Massachusetts Institute of Technology
Department of Biology
7.22, Fall 2005 - Developmental Biology
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## 7.22 Example Problems for Exam 1

**The exam will be of this format. It will consist of 2-3 sets scenarios.**

### 1. The Observation

During the first cleavage division of the nematode Parascaris aequorum, special cytoplasm, termed the germ plasm, is segregated into one specific daughter cell. Cells that do not inherit the germ plasm undergo a process called chromosome diminution (the chromosomes fragment and much of each chromosome is lost at subsequent divisions). All germ cells are descended from the cell that does inherit the germ plasm and these cells retain their full complement of DNA.

### The Tasks

1.1 Offer a hypothesis about the molecular mechanism (involving, for example, a specific protein or RNA- feel free to give this(these) a name(s)) that might be responsible for the phenomenon (germ plasm vs chromosome fragmentation) described above.

1.2a Describe an experiment to determine if the mechanism you have hypothesized and the phenomenon are correlated (correlation; “show it”).

1.2b Describe a result that is consistent with your hypothesis.

1.2c Describe a result that is inconsistent with your hypothesis.

1.3a Describe an experiment to determine if the mechanism you have hypothesized is necessary for the phenomenon to occur (loss-of-function; “block it”).

1.3b Describe a result that is consistent with your hypothesis.

1.3c Describe a result that is inconsistent with your hypothesis.

1.4a Describe an experiment to determine if the mechanism you have hypothesized is sufficient to the phenomenon to happen (gain-of-function; “move it”).
1.4b Describe a result that is consistent with your hypothesis.

1.4c Describe a result that is inconsistent with your hypothesis.

**2. The Observation**
A key question in evolution and development is how the front (fore) limbs and back (hind) limbs become different from one another. That is, how their identity is established. One possible clue comes from expression of the Tbx5 transcription factor, which is normally expressed in the developing forelimbs, but not the developing hindlimb.

**The Tasks**
2.1 Formulate a hypothesis regarding the possible function of Tbx5 in directing limb identity.

2.2a Describe an experiment to determine if Tbx5 is necessary for the function you have hypothesized (loss-of-function; “block it”).

2.2b Describe a result that is consistent with your hypothesis.

2.2c Describe a result that is inconsistent with your hypothesis.

2.3a Describe an experiment to determine if Tbx5 is sufficient to cause the function you have hypothesized (gain-of-function; “move it”).

2.3b Describe a result that is consistent with your hypothesis.

2.3c Describe a result that is inconsistent with your hypothesis.

**3. The observation**

In classic "transplant" experiments, the future neural plate (nervous system) of a frog embryo was moved from its usual dorsal position to the ventral region of a host embryo. The host and donor embryos were either at the early gastrula or late gastrula stage when the transplant was performed.

When the future neural plate of an early gastrula donor is transplanted, it develops as non-neural tissue (epidermis) on the ventral side of the host. However, when the future neural plate of a late gastrula donor is transplanted, it develops as a second neural plate on the ventral side of the host, as diagrammed below.

