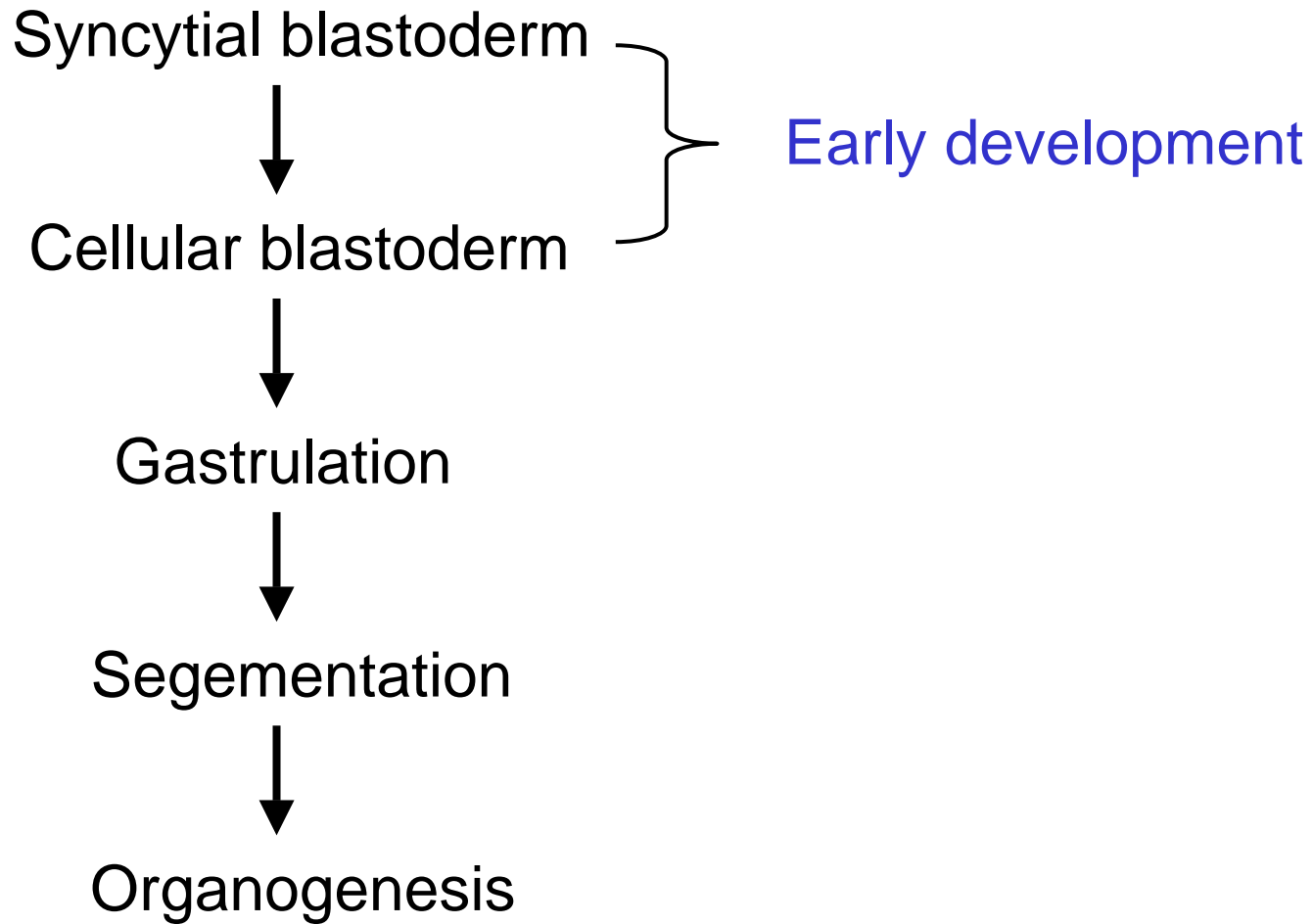


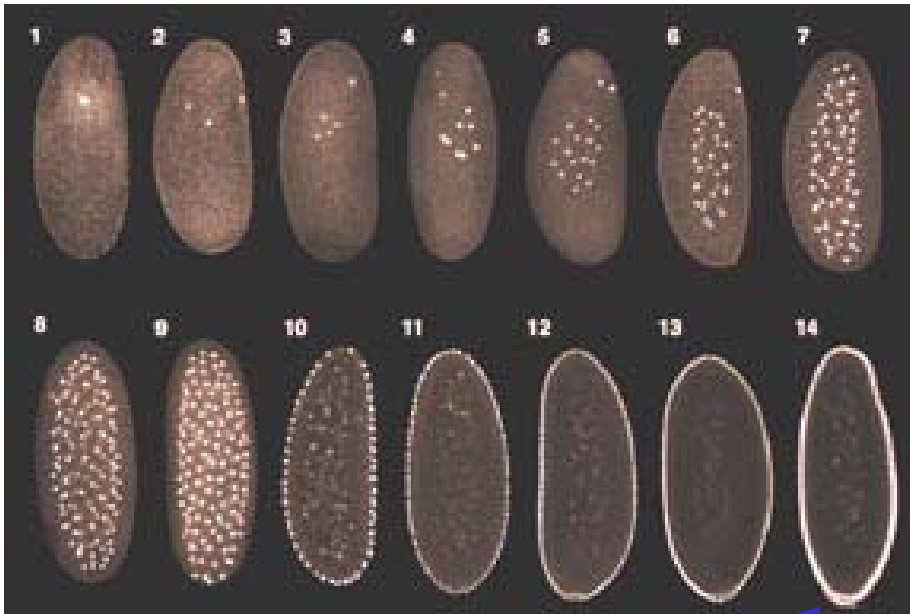
Chapter 9 The genetics of axis specification in *Drosophila*

1. Embryogenesis
2. Determination of the anterior-posterior axis
 - a. Maternal vs. zygotic gene activity
 - b. Gene hierarchy
 - c. Establishment of segments (parasegments)
 - d. Specification of segments
3. Determination of the dorsal-ventral axis
 - a. both axes are determined during oogenesis
 - b. The Toll pathway

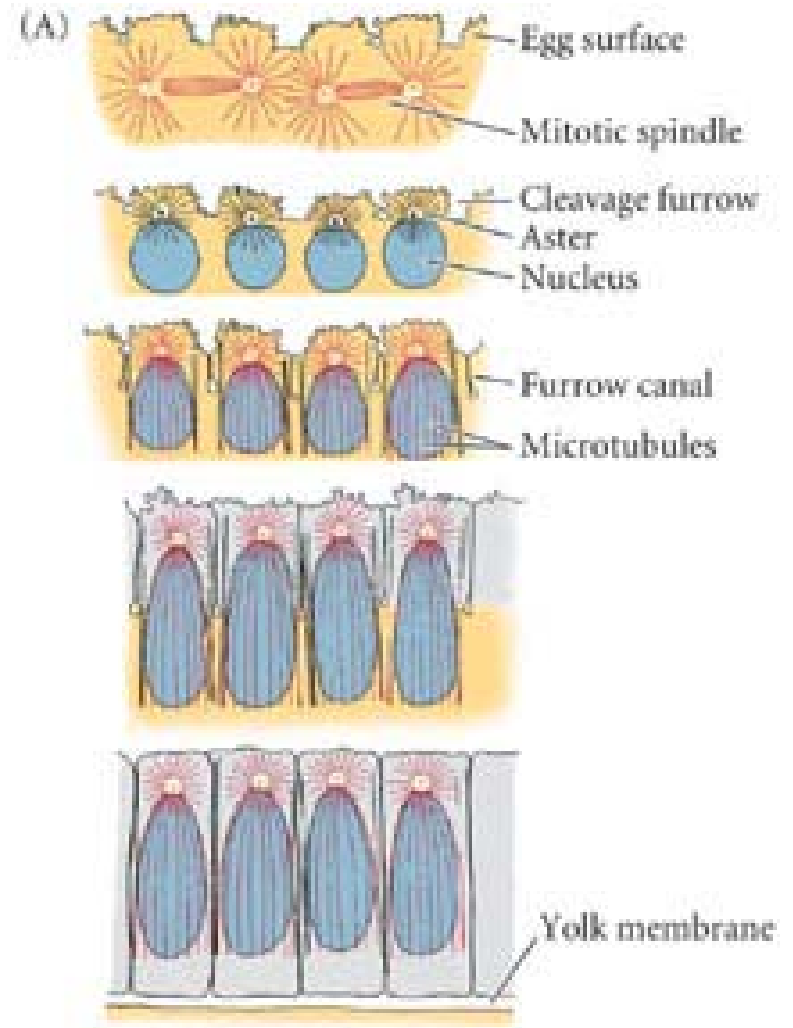
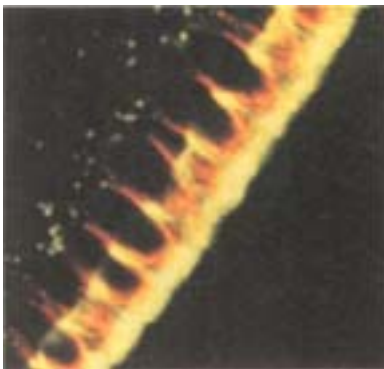
Embryogenesis



