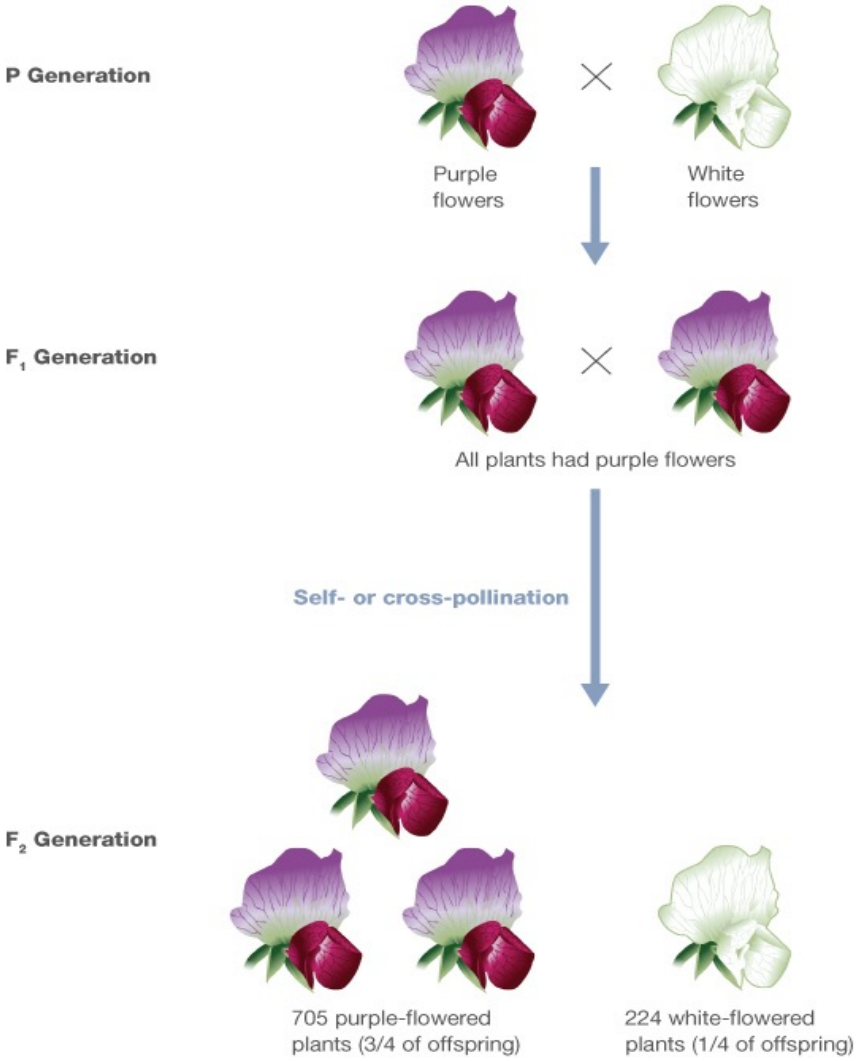
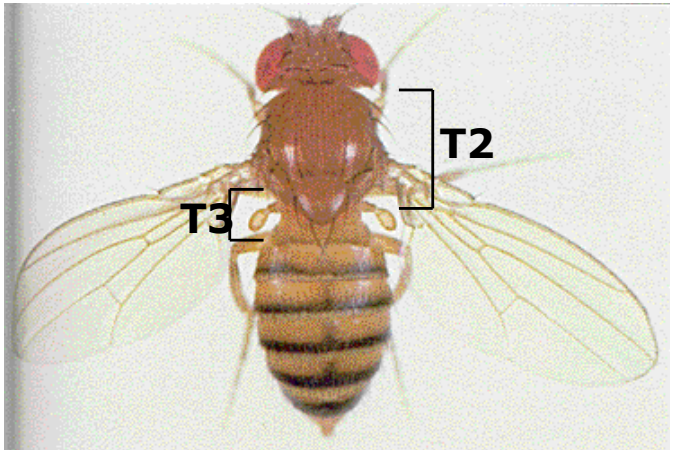
Studying how we inherit traits of life