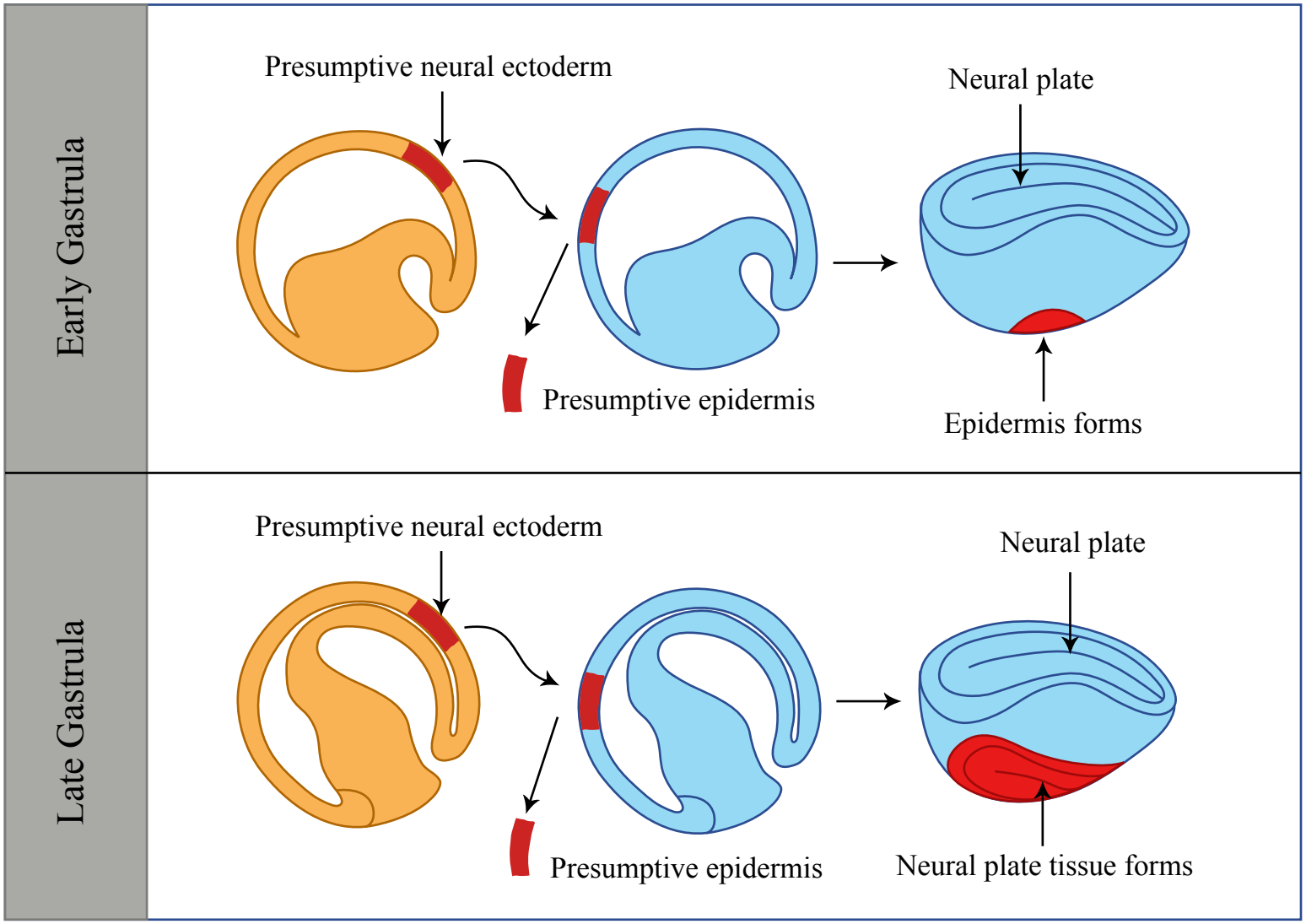


Figure by MIT OCW.

**The Tasks**

3.1 In order to perform this experiment, you need to know which piece of tissue is going to give rise to the normal neural plate, How would you determine this? What is this type of experiment called?

3.2 Formulate two possible hypotheses that would explain the results described.

3.3 The transcription factor NeuroD is expressed in late gastrula neural plate.

3.3a Describe an experiment to test correlation of NeuroD expression with the ability to form a neural plate (show it).

3.3b Describe a result consistent with this correlation.

3.3c Describe a result inconsistent with this correlation.

3.4a Describe a gain of function experiment to test function of NeuroD in neural plate formation (move it)

3.4b Describe a result consistent with this function.

3.4c Describe a result inconsistent with this function.

3.5a Describe a loss of function experiment to test function of NeuroD in neural plate formation (lose it)

3.5b Describe a result consistent with this function.

3.5c Describe a result inconsistent with this function.

## 4. The Observation

In an example we discussed in class, it was shown that while the animal half of an early sea urchin embryo does not form a normal pluteus larva, the micromeres can rescue development of the animal half. However, the micromeres contribute to only a few of the rescued embryos tissues.

