

CourseSource - Developmental Biology Learning Matrix

TOPIC	THEMES/SUPTOPICS	LEARNING GOALS	SAMPLE LEARNING OBJECTIVES
Early Embryonic Development	Gametogenesis	How do organisms maintain gamete populations?	Compare and contrast spermatogenesis and oogenesis.
			Draw and compare the functions of meiosis and mitosis.
	Fertilization	How does sperm entry trigger post-fertilization processes in the egg/activation of oocyte?	Compare and contrast the fertilization process in mammals and plants.
	From zygote to gastrulation	How is the basic body plan formed?	Design experiments that would demonstrate the cell movements of gastrulation.
Morphogenesis			Explain fertilization and cleavage, and justify why cleavage is an important step in development.
	Cell differentiation	How does loss of totipotency and pluripotency lead to progressive specification in cells?	Design experiments that would demonstrate the principles of cell fate, cell commitment (determination), and differentiation.
	Cell migration	How do differential cell adhesion, attraction, and repulsion result in morphogenetic changes?	Design experiments that explain migration of neural crest cells.
	Cell death	How does apoptosis/cell death regulate growth, shape and pattern?	Propose an experiment to determine if apoptosis is an important component of organ formation in a model system.
Patterning	Axis formation	How are the axes formed?	Evaluate experiments that demonstrate the establishment and patterning of axes in embryos.
			Explain how Hox genes control patterning along the anterior-posterior axis and in many developing organs.
	Symmetry/Asymmetry	How do genetically identical, totipotent cells change into daughter cells with restricted potency, fate, properties and behaviors?	Explain how Hox genes control patterning along the anterior-posterior axis in different developing organs.
			Design experiments that would demonstrate the principles of cell fate, cell commitment (determination), and differentiation.
	Growth control	How does cell cycle regulation control cell size, growth, shape and pattern?	Draw and compare the functions of meiosis and mitosis.
	Spatial-temporal correlation	How do progressive, stepwise processes contribute to embryo complexity?	Compare how vertebrates and invertebrates become segmented or divided into repeating units.

Organogenesis	Growth control	How do extracellular factors control organ and tissue growth?	Predict the outcome of a mutation that inhibits Frizzled (Wnt receptor) v. nCAMs
	Symmetry/Asymmetry	How does asymmetry arise and contribute to complexity? (localized determinants, cilia directional movement, etc.)	Describe the mechanism whereby physical or chemical signals are used as an asymmetrical developmental trigger in plant or animal cells.
	Cell determination v. Cell specification	What roles do cell determination and cell specification play in organogenesis?	Predict the lineage outcome (heart or tail) of transplanting mesodermal cell populations from anterior heart fields to posterior presomitic tail bud.
	Tissue organization	How do morphogen gradients regulate tissue organization?	Describe the mechanism whereby physical or chemical signals are used as a developmental trigger in plant or animal cells and tissues.
		How do differential cell adhesion, attraction and repulsion, and ECM regulate tissue organization?	Interpret the effects of lateral inhibition in establishing neural fates. Explain why neural crest cells migrate across a specific part of the somite?
	Regeneration	How do developmental processes affect tissue homeostasis and restoration?	Compare and contrast muscle regeneration and myogenesis.
Signaling	Intracellular	How does the intracellular communication regulate gene transcription, cell polarity, shape and fate?	Compare the roles of different transmembrane signaling pathways in development.
		How does differential gene expression mediate progressive acquisition of cell fate?	Explain how Hox genes control patterning along the anterior-posterior axis and in many developing organs. Explain how proliferative signals moderate transcription factor activity and subsequently lead to lockdown of fate.
	Extracellular	How do induction mechanisms and pathways influence cell fate?	Compare the roles of different transmembrane signaling pathways in development.
		How do mechanical constraints and dynamics influence cell behavior, tissue and organ formation?	Predict changes (or not) in development taken place in microgravity environment.
Gene Networks	Gene expression regulation	How does the control of gene regulation contribute to development?	Predict different mechanisms that could be responsible for control of gene expression in development.
		How do genomic and epigenetic changes modify the transcriptome of a cell?	Explain roles heterochromatin serves during development (e.g. Methylation on MyoD's ability to induce the myogenic program in a non-muscle

			cell). What changes in chromatin prime a cell to respond to later signals?
		How do feedback loops affect multiple levels of gene regulation?	Describe experiments that test the idea that floral homeotic gene (or ABCE gene) expression ensures the development of floral organs in the correct number, type, and precise spatial arrangement.
		How do differences in regulation of gene expression explain the different cell types?	Propose a mechanism that may explain differences in cell type behavior as a result of different gene expression (e.g. In time or site).
		How do differences in regulation of gene expression explain the formation of atypical cells, tissue, organs and structures?	Provide examples of how overexpression of an mRNA affects: 1) axis formation; 2) cell differentiation; 3) tissue formation.
Comparative Development and Evolution	Comparative embryology	How does comparison between species explain the emergence of new features?	Propose a study of different species that can inform us about processes that led to disappearance or appearance of specific features (e.g. Loss of tail).
	Conservation of developmental processes	How do changes in expression patterns of existing genes, or genetic modifications of existing signaling pathways result in new phenotypes?	List a few genes that are found across the phyla and propose mechanisms that allowed them to form different phenotypes.
	Diversity	How do differences in developmental processes explain determinate versus indeterminate growers?	Propose multiple mechanisms by which indeterminate (e.g. eel) and determinate (e.g. guppy) growers may differ in their developmental processes.
		How does the environment contribute to organismal diversity?	Explain the “organizational-activation” theory of steroid hormone action on development. Use two specific examples that lead to “masculinization” or “feminization” of structures in an organism.
			Predict how factors such as temperature could be operative in phenotypic diversity within species (e.g. Turtle).
Experimental Approaches	Methods and tools	How do the methods and tools of developmental biology help us understand cause and effect relationships during embryogenesis? (correlation, gain of function and loss of function; molecular, cellular, tissue, organ)	Design an experiment to detect the identification and/or position of potential stem cells in a tissue that is known to renew itself (e.g. skin, intestinal epithelium). Include positive and negative controls (one of each) that you would perform and the purpose of each control.

Experimental Approaches (cont.)	Methods and tools (cont.)		Given an article about the use of specific reagents in a developing organism and resulting phenotype(s), propose and explain potential mechanisms (e.g. induction, gene knockout) and give other examples using the same mechanisms.
	Organisms	How do different organisms help us understand development? And what are their strengths and limitations?	Explain how studying other species inform us about differences in developmental process that led some organisms to preserve certain characteristics and others to lose them?
			Design a fate mapping experiment in an organism after learning how it is done in a different one.

Bloom's cognitive levels:

1. Remember: arrange, define, duplicate, label, list, memorize, name, order, recognize, relate, recall, repeat, reproduce state.

2. Comprehend: classify, describe, discuss, explain, express, identify, indicate, locate, recognize, report, restate, review, select, translate.

3. Apply: apply, choose, demonstrate, dramatize, employ, illustrate, interpret, operate, practice, schedule, sketch, solve, use, write.

4. Analyze: analyze, appraise, calculate, categorize, compare, contrast, criticize, differentiate, discriminate, distinguish, examine, experiment, question, test.

5. Evaluate: appraise, argue, assess, defend, estimate, judge, predict, rate, select, support, value, evaluate.

6. Create: compose, construct, create, design, develop, formulate, manage, organize, plan, prepare, propose, set up, write.