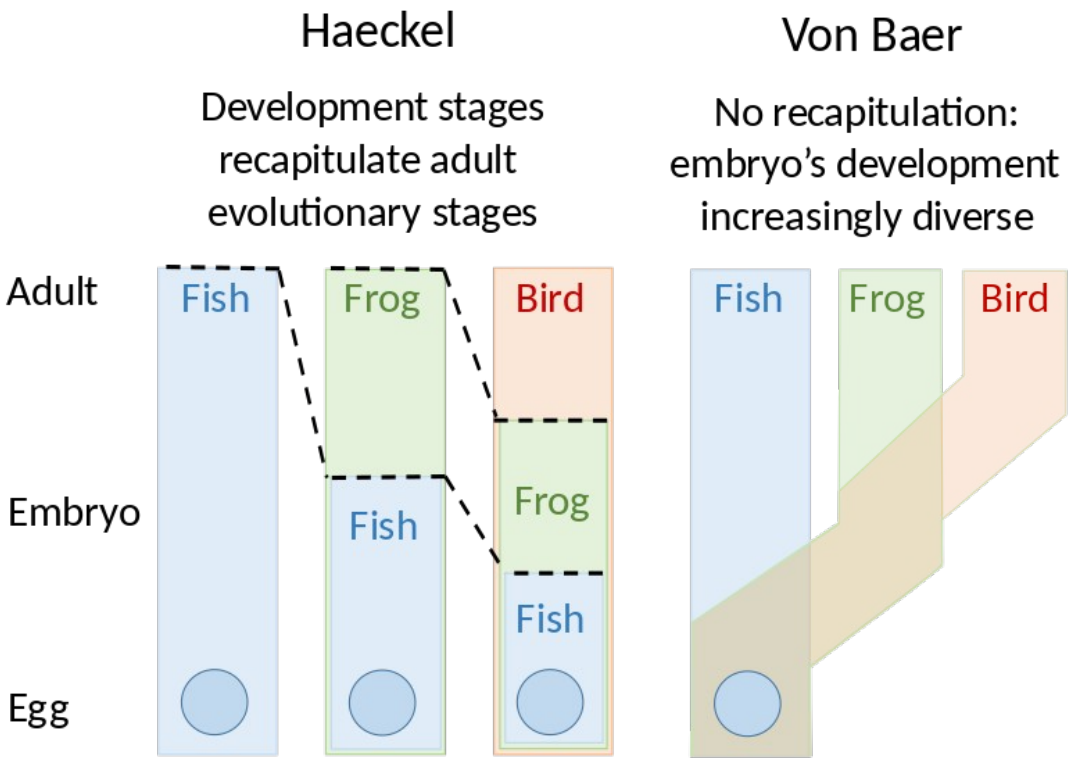
Environment

- Developmental abnormalities without mutations
  - Teratogens (for example alcohol)
  - Vitamins and nutrients deficiency
  - etc.

DEVELOPMENT AND EVOLUTION

Evolutionary developmental biology (EvoDevo)