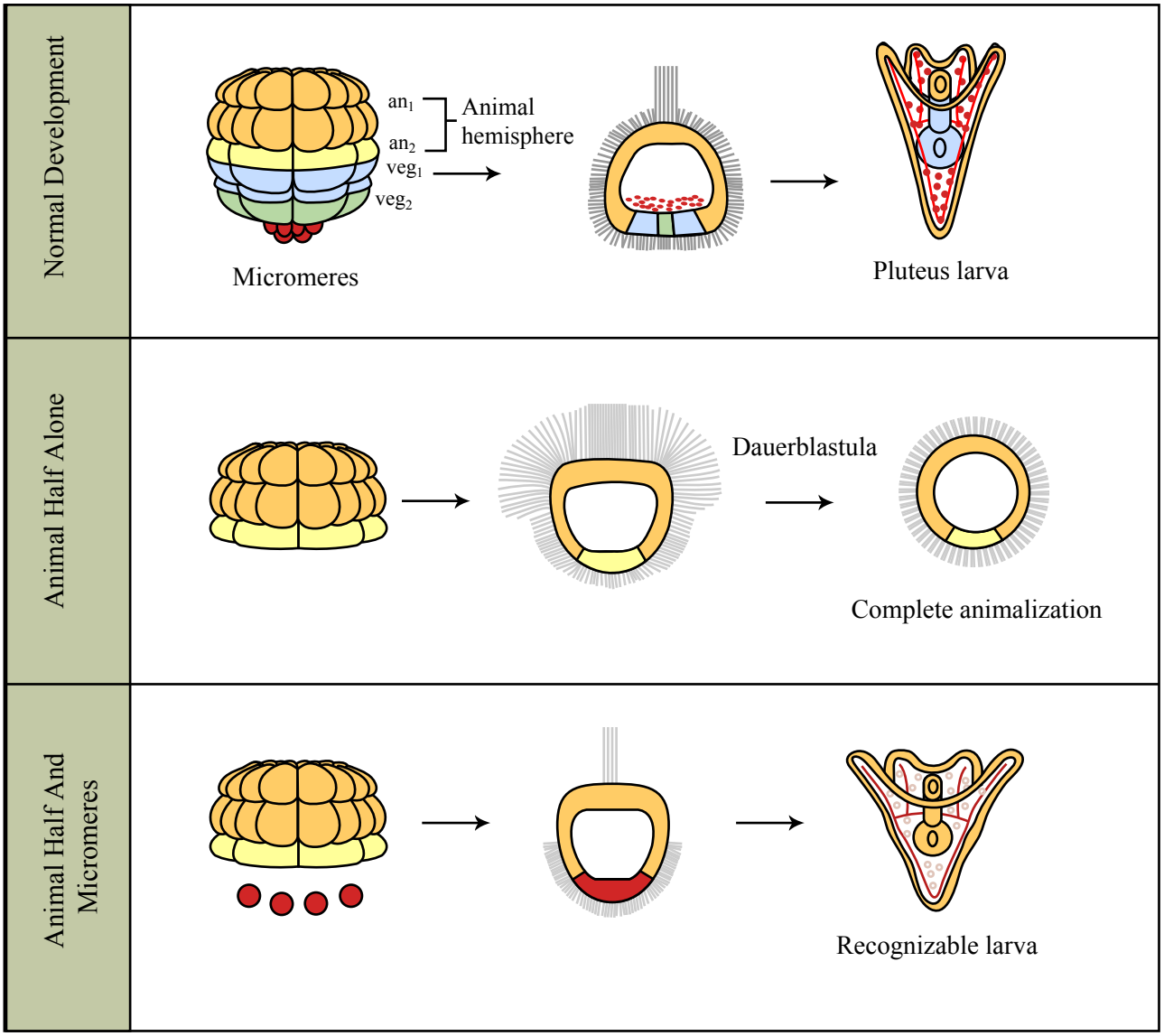


Figure by MIT OCW.

**The Tasks**

4.1 What major process does this observation illustrate?

4.2 What is an “organizer”? Do you think this phenomenon could illustrate the activity of an organizer? Why?

4.3 The Delta protein is expressed in the micromeres of an intact sea urchin embryo. Delta is a secreted protein that acts on cells directly touching the secreting cell, via the Notch receptor.

4.3a Formulate a hypothesis concerning activity of Delta in the micromeres.

4.4a Describe an experiment to analyze correlation of Delta expression with the rescuing activity of the micromeres.

4.4b Describe a result consistent with your hypothesis.

4.4c Describe a result inconsistent with your hypothesis.

4.5a Describe an experiment to analyze necessity of Delta in rescuing activity of the micromeres.

4.5b Describe a result consistent with your hypothesis.

4.5c Describe a result inconsistent with your hypothesis.

4.6a Describe an experiment to analyze sufficiency of Delta in rescuing activity of the micromeres.