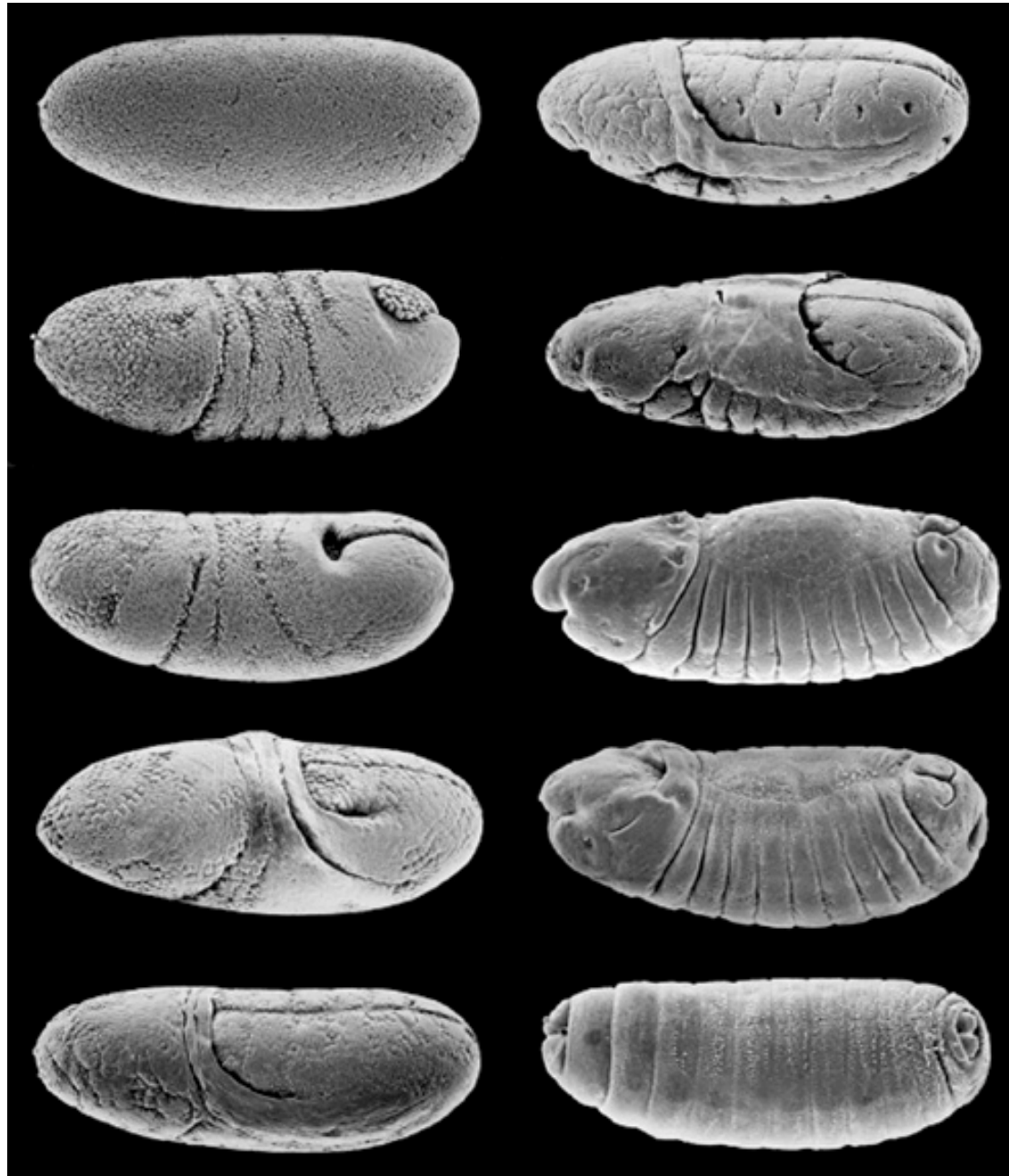
Syncytial blastoderm

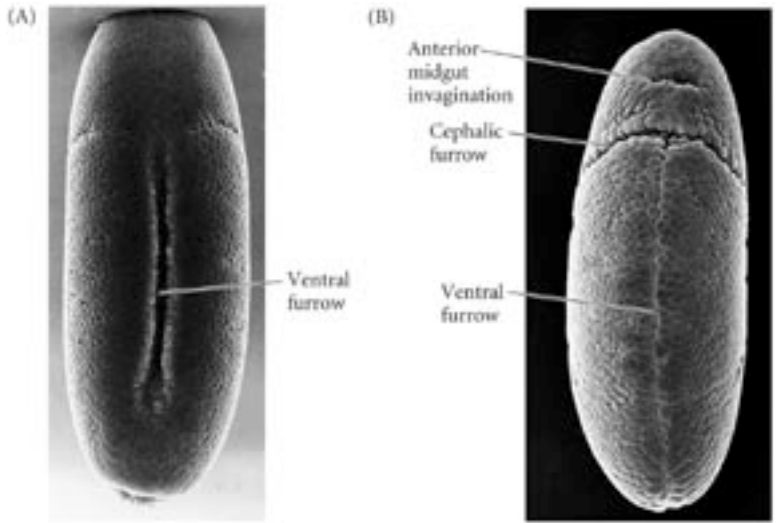


Cellular blastoderm



Morphology of
embryo at
different stages





Gastrulation in *Drosophila* embryo

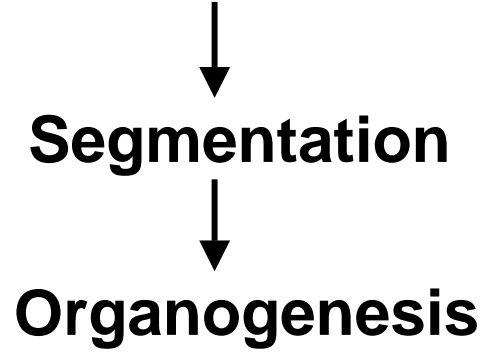
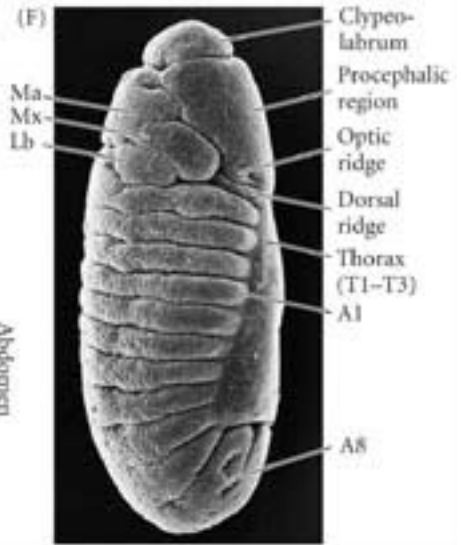
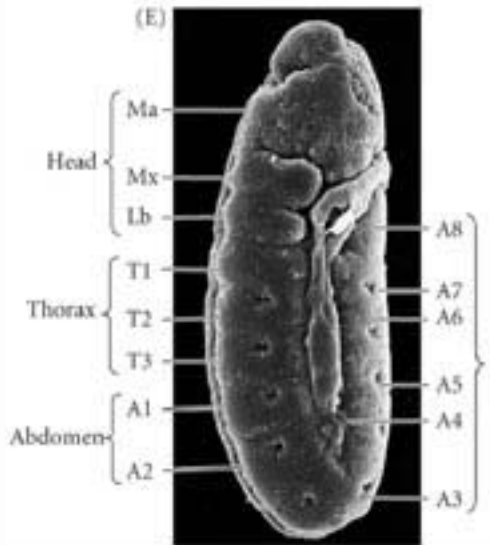
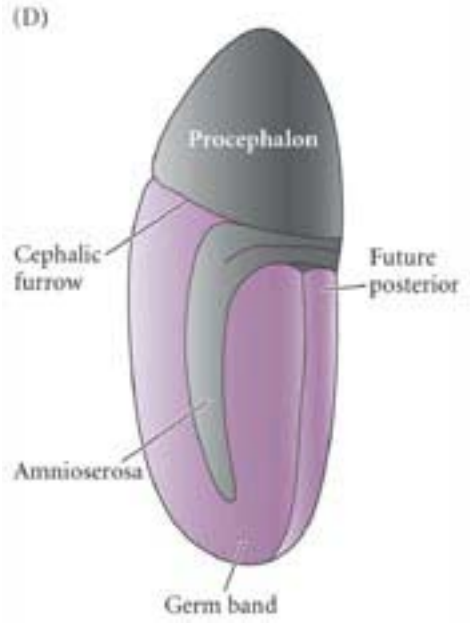
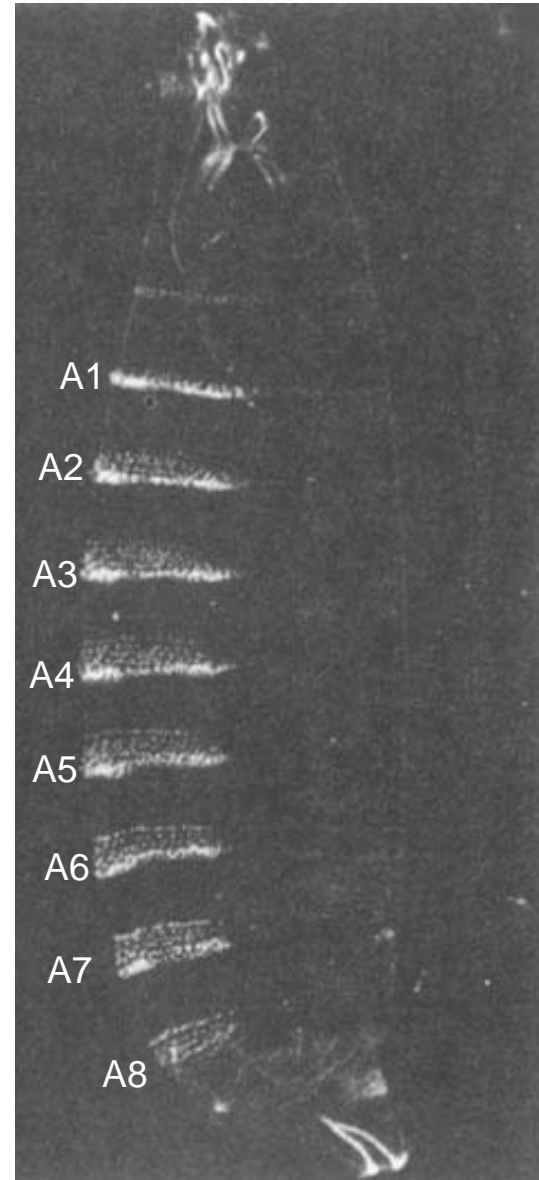


Fig. 9.5



Anterior segment

(G)



Summary

Gene hierarchy

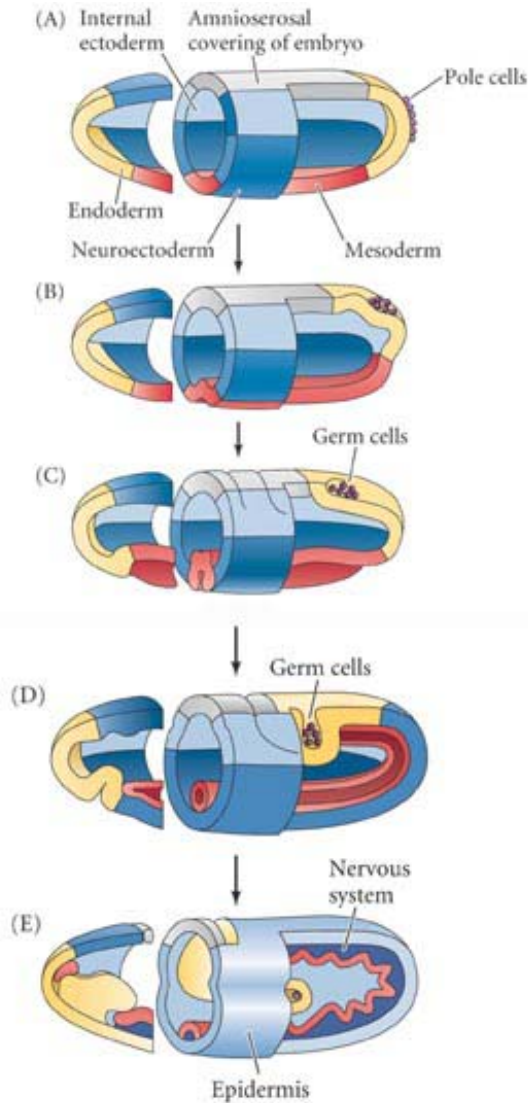
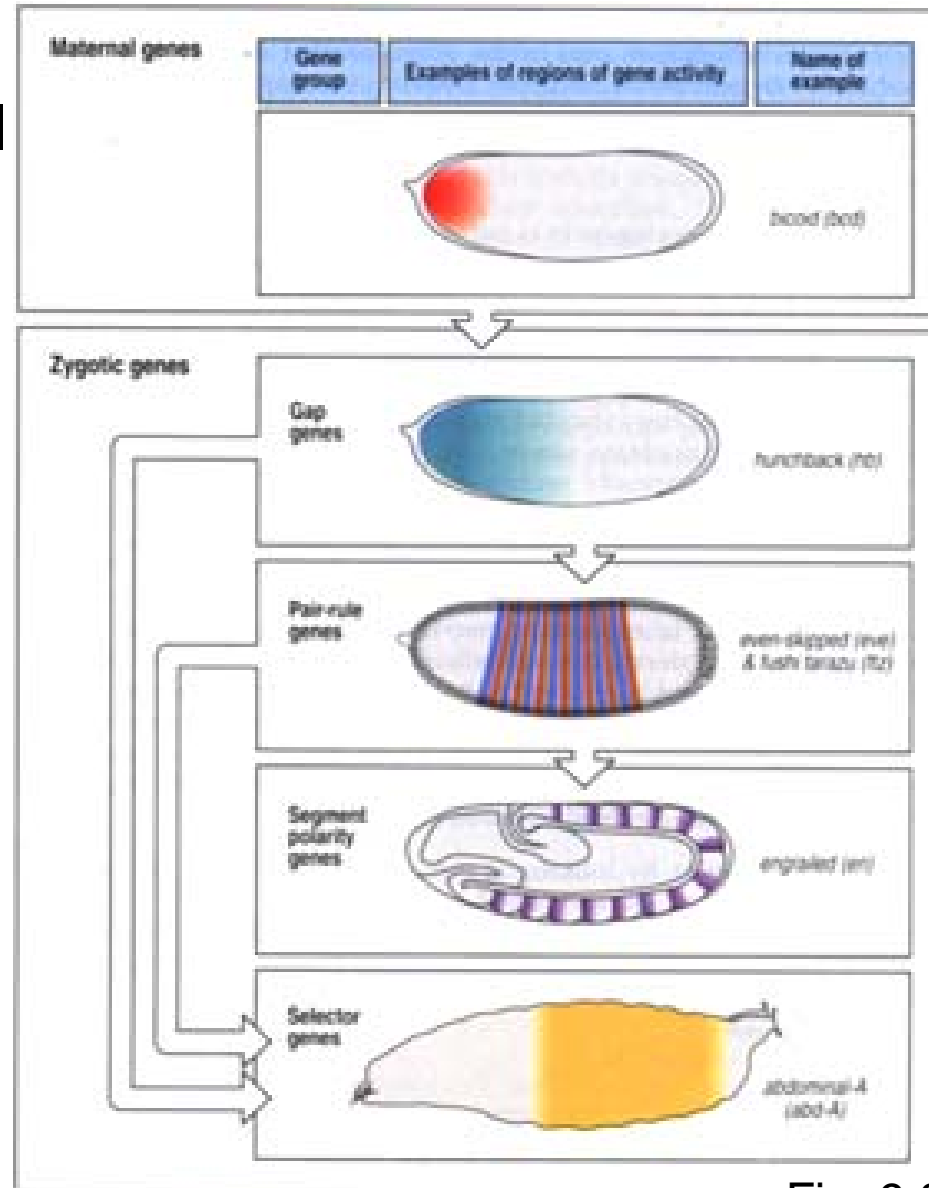


