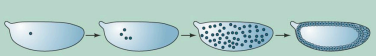
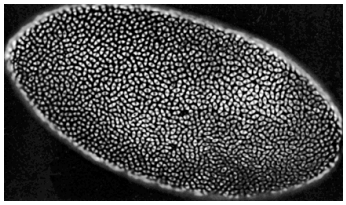
Drosophila early development

II. MEROBLASTIC CLEAVAGE

B. **Centrolecithal**

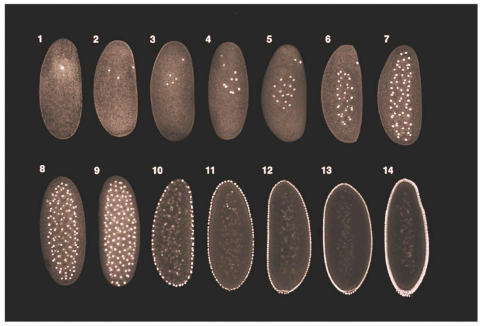
Superficial cleavage
Most insects





Drosophila blastoderm, cycle 13

Figure 9.1 ***Laser Confocal Micrographs of Stained Chromatin Showing Superficial Cleavage in a*** **Drosophila** ***Embryo***



Fly Cellular Blastoderm Fate Map

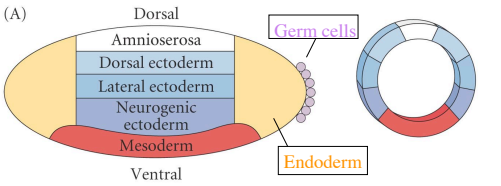


Figure 9.40 *Gastrulation in* Drosophila

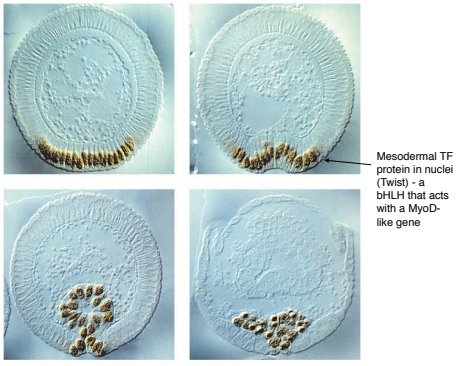


Figure 9.5(1) *Gastrulation in* Drosophila

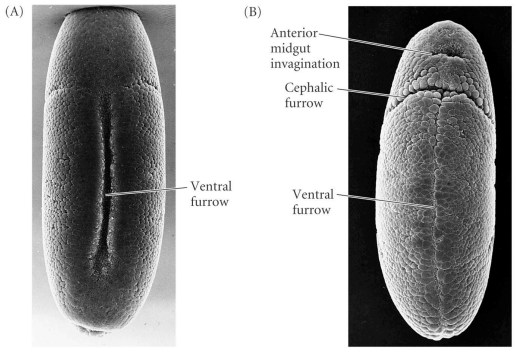


Figure 9.5(2) *Gastrulation in* Drosophila

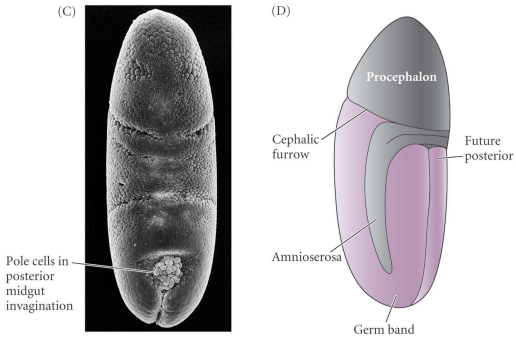


Figure 9.5(3) *Gastrulation in* Drosophila

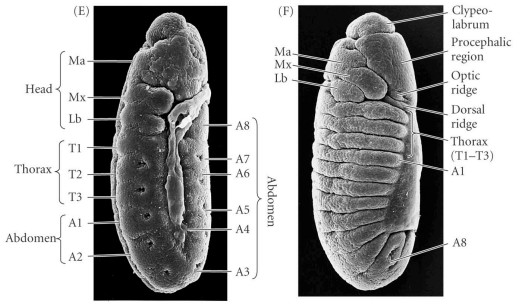


Figure 9.6(1) *Schematic Representation of Gastrulation in* Drosophila

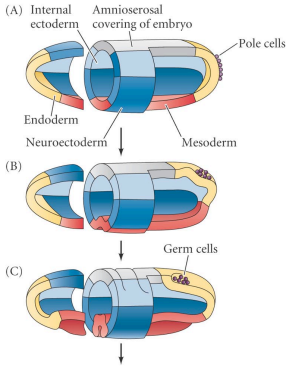


Figure 9.6(2) *Schematic Representation of Gastrulation in* Drosophila

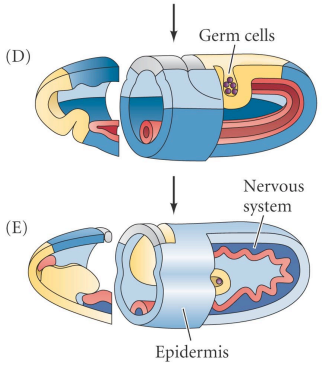
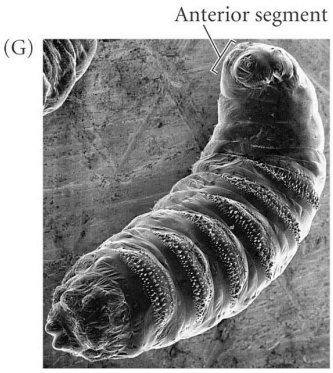
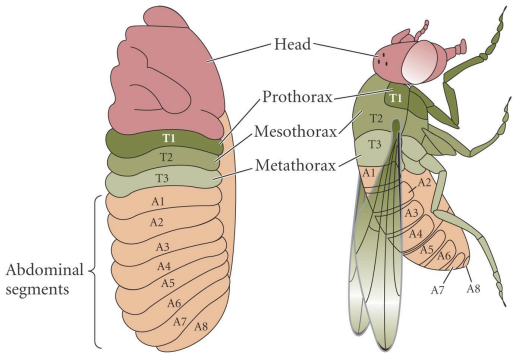


