The most striking feature of life on Earth is its diversity. Swift runners, graceful swimmers, terrifying predators, resplendent sunbathers, diggers, climbers, flyers, and thinkers; there are many ways to make a living. How do we explain the origin of this diversity? This course will investigate, from the perspective of developmental biology, how evolution happens. We will uncover deep homologies that unite living organisms and fundamental rules about how embryos - and the adult forms they generate - change across the eons.

**Assessment**

- 25% quizzes
- 25% homework
- 25% participation
- 25% final essay

**Learning objectives**

- Learn how taking a developmental perspective can revolutionize our understanding of evolution
- Practice reading and interpreting scientific papers
- Learn to make scientific hypotheses and the methods used to test them

**Rules we want to live by in the classroom**

In class 1, we brainstormed a list of rules that we want to enact to help achieve our goals on the course:

- Raise your hand if you want to contribute. The instructor will keep track of the order of speaking.
- Come to class prepared.
- When discussing in groups, sit together in a semi-circle so everyone is included.
- Everyone should have the chance to participate in group and class discussions.
- All questions are okay and everyone should be respectful of the questions or comments of others.
- We should stay on topic (or, at least, close to it)
- Silence is okay. We all need time to think and form our thoughts.
- Half-formed thoughts/ideas are okay; you don’t need a full and thorough point/answer to contribute to a discussion.
Class Schedule

**Introduction** The first part of our class will serve as a refresher on evolution and development and also introduce key evo-devo concepts (developmental constraint, modularity, deep homology and others).

<table>
<thead>
<tr>
<th>Class 1: Two histories</th>
<th>28-March</th>
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<tbody>
<tr>
<td>This class will introduce our course. We will survey course participants to understand their background, decide on some goals for the course, and develop a class covenant — a list of rules we want to live by as we navigate the topic of evo-devo together. We then compare two histories, one evolutionary and one developmental, and finish with an introduction to the idea of <strong>developmental constraint</strong>.</td>
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<tr>
<th>Class 2: The animal kingdom</th>
<th>30-March</th>
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<tbody>
<tr>
<td>Using centipede legs as an example, we will continue our discussion of developmental constraint. After that, we will take a broad look at the animal kingdom and then consider the anatomy of various animals to introduce the concept of <strong>anatomical modularity</strong>.</td>
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<tr>
<th>Class 3: Modularity and homeosis</th>
<th>1-April</th>
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<tr>
<td>After an activity where we will explore the immensity of geological time, we will continue our discussion of modularity and then introduce <strong>homeotic transformations</strong>. This will allow us to conclude that much of evolution changes the number and kind of existing anatomical modules.</td>
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<th>Class 4: Homology runs deep</th>
<th>4-April</th>
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<tr>
<td>We will brainstorm what we mean by <strong>homology</strong> then discuss whether fly legs are homologous to human legs. Learning about <em>distal-less</em> and <em>Dlx</em> genes, we will see that this is a harder question than it first seems. Our discussions should lead us to the concept of <strong>deep homology</strong>.</td>
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<th>Class 5: Homology and co-option</th>
<th>6-April</th>
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<tr>
<td>We will continue our discussion of homology by talking about eyes. This will lead us to <strong>co-option</strong>: the adoption of a new function by an old gene.</td>
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<th>Class 6: Genes and gene expression</th>
<th>8-April</th>
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<tr>
<td>We will recap gene expression and how it is controlled. For the last 15 mins of class, we will have a quiz on the material of the first 5 classes.</td>
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<tr>
<th>Class 7: Cis regulatory elements</th>
<th>11-April</th>
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<tbody>
<tr>
<td>We will talk about <strong>pleiotropy</strong> and then think about how <strong>cis regulatory elements</strong> (enhancers) might help overcome the &quot;problem of pleiotropy&quot;.</td>
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</table>
### Class 8: How the snake lost its legs (13-April)

We will go through a recent case study about the evolution of leg loss in snakes through mutations in cis regulatory elements that control expression of *Sonic hedgehog*. This will also help prepare for the first homework, which is also about the evolution of leg loss in snakes.

### Class 9: Protein-coding mutations & how the hominoid lost its tail (15-April)

To contrast with our recent discussions about cis regulatory elements, today we will consider the protein-coding portions of genes, and the kinds of mutations that might occur during evolution. This will lead us to a recent case study about a possible genetic route for tail loss in hominoids.

### Class 10: Heterotopy (18-April)

With various examples, we will *heterotopy*. Our primary case study will be how webbing has evolved in the feet of ducks. Through this example, we will learn about apoptosis, genetic pathways, and misexpression experiments in chick.

### Class 11: Other mechanisms of change (20-April)

Expanding our discussion of mechanisms of macroevolutionary change, we will cover examples of *heterochrony, heterometry* and *heterotypy*.

### Class 12: Hypotheses (22-April)

Before taking a quiz, we will think about what makes a good scientific hypothesis.

### Class 13: Canalization (25-April)

We will introduce a new concept: *canalization*. This will lead us to discussions of developmental robustness, cryptic variation and gene-environment interactions.