Fig. 9.6

Maternal effect

Zygotic



=Fig. 9.8

Definition of gap, pair-rule and segment polarity genes

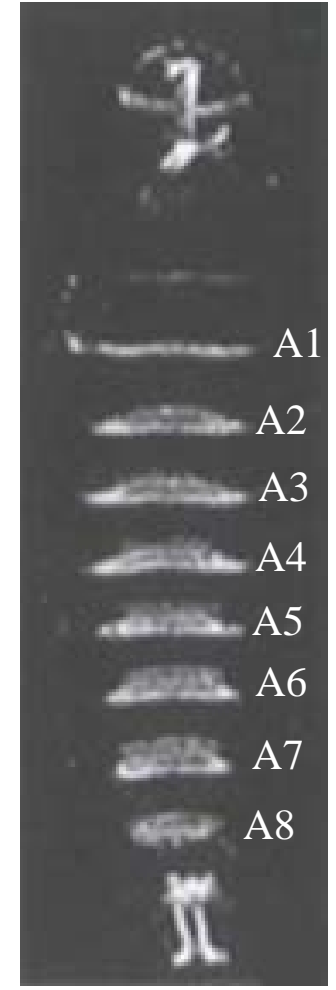
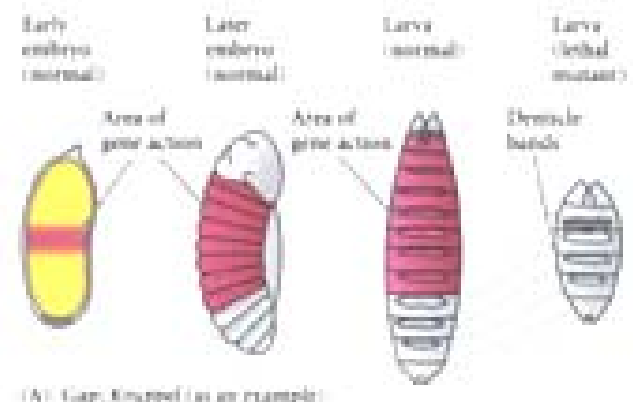
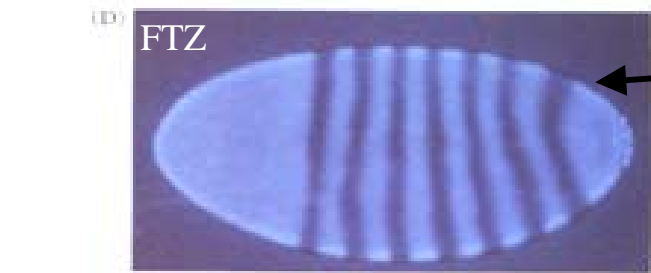
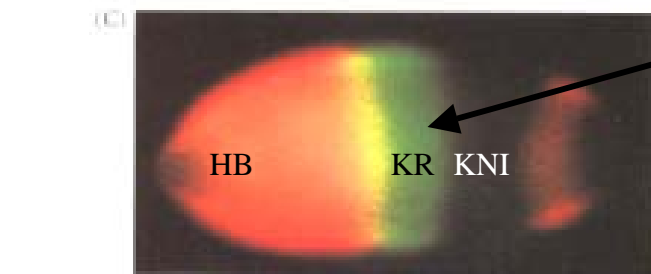
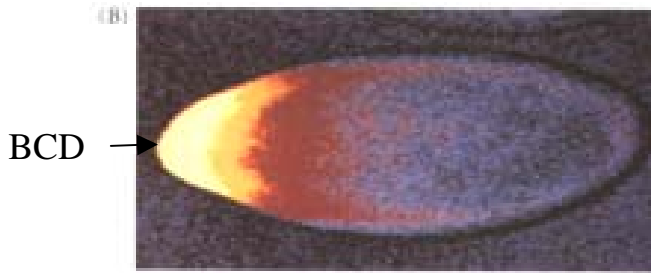


Fig. 9.8

Fig. 9.19

Three maternal systems interact to form the anterior-posterior axis of *Drosophila* embryo

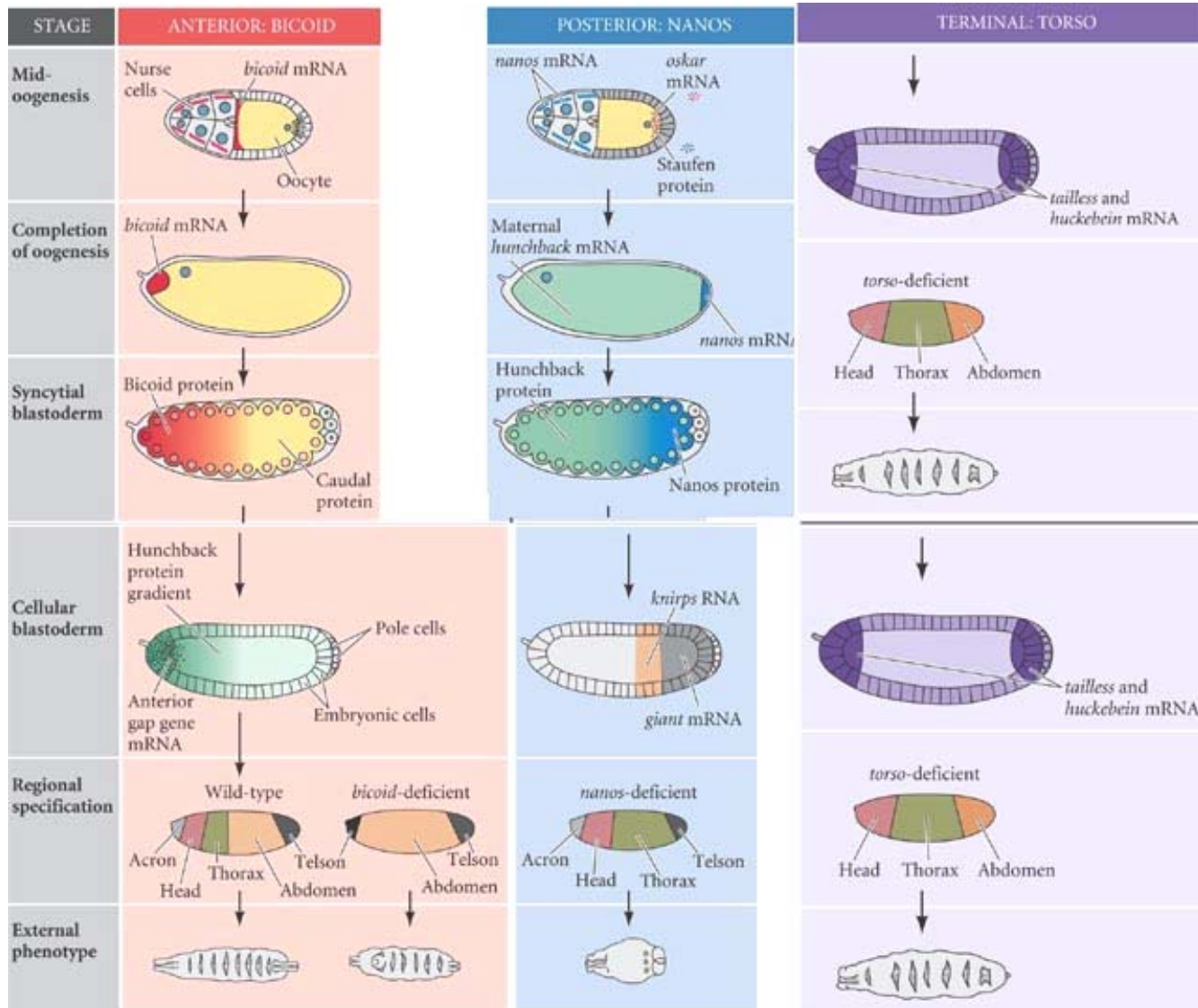


TABLE 9.1 Maternal effect genes that effect the anterior-posterior polarity of the *Drosophila* embryo

Gene	Mutant phenotype	Proposed function and structure
ANTERIOR GROUP		
<i>bicoid</i> (<i>bcd</i>)	Head and thorax deleted, replaced by inverted telson	Graded anterior morphogen; contains homeodomain; represses caudal
<i>exuperantia</i> (<i>exu</i>)	Anterior head structures deleted	Anchors <i>bicoid</i> mRNA
<i>swallow</i> (<i>swa</i>)	Anterior head structures deleted	Anchors <i>bicoid</i> mRNA
POSTERIOR GROUP		
<i>nanos</i> (<i>nos</i>)	No abdomen	Posterior morphogen; represses <i>hunchback</i> mRNA
<i>tudor</i> (<i>tud</i>)	No abdomen, no pole cells	Localization of Nanos protein
<i>oskar</i> (<i>osk</i>)	No abdomen, no pole cells	Localization of Nanos protein
<i>vasa</i> (<i>vas</i>)	No abdomen, no pole cells; oogenesis defective	Localization of Nanos protein
<i>valois</i> (<i>val</i>)	No abdomen, no pole cells; cellularization defective	Stabilization of the Nanos localization complex
<i>pumilio</i> (<i>pum</i>)	No abdomen	Helps Nanos protein bind <i>hunchback</i> message
<i>caudal</i> (<i>cad</i>)	No abdomen	Activates posterior terminal genes
TERMINAL GROUP		
<i>torso</i> (<i>tor</i>)	No termini	Possible morphogen for termini
<i>trunk</i> (<i>trk</i>)	No termini	Transmits Torso-like signal to Torso
<i>fs(1)Nasrat</i> [<i>fs(1)N</i>]	No termini; collapsed eggs	Transmits Torso-like signal to Torso
<i>fs(1)polehole</i> [<i>fs(1)ph</i>]	No termini; collapsed eggs	Transmits Torso-like signal to Torso

