Pattern Formation

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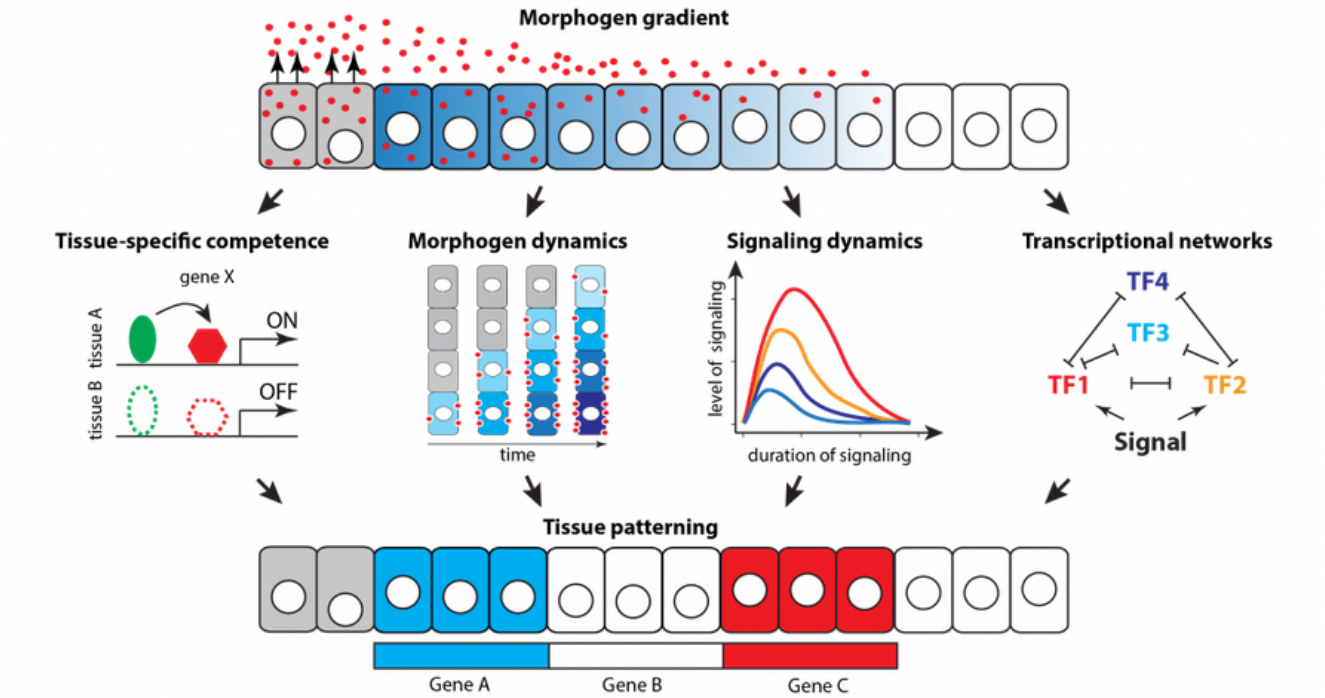
SS 19