### Class 14: How cavefish lost their eyes (27-April)

This class will involve looking at primary data about how the unmasking of cryptic variation may have contributed to eye loss in cavefish.

### Class 15: The tools and methods of science (29-April)

We will analyze more deeply what loss- and gain-of-function experiments truly demonstrate with respect to evo-devo studies. We will also remind ourselves of which kinds of experiments can be performed in different animal systems. Last, we will talk about reductionism in science and how this philosophy is both useful but can also be impoverishing.
<table>
<thead>
<tr>
<th>Quizzes</th>
<th>Homework hand in</th>
<th>No class</th>
<th>Essay deadline</th>
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<tbody>
<tr>
<td>Quiz 1: 8-April</td>
<td>Homework 1: 15-April</td>
<td>30-May</td>
<td>8-June</td>
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<tr>
<td>Quiz 2: 22-April</td>
<td>Homework 2: 29-April</td>
<td>3-June</td>
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<tr>
<td>Quiz 3: 6-May</td>
<td>Homework 3: 13-May</td>
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<tr>
<td>Quiz 4: 20-May</td>
<td>Homework 4: 27-May</td>
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Assessment criteria

Quizzes (25%)
Four classes will involve in-class quizzes. These will be 15 mins long and should be completed alone without using reference to previous notes or the internet. Your lowest quiz grade of the four will not be counted.

Homework (25%)
Four sets of homework will be given. These will usually involve analyzing data from the literature and drawing out some key concepts. For these, you are welcome to refer to notes or other research material, and you can discuss with other students if you like, but the final work you hand in should be your own.

Participation (25%)
Please participate in class discussions and complete all assigned readings and tasks. You should come to the class prepared with impressions about any pre-class materials. The most obvious way to show your participation is by being vocal during discussions, but there are other ways. You could make detailed notes during or after class and attach them as an appendix to a homework. You could come to office hours to discuss a class topic in more detail. You could excel in any presentation you are asked to give as part of the class. Ultimately, you should find ways to make your participation visible to me, and I am available to discuss how that can be achieved or to provide feedback as the course continues.

Final essay (25%)
Your task is to submit an approx. 2,000-word essay (12-pt font, double spaced) by Wednesday 8th June. This is an opportunity to demonstrate what you have learned and synthesized about Evo-Devo, including any additional reading you have done, and to reflect on the topics of the course. You should answer one of the following questions, and you get to decide which one:

"If I could control the timing of gene activation, I could cause a fertilized snail egg to develop into an elephant". Discuss.

Describe the importance of modularity in the evolution of development.

"Evolution of form is very much a matter of teaching very old genes new tricks". Providing examples, discuss your informed reaction to this quote.

Adaptive morphological evolution is driven by changes in cis-regulatory elements rather than in protein-coding regions of genes. Do you agree with this statement? Why or why not?

JBS Haldane said, "The usual course of evolution appears to have been a modification of the relative sizes and shapes of various structures, with very little real novelty". How does "real novelty" appear?

What, if any, constraints does development place on evolution?

Are all eyes in the animal kingdom homologous?

Tips for a successful essay: start early, discuss with me your plans for your answer.

You can also design your own question to answer, but you must get my okay on this beforehand.
Additional Notes

Contacting Me. If you want to contact me, you can e-mail me at dtgrimes@uoregon.edu. In the subject line of your email, include "Bio410/510: (your subject)". If you don’t do this, your e-mail will not be shuttled to the correct part of my inbox and it will likely be missed. My apologies in advance if that happens, but if you do correctly include that subject line I will respond to your email in a timely manner (meaning within 2-3 days; I will often respond faster than that, but I can’t guarantee it).

This term, my office hours will be Friday's at 12.00-1.00pm. If you plan to attend, it is very useful if you email me in advance so I know. If you can tell me the topic you’d like to discuss, that can also be useful for grouping a small number of people together in a meeting if you all want to talk about similar things. If you absolutely cannot make this time, I am available at other times during the week. If you would like to arrange a meeting with me, contact me by email at least 2-3 days in advance and offer me 3-4 blocks of time when you could meet. I will pick one. An example of a good e-mail would be:

Dear Prof. Grimes,

I would like to meet with you this week for office hours but I am not available on Friday’s from 12.00-1.00pm. I am available on Monday 26th (either 1.00-1.30 or 2.30-3.00), Tuesday 27th (10.30-12.00) or Wednesday 28th (2.30-5.00).

Best,

Again, you can include more details in the e-mail if you think it might be useful, such as which topics you want to discuss or if you have a particular question.

Taking Things Further. I will sometimes provide you with additional notes or suggestions for further reading material after some classes and on canvas. These would be an ideal starting point for more deeply engaging with the material. I am always happy to discuss avenues you can take to delve more deeply into particular topics either by e-mail or in office hours.

Accommodations. If you require any accommodations I should be aware of, please contact me either directly or through the Accessible Education Center. Some accommodations are already build into the design of the course. For example, quizzes will be started in class with 25 mins remaining. These quizzes are expected to take 15 mins, but anyone who requires additional time should continue for up to 25 mins.