Zoology 470 - Exam #3 – 2008

This exam has **6** pages and a total of **50 points**. You will have 120 minutes to complete it. Answer all short answer questions as briefly as possible. Make sure your name and ID number are on all pages.

1. Provide concise definitions for each of the following (**5 points**)

a. neuropore: *Openings at the anterior and posterior ends of the neural tube in chordates. Failure to close the anterior neuropore results in anencephaly; failure to close the posterior neuropore results in spina bifida.*

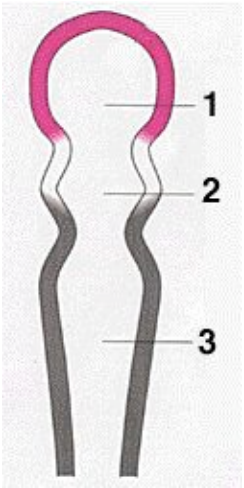
b. cerberus: A secreted protein that acts to inhibit Wnt signals in the anterior, and therefore it is involved in induction of head structures (including anterior neural structures)

c. sclerotome: *Somite derivative that gives rise to mesenchymal cells that form the vertebral column.*

d. netrin: *Neuronal guidance molecule that acts as a chemoattractant for commissural axons in the vertebrate spinal cord, and can also act as a repellant for other neuronal cells types. Netrins homologues are found in a wide range of animal embryos, including C. elegans.*

e. metamerism: *Phenomenon in animal embryos involving segmental repetition of body parts. Examples include segmentation in arthropods, and somites, rhombomeres, and the vertebral column in vertebrates.*

2. For each embryonic brain region listed below, indicate from which structure on the right it is generated. If none is appropriate, write "none" (**2 points**).



Structure:

a. hippocampus ____*1*_____ b. rhombomere _____*3*_____

c. cerebrum _____*1*_____ d. lens of the eye ____*none*_____

3. Neural crest cells and their progeny appear to be pluripotent. Describe **one** piece of evidence that neural crest cells are pluripotent (**1 point**)

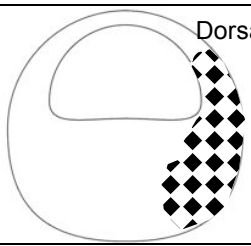
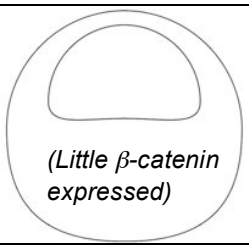
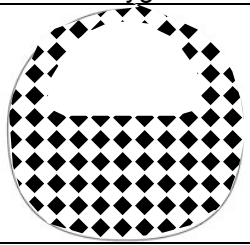
Evidence for pluripotency:

Possibilities: (1) Lineage tracer injections into single NCs result in multiple tissues types containing label. (2) Treating NCs in culture with various growth factors (e.g., nerve growth factor, retinoic acid, etc.) results in different differentiated derivatives.

4. Circle true (T) or false (F) for each of the following (**7 points**)

T	In mammals, the chorion has lost its protective function and has been modified to form the placenta.
F	The splanchnopleure is formed from the splanchnic mesoderm and ectoderm in vertebrates. *(Mesoderm + endoderm)*
F	The umbilical artery carries oxygenated blood from the placenta back to the fetal heart. (*It carries deoxygenated blood to the placenta; the umbilical vein returns oxygenated blood.)*
F	Pigmented cells form from neural crest cells that migrate under the anterior half of somites. (*Pigmented cells form from NCs that migrate dorsally over the somites)*
F	Many internal organs, such as the liver and pancreas, form from simple outpocketings of the ectoderm in amniotes. *(They form from endoderm)*
T	In vertebrates, the retina forms from neural ectoderm.
F	Like amphibians, the floor of the blastocoel is initially lined with endoderm prior to gastrulation in amniotes. *(Endoderm must ingress through the primitive streak)*
T F	Keller explants indicate that "vertical" neural induction can occur in the central nervous system in vertebrates. *(They show "planar" induction can occur, not vertical)*
F	When a pregnant woman says that her "water broke" prior to giving birth, she is describing the release of fluid from the allantois *(From the amnion)*
T	In mammals, the yolk sac still retains its role in producing blood cells.
T	In vertebrates, the heart forms from two initially separate primordia
T	The anterior region of amniote embryos is developmentally more advanced that the posterior.
F	A ventral, hollow nerve cord is a diagnostic feature of vertebrate embryos. *(dorsal hollow nerve cord)*
F	E-cadherin, which is normally expressed in neural ectoderm, is important for the movements of neurulation. *(E = "epidermal"; E-cadherin is expressed in epidermal ectoderm)*