Reaction-Diffusion vs. Positional Information

thinking about the physico-chemical nature of pattern formation

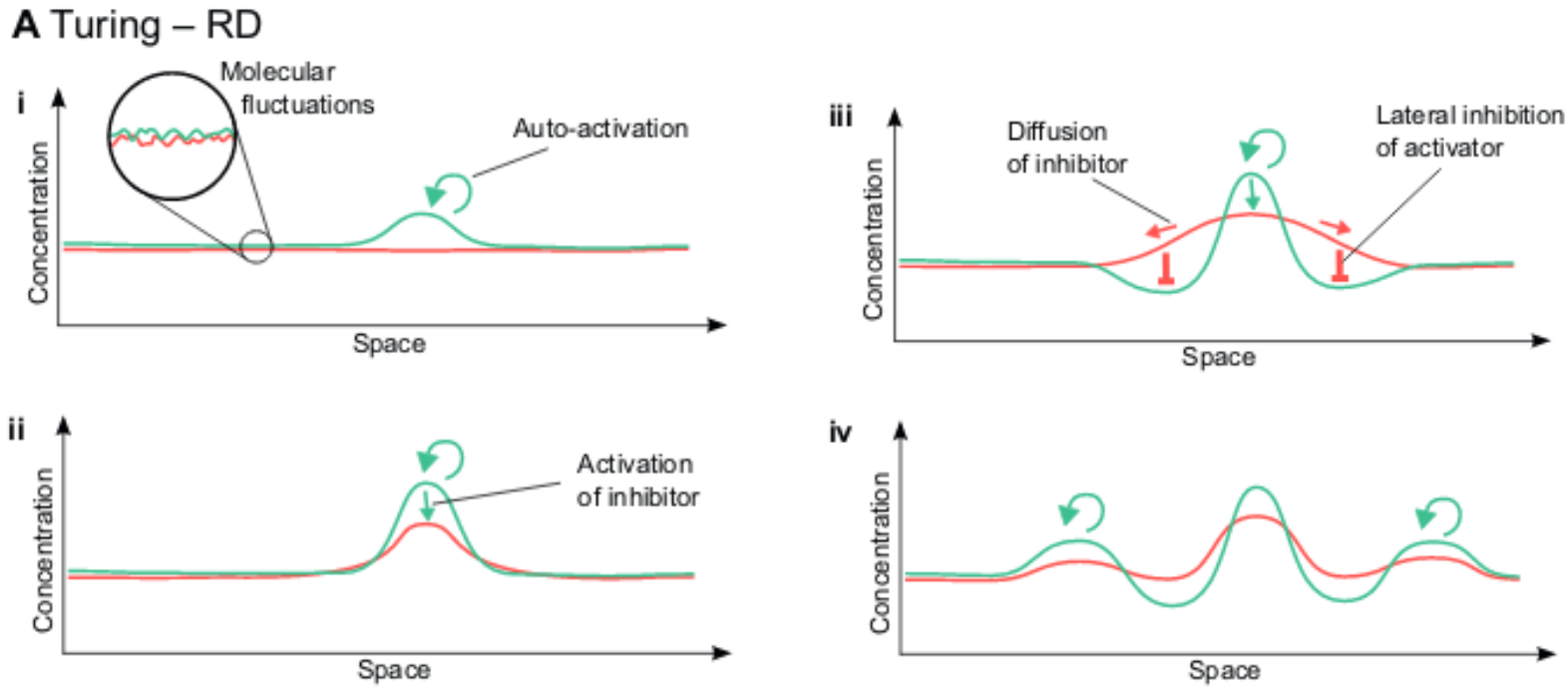


Tissue patterning during embryonic development relies on the differential induction of target genes by morphogen gradients. Induction of target genes depends not only on the level of the morphogen, but also the specific competence of receiving cells, the ability of cells to decode dynamics of morphogen signaling, and the regulatory logic of downstream transcriptional networks.

Green JBA and Sharpe J; 2015
HYPOTHESIS: Positional information and reaction-diffusion: two big ideas indevelopmental biology combine
The Company of Biologists Ltd, Development 142, 1203-1211