Link between development and evolution

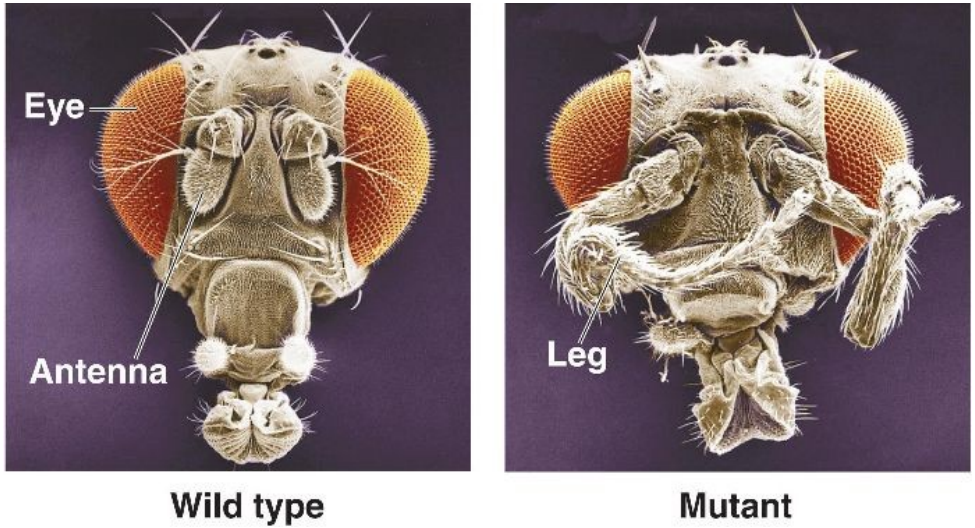


- Early (19th century) comparative studies of embryonic development
- Modern evolutionary developmental biology (EvoDevo) since late 70s

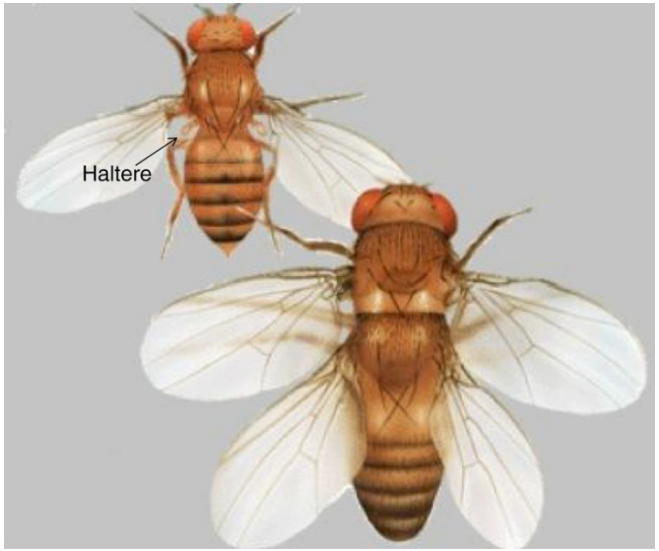
https://en.wikipedia.org/wiki/Evolutionary_developmental_biology

Homeotic mutations (again)

Hypothetical ancestors of arthropods had identical segments with a pair of legs each