Genetics and Laws of inheritance



Ultrabithorax (Ubx) and differential development of Wing and Haltere

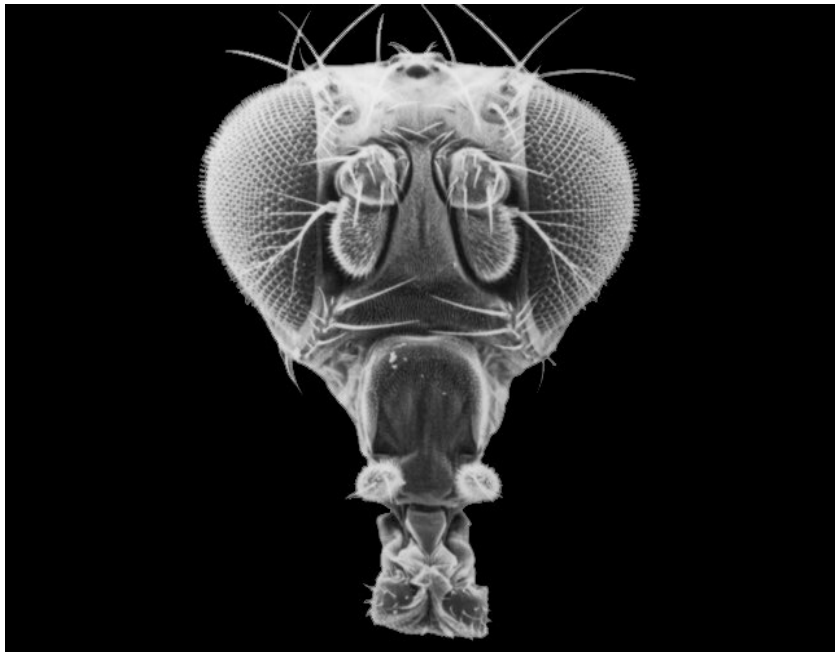
No *Ubx* in T3

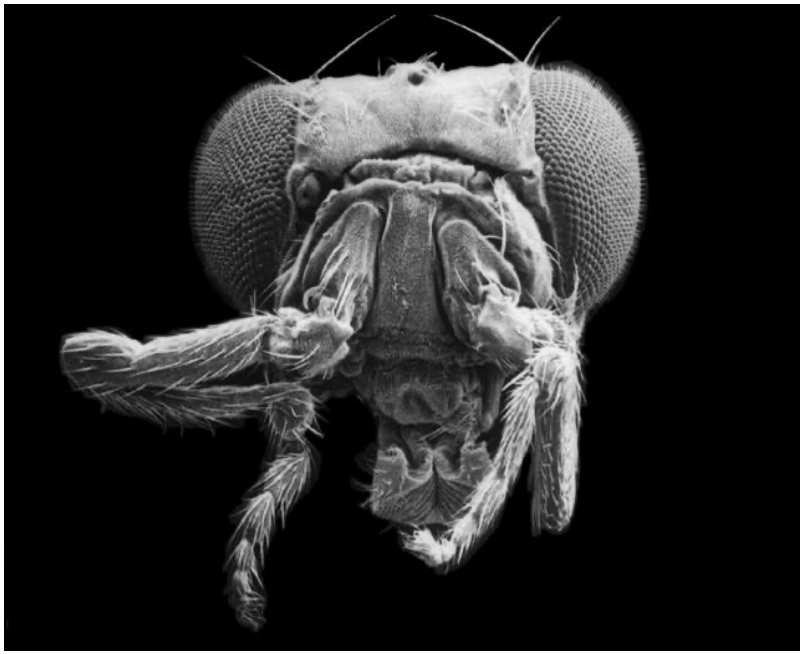


Wildtype

***Ubx* in both T2 and T3**

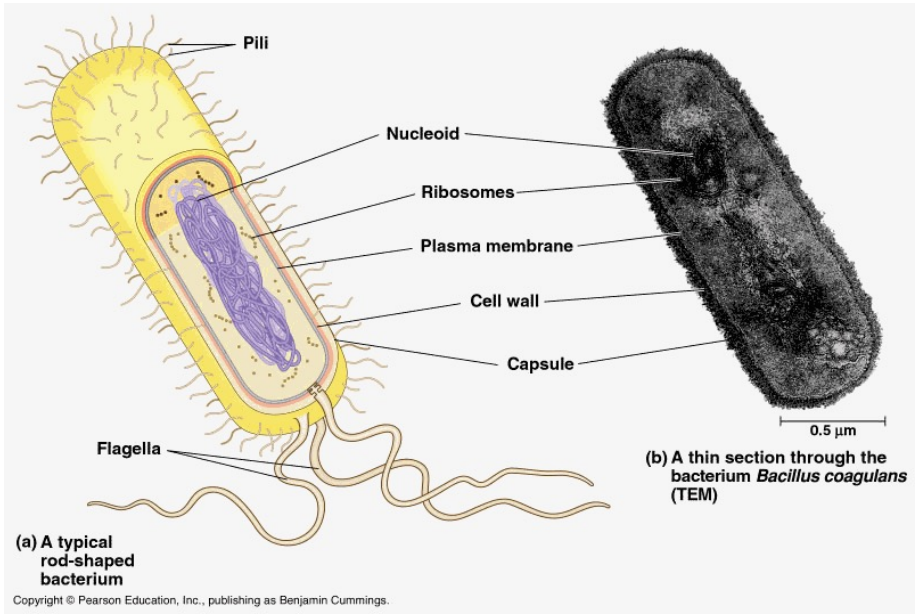
Ed Lewis, and many others



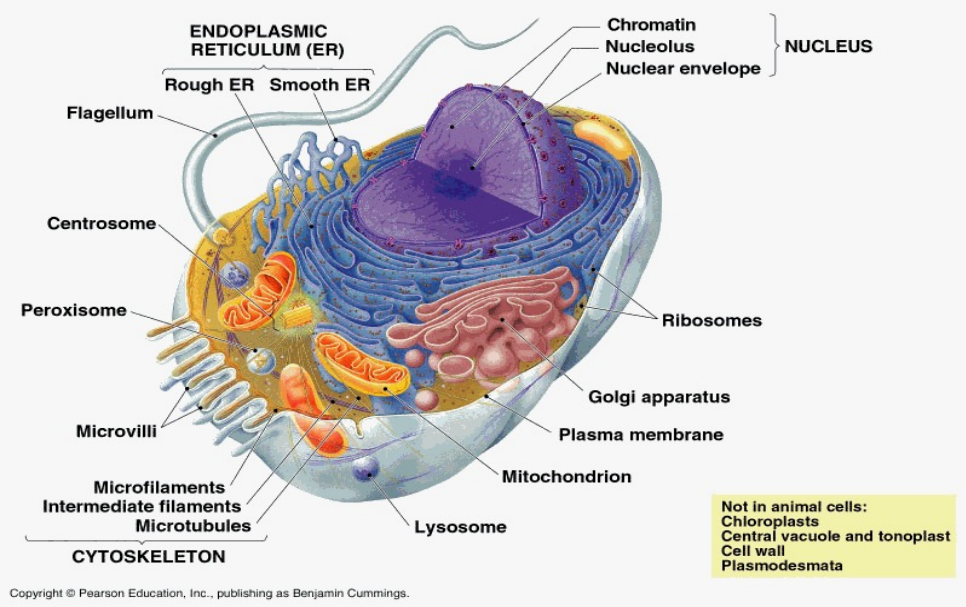


From Genotype to Phenotype
From Cell as a unit of life to cell as life itself

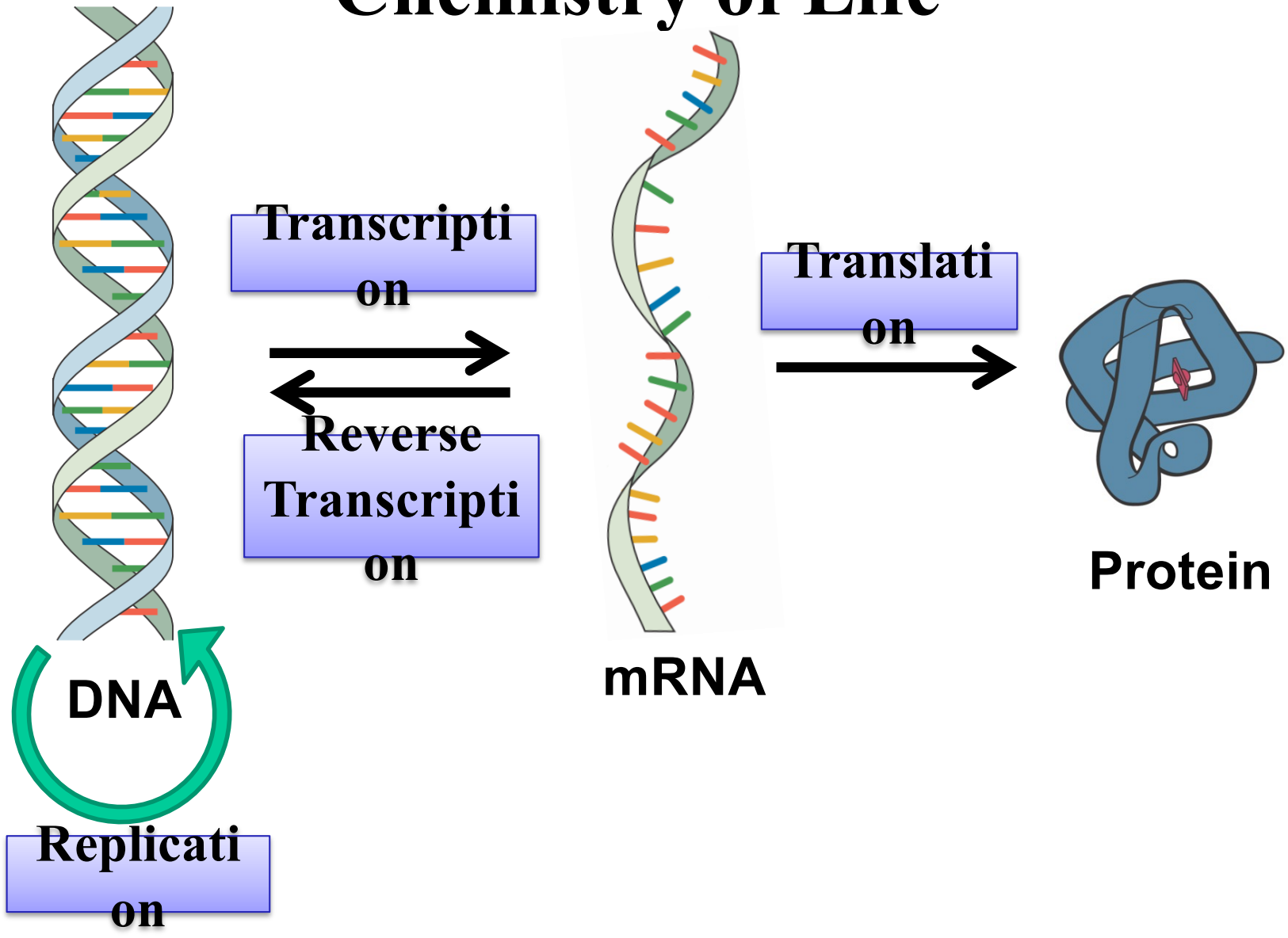
Prokaryotic cell



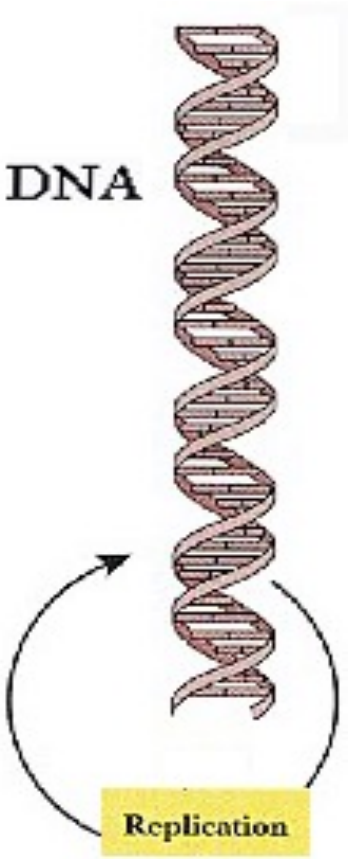
Eukaryotic cell



Chemistry of Life



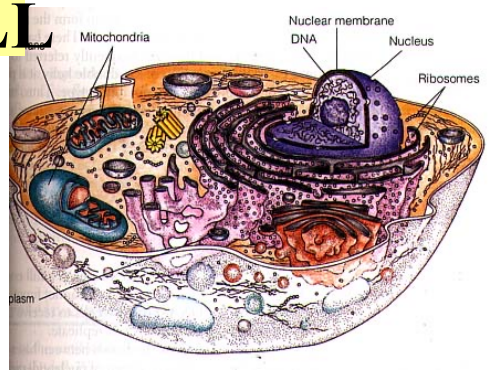
Basic features of all forms of life

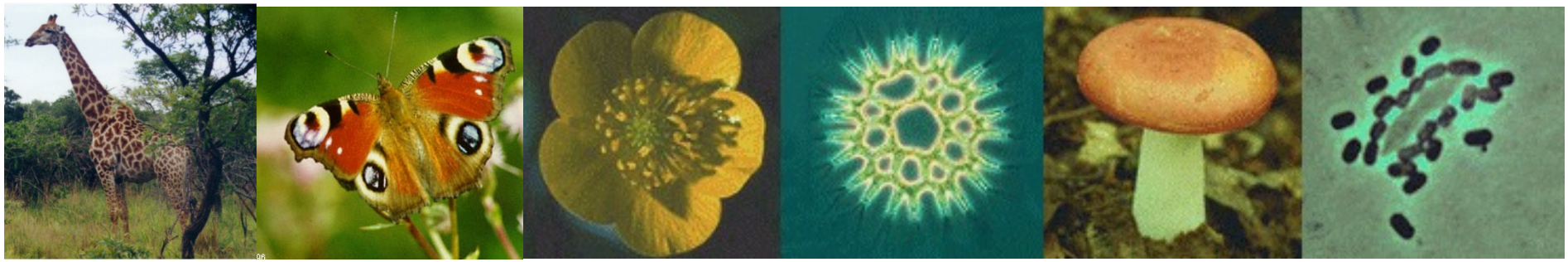


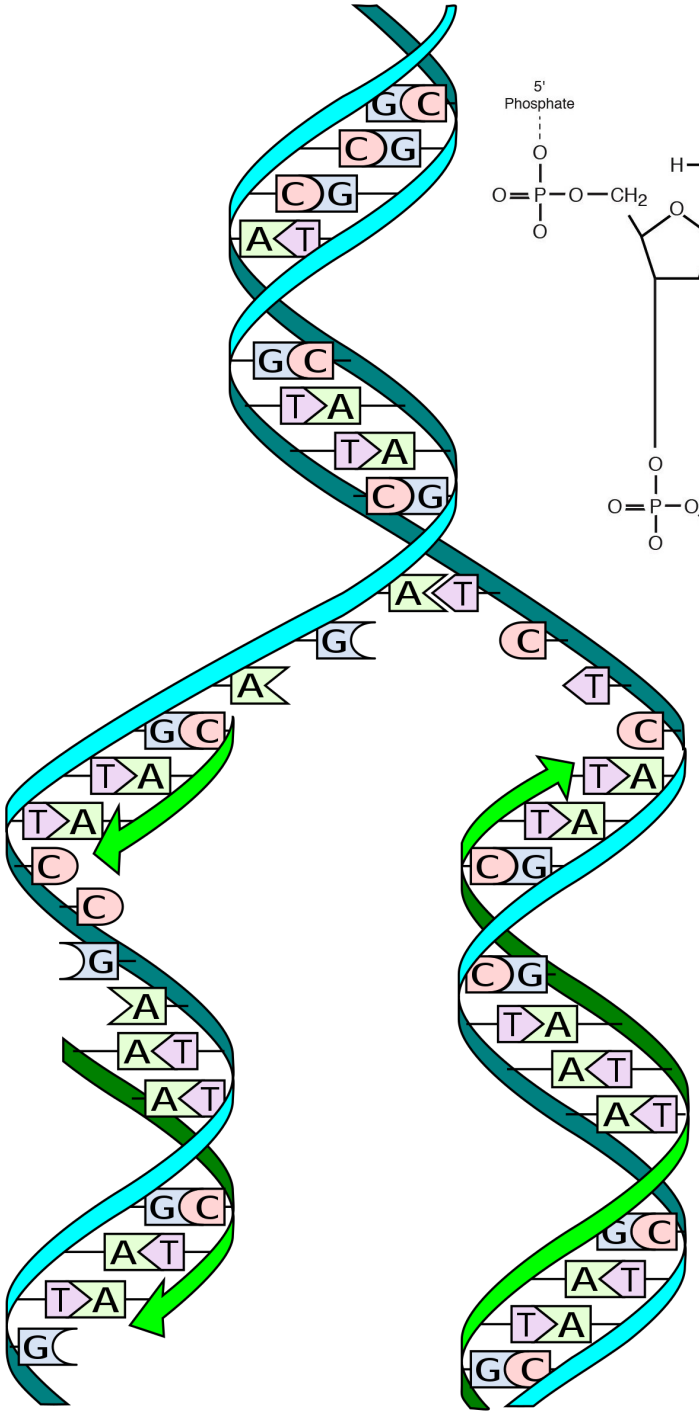
RNA

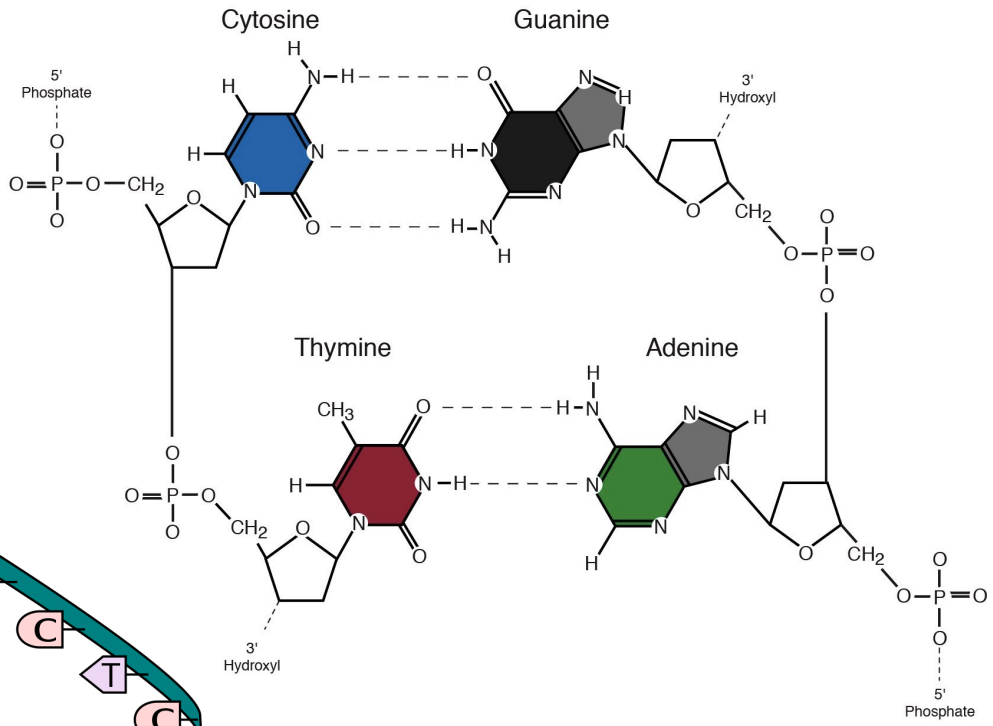
PROTEIN

CELL

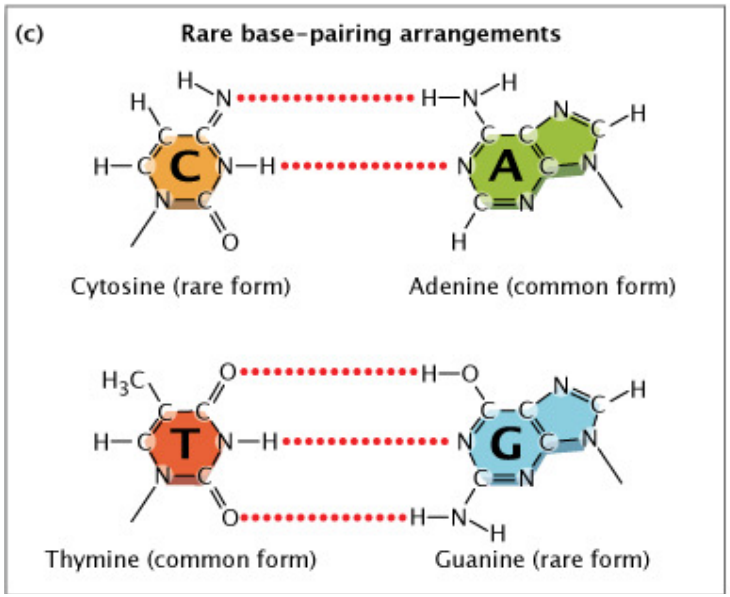








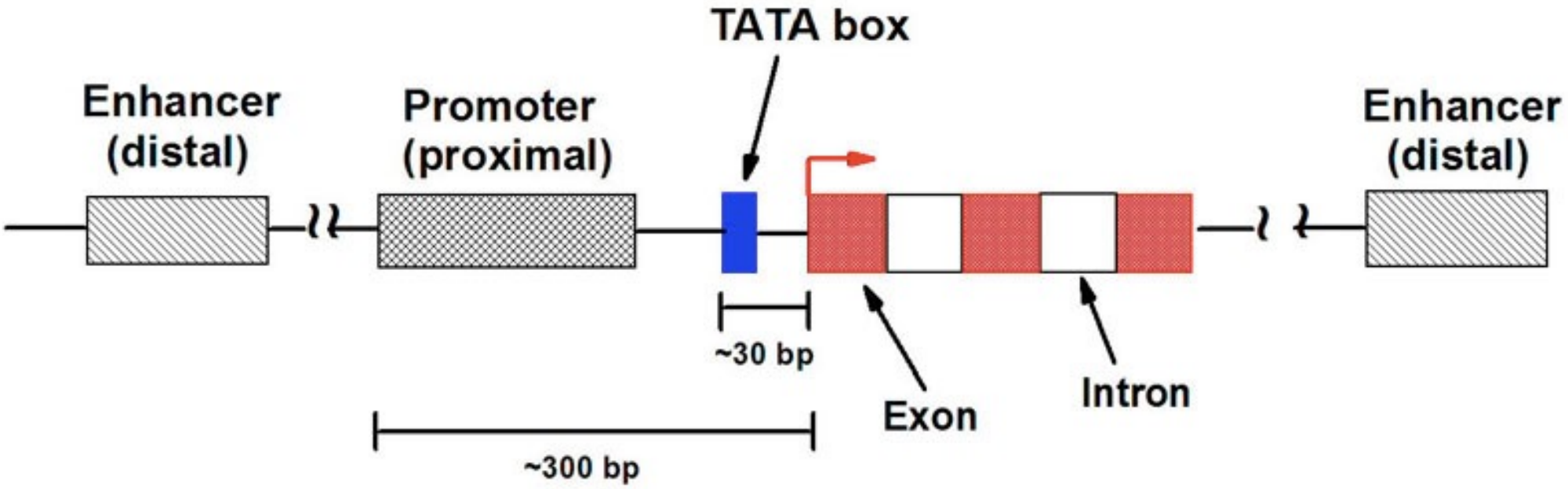
Variations in DNA copying mechanism



What is Life?