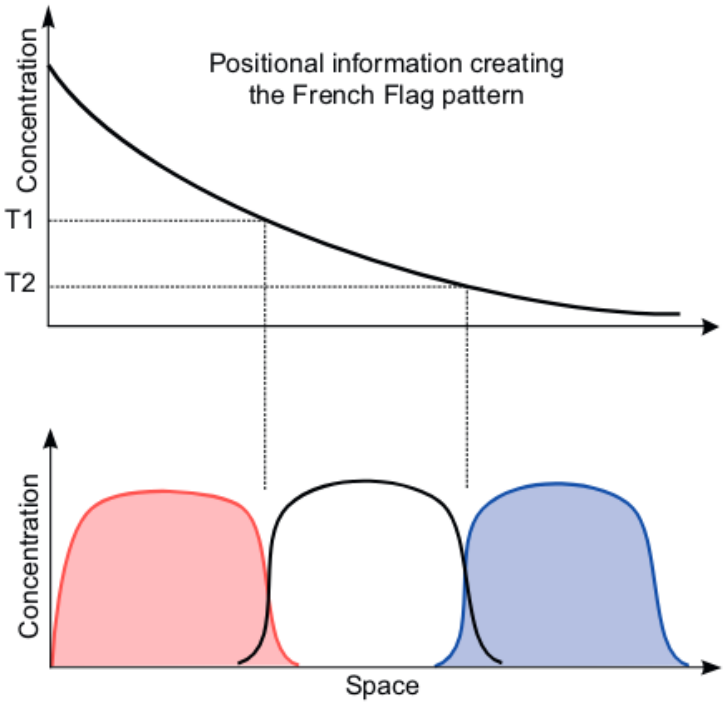
Auto-activated Periodic Patterns

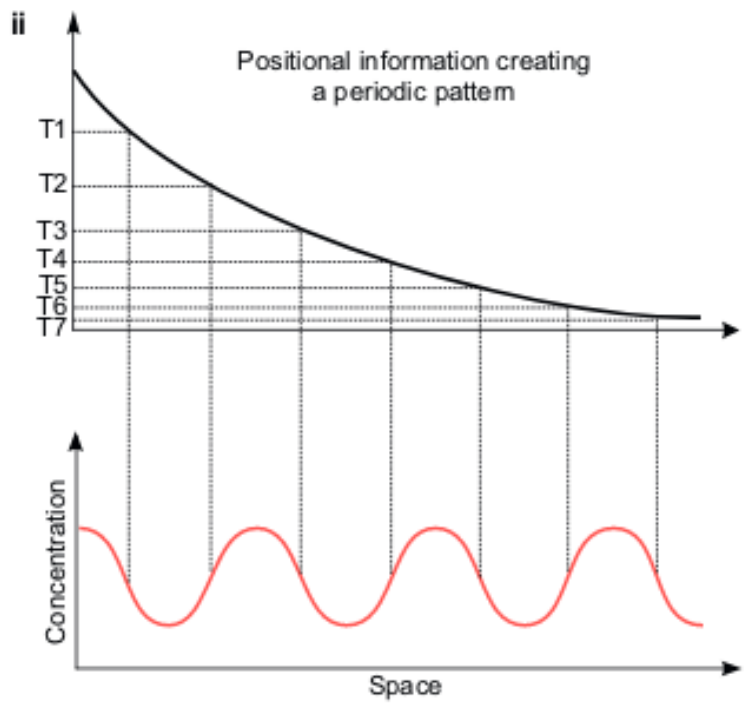
- **Reaction-Diffusion** – idea by **Turing**
- activator-inhibitor model and the substrate-depletion model
- self-organized pattern formation
- arises from homogeneity
- resulting pattern is directly coupled to the prior morphogen distribution



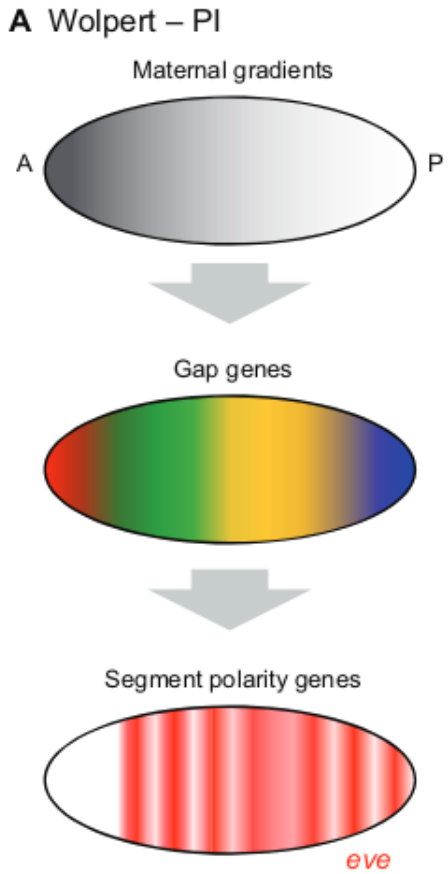
The "French Flag" in Cellular Patterning Mechanisms