Figure 9.5(4) *Gastrulation in* Drosophila



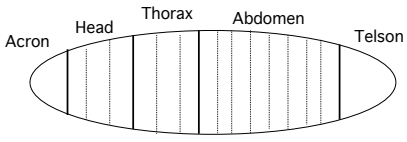
SEM of fly maggot

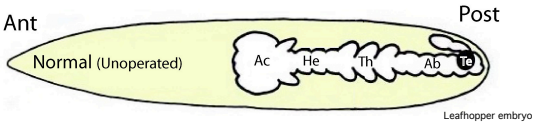
Figure 9.7 *Comparison of Larval and Adult Segmentation in* Drosophila



Classic Embryology Experiments in Insect Patterning - Sander, Kalthoff

Basic Anterior-Posterior Pattern of Insect Embryo





Leafhopper embryo

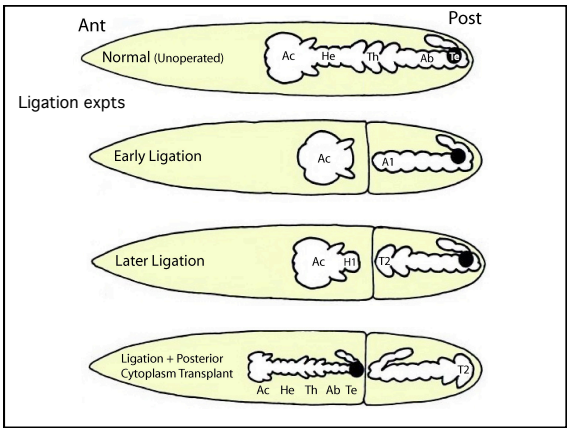
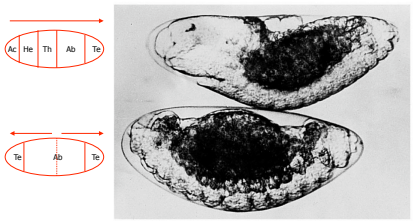


Figure 9.9 ***Normal and Irradiated Embryos of the Midge*** **Smittia**



Normal

UV-treated in anterior

Sander's experiments destroying the "anterior organizing center"
Treatment with either UV to anterior end, or RNAse to embryos with anterior holes resulted in mirror-image, two-tailed embryos

Nüsslein-Volhard & Wieschaus: Saturation Mutagenesis for Embryonic Mutants

- found mutants with phenotypes like embryos from Sander & Kalthoff's experiments

- greatest disruption of pattern seen in **maternal effect** mutants

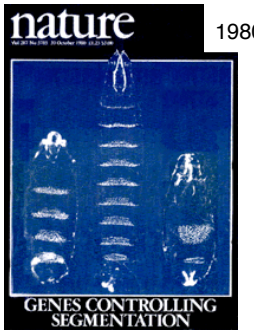
e.g., two-tailed embryos – progeny of bicoid(-)/bicoid(-) mothers – resembled those of Kalthoff's expts destroying "anterior organizing center"

- embryos with 'gaps' in A-P pattern - like results of Sander's ligation experiments; were zygotic mutants.

[Saturation mutagenesis - make so many mutants that you begin to find multiple alleles of genes, and few to no new genes]

Nüsslein-Volhard & Wieschaus
Saturation Mutagenesis for Embryonic Mutants

1970's



1980

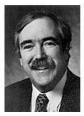
Nobelprize.org

The Nobel Prize in Physiology or Medicine 1995

"for their discoveries concerning the genetic control of early embryonic development"

Edward B. Lewis
1/3 of the prize
USA
California Institute of Technology (Caltech)
Pasadena, CA, USA
b. 1918
d. 2004

Christiane Nüsslein-Volhard
1/3 of the prize
Federal Republic of Germany
Max-Planck-Institut für Entwicklungsbiologie
Tübingen, Federal Republic of Germany
b. 1942



Eric F. Wieschaus
1/3 of the prize
USA
Princeton University
Princeton, NJ, USA
b. 1947

Nüsslein-Volhard & Wieschaus today

Max-Planck-Institut für Entwicklungsbiologie

Prof. Dr. Christiane Nüsslein-Volhard

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Max-Planck-Institut für Entwicklungsbiologie
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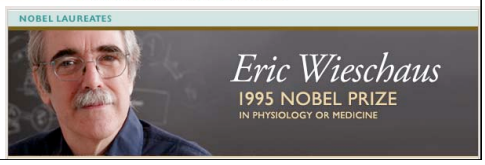
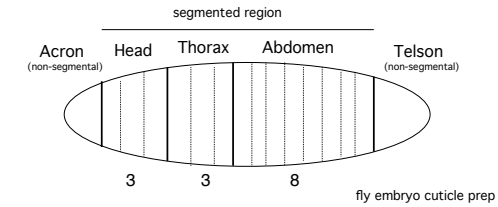
Germany

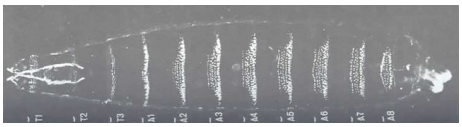
Phone: +49-70 71-601-489
Fax: +49-70 71-601-384
christiane.nuesslein-volhard@tuebingen.mpg.de