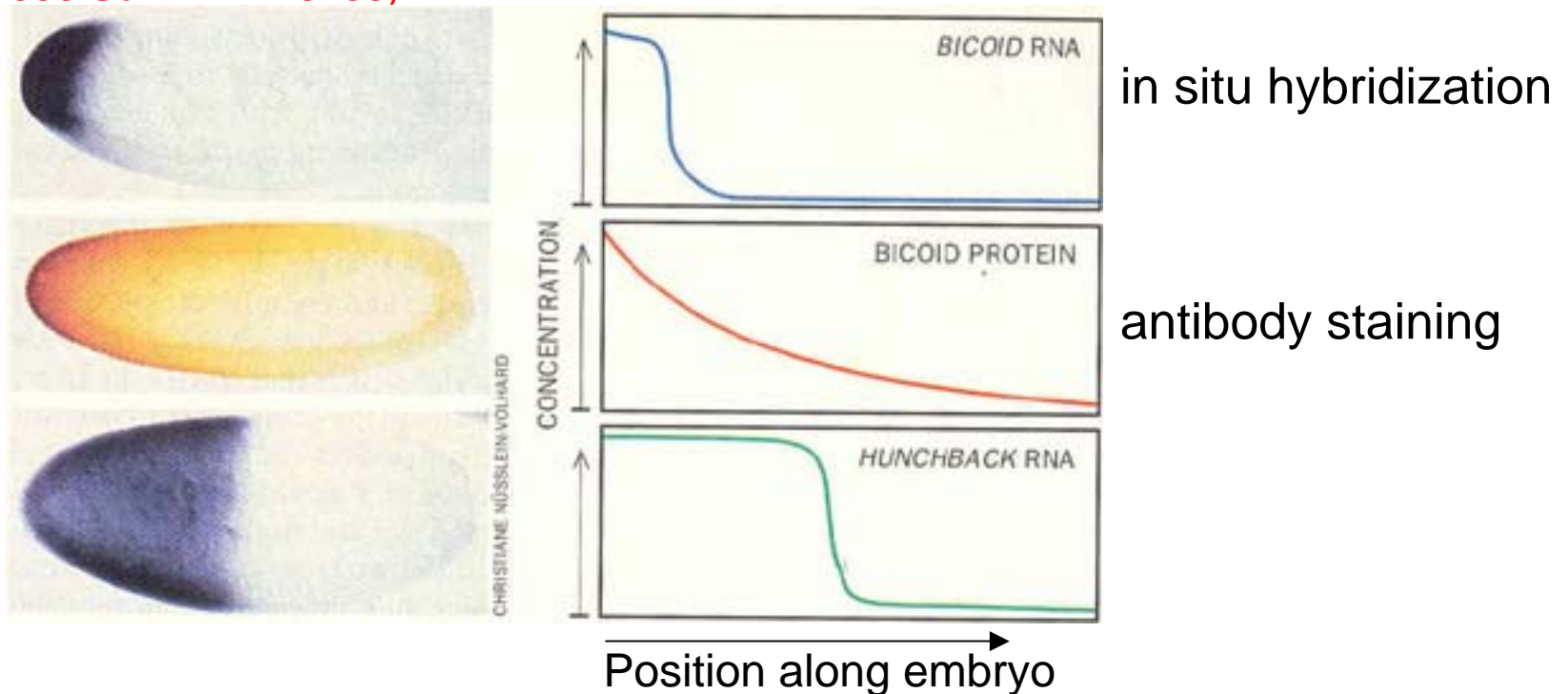
Source: After Anderson 1989.

The molecular model: Protein gradient

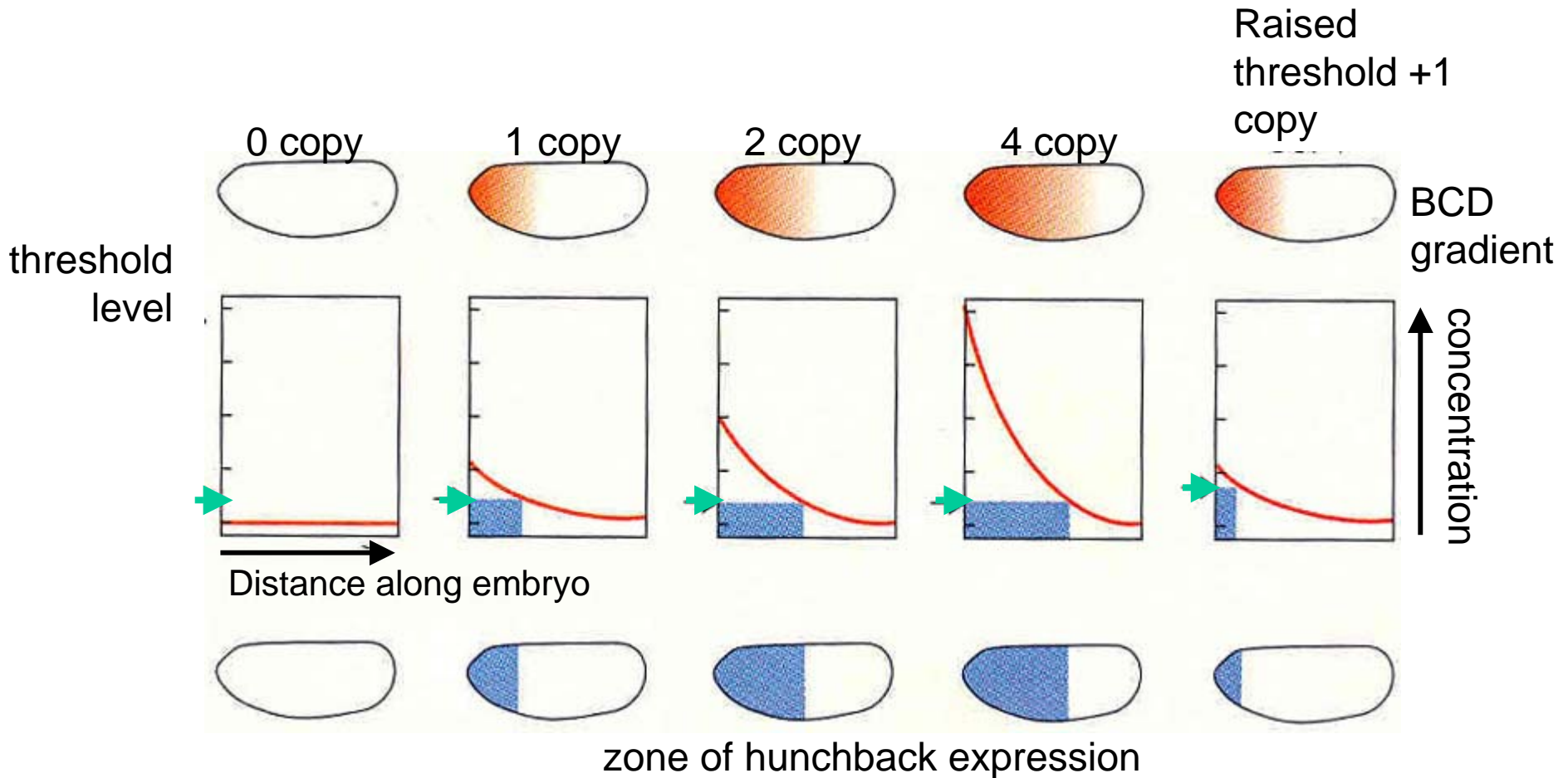
So called: **Morphogen**

- Form a gradient over space (from source to descent)
- Different sensors or cellular responses

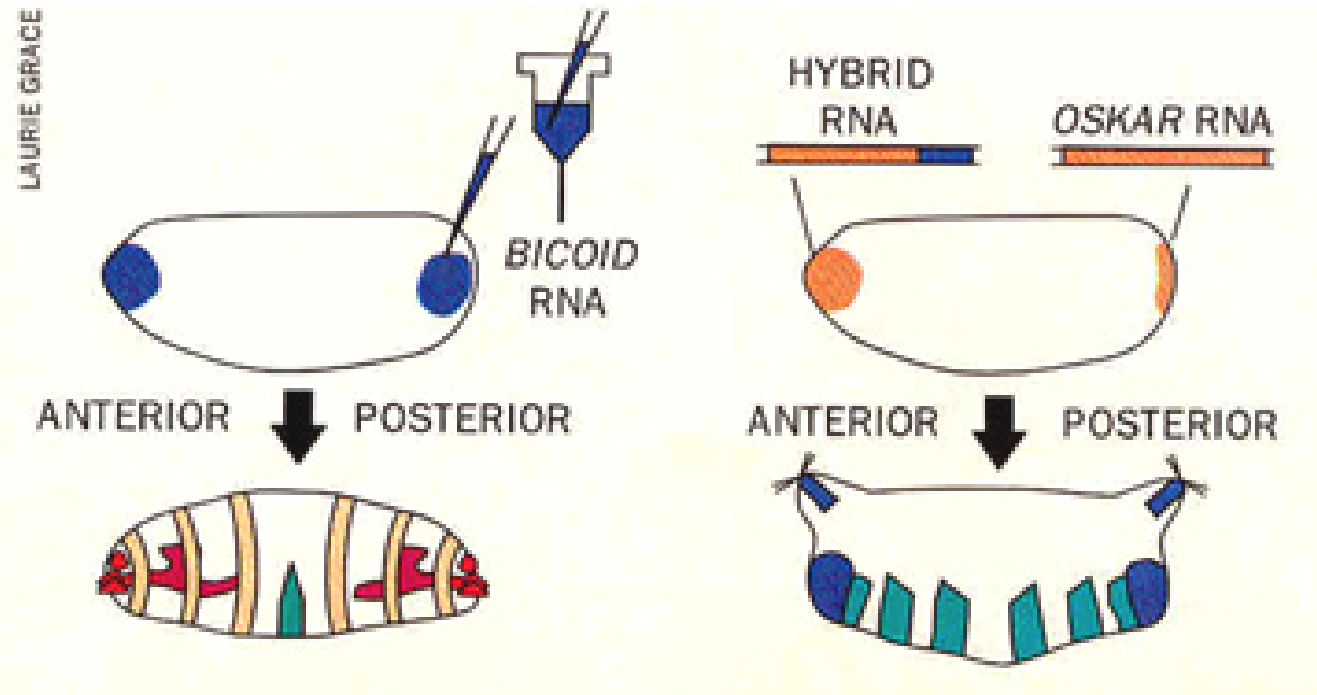
Evidences for that the BCD gradient controls development of anterior portion of larva (Nusslein-Volhard 1996 *Sci. Am.* 275: 38)



Bicoid (BCD) level affects the expressional domain of *hunchback*



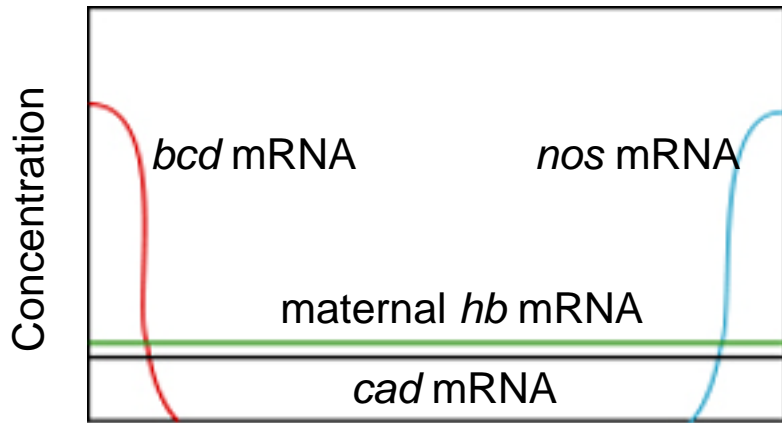
bcd activity is essential for the larval head development of *Drosophila* embryo



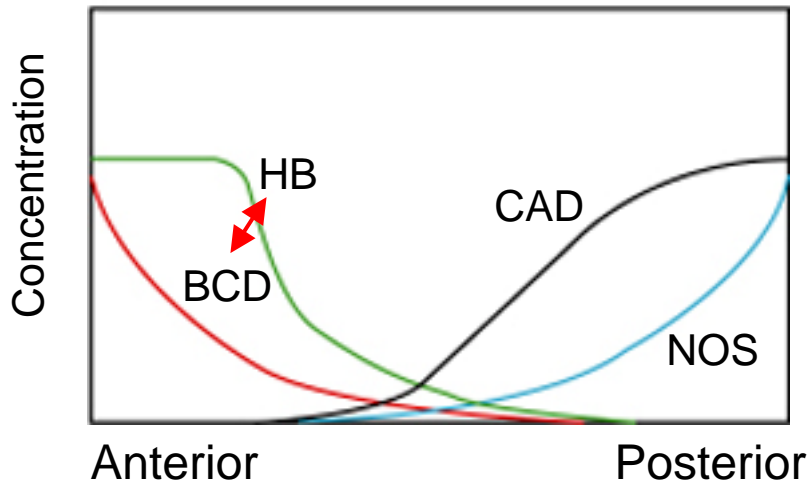
How do maternal anterior and posterior specify the anterior-posterior axis of larvae?