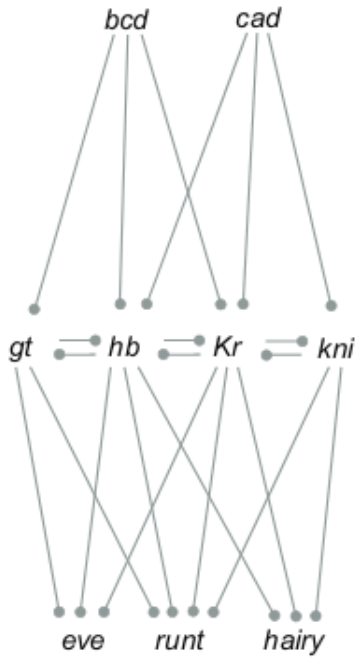
- **Positional Information** – idea by **Wolpert**
- derive complex pattern from heterogeneity or polarities
  e.g. a pole, axis, morphogene gradient
- reject the direct coupling of the resulting pattern to the prior morphogen distribution
- instead introduce an "interpretation step"
- morphogen concentrations act as positional coordinates along an axis

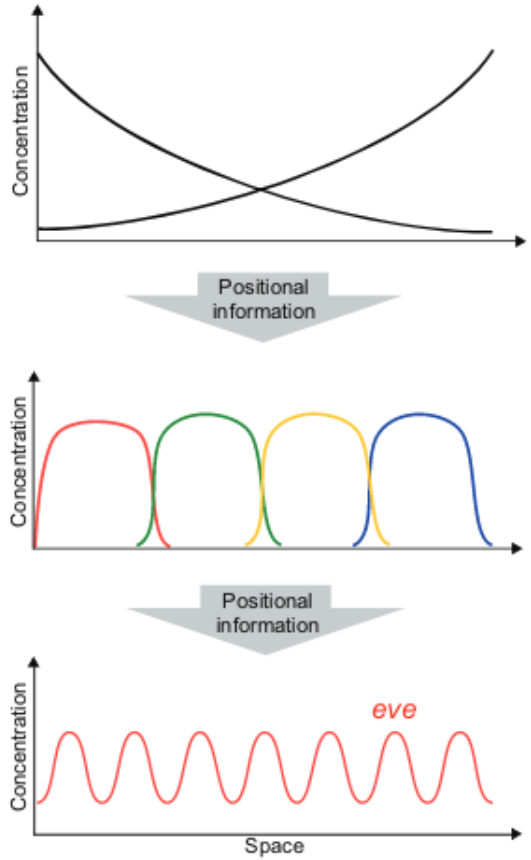




Example: Stripes in Drosophila







Important consequences

- two mechanistically distinguishable steps:

  - establishment of the positional information (most commonly a morphogen gradient)

  - interpretation of the positional information

- advantage over reaction-diffusion:

  overt biological pattern canvary evolutionarily while the underlying morphogen coordinatesystem is preserved and reused in multiple species and during thedevelopment of multiple tissues

- Example:

