1. (20pts) Regeneration occurs to some degree to most metazoans. When you remove the head of a hydra a new one regenerates. Graph the inhibitor (I) and activator (P) gradient levels after head removal along with simple depictions of the hydra as the head regenerates. What is the advantage of two morphogen gradients versus one? What is the difference between epimorphosis versus morphallaxis? Which does the hydra utilize?

2. (15pts) Draw the gradients of hunchback, bicoid, nanos, and caudal for Drosophila oocytes (1st graph) and early cleavage embryos (2nd graph). Identify which are messages (mRNAs) and which are proteins. Describe how they interact, i.e. regulate one another.

3. (15pts) What are the two clusters of genes in the HOX complex in Drosophila called? What is a homeodomain? What type or class of proteins possess a homeodomain? Why was the discovery of the HOX complex so important?

4. (20pts) The functional roles of the limb mesoderm and the AER have been determined through experimentation. In the figure you can see the results of many of these experiments, complete the diagram by describing (in words or in words and cartoons) the resulting forelimb structure. What conclusions can be drawn from these experiments? What type (of the three classic ones) of experiment is being utilized for each approach?
5. (15pts) The illustration below shows the medial-lateral fate map of the neural plate and the shape changes associated with neuralation. Fill in the boxes with proper terms and explain each stage below the illustration.

(1a)

(1b)

(2)
6. (15pts) What is the ZPA? What is the molecule secreted from the ZPA and what type of molecule is this? What happens to a limb’s development when an additional ZPA is transplanted to the anterior limb primordium? Describe a model that accounts for the results of the extra transplanted ZPA.

Answers

1. (20pts)

-Two morphogen gradients allow a finer control of body plan. For example, if a really long or short organism used only one morphogen gradient from high to low promoting anterior structure formation from the head to the tail, the short one may never get low enough signals in the posterior for tail induction while the long one may get too much posterior patterning. Epimorphosis is regeneration with replacement growth in cell number. Morphallaxis is regeneration without the increase in cell number. Hydra utilizes morphallaxis.

2. (15pts) Fertilization triggers the translation of maternal mRNAs and the establishment of the anterior and posterior morphogen gradients of Bicoid and Nanos proteins. Bicoid proteins represses the anterior expression of Caudal, while Nanos protein represses the posterior expression of Hunchback. At the early cleavage stage you now see the four protein gradients that determine the allocation of anterior and posterior structures.
3. (10pts) Antennapedia complex and the bithorax complex. A homeodomain is a helix-loop-helix DNA binding motif, characteristic for transcription factors. The homeodomain is so highly conserved that human and mouse homeodomains can rescue fly mutants! Bespeaks an essential and conserved role in evolution. ie this is one reason to study flies - to learn about our own biology.
4. (20pts) Conclusions from these experiments suggest that the limb mesoderm both supports limb development and also specifies the identity of the limb (fore limb vs. hind limb). The AER is important both for supporting limb development and also in patterning the limb. Notice in the last experiment that a bead of Fgf can support limb development in the absence of an AER. This strongly suggests that the AER secretes Fgf to maintain proliferation of the limb mesoderm.
6. (10pts) Zone of Polarizing Activity, secretes the MORPHOGEN sonic hedgehog (shh). A duplication of the limb structures. Any reasonable model is accepted.