Basic Anterior-Posterior Pattern of Insect Embryo



fly embryo cuticle prep

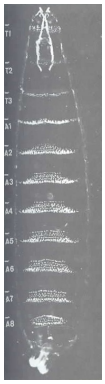


Cuticle preparations of *Drosophila* embryos

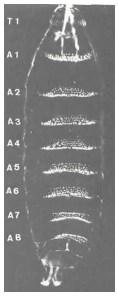
anterior

Wildtype

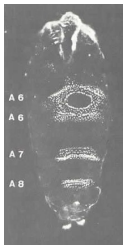
Ventral views, showing denticle bands



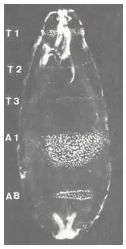
hunchback



Krüppel



knirps



Nüsslein-Volhard & Wieschaus - Saturation Mutagenesis for Embryonic Mutants

Maternal Group

- Anterior - *bicoid (bcd)*
- Posterior - *nanos (nos)*
- Terminal - *torso (tor)*

Nüsslein-Volhard & Wieschaus - Saturation Mutagenesis for Embryonic Mutants

Maternal Group

Anterior - *bicoid (bcd)*
Posterior - *nanos (nos)*
Terminal - *torso (tor)*

Zygotic Group

Segmentation Genes
Gap - *hunchback (hb), Krüppel, knirps, giant, huckebein, tailless*
Pair Rule, primary - *even-skipped (eve), hairy, runt*
Pair Rule, secondary - *fushi tarazu (ftz), odd-paired, odd-skipped, paired*
Segment Polarity - *wingless, hedgehog, frizzled, patched, engrailed, gooseberry*

Nüsslein-Volhard & Wieschaus - Saturation Mutagenesis for Embryonic Mutants

Maternal Group

Anterior - *bicoid (bcd)*
Posterior - *nanos (nos)*
Terminal - *torso (tor)*

Zygotic Group

Segmentation Genes
Gap - *hunchback (hb), Krüppel, knirps, giant, huckebein, tailless*
Pair Rule, primary - *even-skipped (eve), hairy, runt*
Pair Rule, secondary - *fushi tarazu (ftz), odd-paired, odd-skipped, paired*
Segment Polarity - *wingless, hedgehog, frizzled, patched, engrailed, gooseberry*

Homeotic Selector/Segmental Identity Genes
Antennapedia complex - lab, pb, def, scr, Antp
Bithorax complex - bithorax, abdA, abdB

Figure 9.8(1) ***Model of* Drosophila *Anterior-Posterior Pattern Formation***

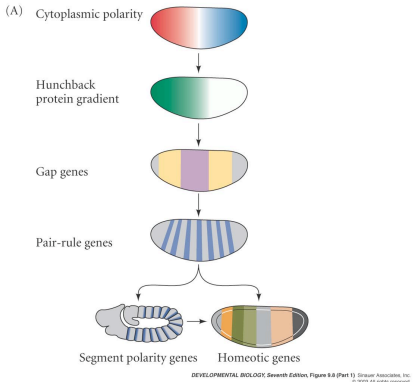
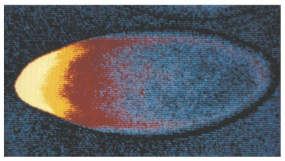
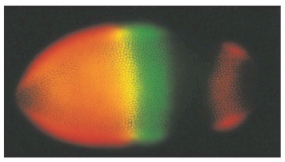


Figure 9.8(2) ***Model of*** **Drosophila** ***Anterior-Posterior Pattern Formation***



Maternal Genes (anterior)

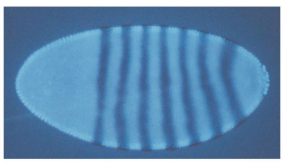
Gradient of Bcd protein



Gap Genes

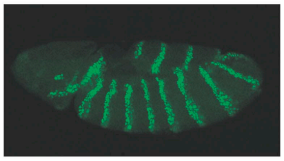
Hb protein (orange) overlaps with Kr protein (green)

Figure 9.8(3) ***Model of*** **Drosophila** ***Anterior-Posterior Pattern Formation***



Pair-rule genes

Ftz in 7 bands

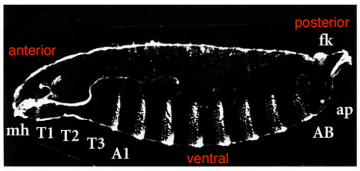


Segment Polarity genes

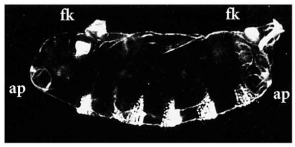
Engrailed in 14 half segments

Figure 9.13 ***Phenotype of a Strongly Affected Embryo From a Female Fly Deficient in the*** **Bicoid** ***Gene***

Wild type cuticle, side view



bcd mutant cuticle, side view



A8 A7 A6 A7 A8

Figure 9.14(1) ***Gradient of Bicoid Protein in the Early*** **Drosophila** ***Embryo***

In situ hybridization showing *bcd* mRNA

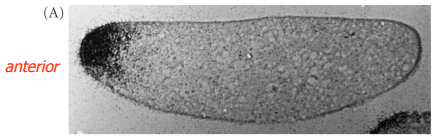


Figure 9.14(2) ***Gradient of Bicoid Protein in the Early*** **Drosophila** ***Embryo***