  - Hox gene expression along the anterior-posterior axis

  - found in **all** animals

  - reused in limb, hair folicle, uterus formation

Stripes in Drosophila – How Biology Does It

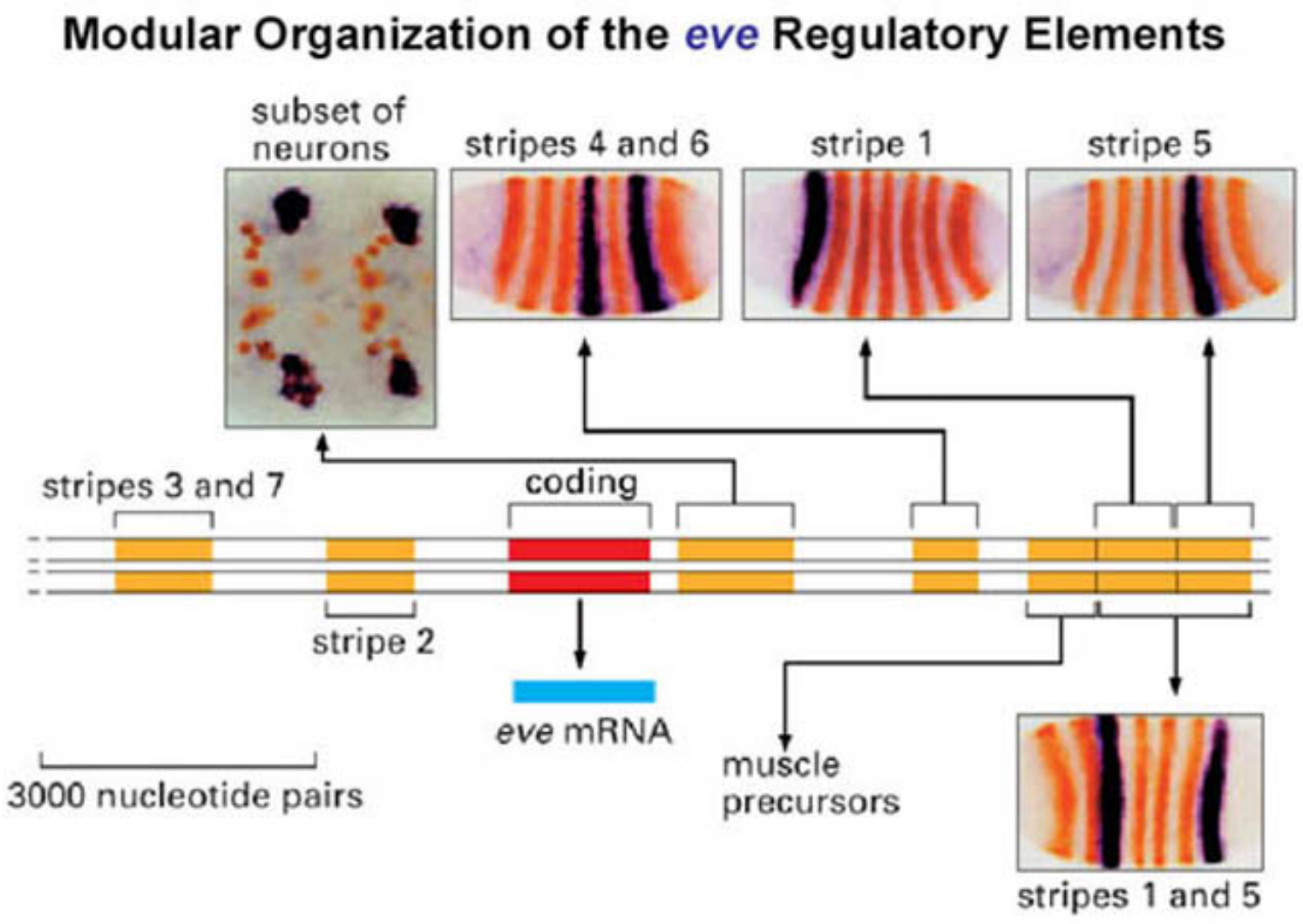