- **An organized state of chemical reactions**
- **With well-defined boundary conditions, which facilitate balance between Energy vs entropy**
- **Viscosity/rate of diffusion maintain relative concentrations of biomolecules in time and space and their relative physical location, together ensure near-certain biochemical reactions to attain a state that we call "life”**
- **It makes copies of itself, but they are not identical.**

Typical structure of a Eukaryotic gene



DNA has information not only to make a specific protein, but also when, where and how much

From egg to embryo to organism…

Positional information

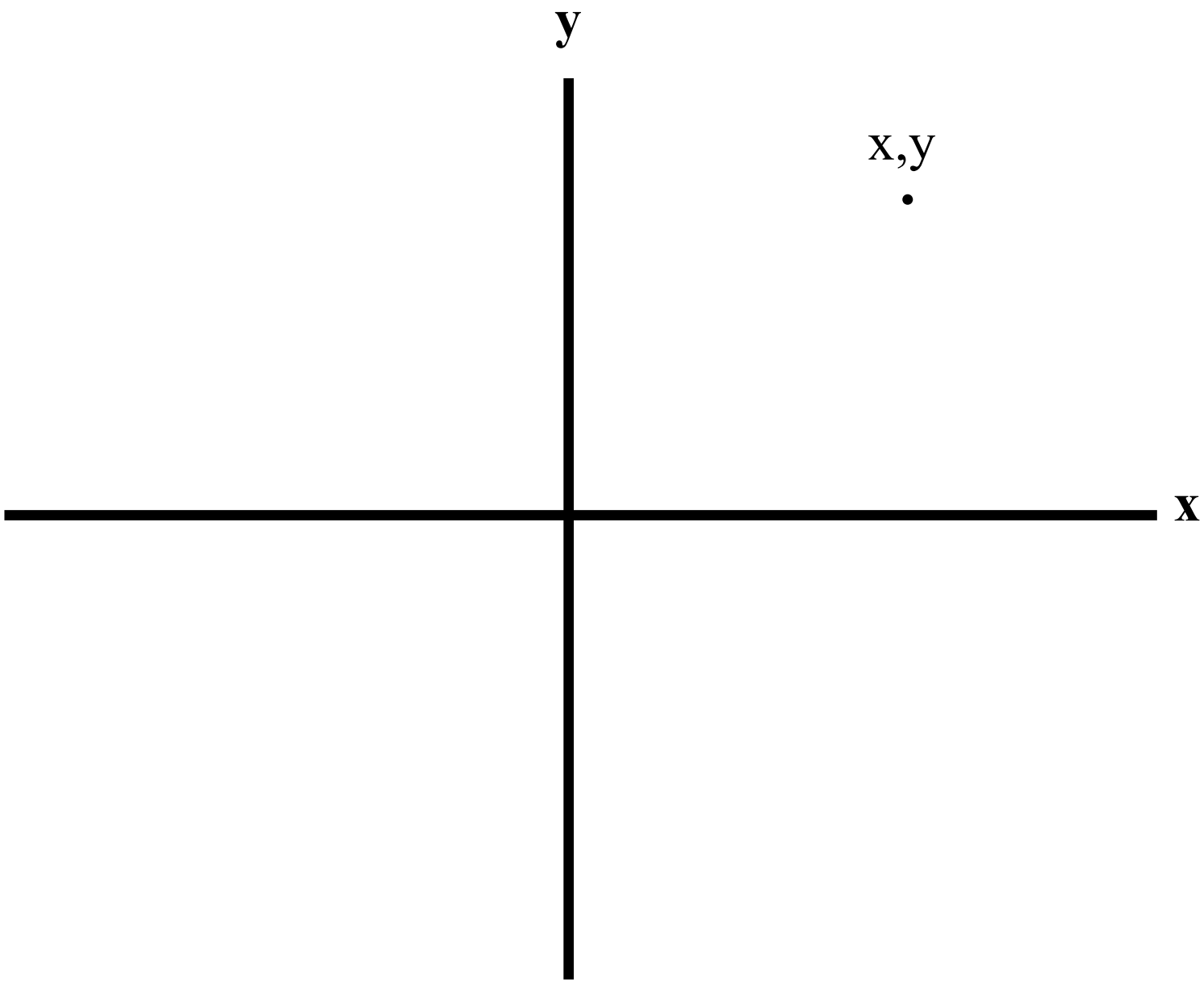
Size and shape of organs and tissues

Physiological connections

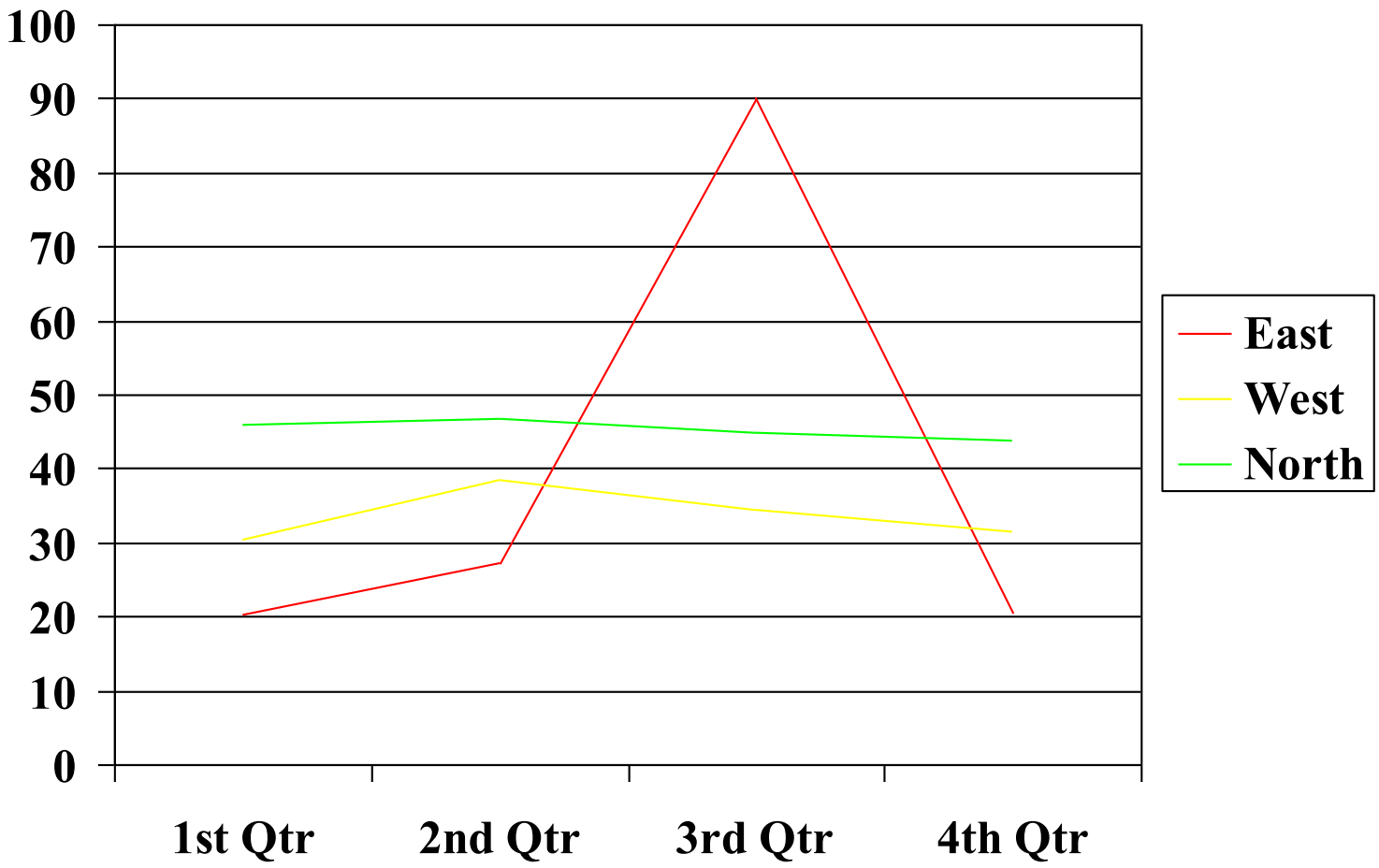
Improvised use of basic cellular mechanisms

Complex regulatory circuits controlling cell division

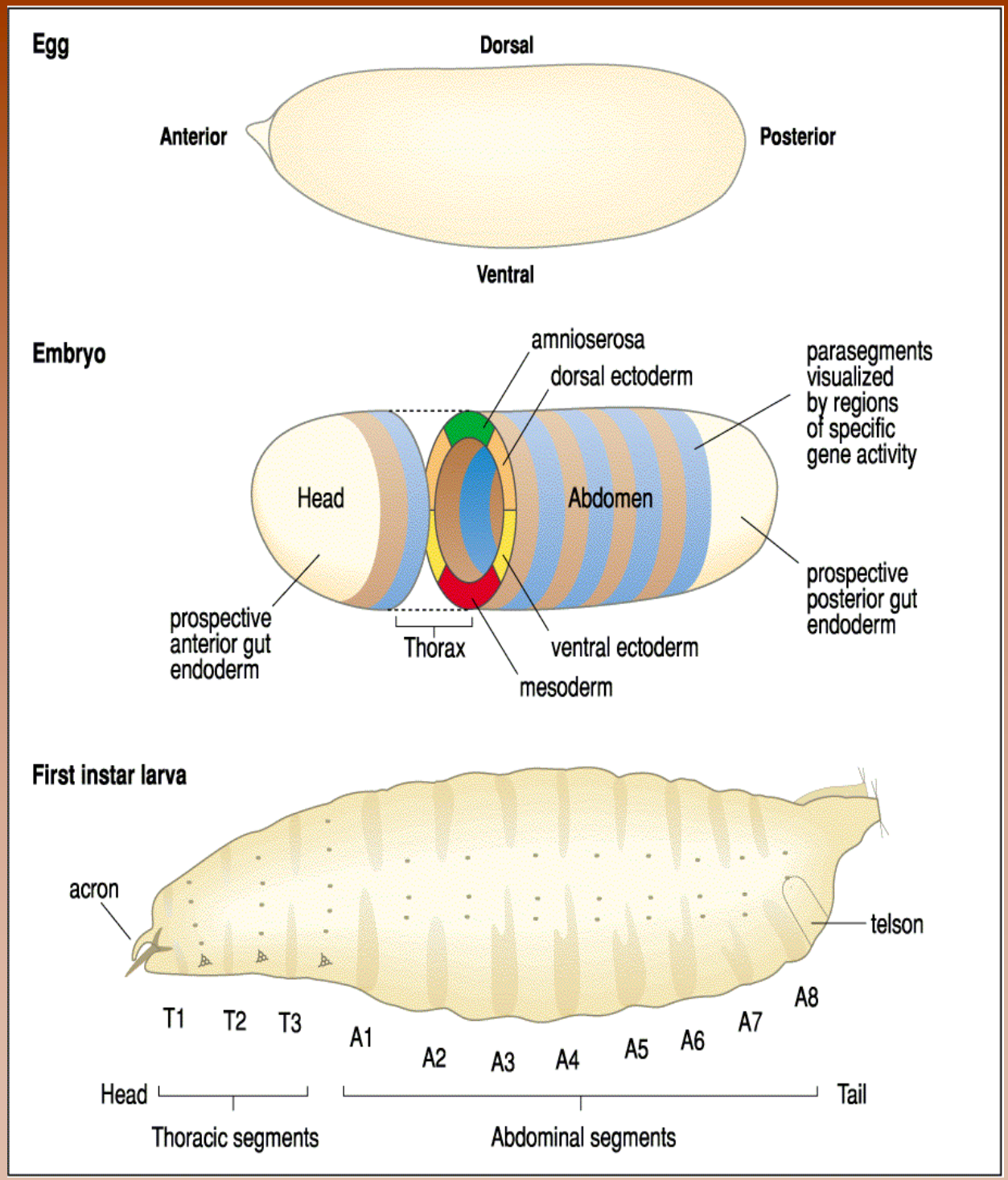
Spatio-temporal regulation of gene expression