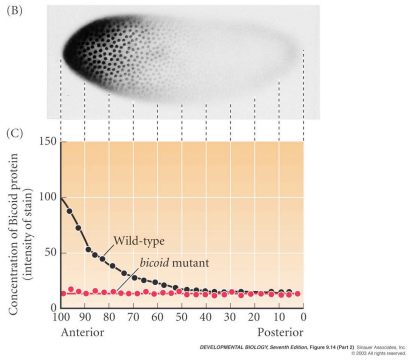


Figure 9.15(1) ***Experiments Demonstrating That the*** **Bicoid** ***Gene Encodes the Morphogen Responsible for Head Structures in*** **Drosophila**

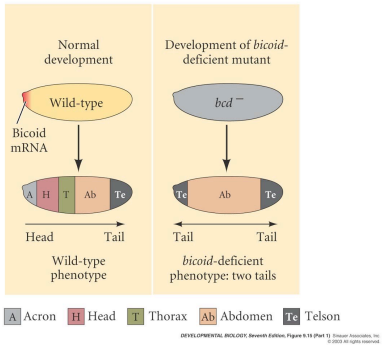


Figure 9.15(2) ***Experiments Demonstrating that the* Bicoid *Gene Encodes the Morphogen Responsible for Head Structures in* Drosophila**

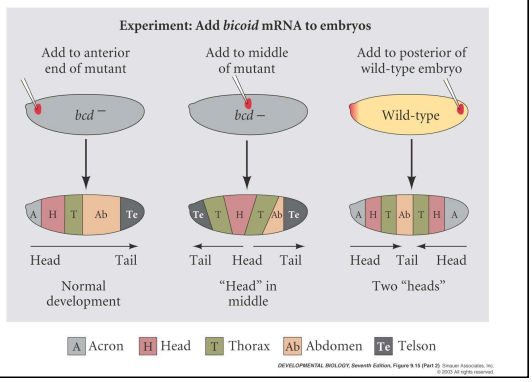


Figure 9.10(1) ***Three independent Genetic Pathways Interact to Form the Anterior-Posterior Axis of the* Drosophila *Embryo***

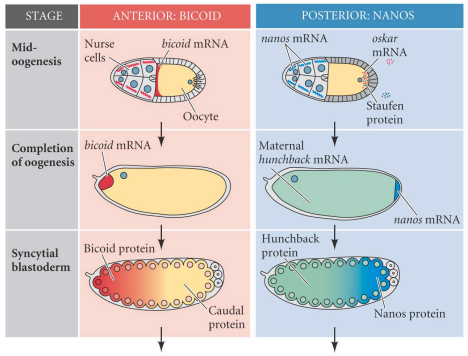


Figure 9.10(2) ***Three independent Genetic Pathways Interact to Form the Anterior-Posterior Axis of the* Drosophila *Embryo***

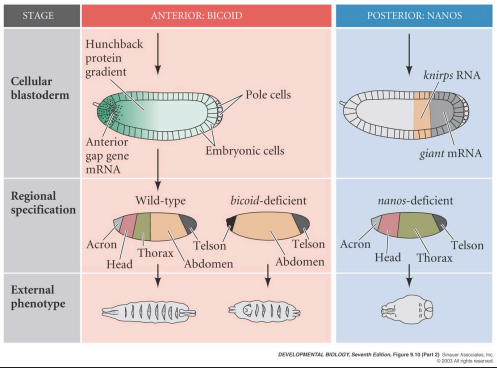


Figure 9.10(4) ***Three independent Genetic Pathways Interact to Form the Anterior-Posterior Axis of the*** **Drosophila** ***Embryo***

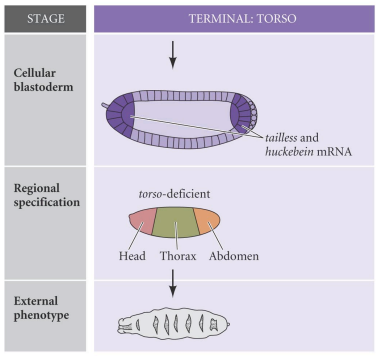


Figure 9.17 ***Control of*** **hunchback** ***mRNA Translation by Nanos Protein***

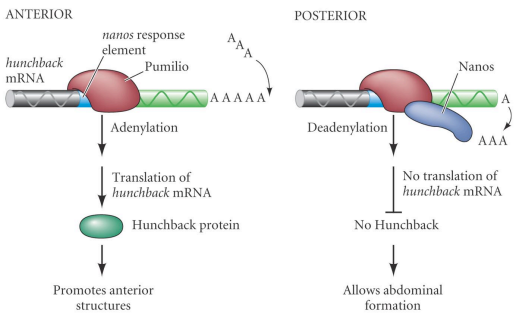
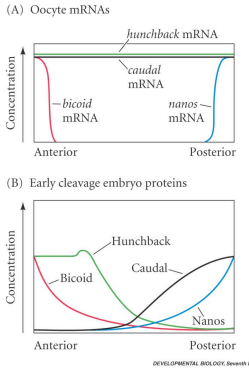


Figure 9.12(1) ***Anterior-Posterior Pattern Generation by the*** **Drosophila** ***Maternal Effect Genes***



4 protein gradients to provide 'positional information' in early embryo

Figure 9.12(2) ***Anterior-Posterior Pattern Generation by the*** **Drosophila** ***Maternal Effect Genes***

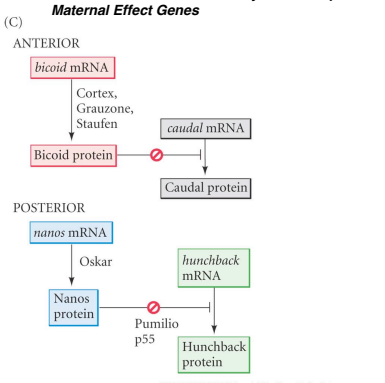


Figure 9.16 ***Gradient of Caudal Protein in the Syncitial Blastoderm of a Wild-type*** **Drosophila** ***Embryo***