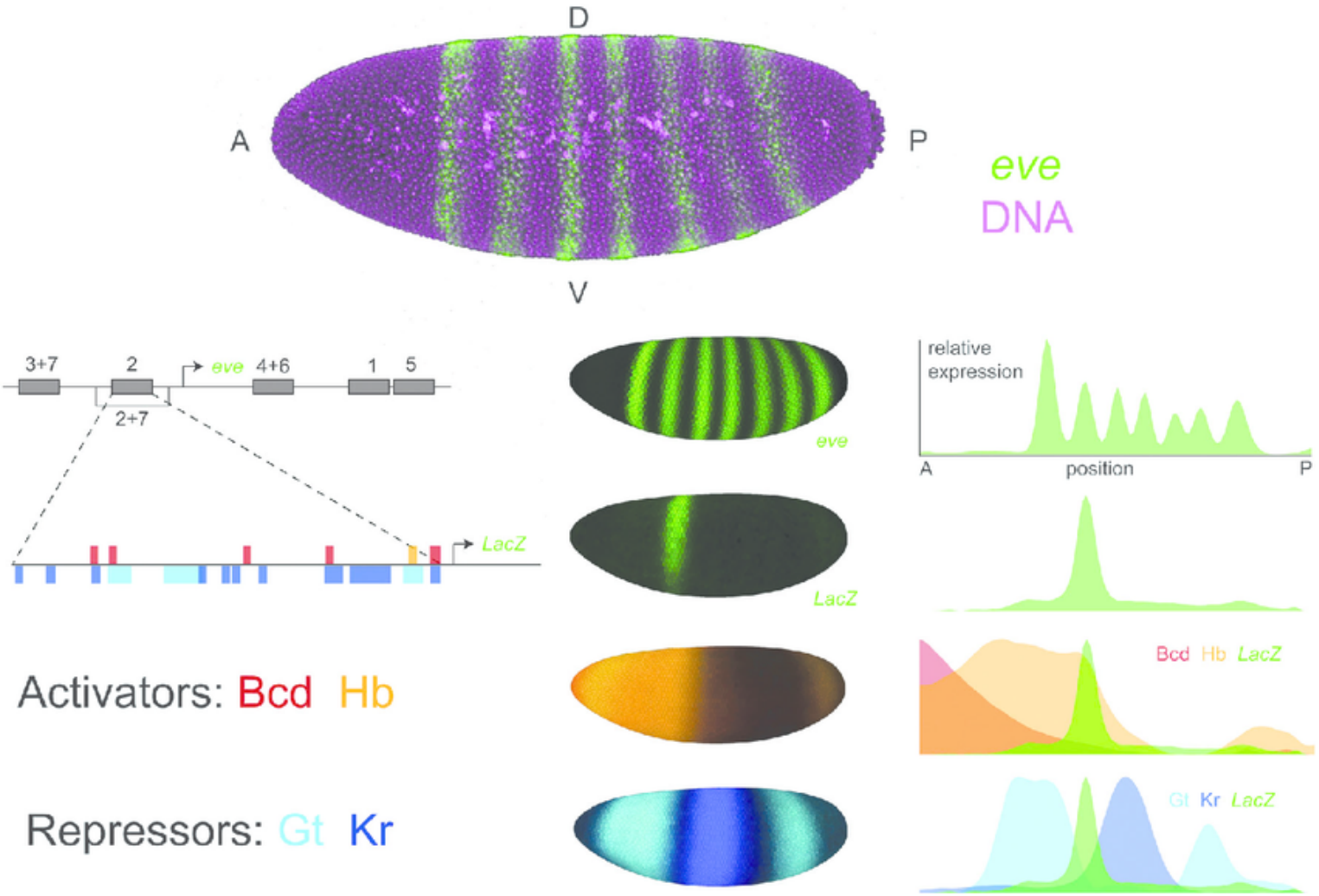
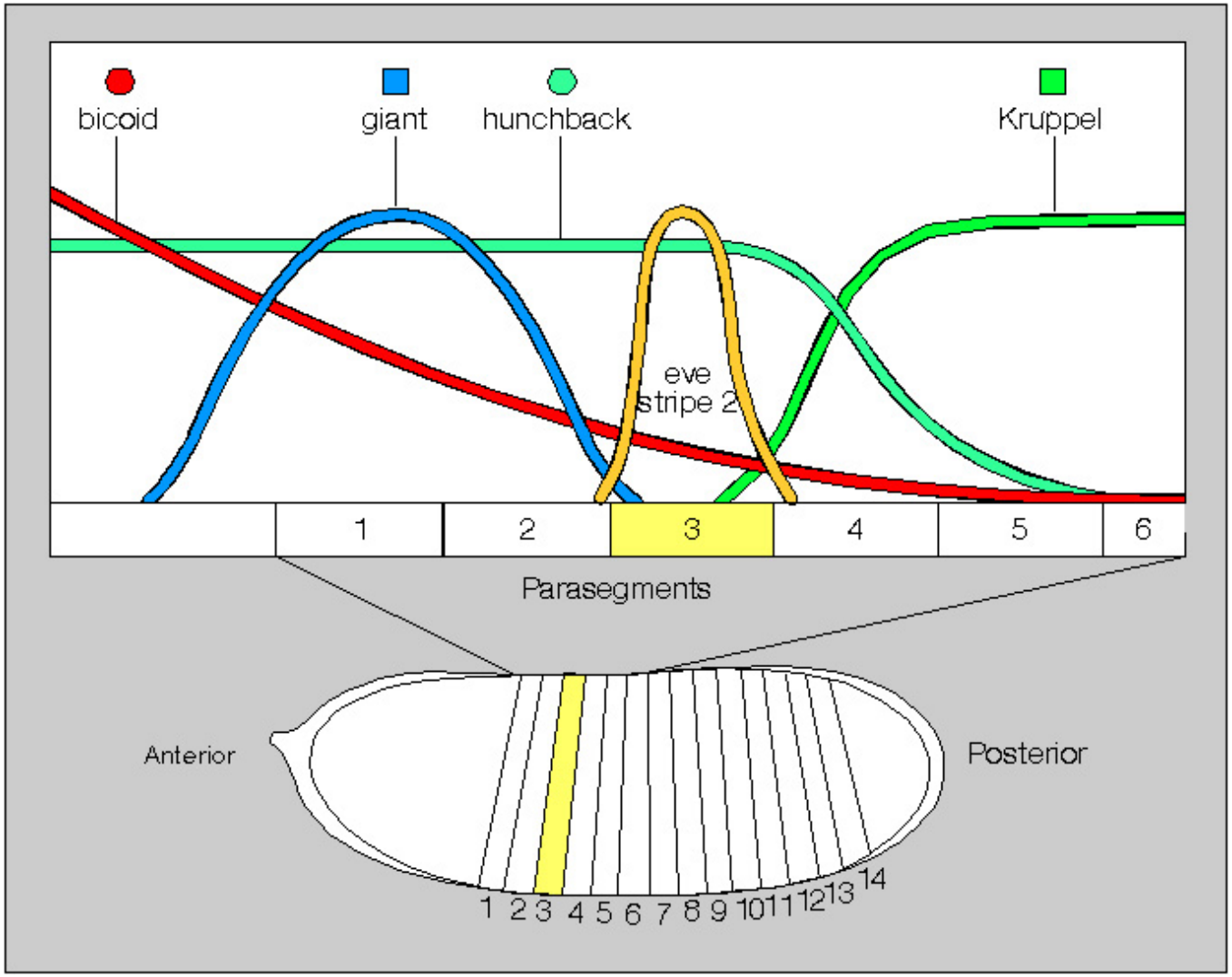


