LECTURE 29
Body plan genes, Drosophila as model
From CHAPTER 21: DEVELOPMENT OF MULTICELLULAR ORGANISMS
p. 1167-1185
Figures covered: Fig. 21-23 to 21-35

DROSOPHILA MOLECULAR GENETICS OF PATTERN FORMATION:
Genesis of the Body Plan
- Studies of *Drosophila*, more than any other organism, have transformed our understanding of genes directing animal development
- *Drosophila* anatomy more complex than *C. elegans*; shows more parallels to vertebrate body plan
- ~twice as much non-coding DNA as *C. elegans* (more highly evolved gene regulatory regions)
- large numbers of systematic mutant screens by many labs
- most genes that regulate Dros. body plan dev. have counterparts (homologs) w/ similar functions in higher animals (including humans)

Stages of fly development: Fig. 21-24, 21-27
- day 0-1: 24h embryogenesis (embryo is immobile, non-feeding)
  - **syncytial blastoderm stage:** 2h (formed by ~9 rapid & synchronous mitotic divisions with no cytokinesis, nuclei move to periphery during last cycle) (Fig. 21-25A&D, Fig. 21-27)
  - **cellular blastoderm stage:** 4 division cycles after syn. blast., then cell membranes form (Fig. 21-27), ~6000 cells; mitotic rate slows; zygotic gene expr'n begins
  - **gastrulation** (mesoderm invaginates)
  - **embryonic segments become visible:** 5h (Fig. 21-25B,E)
  - embryogenesi ends with hatching of larva
- day 1-5: larval stages (larvae mobile, feed) (1st, 2nd and 3rd instar stages, separated by molts)
- day 5-9: pupal stages (metamorphosis to adult)
- day 9-10: adult emerges from pupal case

INSECT BODY IS A SERIES OF SEGMENTAL UNITS:
- head (complex, at least 4 segments)
- thorax (3 segments, T1-T3) (legs ventrally on all, wings dorsally on T2, haltere dorsally on T3)
- abdomen (A1-A8 or 9)

Correspondence between embryonic, larval and adult body segments
- Fig. 21-25: embryonic body segmts appear betw/ 5-10h of embryogenesis
- Fig. 21-26: correspondence betw/ embryonic & larval body segments
- Parasegments: out of register w/ visible segmts; corresp. to gene expression patterns underlying segment'n; more later)
- Imaginal discs: precursor cells for adult eyes, antennae, legs, wings, haltere, genitalia, proboscis. Arise from specific embry.. ectodermal sites.

Fate map of *Drosophila* cellular blastoderm stage embryo: Fig. 21-28
- Before gastrul'n, future mesoderm I sventral, future nervous system and ventral epidermis is lateral, future digestive tract at termini

Genetics screens defined groups of *Drosophila* genes that regulate early

development
- Egg polarity genes (maternal effect genes): products serve as localized positional inform'n for specific'n of embryonic axes. 3 systems define AP axis (Fig. 21-29, -31) and termini, 4th defines DV axis (Fig. 21-31 to -34)
- Embryonic segmentation genes (next lecture): refine positional information provided by egg polarity genes; define body segments:
  - 3 classes: gap, pair-rule, and segment polarity genes
- Homeotic genes (next lecture): regulate body part formation

Egg Polarity Genes are all maternal effect genes:
- **Fig. 21-29:** Larval body plan defects that result when one or more of the egg polarity systems affecting AP axis are defective
  - Anterior system: affect head and thorax dev
  - Posterior system: affect dev of posterior body and germ cells
  - Terminal system: affect both extremities/ends of embryo
- egg polarity gradients determined by oocyte interxns with nurse and follicle cells during oogenesis.
- Fig. 21-30: egg capsule w/ 16 connected cells (from same PGC), one of which becomes **oocyte,** rest **nurse cells.** Maternal somatic cells (diploid, non-germ line) surrounding oocyte & nurse cells: **follicle cells.**
- Egg Polarity Genes: establish 4 gradient systems in egg
  - **Anterior system:** *bicoid* RNA tethered in ant. egg; Bicoid (TF) forms anterior gradient in early embryo
  - **Posterior system:** *nanos* RNA tethered in post. egg*;* Nanos protein forms post. gradient (Nanos binds/blocks transl'n of RNAs encoding proteins req. for ant. dev.)
  - **Terminal system:** includes transm. receptor Torso (terminal follicle cells provide ligand)
  - **Dorsoventral:** includes Toll; ventral follicle cells provide ligand; activ'n of Toll frees Dorsal (rel family TF, related to vert. NFkB, Chapt 15); it enters nuclei of ventral embryonic cells

Genes that pattern the dorsoventral axis
- Fig. 21-33: 2 opposing morphogen gradients in syncytial blastoderm embryo pattern DV axis
  - **Dorsal:** V to D nuclear gradient; activation of target gene *twist* in ventral cells (presumptive mesoderm)
  - **Dpp:** D to V gradient (no Dpp in ventral cells because Dorsal represses *dpp* transcription)
- Dpp diffusing to ventrolateral regions (neuroect) is inhibited by Sog (steepens Dpp morphogen gradient)
- Insect DV axis inverted relative to vertebrate DV axis (Fig. 21-35): in vert. blastula embryos, high Chordin (Sog homolog) defines future neurogenic region, high BMP4 (Dpp homolog) defines non-neural ectoderm, supports theory that ventral in invert. embryos equiv. to dorsal in vert. embryos.

Terms to know:
metamorphosis
segment, parasegment, thorax, abdomen
syncytial blastoderm, cellular blastoderm
body axes: anterior-posterior, dorsal-ventral
imaginal discs, neurogenic region
egg polarity genes; anterior, posterior and terminal systems
Bicoid, Nanos, Torso, Toll, Dorsal, Twist, Dpp, Sog,