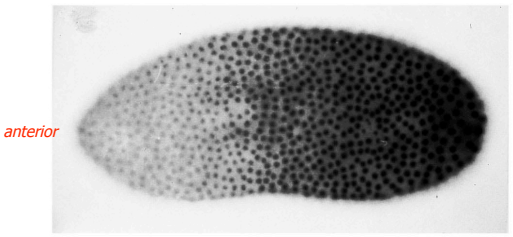
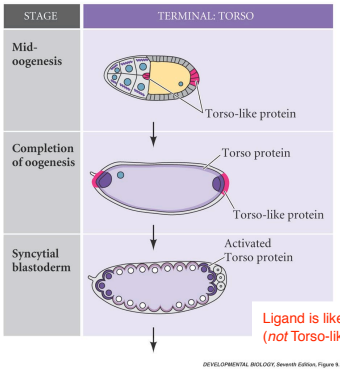
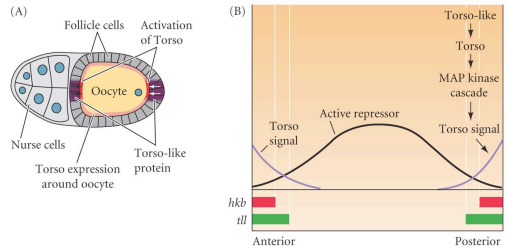


Figure 9.10(3) ***Three independent Genetic Pathways Interact to Form the Anterior-Posterior Axis of the*** **Drosophila** ***Embryo***

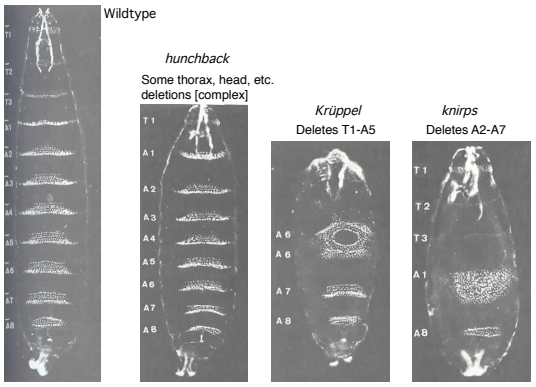


Ligand is likely **Trunk** (*not* Torso-like)

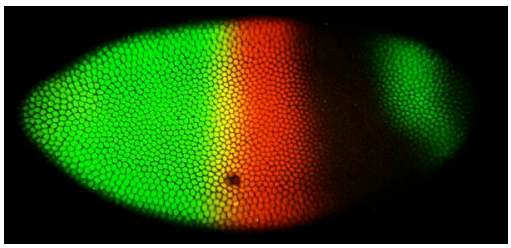
Figure 9.18 ***Formation of the Unsegmented Extremities by Torso Signaling***



Cuticle preparations of *Drosophila* embryos - Gap mutants

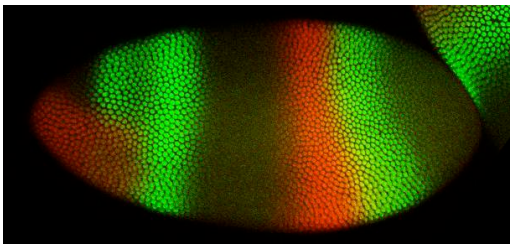


***Drosophila* Gap gene expression patterns**



Hunchback (green) and *Krüppel* (red)

Drosophila Gap gene expression patterns



giant (green) and *knirps* (red) - note the central dark band *(Krüppel)*

Figure 9.22(1) ***Conversion of Maternal Protein Gradients into Zygotic Gap Gene Expression***

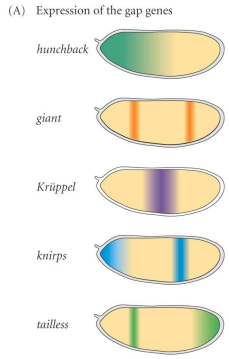


Figure 9.22(2) ***Conversion of Maternal Protein Gradients into Zygotic Gap Gene Expression***

