**AP Bio Ch. 14**

**Modeling the Cambrian explosion.**

A study of Hox gene involvement in Evo Devo Biology.

In this activity we will demonstrate how differential expression of a small group of genes could have had a major impact on the course of evolution.

The Cambrian Explosion was a major event in the history of life on earth. It occurred about 540 million years ago. Prior to the event, life in the oceans was quite sparse with only limited biodiversity. After the explosion, the fossil record shows a massive increase in diversity of life forms and complexity. The event was quite literally an explosion in the number, kinds and complexity of animal forms that came into existence…. And it happened it the blink of a geological eye.

**Step1**. Draw an oval on your page. Don’t worry about how your oval compares to others. Make it take up a good portion of the page.

**Step 2**. Imagine the points of a compass applied to your oval. Instead of N, E, S, W, label it with an A, D, P, V. (Congratulations. You have just created an embryo of an invertebrate species, which is the ancestor common to many of the new, novel species that arose during the Cambrian explosion.

Importantly, you have also established the fundamental body plan of your embryo. Anterior to Posterior = front to back axis. Dorsal to ventral axis = top to bottom axis.

D

A P

V

**Maternal Effect Genes**. In a developing embryo, this basic body plan axis is established by a set of genes called the Maternal Effect Genes. Two such genes are *Bicoid* and *Nanos*. *Bicoid* and *Nanos* encode cytoplasmic determinantsthat establish front, back, top and bottom.

**Step 3.** Orient your embryo so that the Dorsal (D) surface is at the top. Close you eyes and place your finger at a random point in your embryo. Make a dot there. Repeat. At each of the 2 dots, draw a line that extends from the dorsal surface to the ventral surface. This will delineate the boundaries between the head, thorax and abdomen.

D

A P

V

**Segmentation genes** come in several types.

**i. Gap Genes** establish broad regions along the anterior/posterior axis. These will eventually develop into the head, thorax and abdomen. Mutations in the Gap genes result in the omission of segments.

**Step 4**. Lets deal with the anterior (head) first.

1. Roll a dice one time. The number you roll will determine how many pairs of segments will be established in the head. So, if you roll a 3, you should divide the head region into 3 pairs (6) segments.
2. Repeat step A for the Thoracic segment, and again for the abdominal segment.

D

A P

V

**ii. Pair Rule Genes** divide each broad segment into smaller pairs of segments, or modules.

This segmentation allows for modularity, a concept critical to the evolution of new forms and body plans. More on modularity later.

Once the segments have been established. The cells in each segment need to receive spatial information, so each cell “knows” where it is relative to the rest of the developing embryo. This spatial awareness is achieved through the activity of a set of genes called the **Segment Polarity genes**. They establish the anterior /posterior axis for each segment. Mutations to this gene group can result is reversals of structures stemming from segments.

**Hox Gene family.**

The Hox genes are a family of genes with big picture architectural applications. Hox genes encode transcription factors that bind to promoters of target genes, effectively switching genes on or off. Thus, they are responsible for regulating the appearance and development, presence or absence of various structures in animals with an anterior/posterior axis. Hox genes instruct cells in certain segments to:

* “build legs here” or “Don’t build legs here”.
* “build jaw here” or “Don’t build jaw here”
* “build wings here” or “Don’t build wings here”
* “build eyes here” or “Don’t build eyes here”
* “build antennae here” or “Don’t build antennae here”

Different Hox genes may have different activity (Switched on/off) in each of the segments along the anterior axis, causing embryos to develop respective structures in some segments but not in others, giving each segment its identity and characteristic traits. This idea is known as **modularity**. Variations in Hox gene activity patterns in different embryos could see each embryo develop very different structures and body forms. The Hox gene family is highly conserved in all animals with an anterior/posterior axis.

**Step 5**. Working along the anterior>>>>posterior axis. For each **pair** of segments along the axis you will roll the dice.

**Head Segment**

**Eyes:** For each **pair** of segments that make up the **head**, you will roll the dice. First pair of segments, if you roll an even number, draw an eye in each of the segments. If you roll an odd number, the segments get no eyes. Repeat for each pair of segments in the head.

**Antennae:** For each **pair** of segments that make up the **head**, you will roll the dice. First pair of segments, if you roll an even number, draw antennae in each of the segments. If you roll an odd number, the segments get no antennae. Repeat for each pair of segments in the head.

**Thoracic segments.**

**Appendages:** For each **pair** of segments that make up the **thoracic segment**, you will roll the dice. First pair of segments, if you roll an even number, draw legs in each of the segments. If you roll an odd number, the segments get no legs. Repeat for each pair of segments in the **thoracic segment**.

**Wings**: For each **pair** of segments that make up the **thoracic segment**, you will roll the dice. First pair of segments, if you roll an even number, draw wings on the dorsal surface in each of the segments. If you roll an odd number, the segments get no wings. Repeat for each pair of segments in the **thoracic segment**.

**Abdominal segments.**

Lets assume for illustrative purposes, that the idea of modularity does not apply to the abdominal segments. That means, that whichever gene is active, effects all of the abdominal segments.

Step 6. Roll the dice once. The list below dictates which Hox gene will be active in each of the abdominal segments.

**1. legs 2. Swimmerettes 3. Dorsal spikes**

**4. sensory whiskers 5. Legs & dorsal spikes. 6. Make one up.**

Use a little creative license to convert your “embryo” into a sketch. Be sure to apply all of the traits the activity produced.

Do a search of Cambrian Explosion life forms. Do you see any organisms that resemble yours.

Compare your embryo to your class mates.

Do you think we could arrange the class animals into different “lineages” based on shared characteristics?

Which animal would be your closest relative?

Describe the significance modularity and Hox gene activity in establishing new, novel animals.

For more on genes, body plans and evolutionary developmental biology, check out the following link.

<https://learn.genetics.utah.edu/content/basics/hoxgenes/>