Date	Title	Topic(s)	Learning Outcomes:
Sept 28	1. What is developmental biology and why should we care?	• Developmental processes • Differential gene expression • Introduction to determination • The model organisms used to study developmental processes	• Describe the basic cellular processes take place during development • Define differential gene expression • Describe experiments that proved that development does not occur through the differential inheritance of genetic material • Define determination and describe how is it tested • Name the pros and cons of different model organisms for studying development
Oct 3	2. What is so special about stem cells and gametes?	• Germ cells, stem cells, and gametes • Gametogenesis in Drosophila vs other organisms • maternal mRNA • Imprinting	• Compare and contrast spermatogenesis and oogenesis • Describe the unique features of oogenesis in Drosophila • Describe the experiment that demonstrates the importance of maternal mRNA in sea urchins • Describe mechanisms used to stabilize maternal mRNAs (a) and (b) to localize them • Define imprinting and in which species it occurs
Oct 5	3. How does fertilization kick start the formation of an embryo?	• Fertilization • Activation and cleavage of the newly formed embryo • Compaction in the mammalian embryo • Maternal to zygotic transition (MZT)	• Outline the basic steps in fertilization • Describe the slow and fast blocks to polyspermy • Describe why cleavage of embryos is very rapid in many species, but not in mammals • Compare and contrast the mammalian and Drosophila egg and early cleavage stage embryo with respect to yolk distribution and cleavage pattern • Describe compaction and its consequences in the mammalian embryo • Define the MZT and what controls its timing
Oct 10	4. Getting down to business: How do we study gene expression and development in embryos?	• Transcription factors and enhancers • Post-translational modifications • Methods to visualize gene expression in embryos • Gain and loss of function approaches to study gene function	• Describe what is meant by combinatorial action of transcription factors • Name types of post-translational mechanisms that impact gene expression during development • Draw positive and negative feedback loops and explain what impact can they have on gene expression patterns • Describe methods used to visualize expression of specific (a) mRNAs or (b) proteins expression in an embryo • Describe methods are used to define all of the mRNAs expressed in a particular embryo or part of an embryo • Explain how gene targeting, CRISPR/Cas and transgenic (overexpression) methods can be used to introduce mutations into specific genes
Oct 12	5. The amazing oocyte: Ooplasmic (cytoplasmic) determinants and the emergence of pattern	• Cytoplasmic determinants and maternal effect genes • Consequences of cleavage on cell fate • *bicoid* and *nanos* in Drosophila	• Describe types of experiments that provide evidence for the existence of cytoplasmic determinants • Explain the differences between maternal mRNAs in general vs cytoplasmic determinants

		• How are mRNAs like *bicoid* and *nanos* localized?	• Define what is meant by inductive interaction • Describe experiments establishing that there are germ cell determinants in Drosophila and frog embryos • Compare and contrast maternal effect vs. zygotic genes • Explain the functions of bicoid and nanos
Oct 17	6. Maternal control of pattern formation in the early Drosophila embryo	• Morphogens • Cleavage in the early Drosophila embryo • Defining the A/P axis of the Drosophila oocyte • Interactions between the Drosophila oocyte and surrounding follicle cells • Toll signaling and dorsal/ventral axis	• Describe the key attributes of a morphogen • Describe some mechanisms used to localize maternal mRNAs in the Drosophila oocyte • Outline how Gurken and Torpedo act define the A/P and D/V axes of the Drosophila egg • Describe how Toll signaling refines the D/V axis and name some basic components of this pathway • Describe how Dorsal activity specifies cell identity along the D/V axis