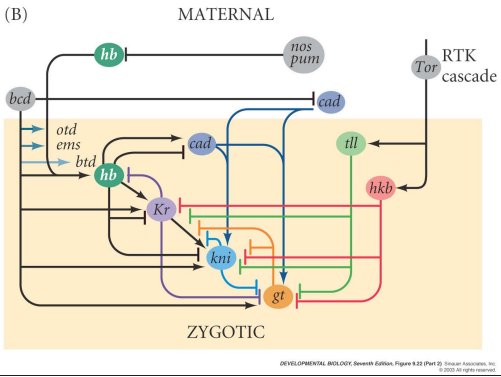


Figure 9.22 (modified A) ***Gap Gene Interactions***

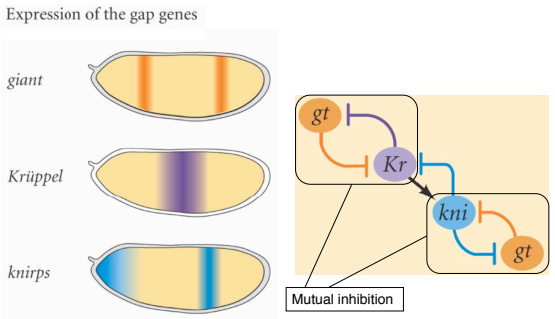


Figure 9.22 (modified B) ***Gap Gene Interactions***

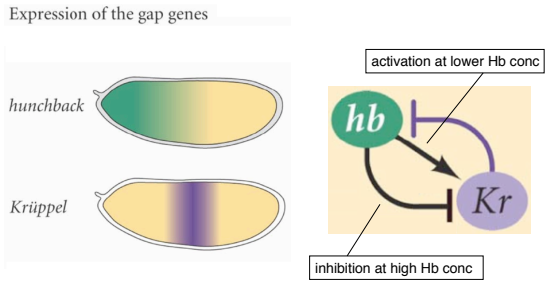


Figure 9.19 ***Segments and Parasegments***

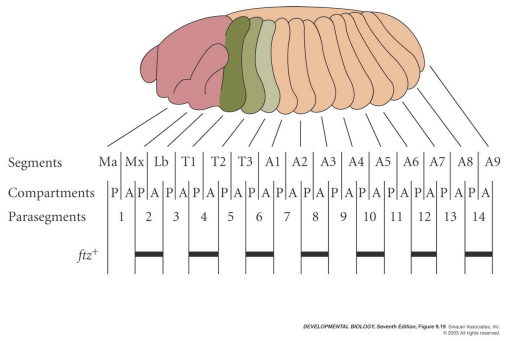


Figure 9.20(1) ***Three Types of Segmentation Gene Mutations***

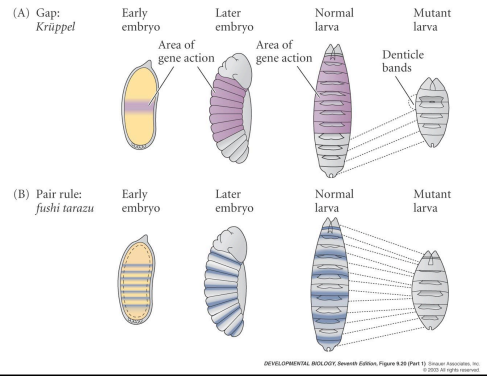


Figure 9.20(2) ***Three Types of Segmentation Gene Mutations***

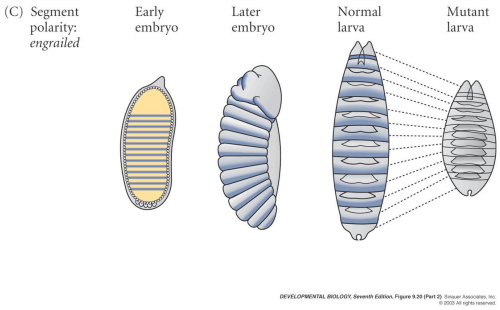


Figure 9.21(1) ***Defects Seen in the*** **Fushi Tarazu** ***Mutant***

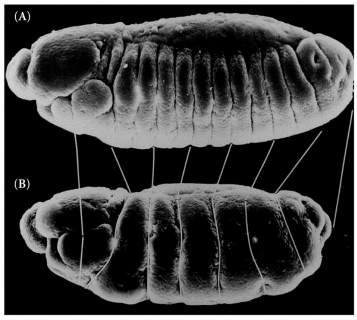
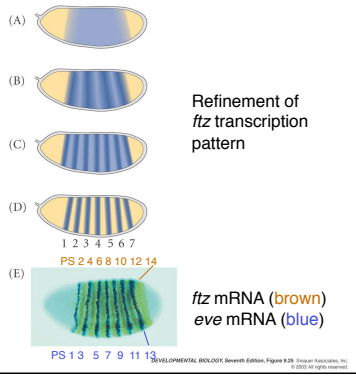


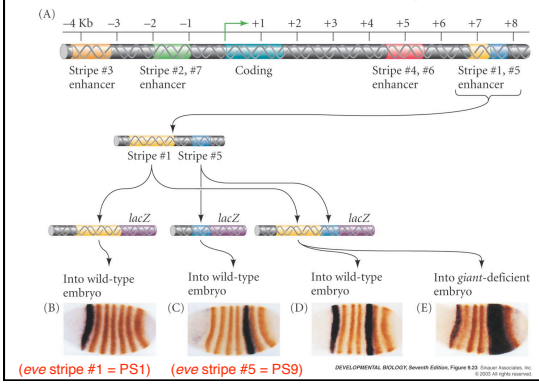
Figure 9.25 ***Transcription of the*** **Fushi Tarazu** ***Gene in the*** **Drosophila** ***Embryo***



Refinement of *ftz* transcription pattern

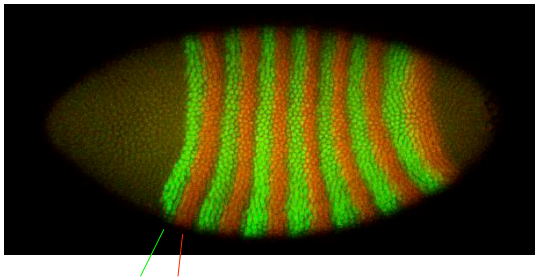
ftz mRNA (brown)
eve mRNA (blue)

Figure 9.23 ***Specific Promoter Regions of the*** **even-skipped** ***(eve) Gene Control Specific Transcription Bands in the Embryo***



(*eve* stripe #1 = PS1) (*eve* stripe #5 = PS9)

Even-skipped ***(eve)*** **+** ***fushi tarazu*** ***(ftz)*** **expression pattern**



PS1 PS2

Figure 9.24(1) ***Hypothesis for the formation of the Second Stripe of Transcription from the* even-skipped *Gene***

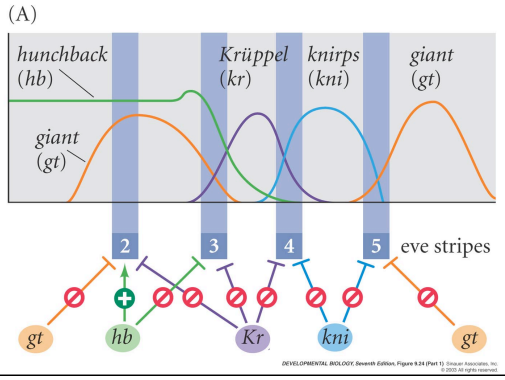
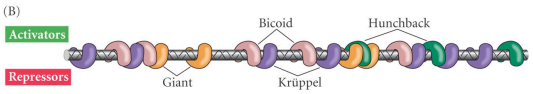


Figure 9.24(2) ***Hypothesis for the Formation of the Second Stripe of Transcription from the* even-skipped *Gene***



Segment polarity genes take over from maternal, gap and pair-rule genes

Segment polarity genes act in cells, not in syncitium.