A model of interaction between anterior and posterior maternal effect gene activities

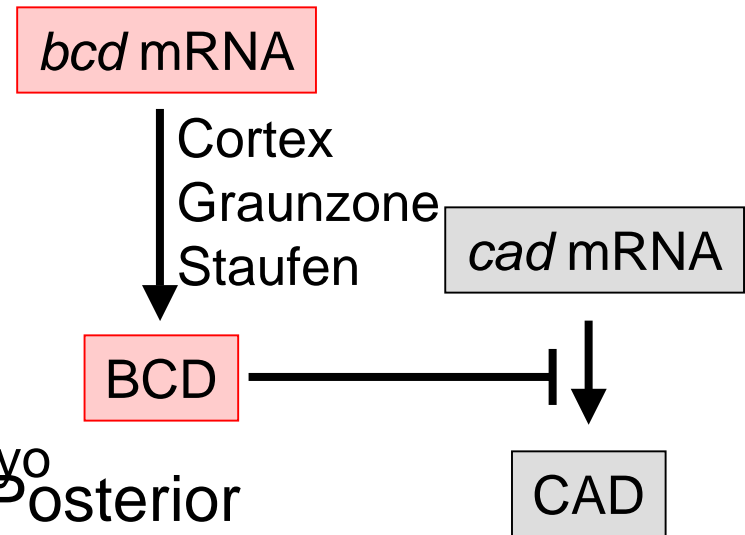
(A) Oocyte mRNAs



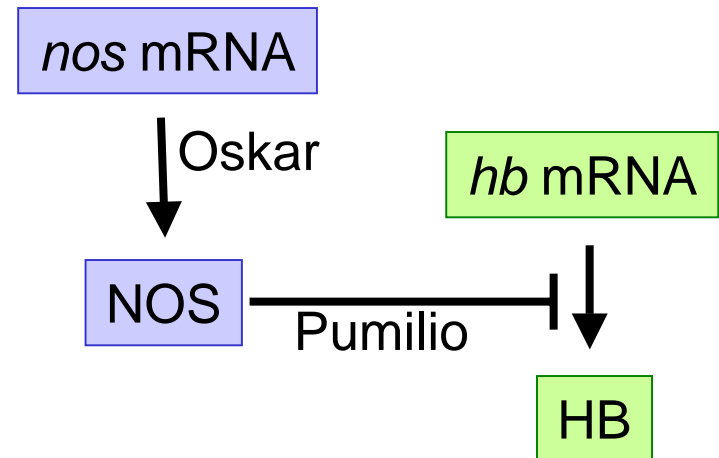
(B) Proteins in early blastoderm embryo



(C) Anterior

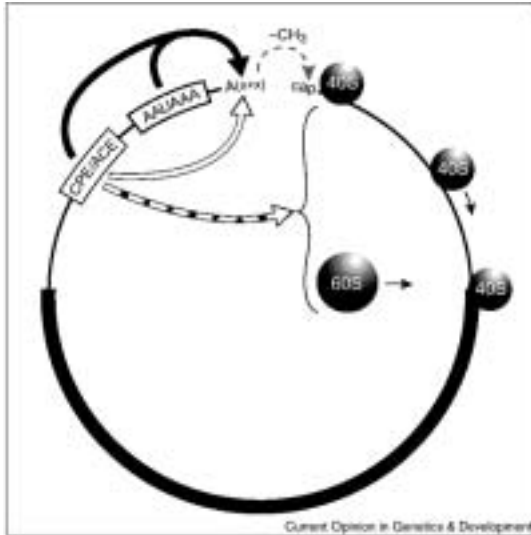


Posterior



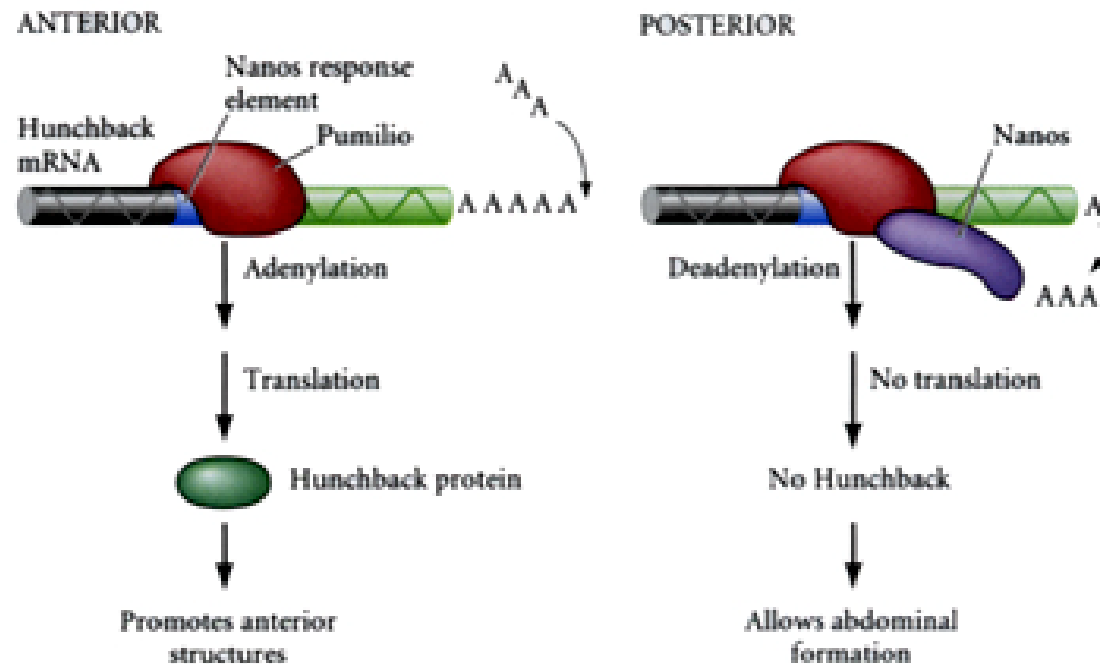
How does NOS control *hb* mRNA translation?

Developmental control: masking and polyadenylation
(common in 3'-UTR)

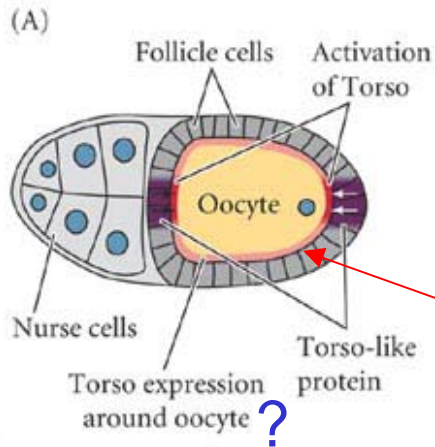


1. A 3'UTR element represses translation by maintaining short polyA tail.
2. Polyadenylation is required to inactivate a 3'-repressor element. Or
3. 3'-UTR element(s) control polyadenylation and translation independently. This hypothesis is not supported by recent stud

mRNA Masking and adenylation control

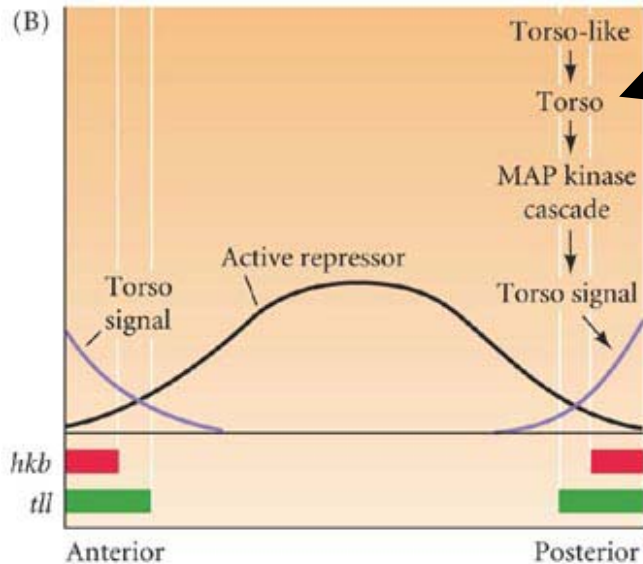


The maternal terminal system specify both ends of larva: **acron** and **telson**



How do you know?

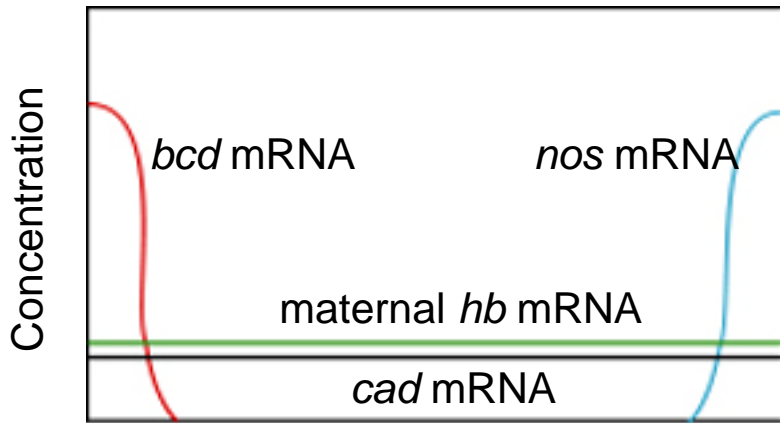
Receptor tyrosine kinase
Uniformly distributed throughout cell membrane of embryo



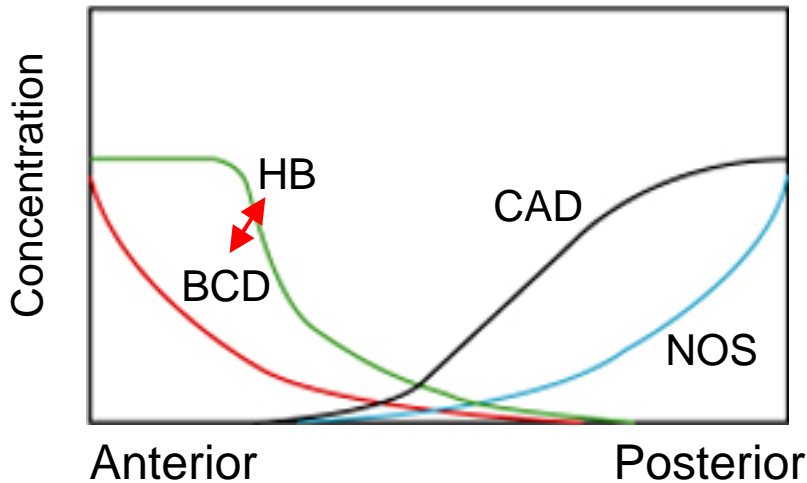
tll expression pattern

Summary

(A) Oocyte mRNAs



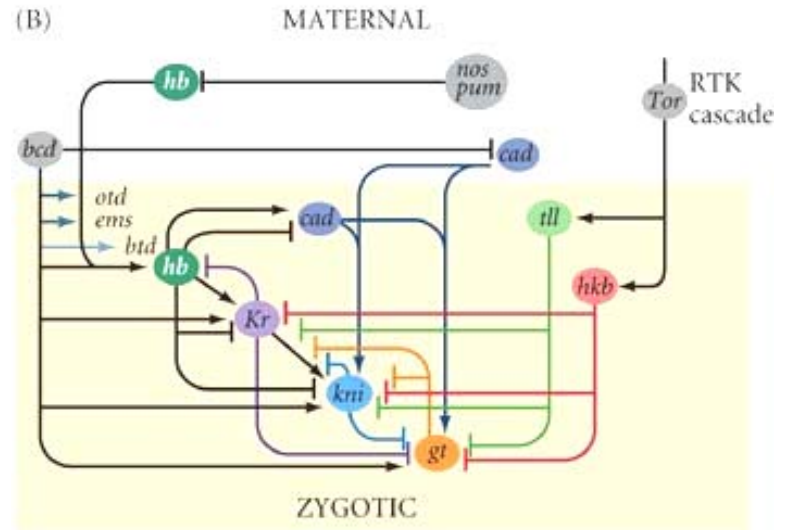
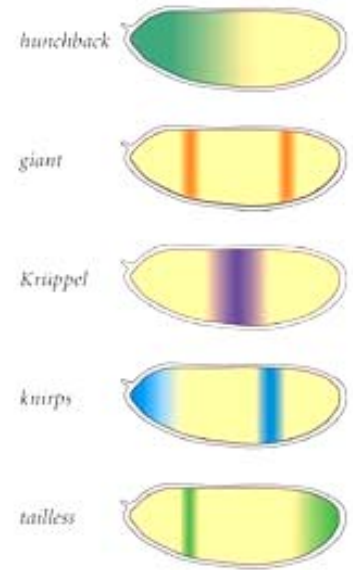
(B) Protein level