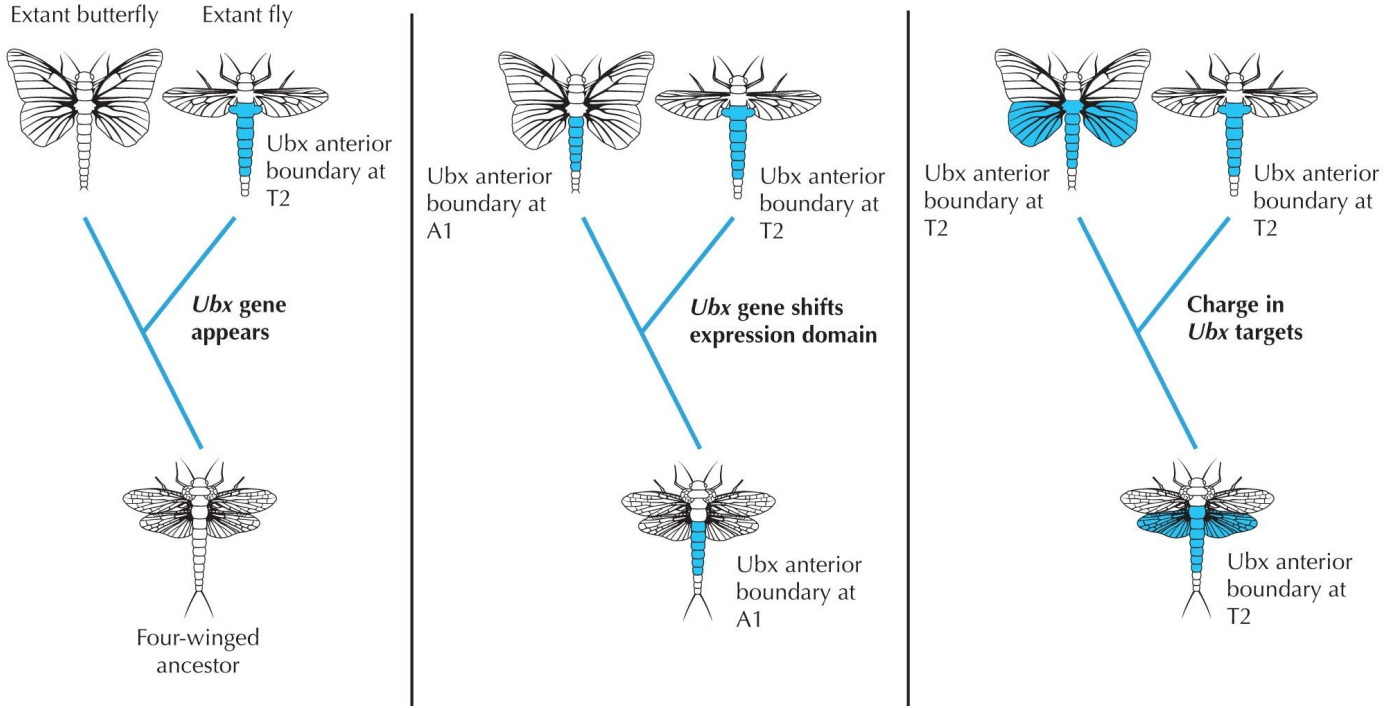
Fly ancestors had 4 wings



https://infograph.venngage.com/p/219814/homeotic-genes

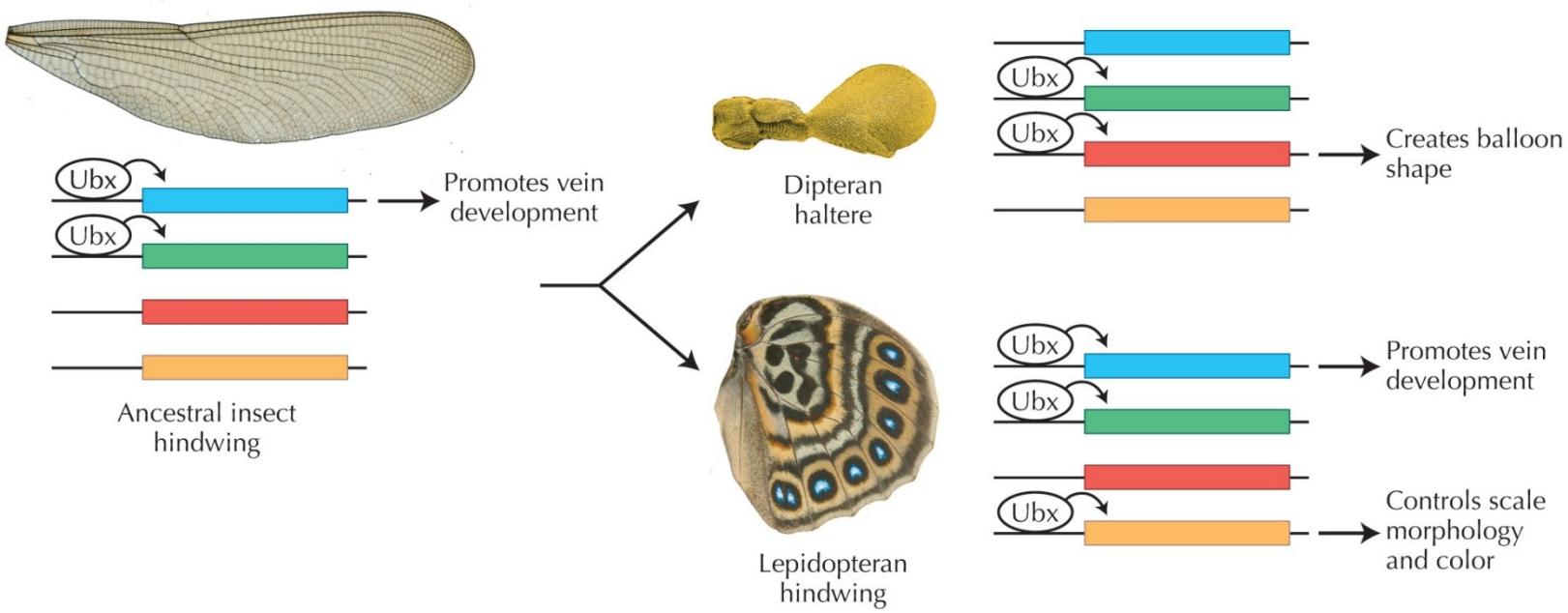
https://www.researchgate.net/figure/The-four-winged-fruit-fly-In-the-homeotic-mutant-bithorax-the-halteres-which-are-a_fig3_25852473