y
x,y
x

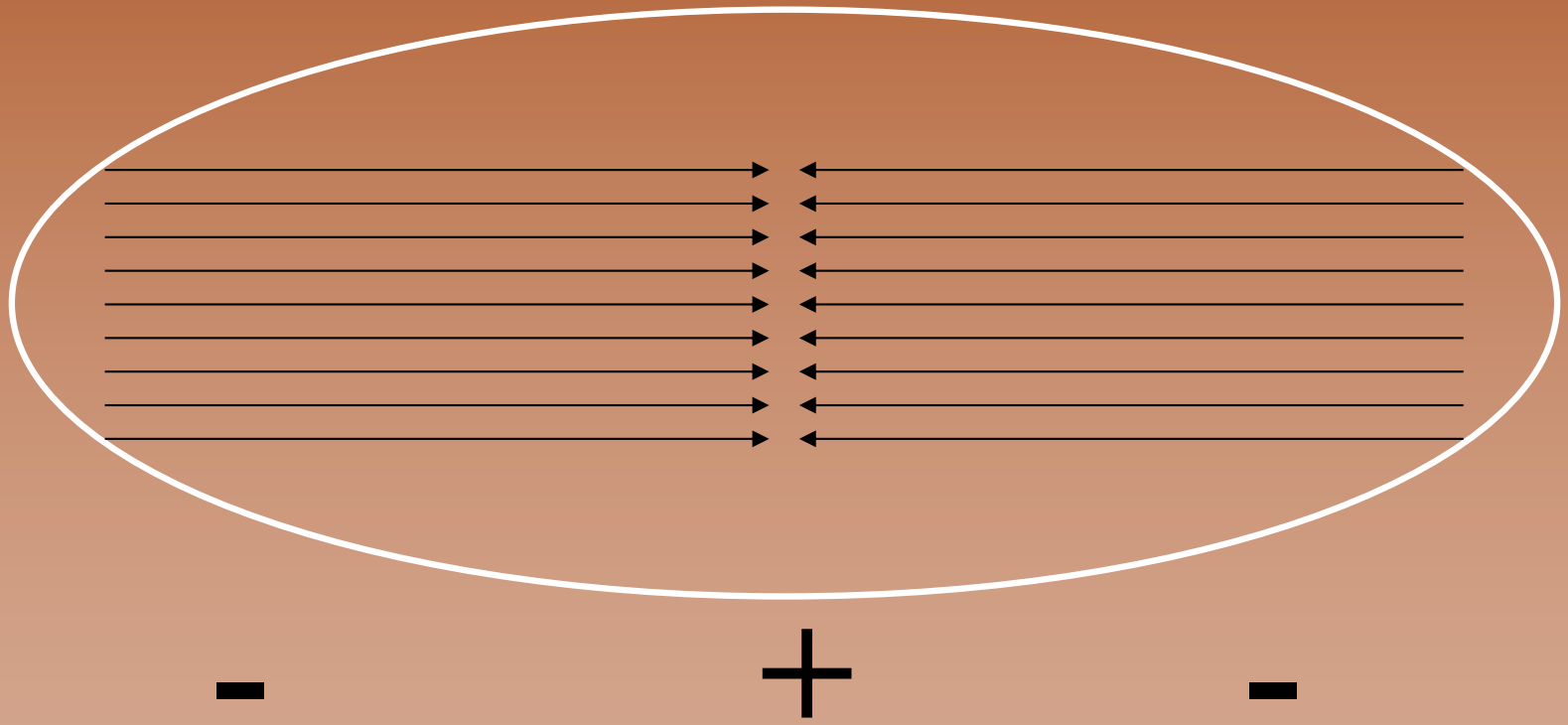

A
B



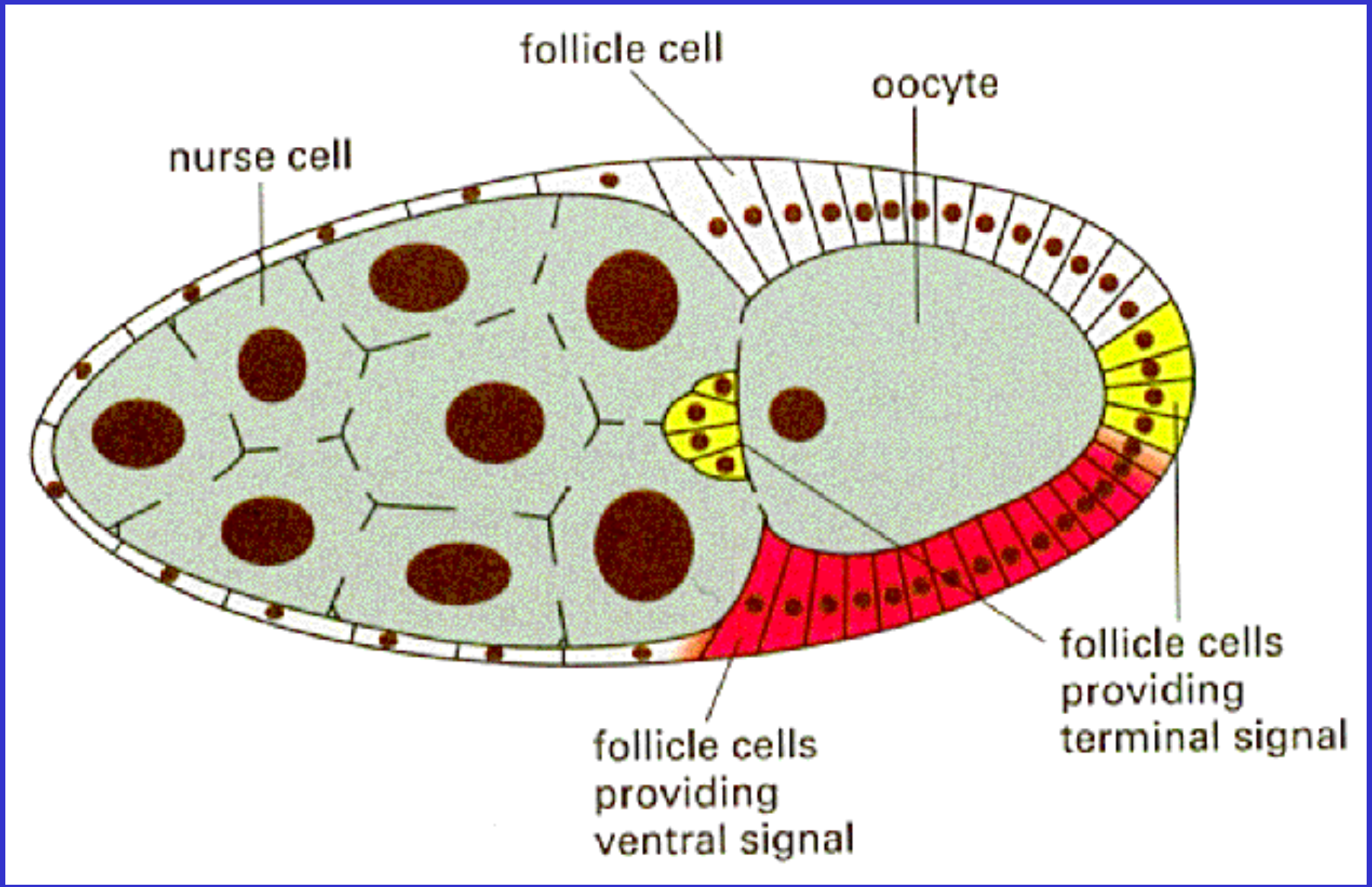
Axes are reference lines from which distances or angles are measured in a coordinate system


Egg
Dorsal
Anterior
Posterior
Ventral
Embryo
amnioserosa
dorsal ectoderm
parasegments visualized by regions of specific gene activity
Head
Abdomen
prospective anterior gut endoderm
Thorax
ventral ectoderm
prospective posterior gut endoderm
mesoderm
First instar larva
acron
telson
T1
T2
T3
A1
A2
A3
A4
A5
A6
A7
A8
Head
Tail
Thoracic segments
Abdominal segments

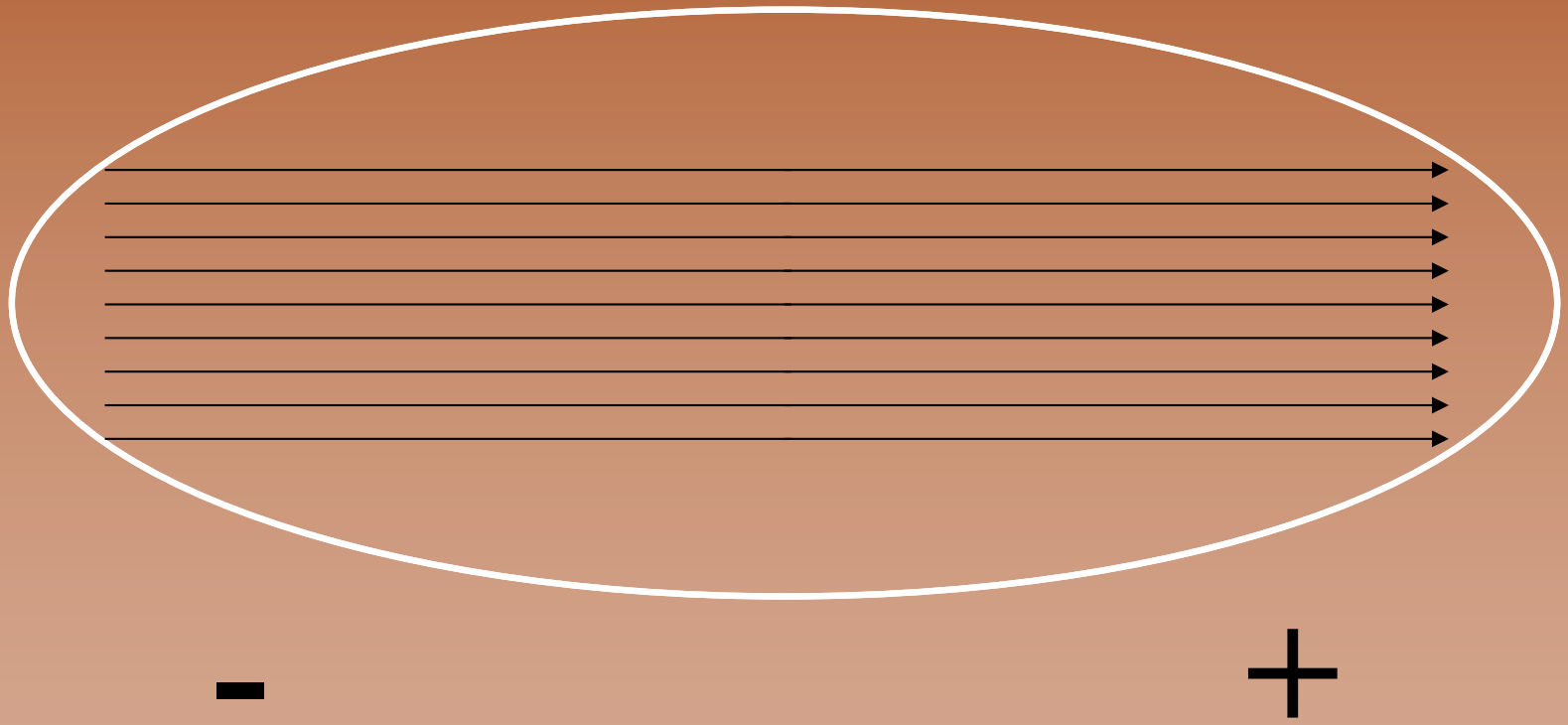
Microtubule organization – prior to oocyte maturation