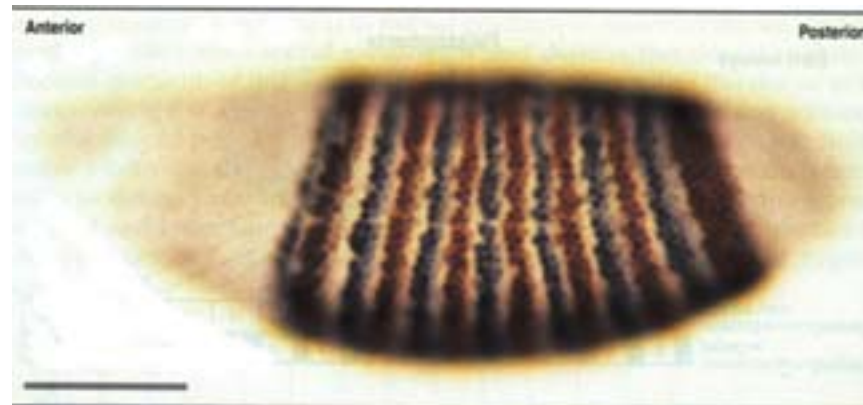
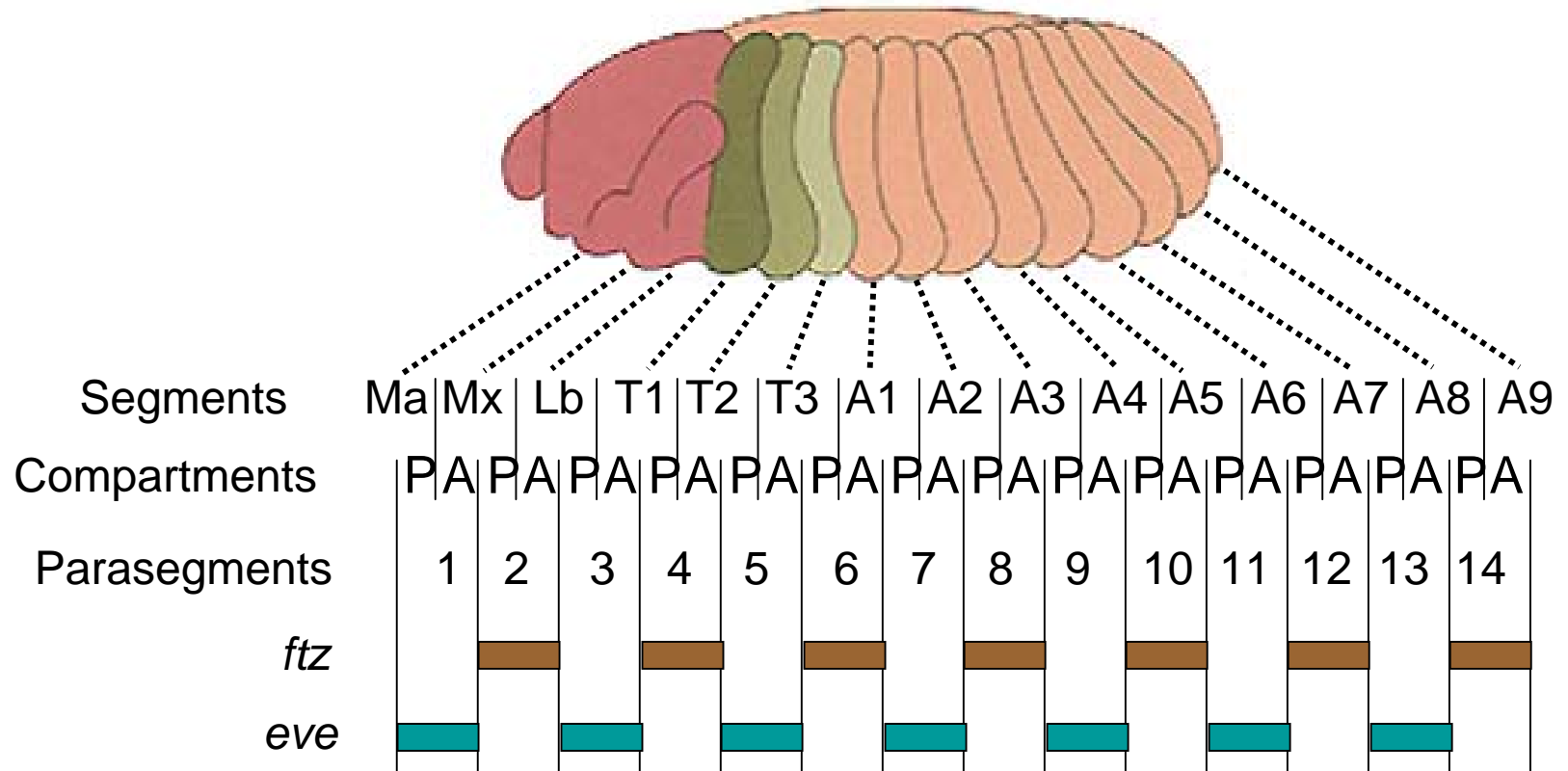
NOS
↓
BCD/HB

The *torso* pathway
kinase cascade

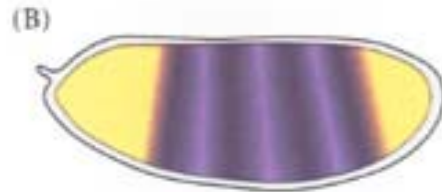
(A) Expression of the gap genes



Parasegments vs. segments



fushi tarazu (*ftz*) expression

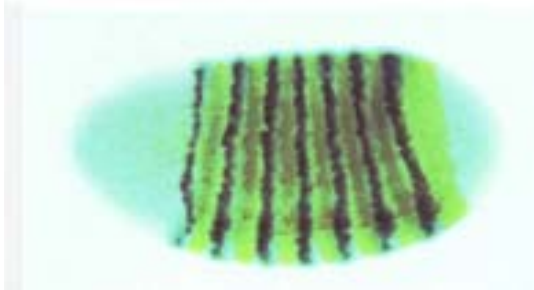


How do gap gene activities control expression of pair-rule genes?

Answer:

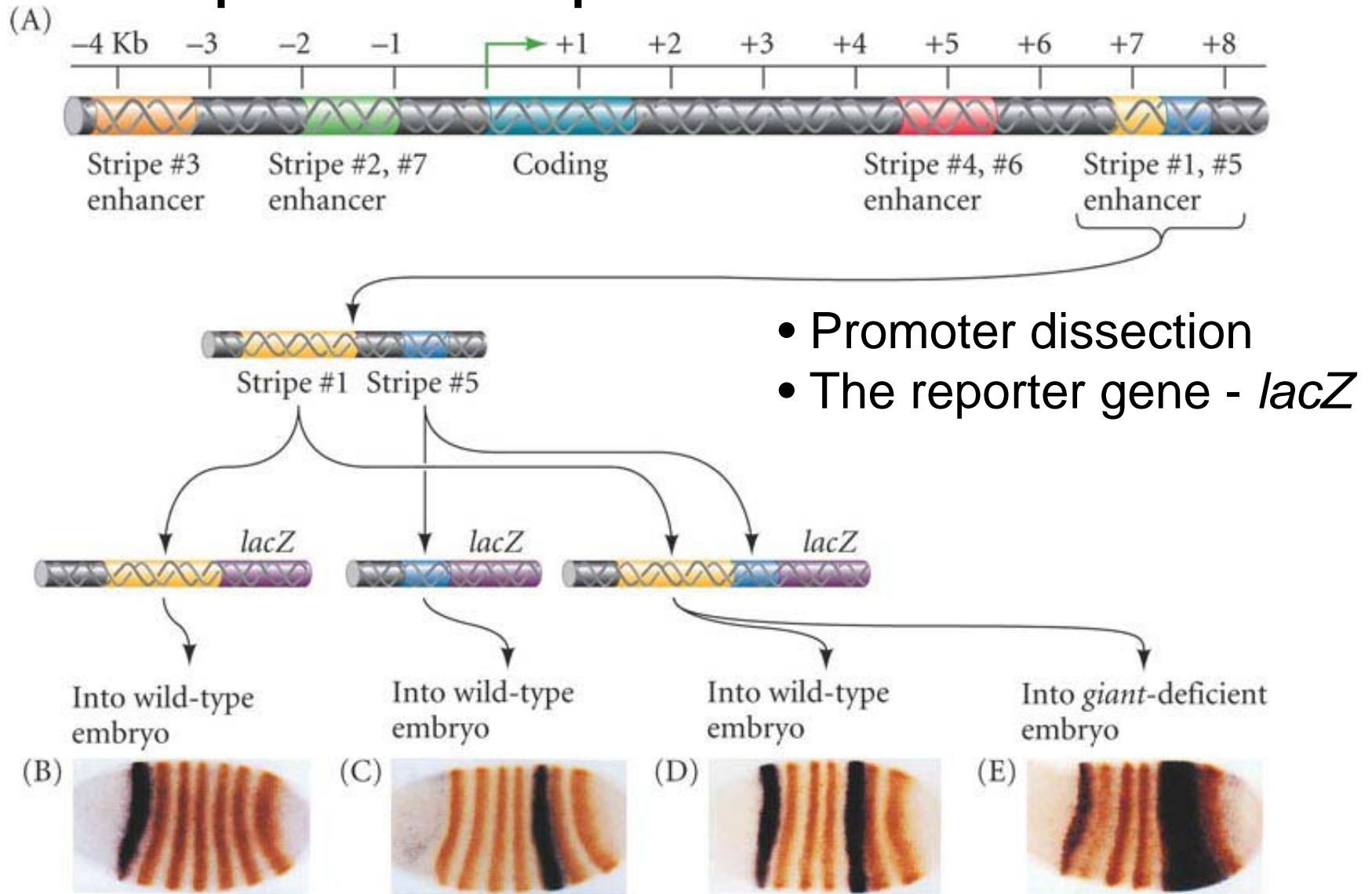
Different spatial cis-regulatory sequences exist and control specific transcriptional bands in the embryo.

(E)



Example: *eve* expression pattern

Fig. 9.22 specific promoter regions in the eve gene control specific transcriptional bands



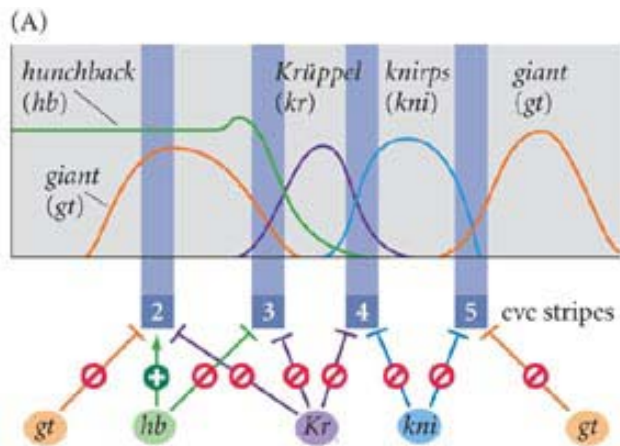
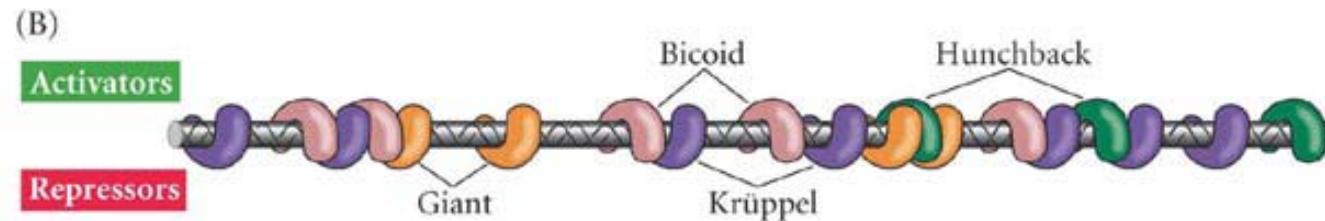