5. The accumulation of β-catenin is a key step in the progressive specification of dorsal structures in amphibian embryos that leads to the differentiation of the organizer. Recall that noggin is a molecular marker for the organizer. For each of the experimental situations below, indicate the localization of β-catenin at the blastula stage by drawing in the provided diagram. Indicate the expected level of expression of noggin using the following classification: High = higher than normal; Normal; Low = lower than normal. (**4 points**)

Treatment:	None (normal)	Zygote is UV irradiated to prevent cortical rotation	Injection of large quantities of activated disheveled into the one-celled zygote
β-catenin localization:			
noggin expression:	normal	*low*	*high*

5 (cont)
b. **Briefly** describe the molecular mechanism of action of *noggin* (**1 point**)

Noggin binds BMPs, making them inactive for signaling. Noggin thus counteracts the ventralizing effects of BMPs in the marginal zone during mesoderm induction, and their "epidermalizing" effects in the ectoderm.

c. An structure equivalent to the Organizer in other vertebrates expresses high levels of *noggin*. Name this equivalent structure in an amniote embryo (**1 point**):

Equivalent structure in amniote: *Henson's node/node*

6. For each phrase referring to various aspects of amphibian gastrulation on the left match ALL appropriate response(s) drawn from the figures on the right. Note: in some cases, the correct answer will require more than one choice. If none of the answers on the right are appropriate, write "none". [Note: 3 indicates the cleft the forms as indicated] (**4 points**)

a. the lip of the blastopore___*3*___

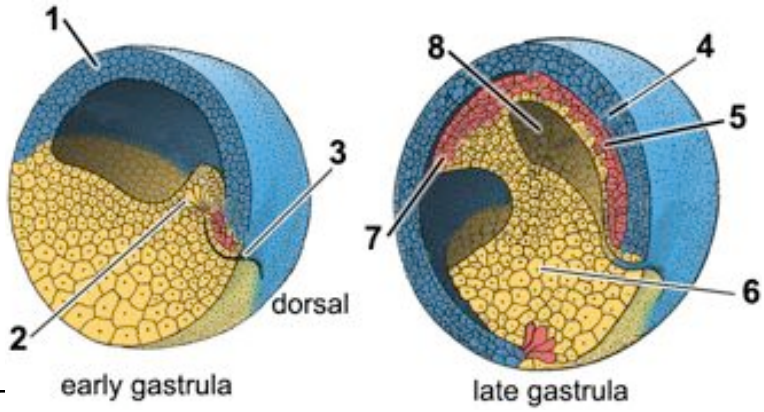
b. undergoes apical constriction___*2*___

c. cell from here form head mesoderm__*7*___

d. undergoes convergent extension__*4,5*____

e. makes ectoderm___*1,4*___

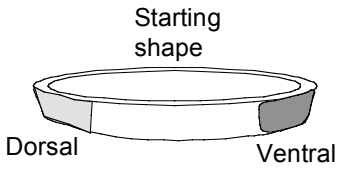
f. the cavity that forms the digestive tract ___*8*___



g. the yolk inside cells from here is metabolized in later development___*6*____

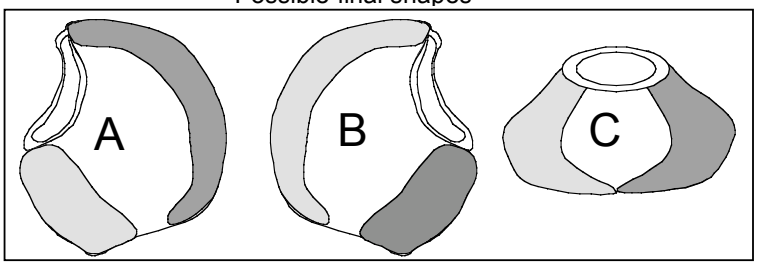
h. aligned fibronectin is found here ___*1*___

7. You are studying a new species of salamander, and you believe its tissues differentiate and behave in a manner similar to *Xenopus*.