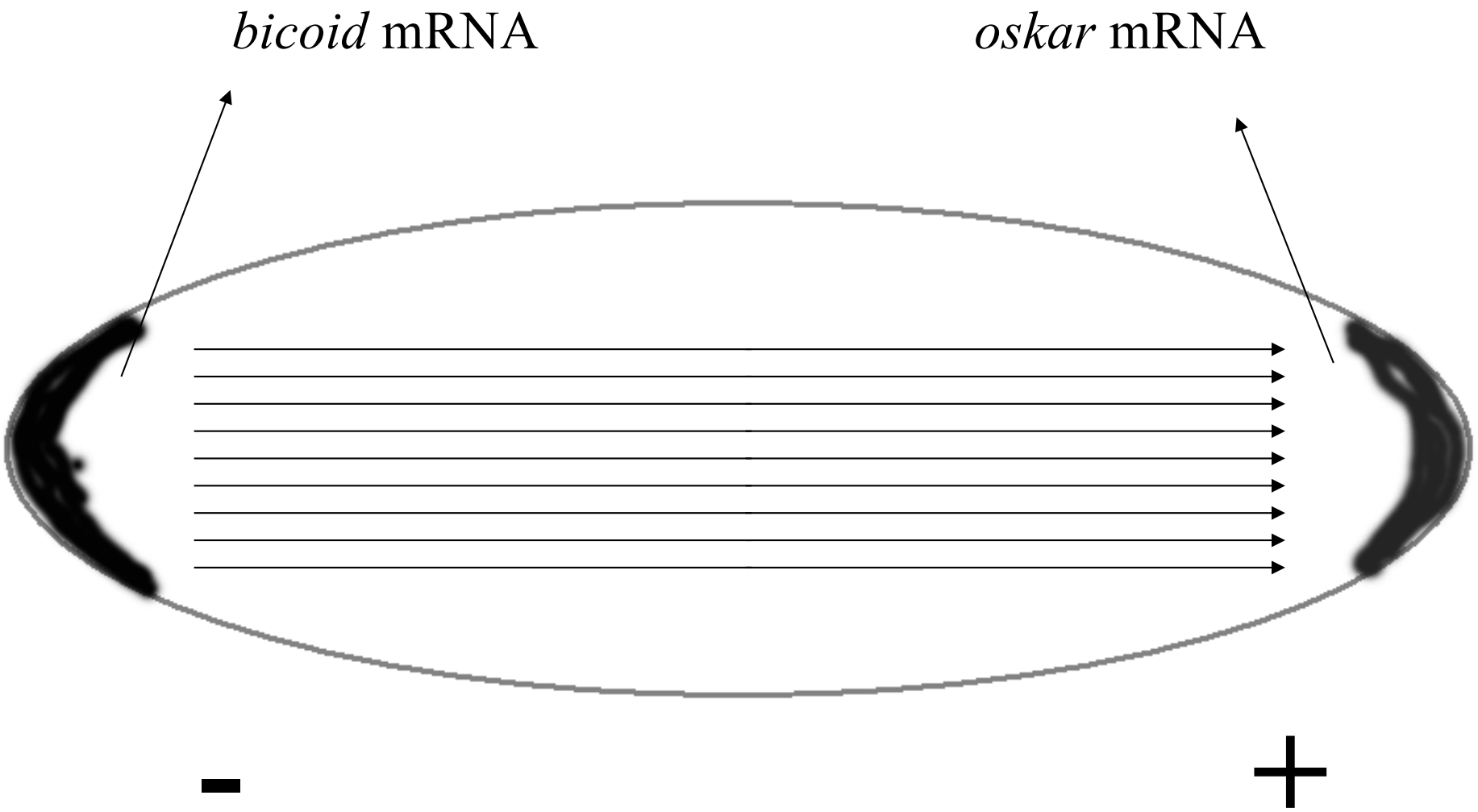


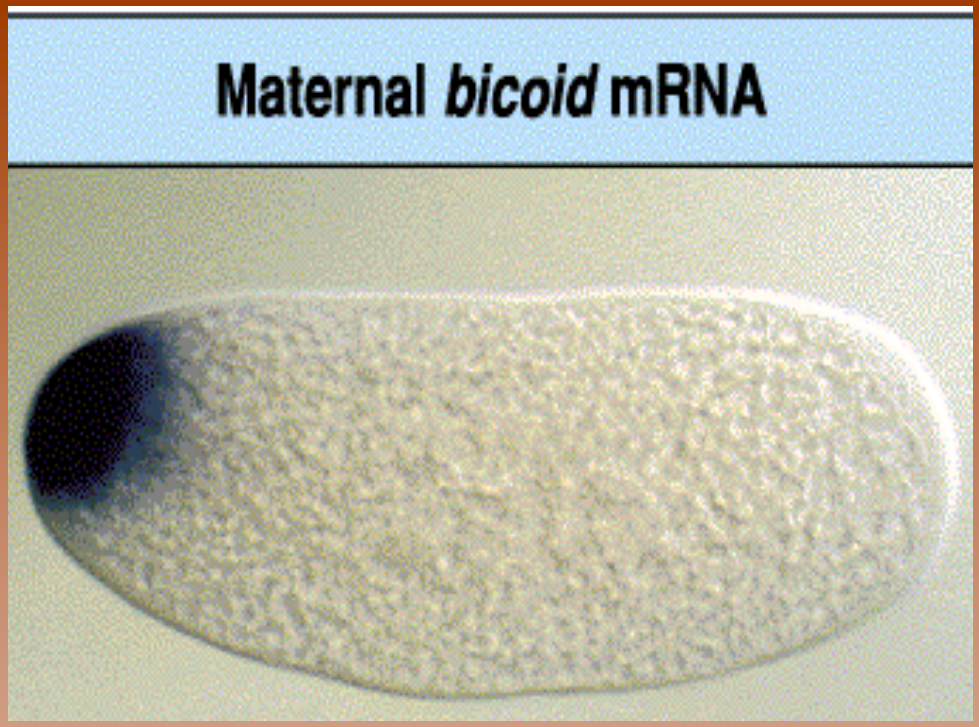
Nurse and Follicle Cells of the Egg Chamber are Instrumental in Patterning the Early Embryo



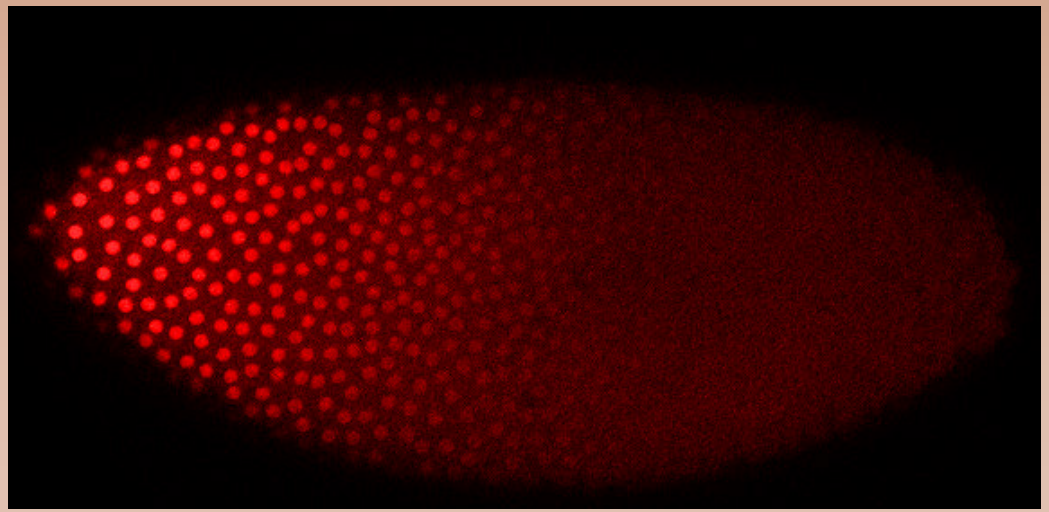
Microtubule organization – in a mature oocyte