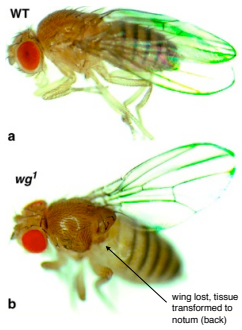
Expression of early patterning genes is transient.

Segment polarity genes turn on to maintain integrity of established pattern.

Some segment polarity genes remain on throughout life of organism to maintain segmental pattern.

Interactions among cells within the segment are key to the *intra*segmental A-P pattern.

Segment Polarity Genes: *wingless (wg)* mutant phenotypes

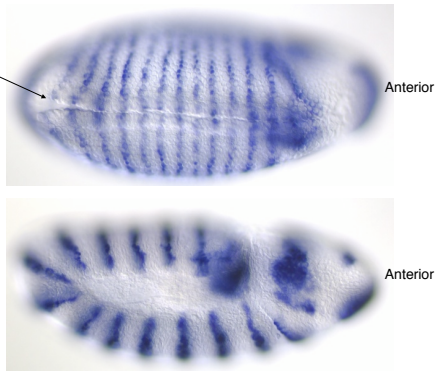


original weak *wg* allele - mutant phenotype: variable loss of wings

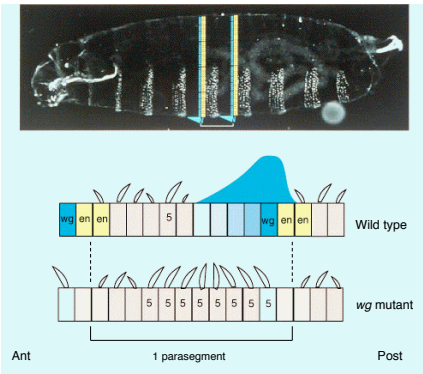
denticle bands in embryonic cuticle preps

Complete loss of function *wg* embryonic (lethal) phenotype: disruption of A-P pattern within each segment

Segment Polarity Genes: Wingless (wg) mRNA expression

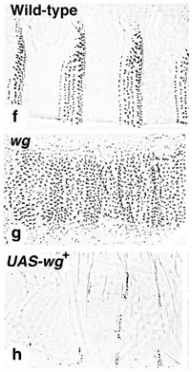


Cell Specification by the Wingless and Engrailed



Cell Specification by the Wingless and Engrailed

denticle bands in embryonic cuticle preps



wg mutant

wingless over-expressed

Figure 9.26(1) ***Model for the Transcription of the Segment Polarity Genes***
engrailed *and* wingless *(*wg*)*

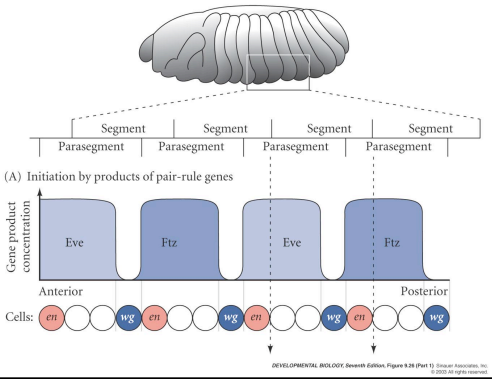


Figure 9.26(2) ***Model for the Transcription of the Segment Polarity Genes***
engrailed *(*en*) and* wingless *(*wg*)*

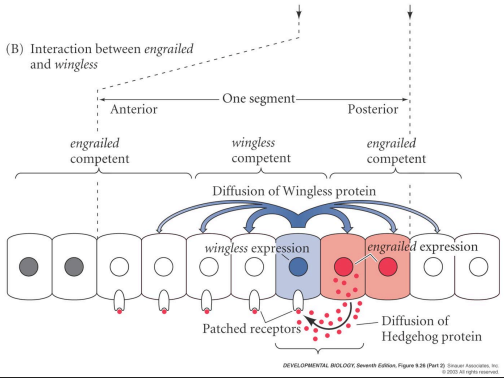


Figure 9.26(3) ***Model for the Transcription of the Segment Polarity Genes*** **engrailed** ***(en) and*** **wingless** ***(wg)***

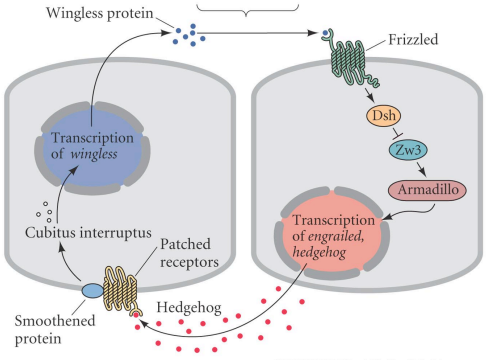
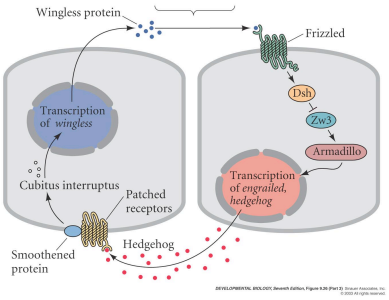
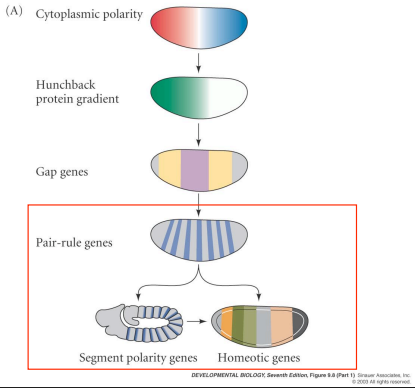