Mesodermal fate mapping

Possible final shapes



a. You perform mesodermal fate mapping on the new species (see the figure above). If the mesoderm has the shape at the left, which of the shapes at the right best represents the shape of the mesoderm near the end of gastrulation? (**1 point**)

Shape: _____*B*_____

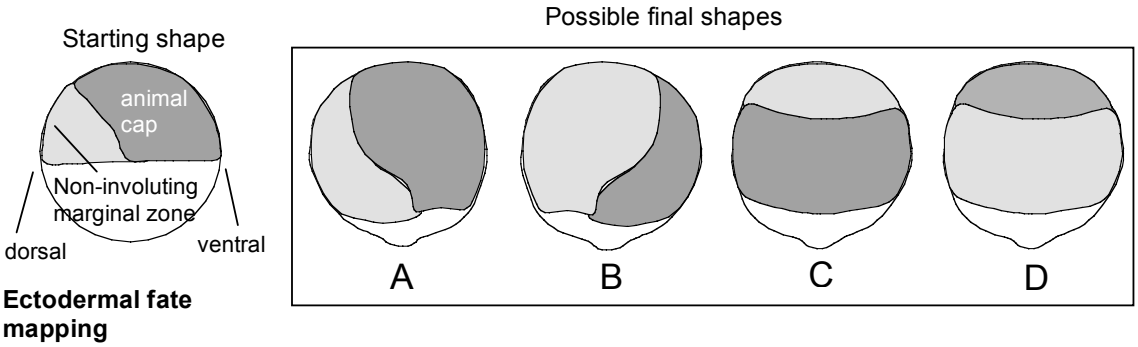
b. You clone the BMP4 gene from the new species, and inject large quantities of mRNA corresponding to this BMP. Which of the shapes at the right above best represents the shape of the mesoderm near the end of gastrulation in the injected embryo? (**1 point**)

Shape: _____*C*_____

7 (cont)
c. You go on to assess the expression of a neural ectodermal marker in embryos like the one in part (b). Will these markers be expressed at higher or lower levels than in a normal embryo? **State your reasoning** (**2 points**)

Lower, since BMPs tend to "epidermalize" ectoderm, which is normally counteracted by signals from the Organizer

d. You then map the ectoderm in the new species. Which of the possible final shapes below is the shape you predict at the end of gastrulation? (**1 point)**



Ectodermal fate mapping

Shape: _____*A*_____

8. Recall that progeny of the micromeres in sea urchin embryos go on to become primary mesenchyme. Rob Maxson, is studying an Antarctic sea urchin at McMurdo Station. Rob repeats classic experiments investigating the adhesive properties of these cells. Complete the following table, which compares the adhesive properties of micromeres with their descendants at a time that primary mesenchyme cells would normally ingress into the blastocoel. **Indicate + for high affinity, and - for low affinity** (**2 points**)

Cell	Affinity for basal lamina	Affinity for hyaline layer
Micromeres	*Low*	*High*
Cultured cells at mesenchyme blastula stage	*High*	*Low*

9. Morphogenesis involves region-specific characteristics of cells that allow them to act together to change the shape of the embryo. Match each phrase on the left to **ALL** appropriate responses on the right. If a cell or tissue engages in more than one of these movements at different times during development, then indicate **all** appropriate responses. If no response is appropriate, then write "none" (**3 points**)

Cells or tissue

1. Dorsal deep cells that form mesoderm in zebrafish

2. Sea urchin archenteron

3. Neural plate in salamanders

4. Sea urchin primary mesenchyme

5. Primitive streak cells in a chick gastrula

6. Chick neural crest cells

Behavior

a. Undergoes directed migration **as single cells** _*4,5,6 [accept 1]*__

b. Undergoes convergent extension ___*1,2,3*_____

c. Undergoes invagination ____*2,3*_____

d. Undergoes ingression____*4,5*_____

e. Known to require planar cell polarity (PCP) signaling for correct morphogenesis ____*1,3*_____