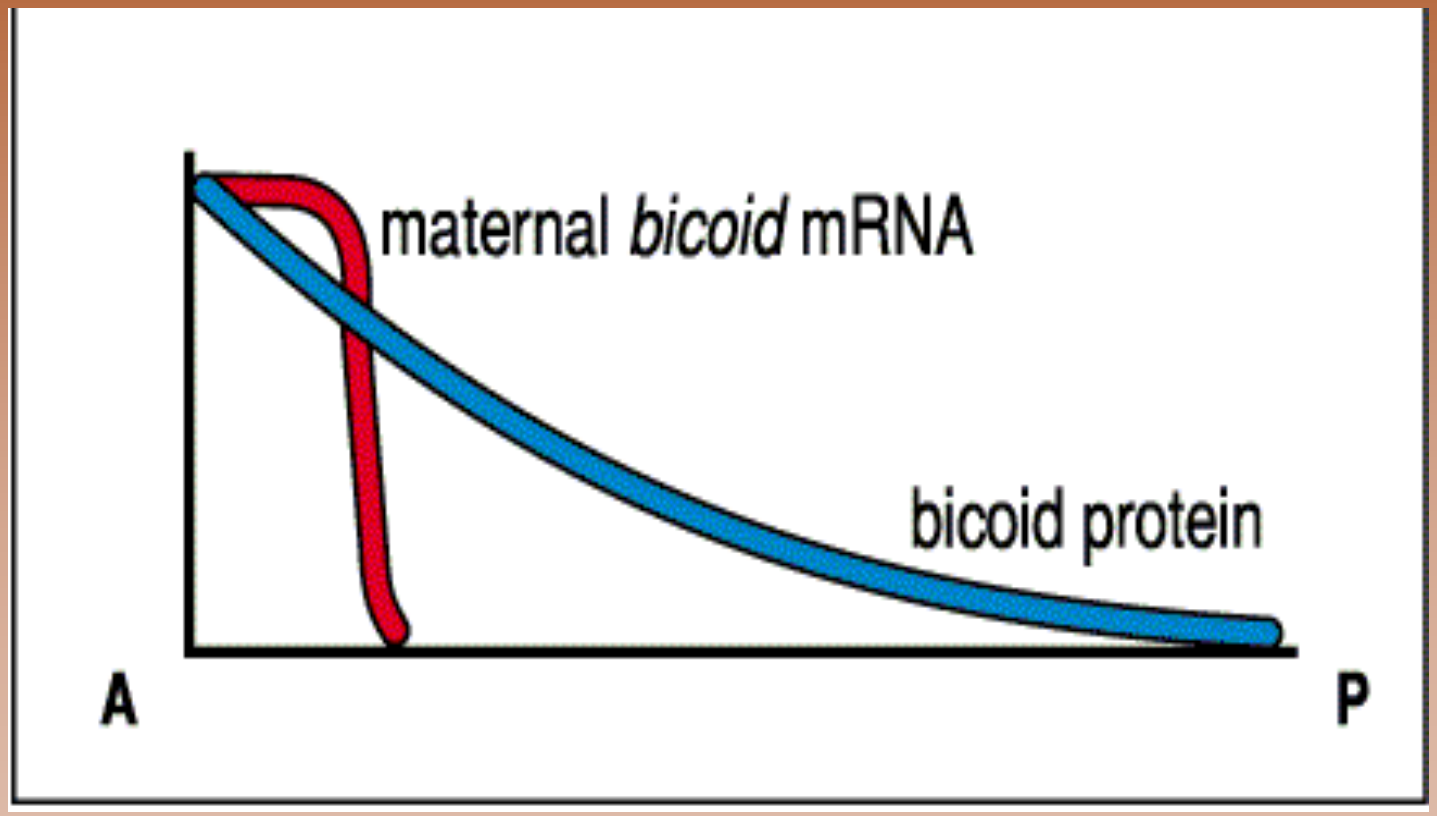


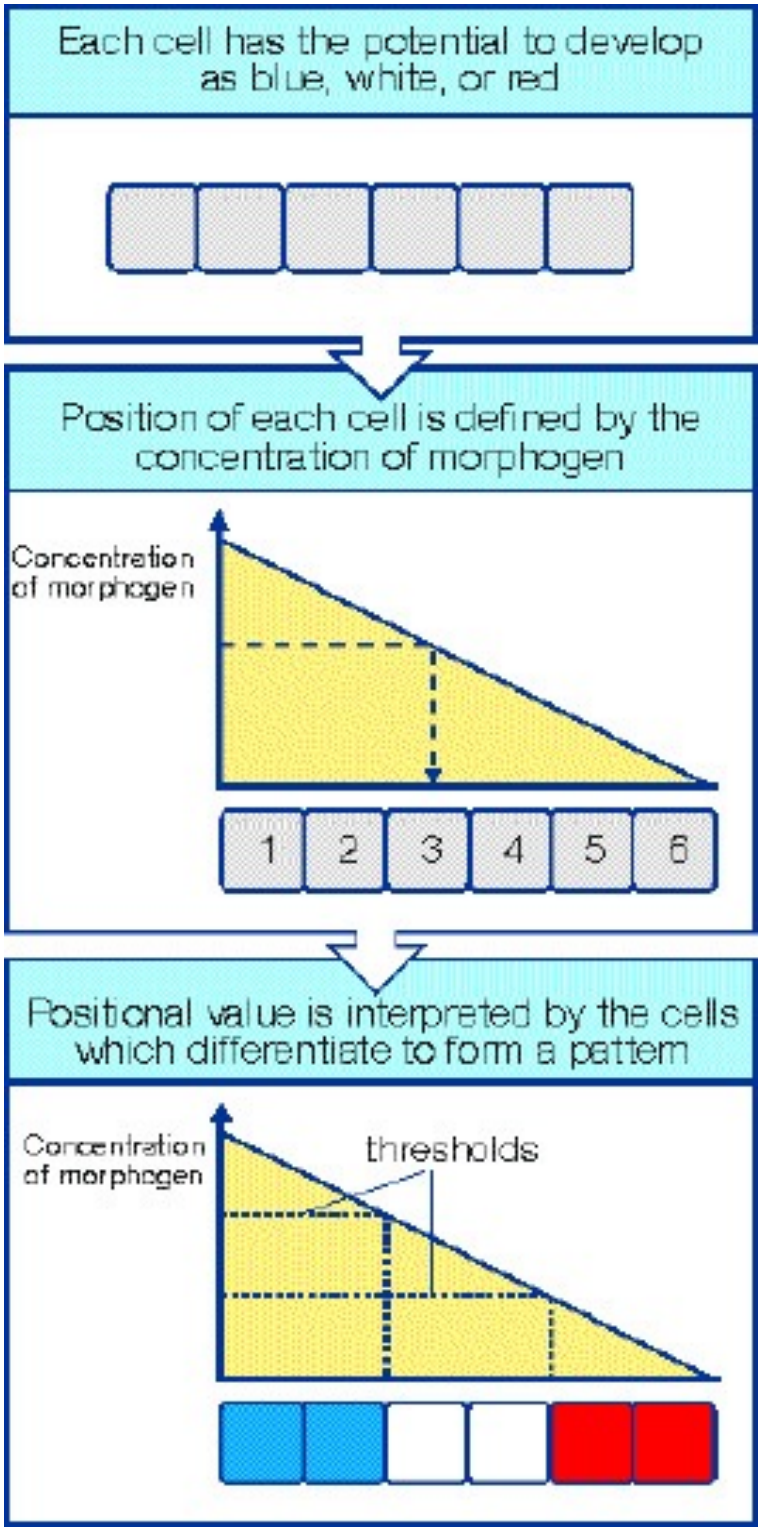

bicoid mRNA
oskar mRNA
-
+

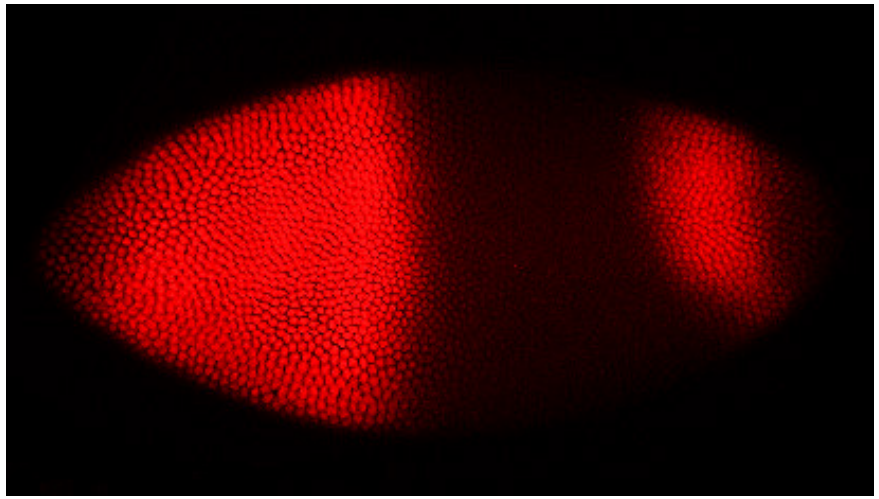


Bicoid Protein

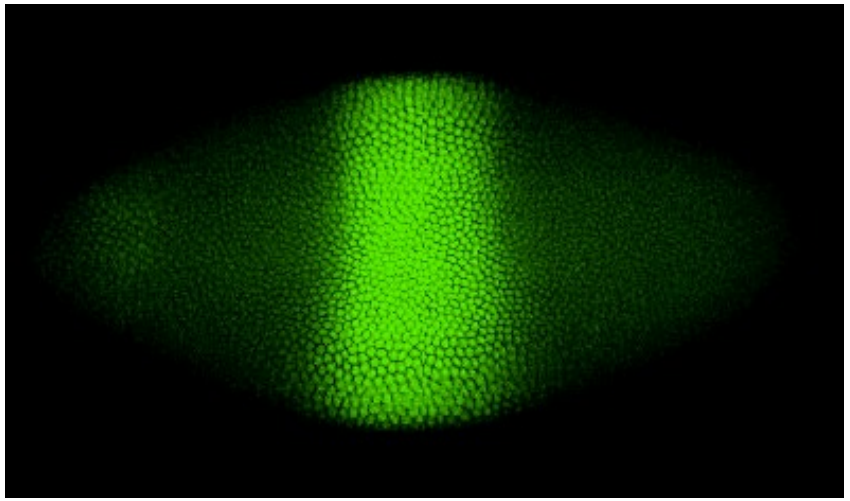



maternal *bicoid* mRNA
bicoid protein
A
P

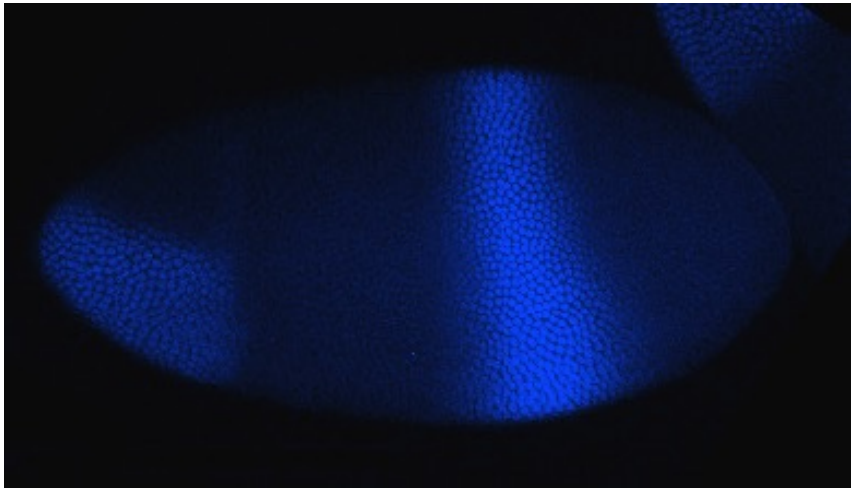

Each cell has the potential to develop as blue, white, or red
Position of each cell is defined by the concentration of morphogen
Concentration of morphogen
1
2
3
4
5
6
Positional value is interpreted by the cells which differentiate to form a pattern
Concentration of morphogen
thresholds