Figure 9.26(3) ***Model for Transcription of Segment Polarity Genes*** **engrailed** ***(en) and*** **wingless** ***(wg)***



Hedgehog signaling pathway **Wnt signaling pathway**

Figure 9.8(1) ***Model of*** **Drosophila** ***Anterior-Posterior Pattern Formation***



Bateson quotation

I therefore propose ... the term *Homoeosis* ... for the essential phenomenon is not that there has merely been a change, but that something has been changed into the likeness of something else.

William Bateson, 1894
in *Materials for the Study of Variation*

Figure 9.30 ***(a) Head of a Wild-type Fruit Fly. (B) Head of a Fly Containing the* Antennapedia *Mutation***

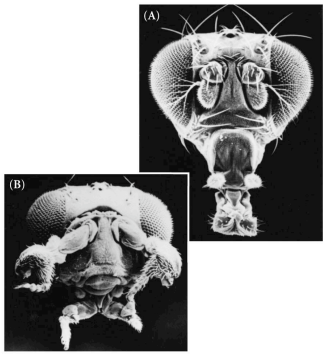
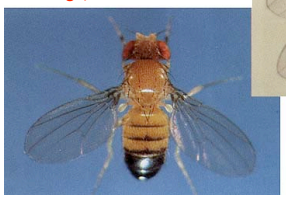


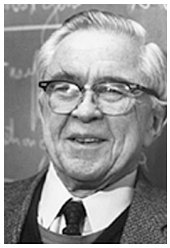
Figure 9.29 ***A Four-winged Fruit Fly Constructed by Putting Together Three Mutations in* cis *Regulators of the* Ultrabithorax *Gene***

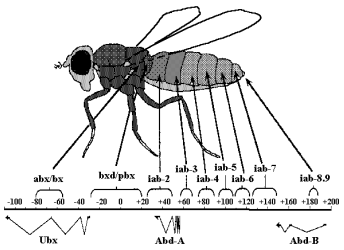
Wild type fly:
2 wings, 2 halteres



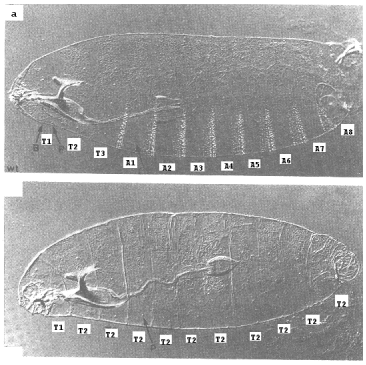
Ubx mutant combination
fly: 4 wings

Ed Lewis and the Bithorax complex





Complete Deletion of the Bithorax complex



Wild type

BXC deletion mutant

Homeotic Selector/Segmental Identity Genes

Antennapedia complex - *lab, pb, def, scr, Antp*

Bithorax complex - *Ubx, abdA, abdB*

can be viewed as a single homeotic gene complex (HOM-C)

Figure 9.28 ***Homeotic Gene Expression in*** **Drosophila**

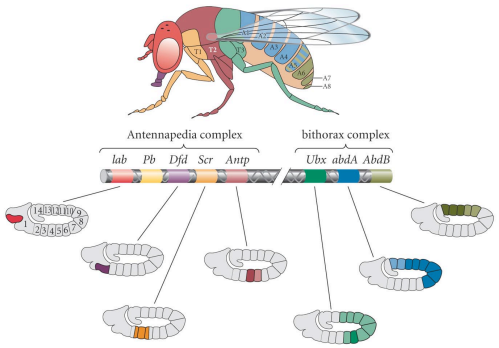


Figure 9.33(1) ***Homeodomain-DNA Interactions***

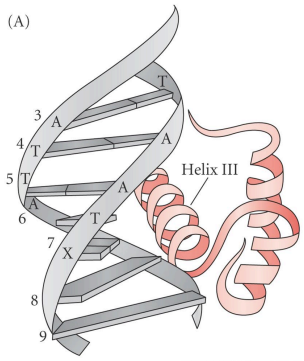


TABLE 9.1 Maternal effect genes that effect the anterior-posterior polarity of the *Drosophila* embryo

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

Source: After Anderson 1989.

TABLE 9.2 Major genes affecting segmentation pattern in *Drosophila*

Category	Gene name
Gap genes	*Krüppel (Kr), knirps (kni), hunchback (hb), giant (gt), tailless (tll), huckebein (hkb), buttonhead (btd), empty spiracles (ems), orthodenticle (otd)*
Pair-rule genes Primary	*hairy (h), even-skipped (eve), runt (run)*
Pair-rule genes Secondary	*fushi tarazu (ftz), odd-paired (opa), odd-skipped (odd), sloppy-paired (slp), paired (prd)*
Segment polarity genes	*engrailed (en), wingless (wg), cubitus interruptusD (ciD), hedgehog (hh), fused (fu), armadillo (arm), patched (ptc), gooseberry (gsb), pangolin (pan)*

frizzled (fz)