Figure 21–38. Molecular Biology of the Cell, 4th Edition.

Stripes in Drosophila – How Biology Does It

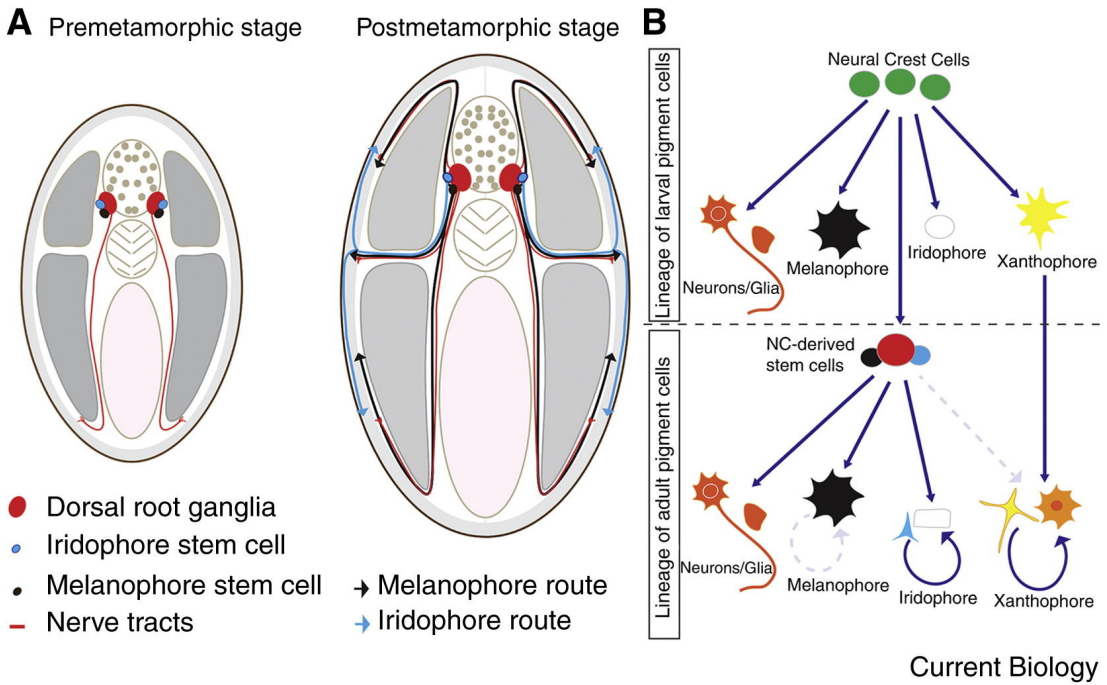


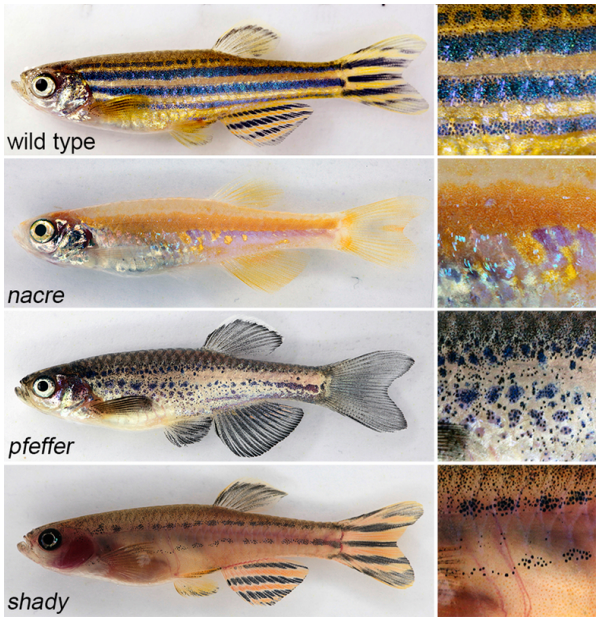
Stripes in Drosophila – How Biology Does It



Stripes in Zebrafish

- cell migration and diversification

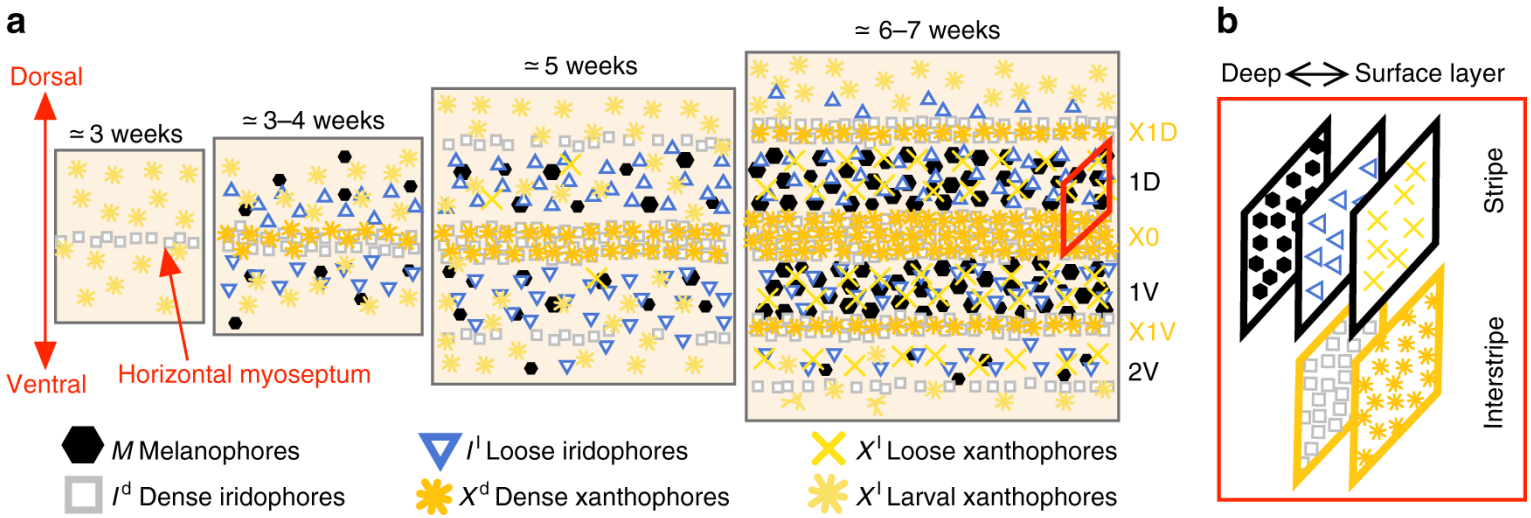




Singh AP and Nüsslein-Volhard; 2015
Zebrafish Stripes as a Model for Vertebrate Colour Pattern Formation
Current Biology, 25(2),pR81-R92

Stripes in Zebrafish

- interaction between cells
- cell density and organization in layers



Volkening A and Sandstede B; 2018
Iridophores as a source of robustness in zebrafish stripes and variability in Danio patterns
Nature Communicationsvolume 9, Article number: 3231