Oct 24	7. The transition from maternal to zygotic control of pattern formation in the Drosophila embryo	• Arranging developmental genes in hierarchies • *Hunchback* and *Krüppel* as gap genes • *Even-skipped* as a pair-rule gene • Compartments • *Hedgehog* and *Wingless* as segmentation genes	• Describe types of experiments used to arrange genes in a hierarchy of gene action • Explain the effects of increasing or decreasing Hb, bicoid, nanos, levels on Kr expression • Describe the main features of gap, pair-rule and segmentation genes. Provide examples of each type of gene. • Describe experiments that were used to identify enhancers that control expression of eve • Define compartments and describe the importance of compartmentalizing the Drosophila embryo • Define planar cell polarity and describe why is it important for patterning the embryo
Oct 26	8. How is identity acquired along the anterior-posterior axis of the embryo? The conservation of homeotic gene function in Drosophila and vertebrates	• Homeotic (Hox) genes • Co-linearity • Conservation of Hox gene function	• Describe the key structural and functional features of Hox genes and Hox complexes • Describe the consequences of loss or gain of Hox gene function • Define co-linearity and describe mechanisms that control co-linear Hox gene expression • Describe the evidence that Hox gene function is conserved across the Animal Kingdom
Oct 31	9. How do cell rearrangements and changes in cell shape drive changes in the form of the embryo?	• Cytoskeletal elements • Adhesion • Cell shape • Types of cell movements/rearrangements during development	• Outline the major differences between epithelial and mesenchymal cell types • Describe how signal transduction pathways can impact cell shape/rearrangement • Compare and contrast (de)compaction, delamination, ingression, apical constriction, invagination, convergent extension, epiboly, involution • Recognize the main movements of gastrulation in (a) frogs, (b) sea urchin, (c) birds and mammals

Nov 2	10. The emergence of form in the frog embryo: germ layer formation and gastrulation	• Gastrulation and germ layers • Dorsal-ventral (D/V) axis formation • Conservation of D/V axis formation in Drosophila and frogs • BMPs and D/V axis formation	• Define the difference between determination and specification • Describe the experiments that demonstrated when different germ layers first arise in the frog embryo • Describe cortical rotation and its impact on the frog embryo • Describe the Neiuwkoop Center and experiments that demonstrate its importance • Explain the functions of beta-catenin, Veg-T, and nodal-related proteins • Describe the Organizer and the experiments that demonstrate its role • Compare and contrast the role of BMP/DPP in frog/Drosophila D/V axis formation
Nov 7	11. Career decisions by cells in the frog embryo: developing or not into brain and neural tissue	• Neural induction • Formation of the dorsal/ventral axis in frogs • Formation of the anterior/posterior axis in frogs • Lateral Inhibition: Delta and Notch	• Describe experiments that demonstrated that the dorsal ectoderm becomes determined to form neural tissue • Describe experiments that demonstrate the importance of the dorsal mesoderm for organizing the remaining tissues along dorsal/ventral axis • Idenfity the molecules produced by the Organizer that are responsible for its properties, and explain how they work. • Explain how Wnt activity specifies the anterior/posterior axis of the frog embryo • Define lateral inhibition and describe its role in neurogenesis • Describe how Delta and Notch mediate lateral inhibition
Nov 14	12. On the importance of being flat: Gastrulation/Mesoderm formation in birds and mammals	• Events in mammalian/bird gastrulation: • Initiation and elongation of the primitive streak • The primitive streak and specification of the D/V axis • Mesoderm/endodnerm induction in the primitive streak • Somites	• Although the morphologies of frog and bird/mammalian embryos are different (round vs. flat), molecule mechanisms of D/V and A/P axis formation are conserved. Explain the conserved functions of Wnts, nodals, BMPs, BMP antagonists, Hox genes • Compare the functions of the frog Organizer and the bird/mammalian node • Explain how the neural tissue is formed in mammals/birds, and compare and contrast this to neural induction in frogs. • Describe somites and the mechanisms that control their orderly formation along the A/P axis • Explain how a negative feedback loop leads to periodic expression of a gene, and how is this related to periodic formation of somites.