4 wings -> 2 wings



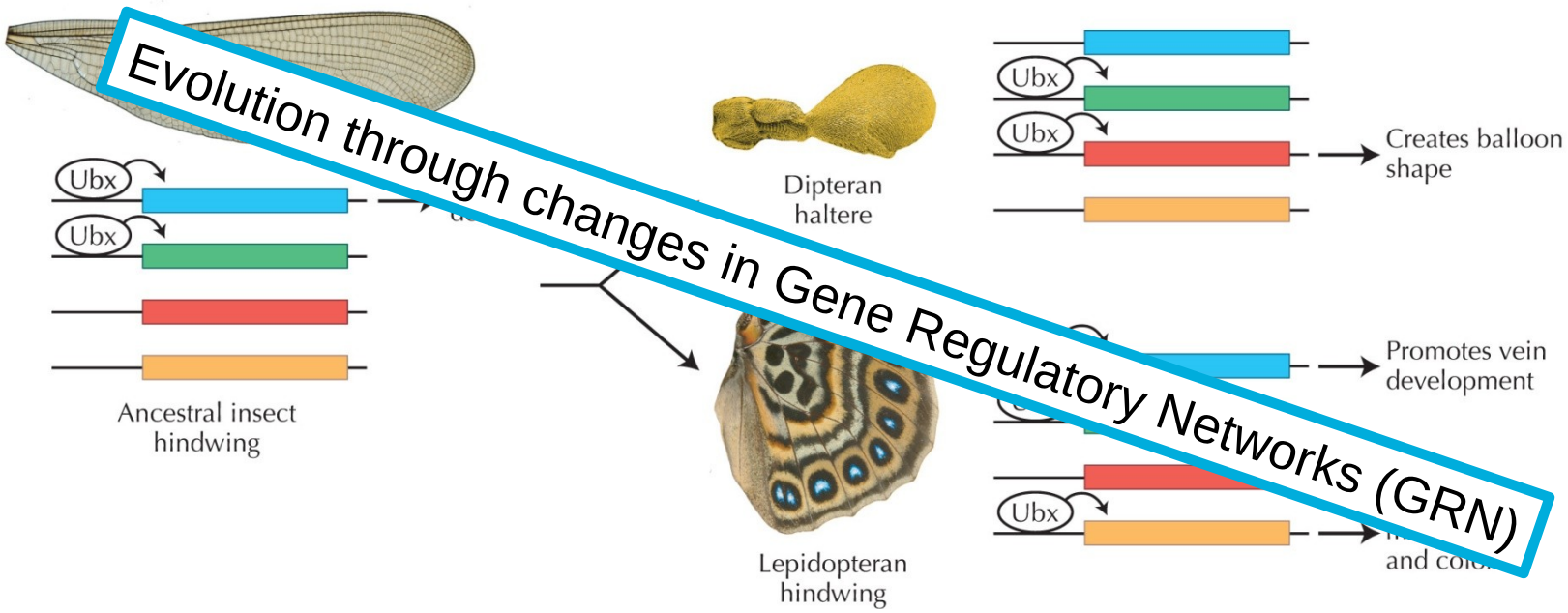
http://evolution-textbook.org

Current hypothesis



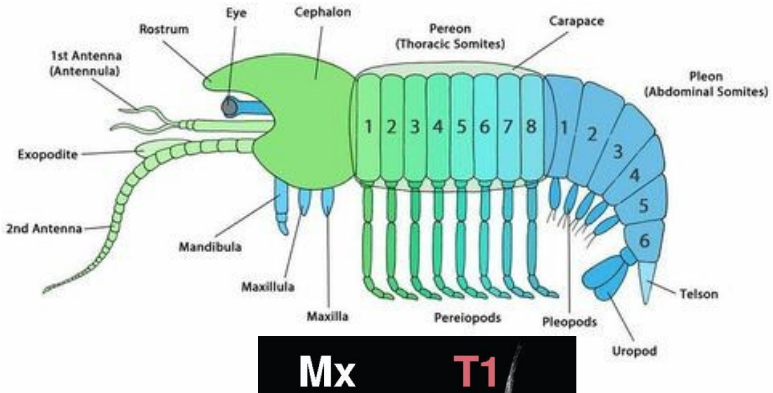
http://evolution-textbook.org

Current hypothesis



http://evolution-textbook.org

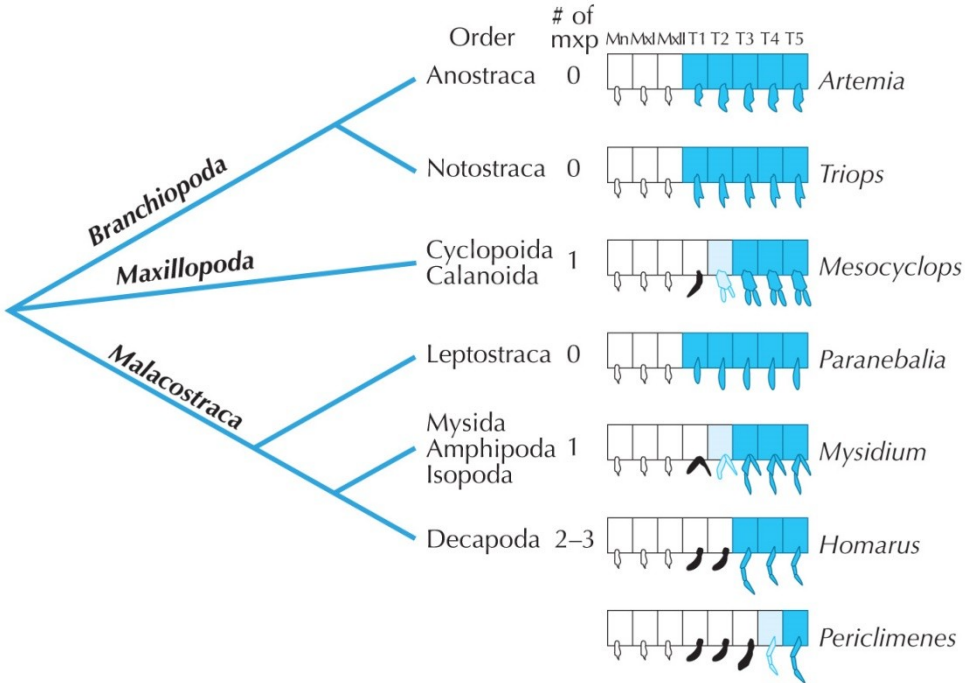
Changes in Hox-genes expression



- Ancestrally in crustaceans head appendages (mandibula and maxillas) are involved in feeding and thoracic ones are involved in locomotion.
- Some groups have **maxillipeds** – T1 (and some T2 and T3) appendages looking and acting as maxillas

http://evolution-textbook.org
https://www.ck12.org/biology/crustaceans/lesson/Crustaceans-Advanced-BIO-ADV/

Changes in Hox-genes expression



- The evolution of maxillipedes can be explained by changes in Ubx expression patterns

Development and Evolution

- New phenotypes can evolve through changes in development – evolution and development are linked
- Development is controlled by time- and space-specific gene expression
- Master regulator genes (Hox-genes are just 1 example) play a crucial role in it
- Changes in GRN via mutations in master regulator genes or regulatory sequences can be involved in profound morphological changes