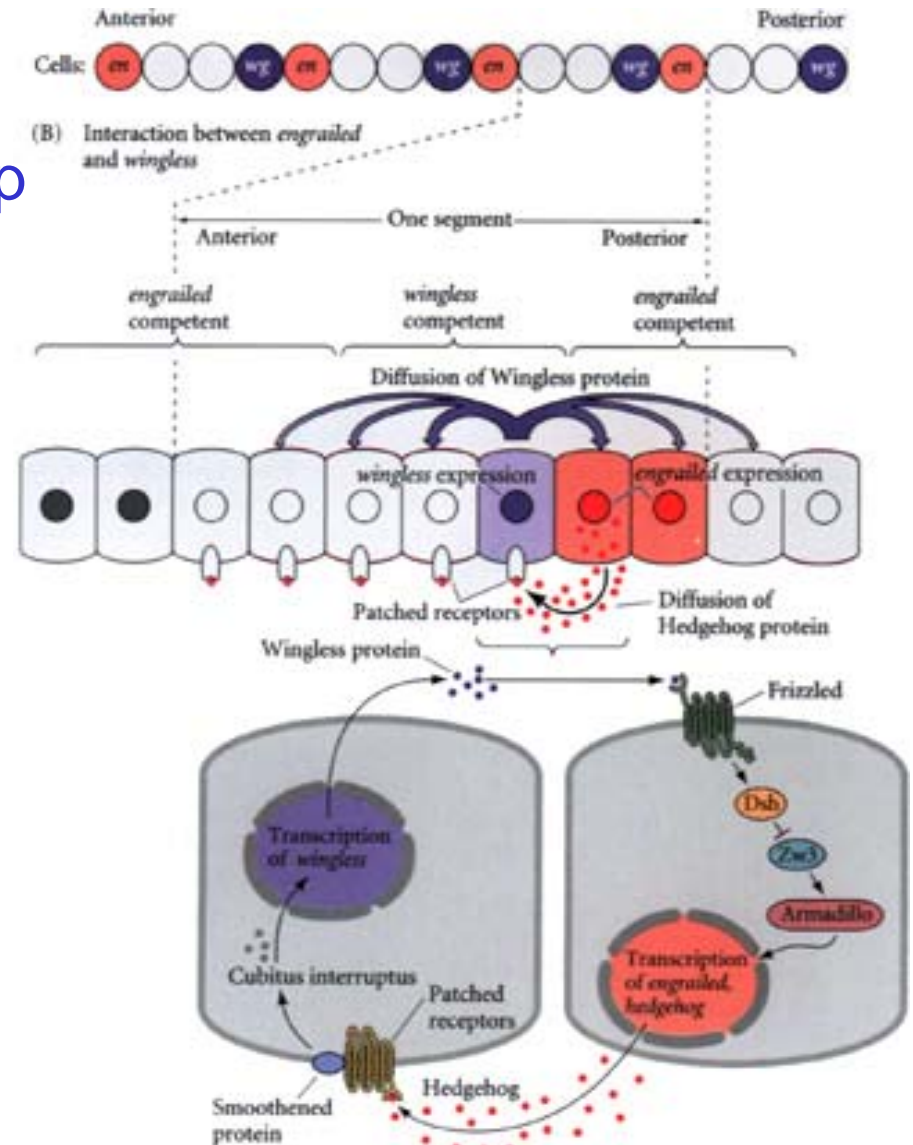
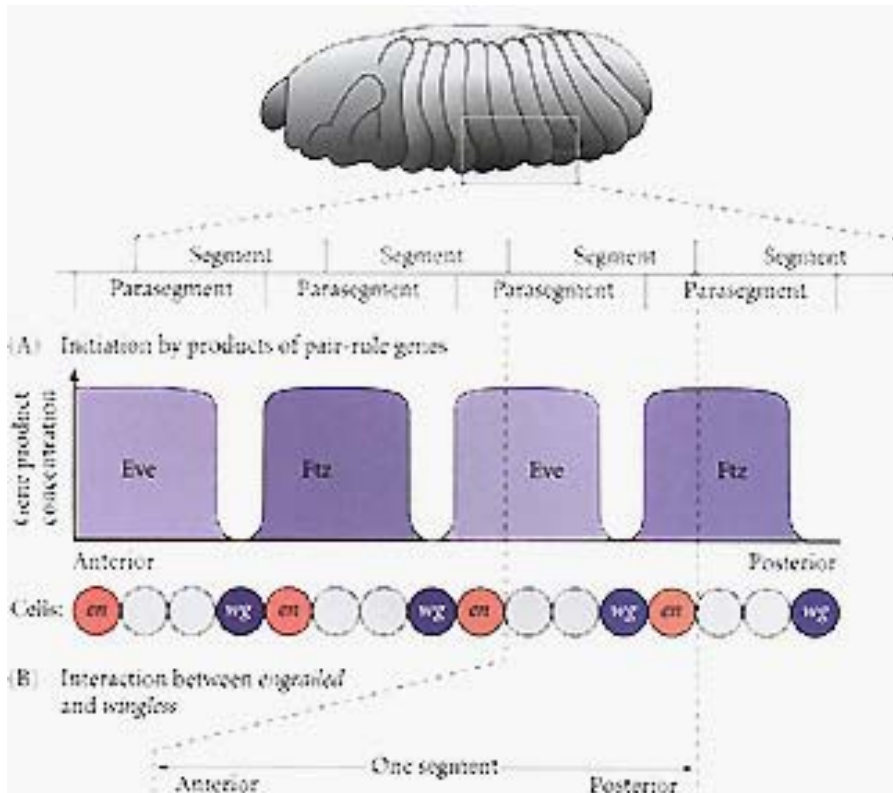
Fig. 9.23 Hypothesis for the formation of the second stripe of transcription from the *eve* gene



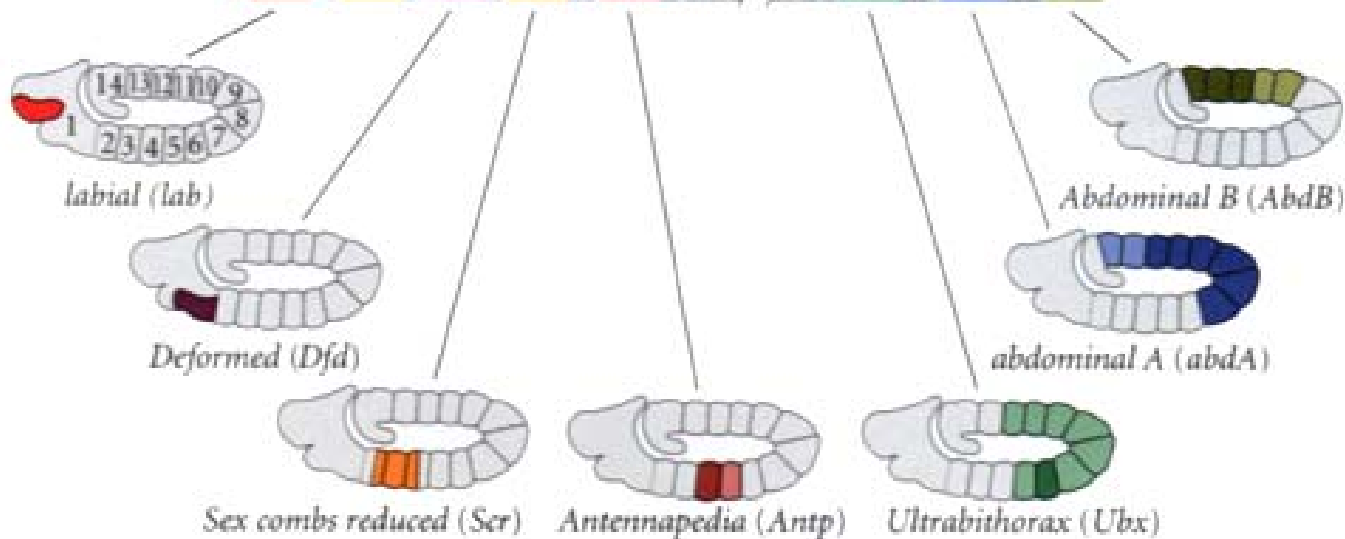
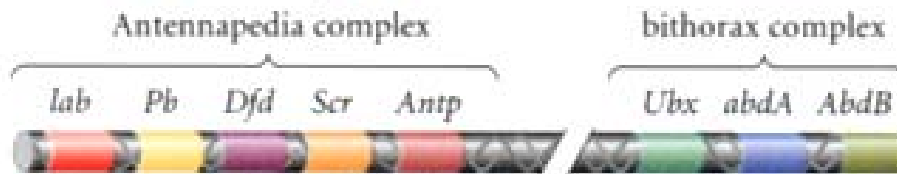
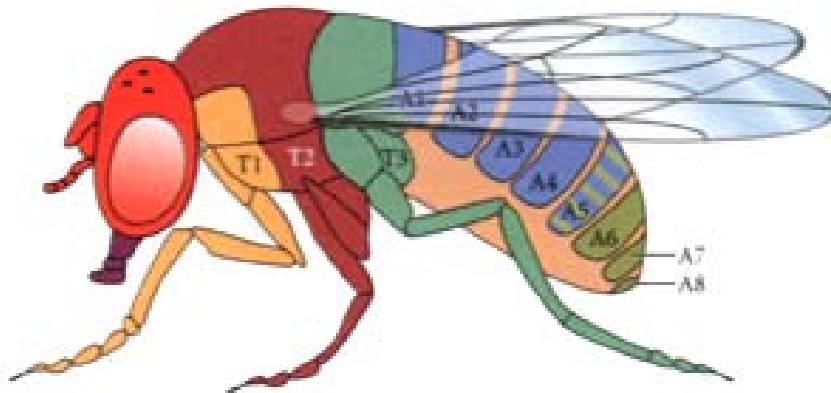
1. determine expression pattern under different mutant background
2. determine their binding site if the mutated gene product is a DNA binding protein
3. mutate the binding site in the specific promoter region, fuse to the *lacZ* gene and examine *lacZ* expression pattern which should be consistent with the expression pattern from step 1.

Fig. 9.25 Model of how segment is established.

Auto-regulation loop

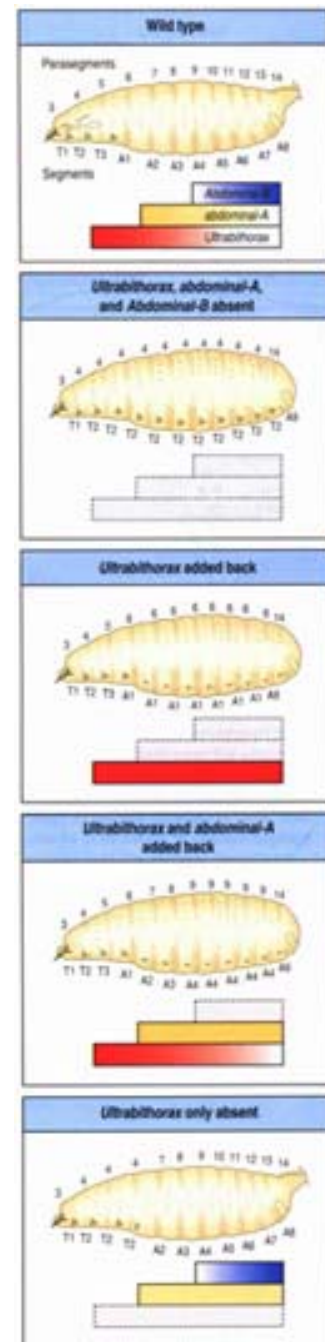


The Homeotic selector genes



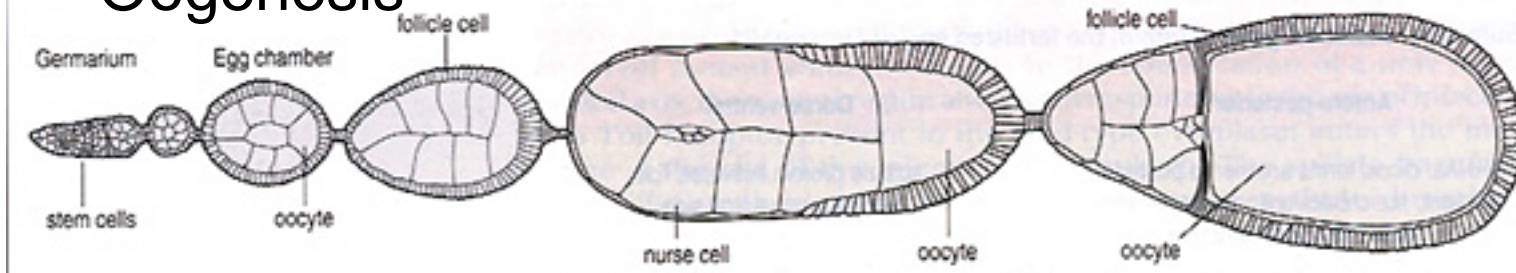
1. Initiation of expression of the selector genes are influenced by the gap, pair-rule, segment polarity gene products.
2. The maintenance of the selector gene expression is complex. Except the selector gene products, products of *trithorax* and *polycomb* groups are required.
3. The expression may repress by adjacent selector gene products (see textbook). In other cases, two or three selector gene products are required to determine segmental identity. →

