

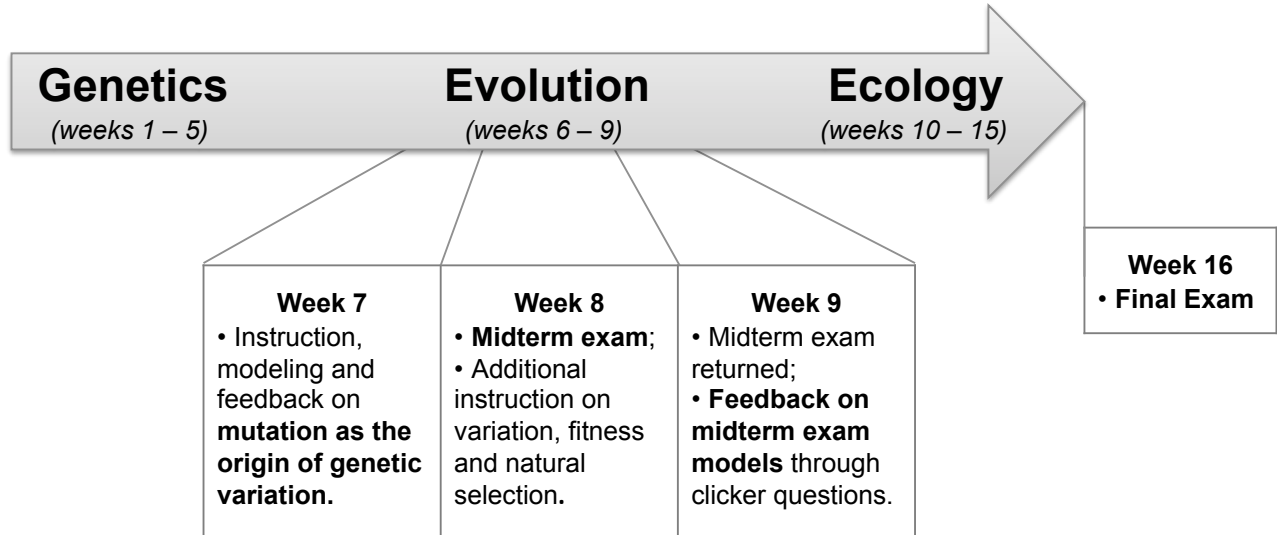
# Supplemental Material

*CBE—Life Sciences Education*

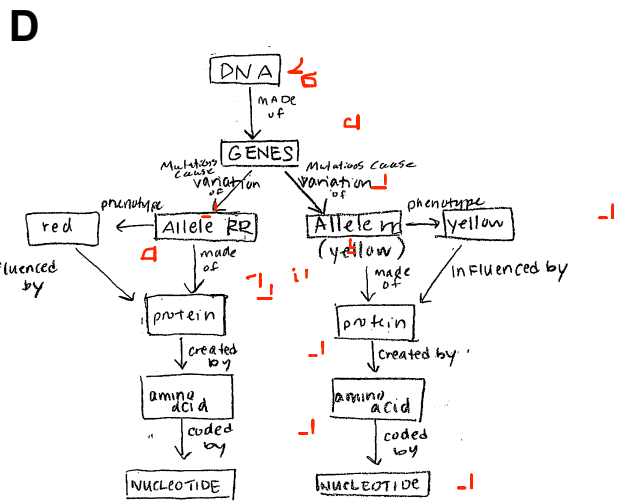
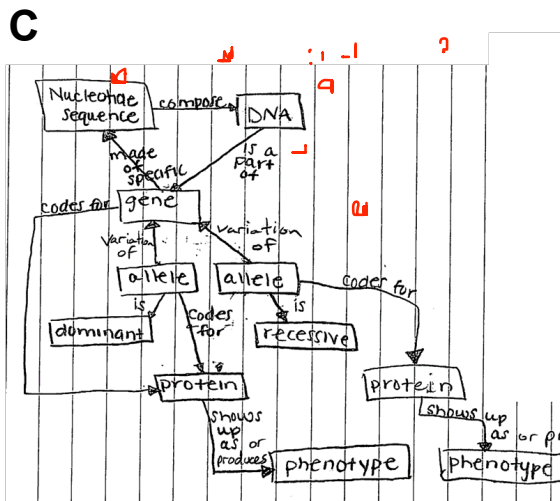
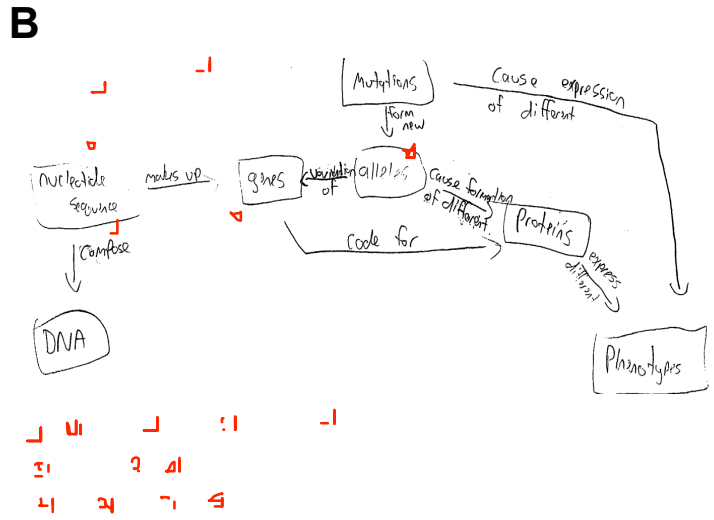
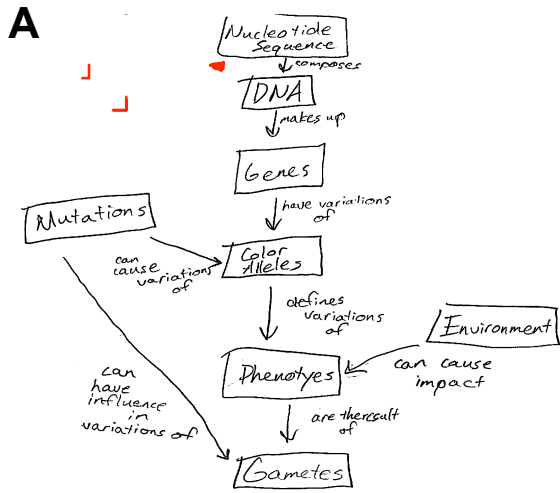
Speth et al.