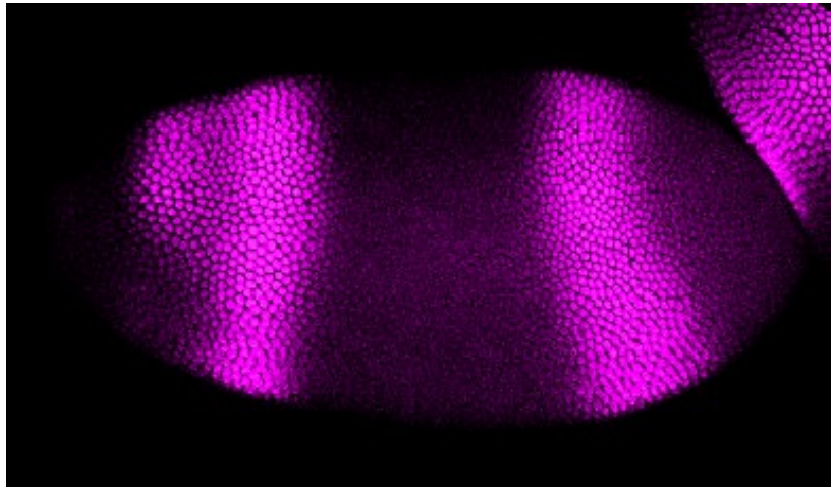
hunchback



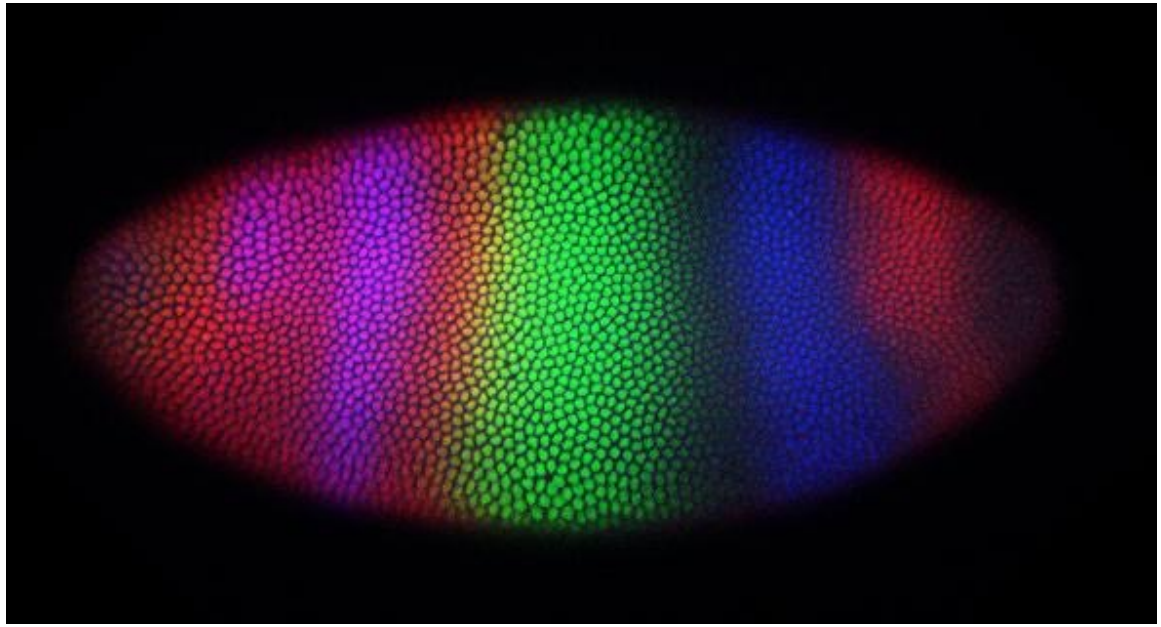
Kruppel



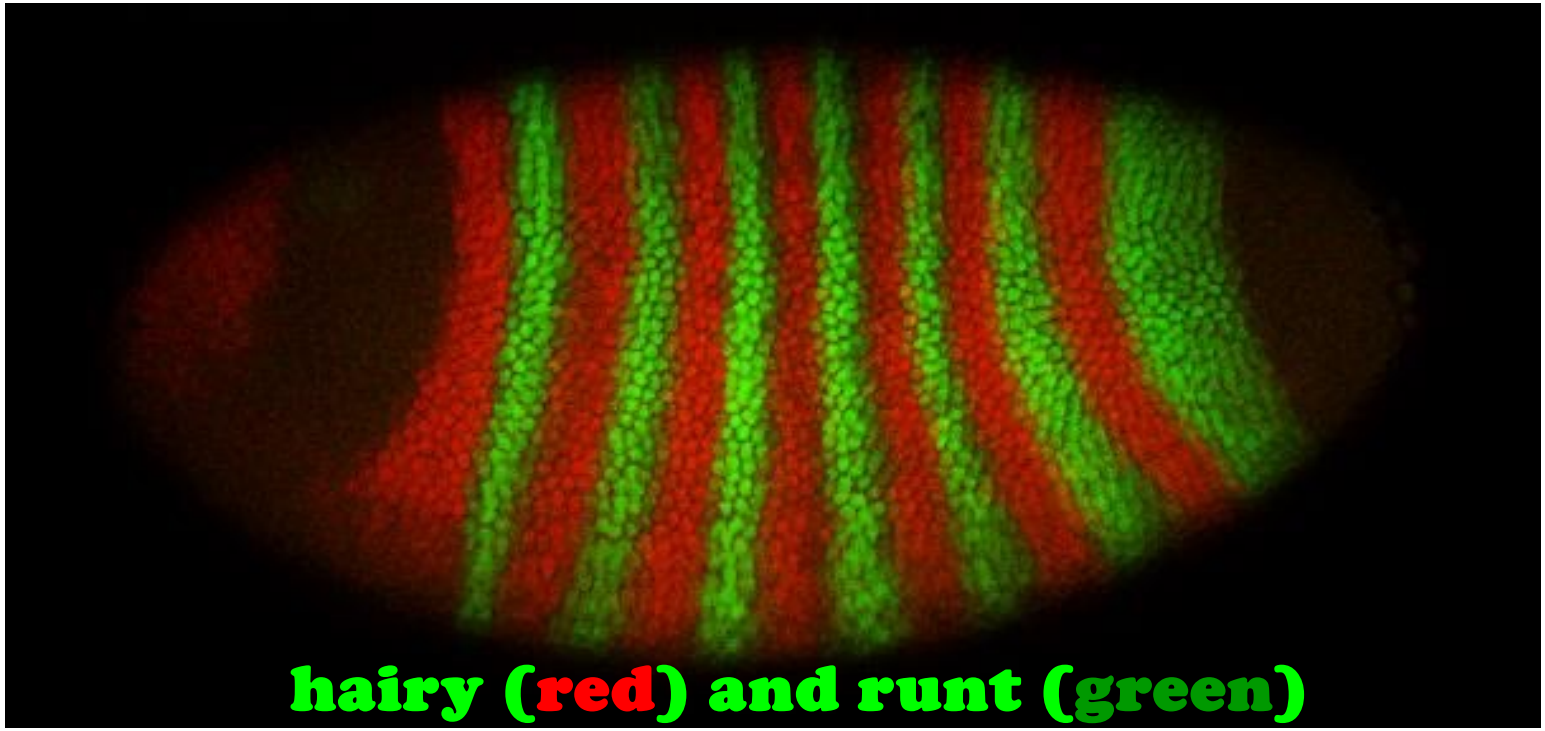
giant

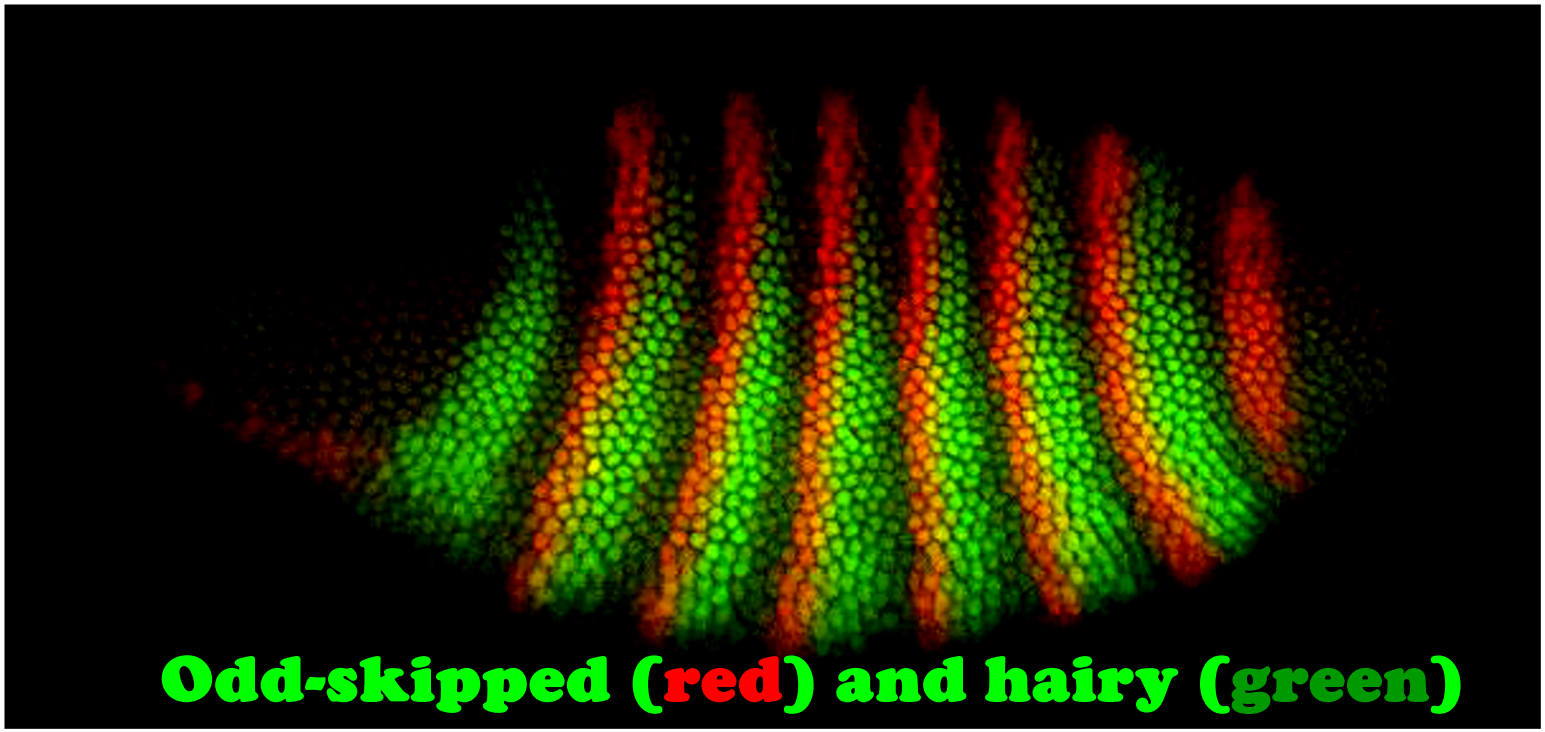


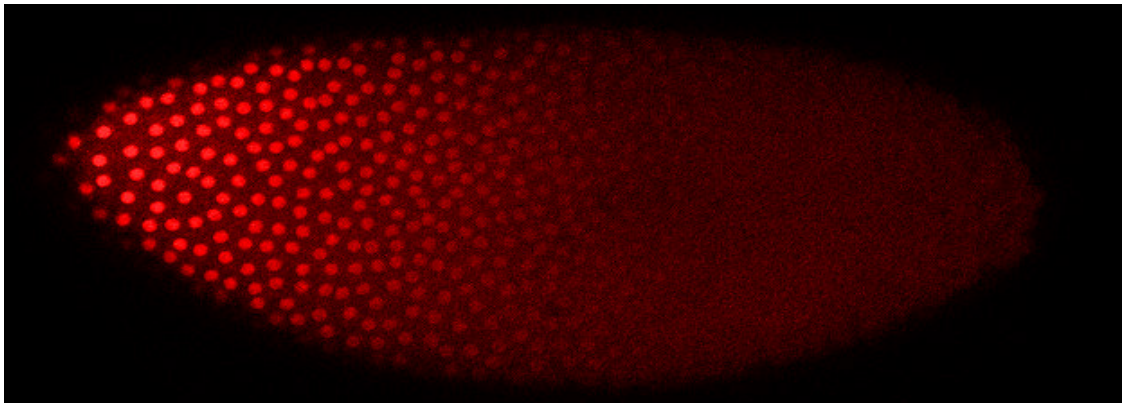
Knirps

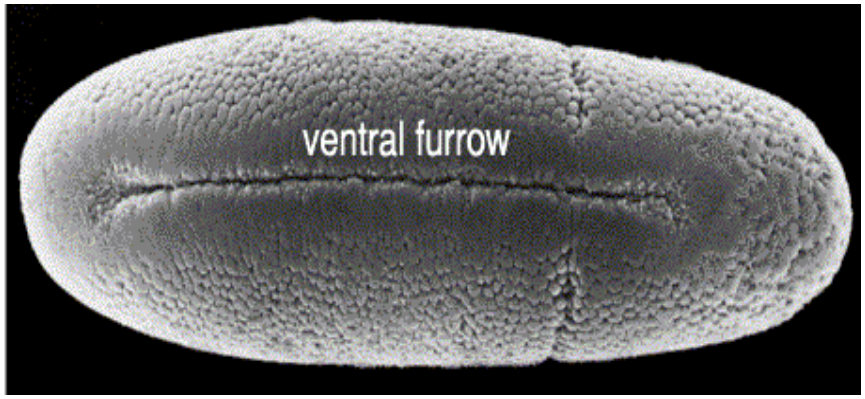


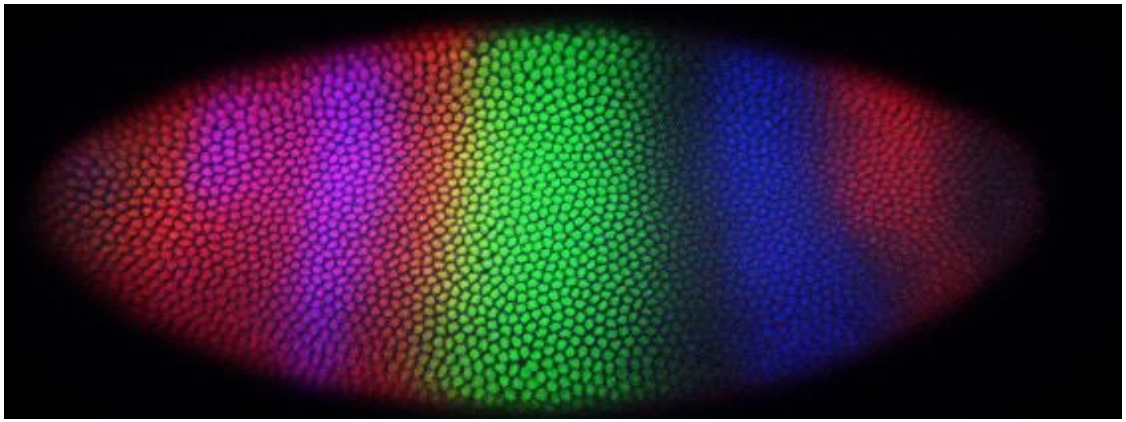
***hunchback* (red), *Kruppel* (green) and *giant* (blue)**

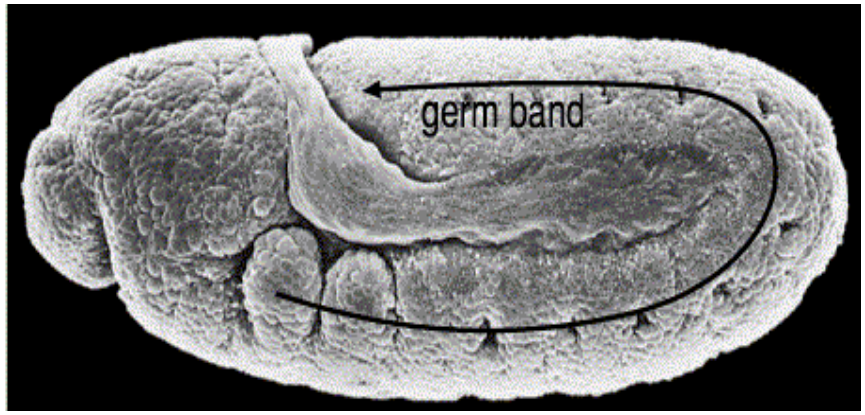

hairy (red) and runt (green)

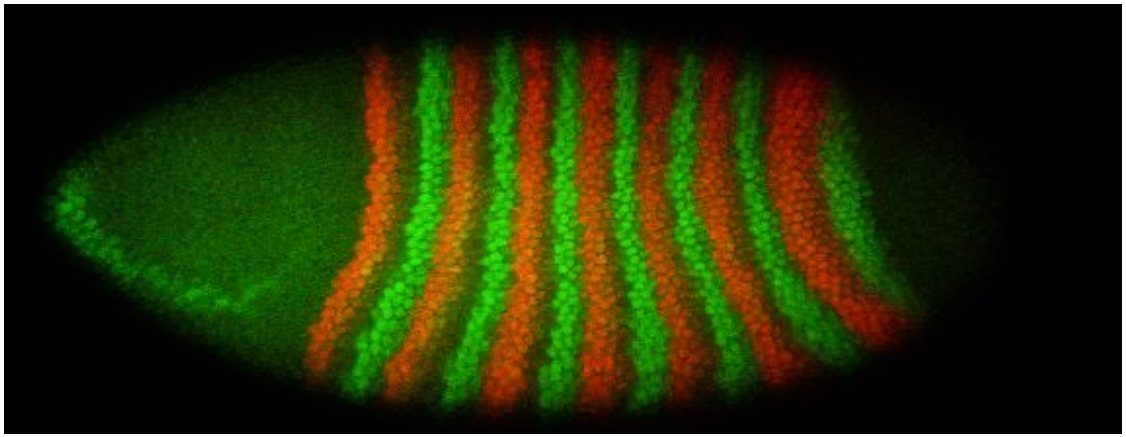

Odd-skipped (red) and hairy (green)

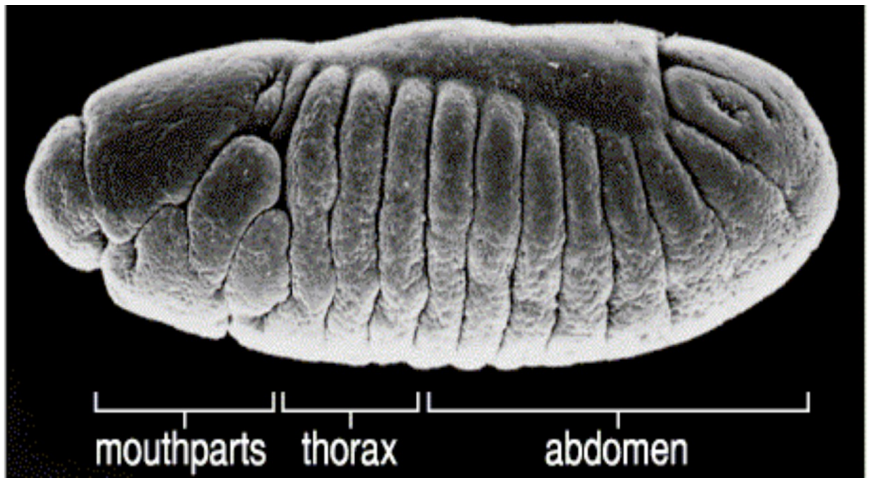




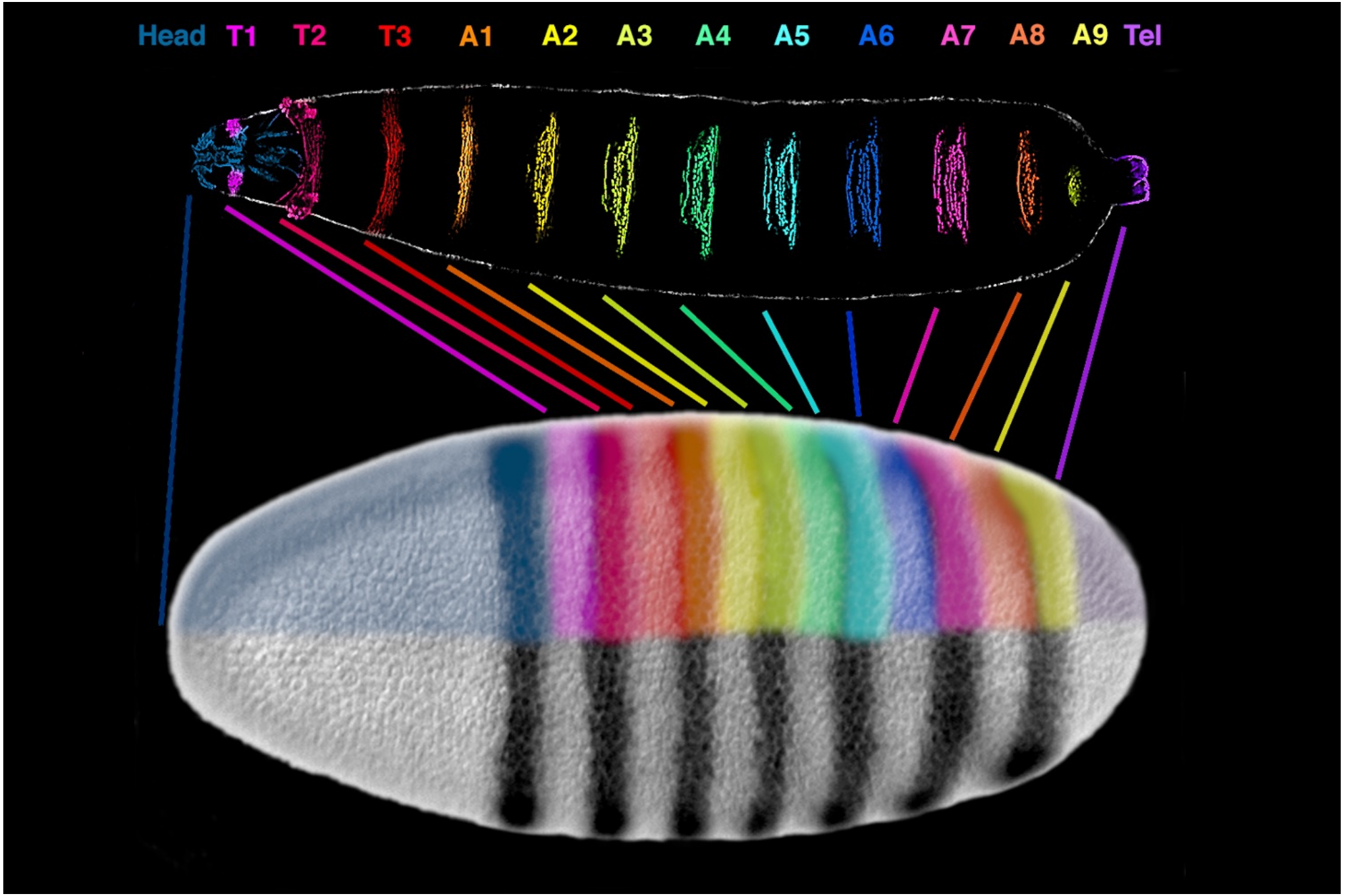






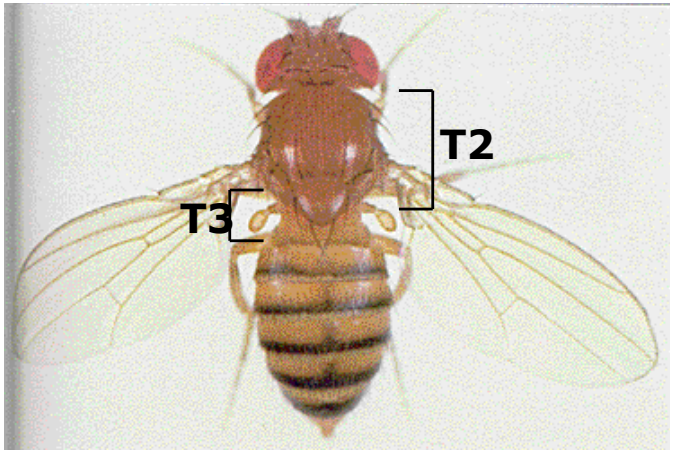


Morphological events are preceded by molecular events


Head
T1
T2
T3
A1
A2
A3
A4
A5
A6
A7
A8
A9
Tel

wing vs haltere in *Drosophila*

No *Ubx* in T3



Wildtype

***Ubx* in both T2 and T3**

Ed Lewis, Antonio Garica-Bellido, Gines Morata, Ernesto Sanchez-Herrero and many others