Nov 16	13. Neural development in vertebrates: Subdivision of the brain and spinal cord into discrete regions	• Regionalization of the neural tube along the A/P axis in vertebrates • Compartments in vertebrates • Regionalization of the neural tube along the D/V axis • Neuronal stem cells and the origins of differentiated neurons	• Describe the evidence that rhombomeres are compartments in vertebrates. • Explain the role of Hox genes in A/P axis formation in the neural tube in vertebrates. • Identify what mechanisms pattern the most anterior regions of the neural tube (i.e, brain). • Discuss an experiment demonstrating the role of Shh in patterning the D/V axis of the neural tube

		• Lateral inhibition and Delta/Notch activity	• Describe how lateral inhibition regulate the timing of the production of neurons in vertebrates
Nov 21	14. Cells on the move in the embryo: Directed cell migration. Axonal pathfinding and neural crest cells in vertebrates	• Examples of long-range and short-range cues that guide cell migration • Mechanisms regulating responsiveness to guidance cues: Robo and Slit • Retinotectal mapping: short-range cues in action • Neural crest cells: formation, migration, and derivatives	• Describe long-range and short-range cues and provide examples of each (attractive and repulsive) • Describe the experiments that support a role for netrin as a long-range cue • Describe the key experiment that suggests netrin produced by the floorplate does NOT act as a long-range cue • Explain how ephrins and ephrin receptors mediate retinotectile mapping. • Explain where neural crest cells originate in the embryo and name some derivatives of neural crest cells
Nov 28	15. Making sense of sensory placodes and ectodermal appendages in vertebrates	• Placodes--definition • Specification of sensory placodes that give rise to sensory structures and cell types (eyes, stereocilia of the ear, olfactory neurons) • Development of the vertebrate eye • Conserved function of Pax6 in Drosophila and vertebrates • Conserved features of formation of ectodermal appendages	• Define ectodermal vs sensory placodes and their derivatives • Describe the inductive interactions that give rise to the vertebrate eye • Describe the role of Pax6 in eye formation and describe the loss-of-function and gain of function experiments (in Drosophila, mouse) that demonstrate conservation of function • Describe why reduced Shh expression leads to cyclopia (one central eye) in humans and describe the consequences of gain of Shh expression in cavefish. How do these examples show conservation of Shh function in specifying D/V axis identity in the neural tube? • Define regional and genetic specificity of induction and the experiments used to demonstrate these concepts • Describe how mutations in Eda or Edar lead to ectodermal dysplasia
Nov 30	16. Branching morphogenesis and endodermal organs in vertebrates	• Endoderm formation in frogs and birds/mammals-review • Establishment of left-right asymmetry in vertebrates • Regionalization of endoderm along the A/P axis: Hox genes and Cdx2 • Branching morphogenesis in organ formation • Intestinal villi and stem cells in vertebrates: role of Wnt signaling	• Compare the process of endoderm specification in frogs vs. birds/mammals • Describe left-right asymmetry, and explain how it is regulated by ciliary function in vertebrates. • Recognize the experiments and relevant mutations that demonstrate asymmetry. • Explain experiments that demonstrate Hox genes and Cdx2 are involved in A/P axis identity in the endoderm in vertebrates. • Define branching morphogenesis, and describe the function FGF10 plays in this process in the lung • Explain how Wnt signaling regulates stem cell maintenance in the intestine. Describe the impact of mutations in Wnt pathway components (TCF/LEF, beta-catenin, APC) in the intestine in vertebrates.
Dec 5	17. Limb Development: Charles Darwin and The	• Components of the limb bud: AER, ZPA/PR and Progress zone	• Discuss the results of experiments that demonstrated the roles of the AER and ZPA/PR in limb development.

	Curious Case of the Bat Wing and the Porpoise Paddle	• Hox genes and A/P and proximal-distal (P/D) identity • SHH as a regulator of A/P and P/D identity • Mechanisms that determine the position of limb buds in the embryo • Molecular mechanisms that may have contributed to limb evolution	• Describe the genetic evidence that Hox genes regulate A/P and P/D identity in the limb • Evaluate the findings from experiments that demonstrate how SHH regulates both A/P and P/D identity in the limb • Describe the roles of FGFs, SHH, and Hox genes in positioning limb buds in the embryo • Describe evidence that genetic changes in SHH expression have contributed to diversification of limb forms during evolution
Dec 7	18. Sex and the Single Mammalian Embryo	• Development of male and female gonads in mammals • Primary vs secondary sexual characteristics--the importance of the testes and testosterone • Origins of germ cells • Role of the Y chromosome and the SRY gene	• Identify experiments demonstrating that the mammalian testes produce soluble substances that define secondary sexual characteristics • Predict the effects of mutations in these soluble substances and their receptors on primary and secondary sexual characteristics • Describe the relationship of Sox9 and SRY, and how these genes control sex determination. • Compare and contrast the fate of germ cells when they enter the developing gonads of male and female embryos.