10. Eph receptor tyrosine kinases and their ligands, the ephrins, are thought to be important regulators of cell migration in early embryos. Based on what you know about the distribution of Eph receptors and ephrins, provide **two** specific examples that indicates that these molecules distributed in a manner consistent with them playing a role in guiding cell migrations or morphogenesis in the embryo. (**2 points**)

Example #1: *Rhombomeres have alternating Eph/ephrin expression*

Example #2: *Retinal/tectal system – tectum has graded distribution of ephrins, retinal cells have graded sitribution of Ephs. This allows for anterior/posterior differences in connectivity in the tectum*

Other: Neural crest cells avoid regions of somites with high levels of ephrins during their migration

11. You are in John Fallon's lab, reexamining the *sonic hedgehog* knockout mouse. Name **two** inductive events that you expect to fail in the knockout mouse, and the expected effect (**3 points**)

Inductive event #1: *Induction of floor plate by notochord (also: FP induces lateral neuronal populations via shh)*	Expected defect due to failure #1: *Holoprosencephaly (loss of brain, cyclopia) [Note: due to differences in emphasis this year, I would accept "neural tube defects", or something similar]*
Inductive event #2: *A-P patterning of limb bud by ZPA*	Expected defect due to failure #2: *Loss of A-P polarity of limb elements, including digits*

12. Your friend works in a *Drosophila* lab, and she has recently shown that a certain mutation in a member of the HOM-C complex results in a dramatic transformation of abdominal structures into more anterior (i.e., thoracic) structures. You work in Mario Capecchi's lab, and want to study a mouse homologue of this gene.

a. Your gene is expressed in the hindbrain within the central nervous system. You notice that the anterior edge of the gene's expression has a sharp boundary that correlates with well-known structures in the hindbrain. What are these structures? (**1 point**):

Structure: *Rhombomeres*

b. After two more years of work, you knock out the mouse gene. Sadly, you see little phenotypic effects on axial structures. Being a bright young developmental biologist, you are not surprised by this, even though you can show that homozygous animals make absolutely no functional mRNA or protein from this locus. **State your reasons** (**2 points**)

Functional redundancy of Hox genes, due to multiple paralogues, results in the mild phenotypes in single KOs

c. You treat mouse embryos with retinoic acid to alter the expression pattern of your gene, and look for obvious defects in development. In addition to defects in the hindbrain, what other structures in the head would you predict would be defective (**1 point**)?

Structure predicted to be defective: *Pharyngeal arches [would also accept answers that reflect knowledge of what the arches generate (cartilaginous structures in the head region, ear bones, etc.)]*

13. Describe the results of the following manipulations in amniote embryos, which are designed to examine mechanisms of limb bud formation (**3 points**)

Operation	Expected Result
Remove the apical ectodermal ridge (AER) from a leg bud and replace it with the AER from a wing bud of the equivalent age	*Normal limb, since the AER provides non-specific growth signals*
Implant a bead soaked with fibroblast growth factors (FGFs), such as FGF2 or FGF8, into a limb bud from which the AER has been removed	*This rescues the loss of the AER, so limb outgropwth should be essentially normal*
Make a mouse "knockout" for FGF10	*This results inloss of limb bud formation, and hence loss of limbs entirely*

14. Kartagener's triad is a human syndrome in which male patients have respiratory problems, immotile sperm, and reversal of left-right symmetry of internal organs.

a. What cellular structure(s) are the primary defect in such patients? (**1 point**)

Structure defective: *Primary cilia [this was required for full credit; if the answer discusses the symptoms instead, such as immotile sperm, respiratory cells have defective cilia, 50% L/R axis reversals (situs inversus), then partial credit was earned]*

b. Fluid flow across the node in mammals is thought to be *sufficient* to determine the direction of the left-right axis. Describe **one** experiment that demonstrates this (**2 points**)

Experiment: *If a mouse embryo is placed in the path of an externally imposed fluid flow that opposes the flow generated by nodal cilia, the normal L/R axis can be reversed, and defects in mutants that normally have defective nodal cilia can be rescued.*