The Dorsal Nuclear Gradient

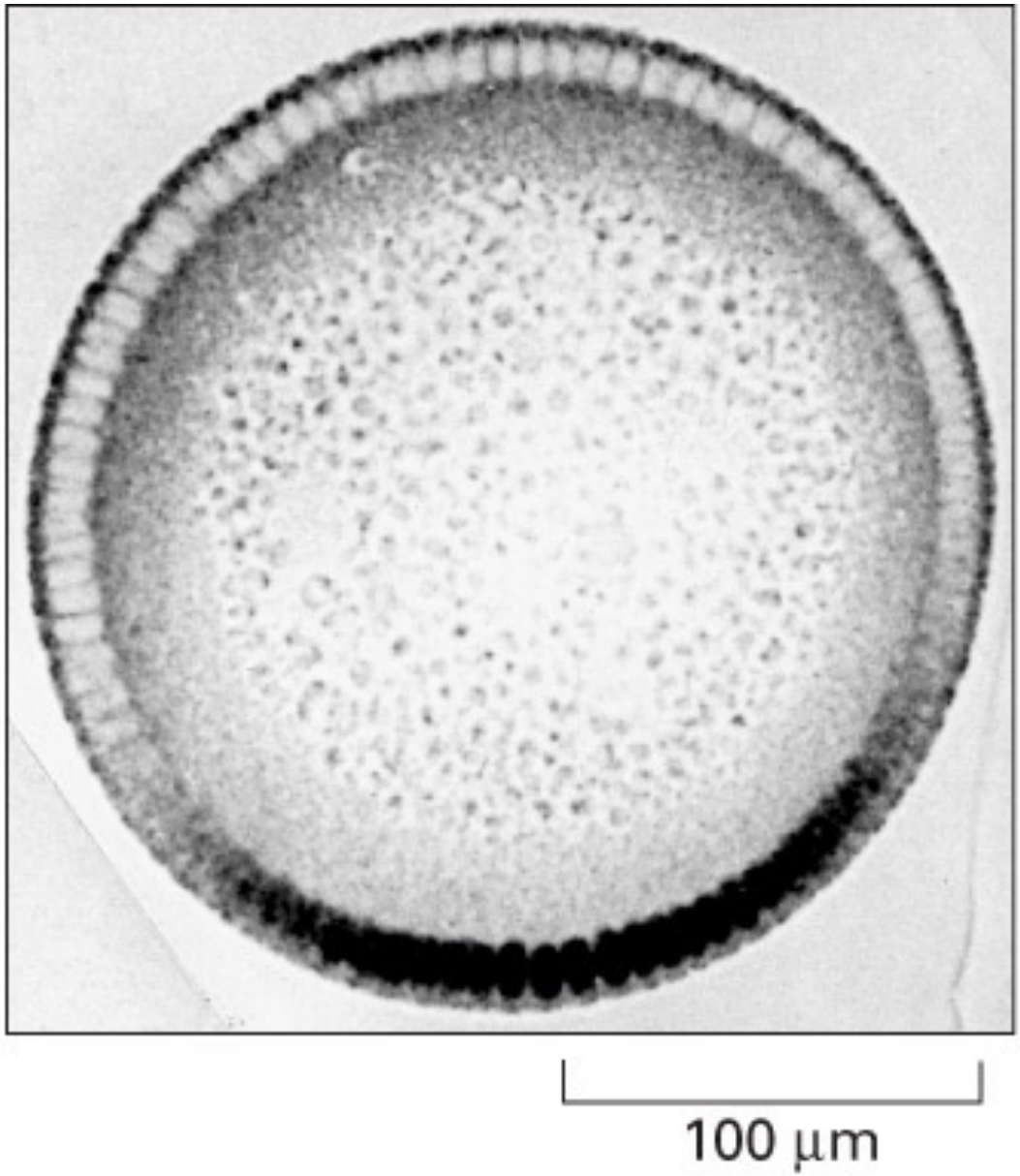
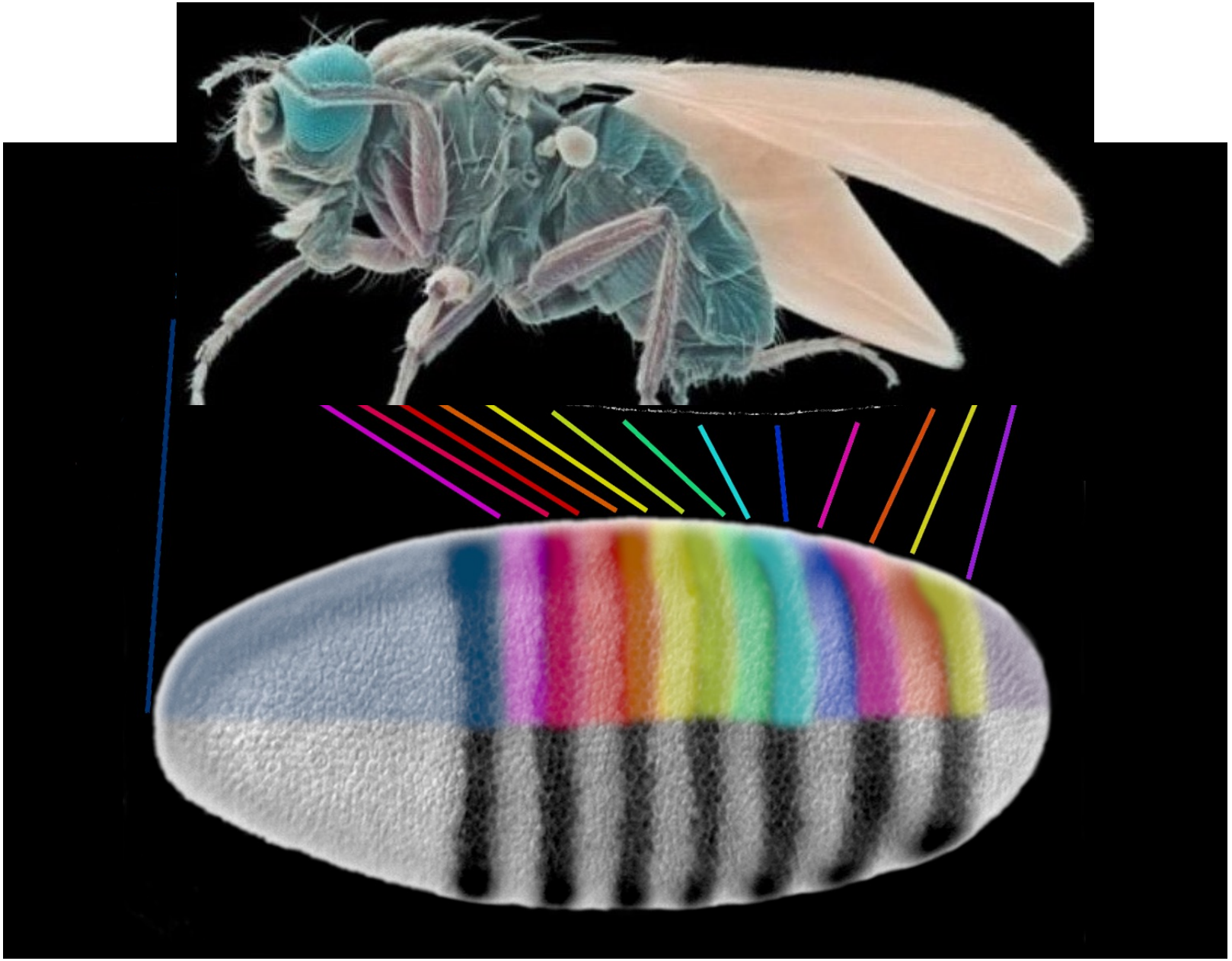
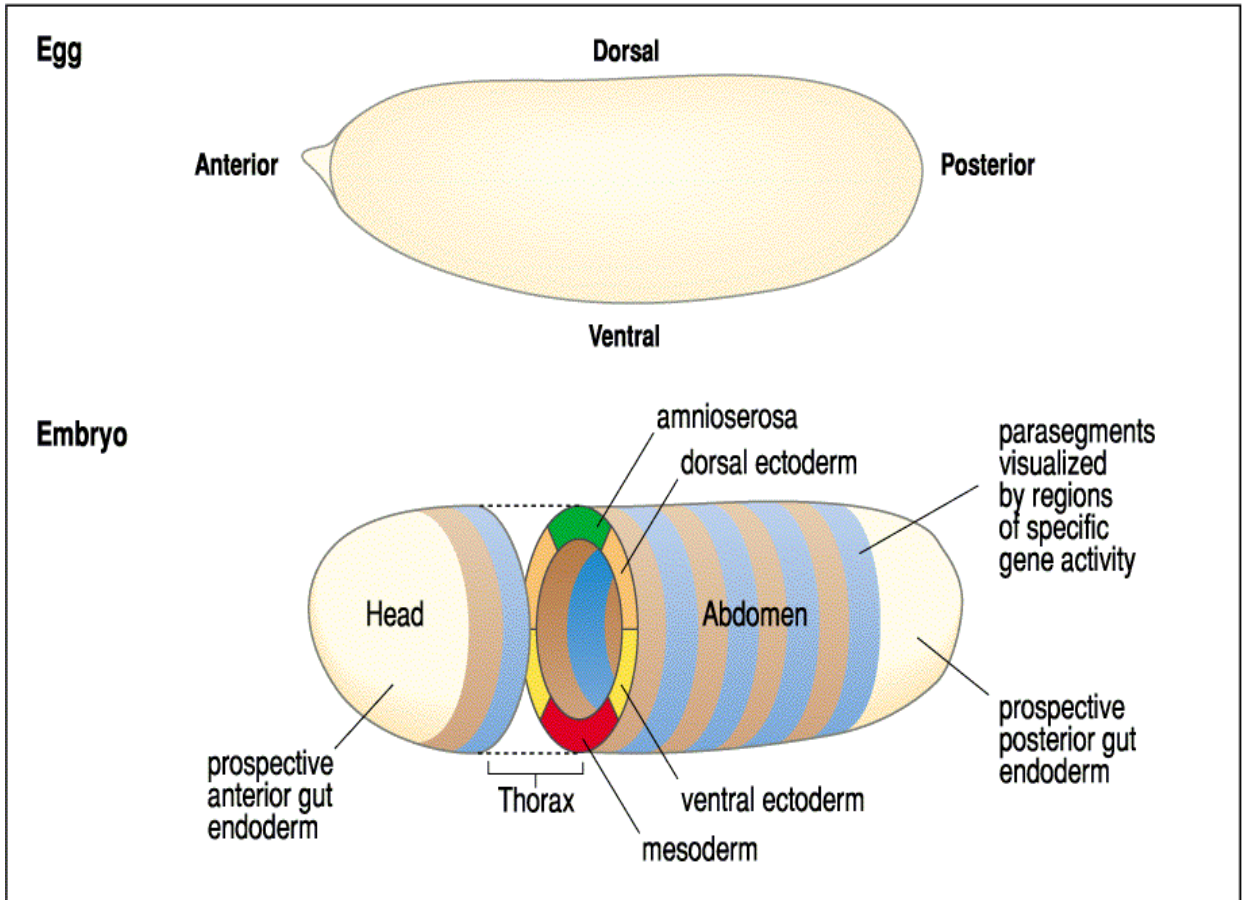


Figure 21–32. Molecular Biology of the Cell, 4th Edition.

Hox genes regulate segment specific developmental pathways




Egg
Dorsal
Anterior
Posterior
Ventral
Embryo
amnioserosa
dorsal ectoderm
parasegments visualized by regions of specific gene activity
Head
Abdomen
prospective anterior gut endoderm
Thorax
ventral ectoderm
prospective posterior gut endoderm
mesoderm

Polarity in egg/zygote among diverse animals

Problems with diffusion:

Pathway and diffusion constant - tortuous path
makes diffusion constant some 5 times less

Reliability

Precision - robustness but…..

Making a gradient

Developmental mechanisms

More morphogen gradients
Self-organizing systems
Induction
Lateral inhibition
Recruitment

One cell to multiple cells; The genome remains the same in all cells

Conferring identity means, activating different sets of genes in different cells.

Spatio-temporal regulation of gene expression

Cytoskeletal dynamics

Is that all?

What about internal and external forces that change the mechanical properties of cells?

Are these shape as per the unravelling developmental programs? Example, cell-cell interactions between two cells vs hundreds-thousands of cells at different developmental stages?

Passive role or lack of it vs active role of cortical actin, microtubular cytoskeleton, membranes, extra-cellular matrix…in shaping size/shape/interactions

If active role: are mechanical forces too part of the programmed changes? For example, programmed changes to ECM or cortical actin?