**SUPPLEMENTAL MATERIALS**

**Supplemental Figure S1:** Timeline of course instruction and assessment.



**Supplemental Figure S2:** Models used in week 7 (prior to the midterm exam) to provide feedback on students' representations of the origin of variation. Instructors' annotations are displayed in red ink; students' original work is in black.



**Supplemental Figure S3:** Excerpt from the group-generated master rubric (Dauer *et al.*, 2013) grounded in students' models. Not every possible student answer is listed, but only the most frequent relationships found in students' models. It is important to note that this rubric was only generated for analytical purpose, not for grading students' work in the course.

Relationship between:	Points
<b>Mutation &amp; Allele</b>	
<ul style="list-style-type: none"> <li>mutation [<i>causes formation, creates/forms/causes (new), results in</i>] allele;</li> <li>allele [<i>formed by, results from, caused by</i>] mutation</li> </ul>	3
<ul style="list-style-type: none"> <li>mutation [<i>gives different, changes, causes/creates variation in, affects</i>] allele</li> </ul>	2
<ul style="list-style-type: none"> <li>mutation [<i>corresponds to, changes traits shown in, codes for, is reflected in, occurs at</i>] allele</li> <li>allele [<i>can be</i>] mutation</li> <li>amino acids [<i>mutate to form</i>] allele</li> <li>chromosome [<i>mutates, mutates to form</i>] allele</li> </ul>	1
<b>Mutation &amp; Nucleotide Sequence/DNA</b>	
<ul style="list-style-type: none"> <li>mutation [<i>alters, changes, causes/creates variations in</i>] nucleotide sequence/DNA;</li> <li>nucleotide sequence/DNA [<i>change in base pair is, vary because, are different because</i>] mutation</li> </ul>	3
<ul style="list-style-type: none"> <li>mutation [<i>occurs in</i>] nucleotide sequence/DNA;</li> <li>nucleotide sequence/DNA [<i>changes, create, error creates, goes through, mistake in replication causes, can go through, changed by</i>] mutation</li> </ul>	2
<ul style="list-style-type: none"> <li>mutation [<i>reflected, codes for, in the, that gives a, are different because, mistake can lead to changes</i>] nucleotide sequence/DNA;</li> <li>nucleotide sequence/DNA [<i>which undergo</i>] mutation</li> </ul>	1
<b>Mutation &amp; Gene</b>	
<ul style="list-style-type: none"> <li>mutation [<i>causes different nucleotide sequence in, causes variation in</i>] gene;</li> </ul>	3
<ul style="list-style-type: none"> <li>mutation [<i>gives different, changes/alters</i>] gene;</li> </ul>	2
<ul style="list-style-type: none"> <li>mutation [<i>corresponds to, results in, occurs at, appears in, make up</i>] gene;</li> <li>gene/s [<i>contain, have</i>] mutation</li> </ul>	1
<b>Nucleotide Sequence &amp; Allele</b>	
<ul style="list-style-type: none"> <li>nucleotide sequence [<i>mutation in sequence forms, mutation within certain, mutation to form, mutations cause</i>] allele</li> <li>allele [<i>originates from mutation in</i>] nucleotide sequences</li> </ul>	3
<ul style="list-style-type: none"> <li>nucleotide sequence [<i>mutation, mutation within</i>] allele</li> </ul>	2
<ul style="list-style-type: none"> <li>nucleotide sequence [<i>causes mutation for</i>] allele</li> </ul>	1
<b>Gene &amp; Allele</b>	
<ul style="list-style-type: none"> <li>gene [<i>mutation, mutates into, mutates to create</i>] allele</li> <li>allele [<i>mutation of a</i>] gene</li> </ul>	2

**Supplemental Figure S4:** clicker questions used in week 9 to provide students' feedback on their midterm exam models. Four models were scanned from students' exams and used to build clicker questions and generate class discussion. The question posed was the same for all four models: "Where in this model is the origin of variation represented?" Students had five options for each question: A, B, C, D, or E = none of the above.