Realistor genes – modulate selector gene activity (skip)



The Dorsal-Ventral Axis

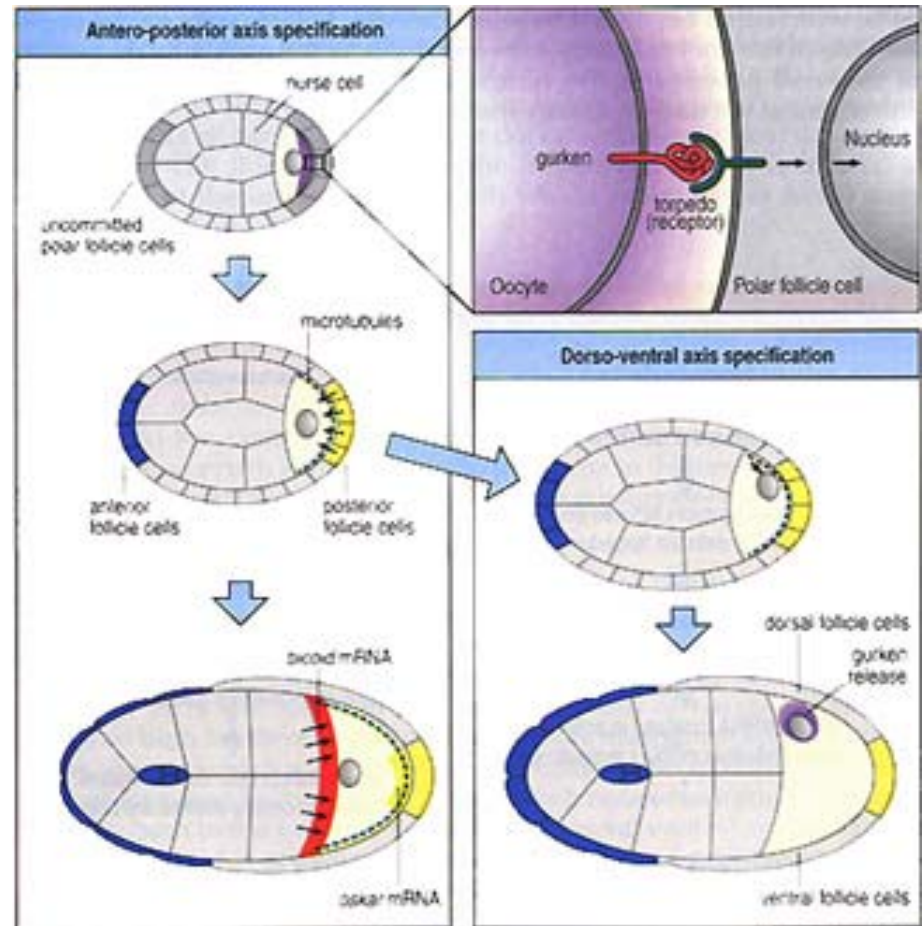
Oogenesis



The A-P and D-V polarity of *Drosophila* embryo is determined during oogenesis.



Fig. 9.36 has more



Schematic presentation of the generation of dorsal-ventral axis

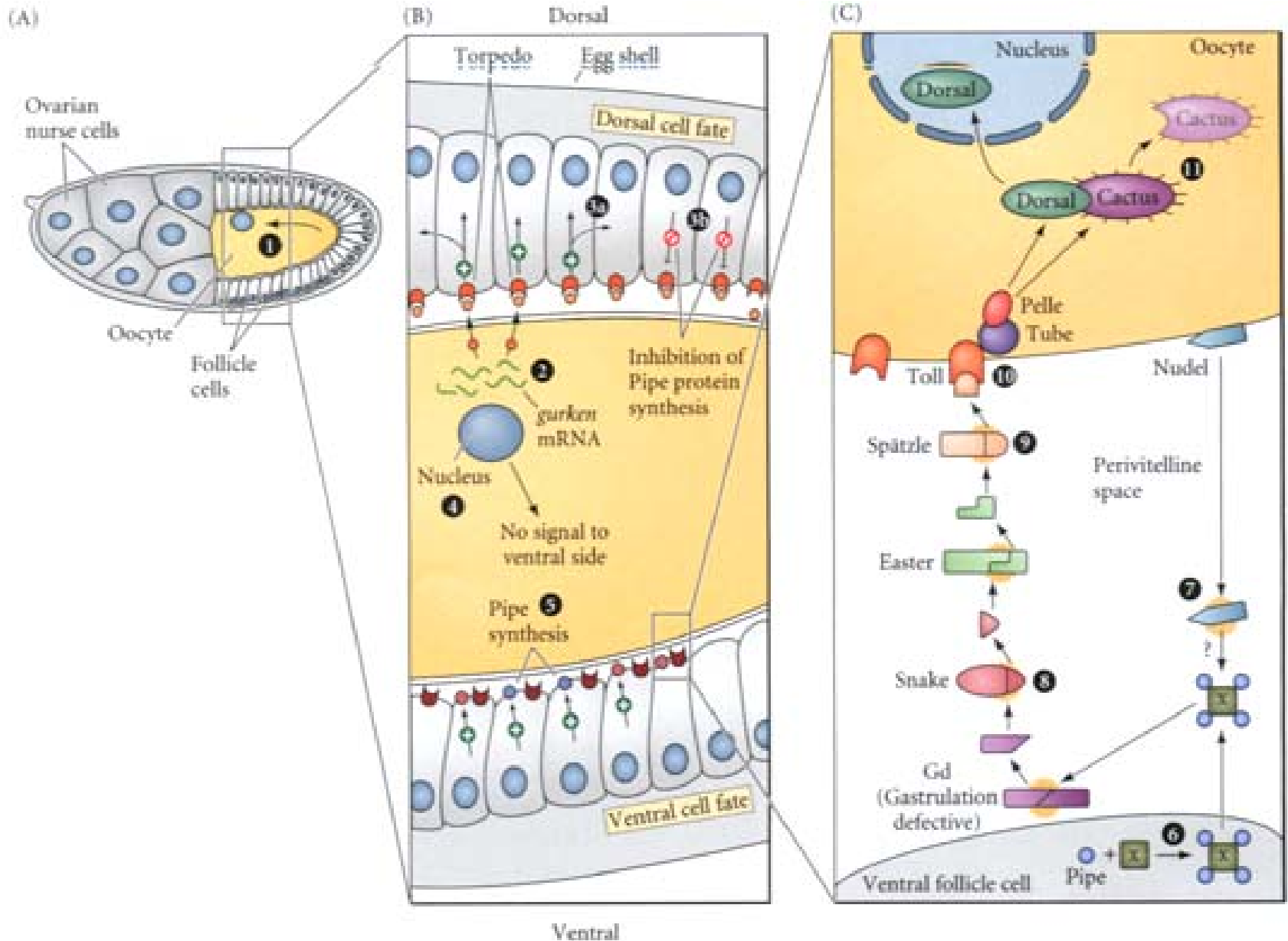
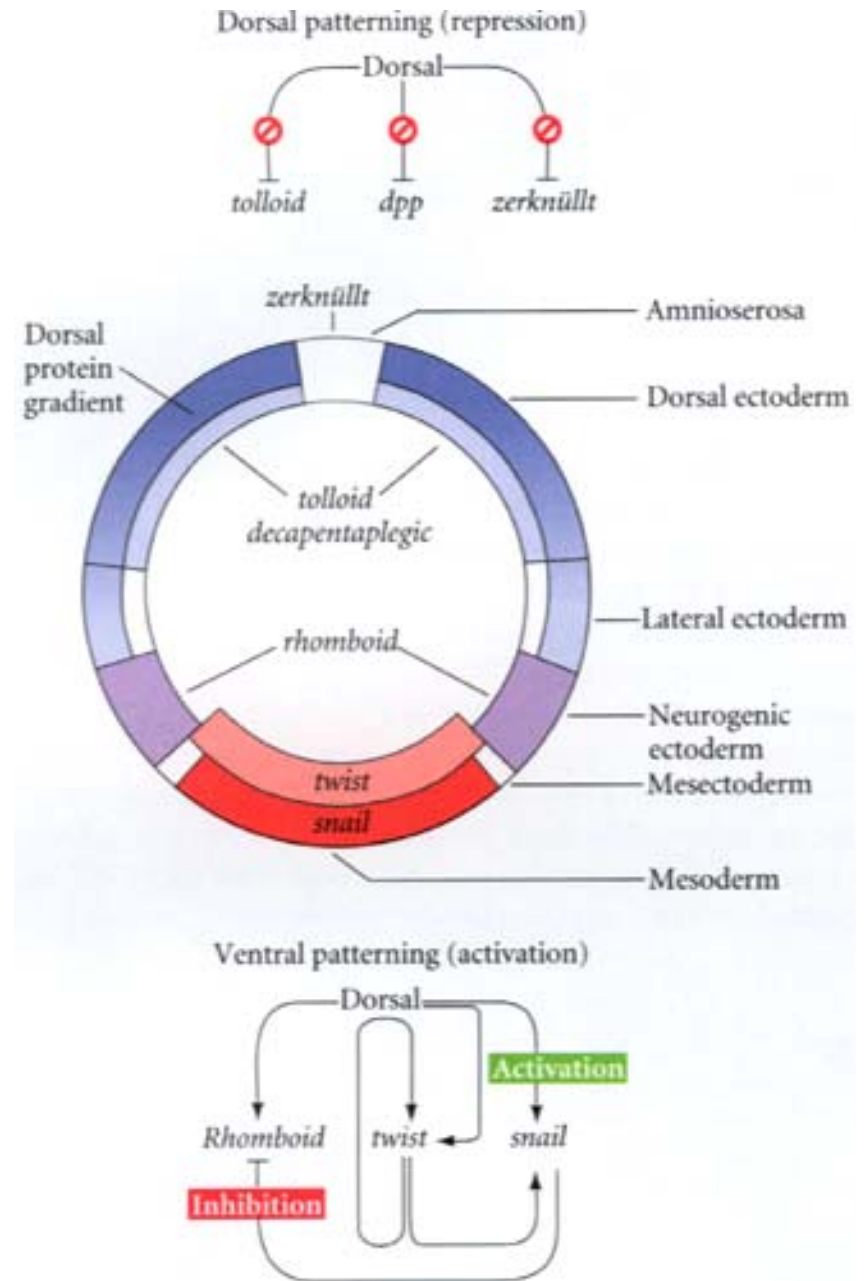


Fig. 9.40 Subdivision of the dorsal-ventral axis by the gradient of Dorsal protein in nuclei.



Summary

1. Unevenly distributed maternal messages, through activation of gap genes, set up the framework of embryogenesis.
2. Expression of pair-rule genes, controlled by gap gene products, is essential for segmentation.
3. Function of segment-polarity gene products is to determine the antero-posterior polarity of each segment.
4. Activation and maintenance of the selector genes is required for specification of different body parts.
5. Factors binding to the cis-regulatory element control expression of their target genes.