4.6b Describe a result consistent with your hypothesis.

4.6c Describe a result inconsistent with your hypothesis.

**5. First observation**

During the early stages of mouse lung formation, a group of epithelial cells divides and forms "primary ($1^o$) tubules" which then branch and form additional secondary ($2^o$) tubules, and eventually tertiary ($3^o$) tubules. The epithelial cells touch a different cell type, the lung mesenchyme.

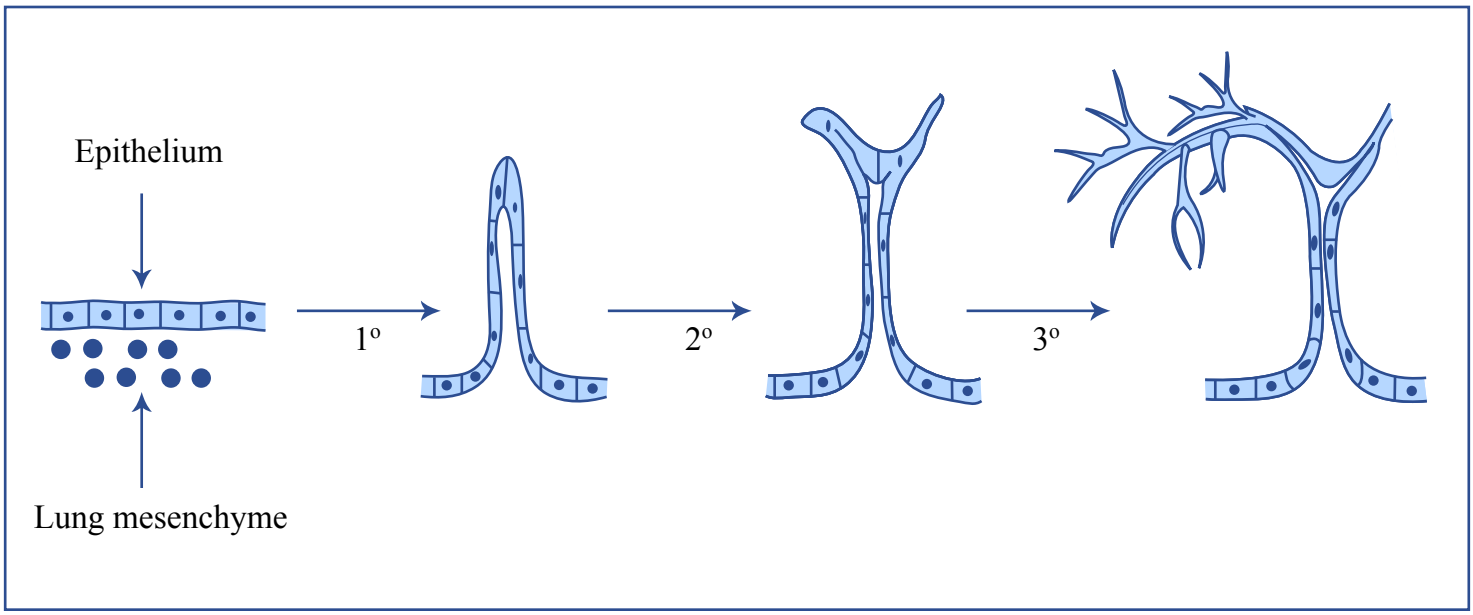


Figure by MIT OCW.

**NOTE: Lung mesenchyme is present throughout the period of lung tubule formation**

**Second observation**

The lung mesenchyme can be removed and/or substituted with kidney mesenchyme, as diagrammed below. In either case, tubules do not form.

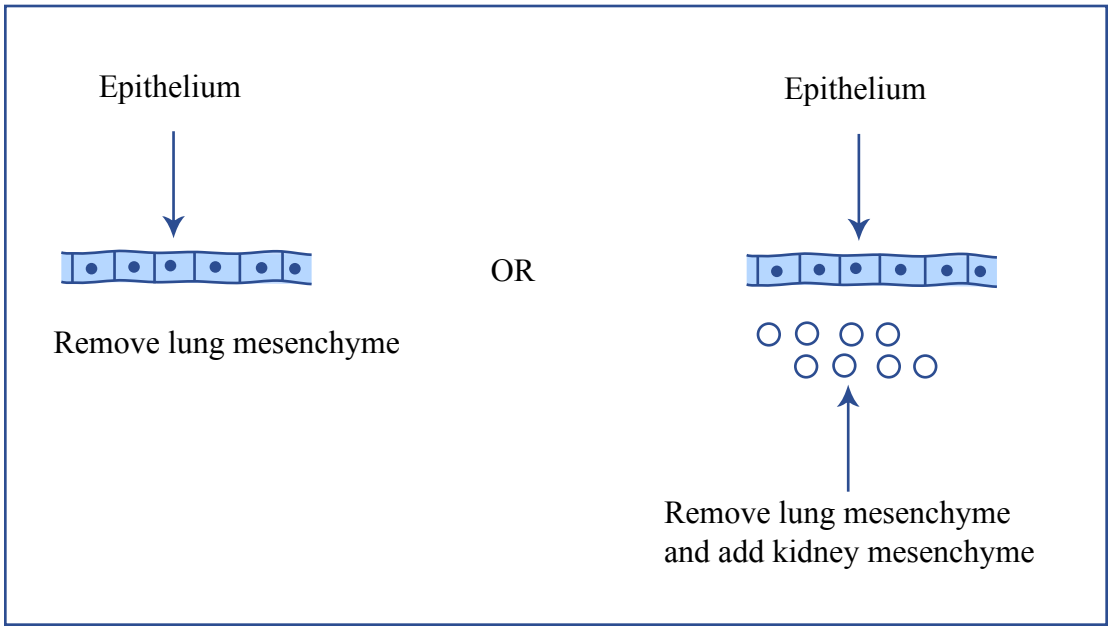


Figure by MIT OCW.

## The tasks

a. **10 points.** Formulate a hypothesis regarding the roles of epithelium and mesenchyme in primary lung tubule formation, that takes the above observations into account.

b. **1 point.** What fundamental process of developmental biology do these observations illustrate? (one word)

c. **15 points.** The Fgf protein is expressed in the lung mesenchyme. Fgf is a secreted protein (a ligand) that acts through a receptor tyrosine kinase.

Describe an experiment to examine correlation of Fgf expression with lung tubule formation.

Describe a result consistent with this correlation.

Describe a result inconsistent with this correlation.

d. **15 points.** Loss of function tests:
Describe an experiment to test necessity (loss of function) of Fgf for lung tubule formation.

Describe a result consistent with necessity.

Describe a result inconsistent with necessity.

e. **15 points.** Gain of function tests:
Describe an experiment to test sufficiency (gain of function) of Fgf in lung tubule formation.

Describe a result consistent with sufficiency.

Describe a result inconsistent with sufficiency.

f. **10 points.** Where might you expect the Fgf receptor protein to be localized? Include the cell types and expected subcellular localization.

How would you test this expectation?

g. **10 points.** While Fgf promotes lung tubule outgrowth, the lung mesenchyme also produces the secreted Sprouty protein, that inhibits outgrowth of the primary lung tubules. The dual action of Fgf and Sprouty therefore lead to primary tubules of the correct length.

Formulate a hypothesis regarding the molecular mechanism by which Sprouty and Fgf might function together to regulate primary lung tubule formation.

**6. The observations**

In vertebrates there are at least 19 different Fgf ligands and 4 different Fgf receptors! Fgf8 is is expressed in the developing hindbrain, that will give rise to the medulla and cerbellum. Fgf8 is essential for normal hindbrain development. Fgf8 is also expressed in the developing limbs, where it is essential for normal limb development.

**The tasks**

a. **10 points.** Limb and hindbrain have very different functions. In what general ways is hindbrain different from limb? Give an answer that uses your knowledge of cell and molecular biology.

b. **I point.** The limb develops primarily from mesoderm, the hindbrain from ectoderm. What is the developmental biological term that describes collectively the ectoderm, mesoderm and endoderm? (one word)

c. **15 points.** If pure Fgf8 protein is applied to isolated ectoderm, the ectoderm goes on to form a rudimentary hindbrain. If Fgf8 protein is applied to isolated mesoderm, the mesoderm goes on to form the beginnings of limbs.

Give the developmental biological term that describes differences in the ability of a tissue to respond to the same stimulus. (one word)

Formulate a hypothesis regarding the molecular mechanism by which the ectoderm and mesoderm respond differently to applied Fgf8 protein.