Supplemental Material

CBE—Life Sciences Education

Maloy *et al.*

Supplemental Materials

Table S1. Seductive detail scripts used in lecture videos. Scripts are listed alongside the associated video lecture topic and the course learning outcome most closely aligned to the associated topic.

Table S1 (Continued).

Associated topic	Associated learning outcome	Seductive detail topic	Seductive detail script
Mendelian genetics and Independent assortment	Explain how independent assortment of alleles during meiosis can lead to new combinations of alleles of unlinked genes.	Artificial selection	Long before humans understood the underlying genetic basis for heredity, we used our observations of simple genetic patterns like the ones Mendel observed in peas to engage in artificial selection of crops and livestock. Roughly 2,000 years ago, farmers in the Netherlands bred a black breed of cattle with a white breed of cattle to produce the familiar black and white spotted cow we commonly see in the U.S. today. This breed, which we now refer to as Holstein cows, was selected by early farmers to produce as much milk as possible while thriving on limited feed resources. In the 1850's, increasing demand for dairy in North America led a Massachusetts man named Winthrop Chenery to import the legendary milk producers to the United States. Now, there are over 9 million dairy cows in the United States, and about 90% of them are the same Holstein breed that was artificially selected by Dutch farmers long ago.
Consanguinuity and pedigree analysis	Calculate the probability that an individual in a pedigree has a particular genotype.	Ellis-Van Crevald Syndrome	Ellis-Van Crevald syndrome is an autosomal recessive condition which causes extra fingers and shorter arms and legs to develop. Only about 150 people around the world have reported having this condition, but the largest group of affected individuals are part of the Old Order Amish population of Pennsylvania and the West Australian native population. This

Table S1 (Continued).

			is because these groups practice endogamy, which means they only marry within the community. As a result of increased awareness, Amish youth are now frequently opting to marry outside of the community.
ABO Blood types	Discuss how various factors might influence the relationship between genotype and phenotype (e.g. incomplete penetrance, variable expressivity, sex-limited phenotypes, and co-dominance).	ABO Incompatibility	Do you know what happens when you are given an incompatible blood type? One experiences something called an ABO incompatibility reaction, which includes symptoms such as difficulty breathing, muscle aches, and urine blood. This is why blood centers around the world take great care to match blood from donors with compatible recipients.
Polygenic traits	Explain how continuous traits are the result of many different gene combinations that can each contribute a varying amount to a phenotype.	Inclusivity in makeup marketing	Many people complain about not being able to find a foundation that will match their skin color. This is why L'Oréal True Match foundation offers 33 shades to choose from, claiming it will fit anyone who tries it. But are there only 33 skin colors possible? Actually, a total of 378 loci are responsible for determining skin color, so even this "broad" range won't cover everyone. This means that less than 10% of skin colors are actually “matched” by True Match.
Chromosomes and ploidy	Explain the meaning of ploidy and how it relates to the number of homologues of each chromosome.	Seedless watermelon	There’s nothing quite like biting into a fresh, juicy watermelon on a hot summer day. And thanks to modern agricultural methods, you don’t have to worry about ending up with a mouthful of hard, inedible watermelon seeds. Seedless watermelons were developed in 1939 by a group of Japanese scientists who crossed a tetraploid parent with a normal diploid parent to produce a triploid variety of watermelon. Because triploid plants

Table S1 (Continued).

			tend to be sterile, this new watermelon didn't have any seeds! Unfortunately, the lack of seeds also made it harder and more expensive to produce seedless watermelons in large quantities. Because of this, seedless watermelons were rare throughout most of the 20th century. More recently, the popularity of seedless watermelons has exploded, and nearly 85% of watermelons sold in the United States today are these seedless triploid watermelons.
Thomas Hunt Morgan's chromosomal theory of heredity	Describe Morgan's experiment which shows that the white gene of Drosophila is inherited in a sex-linked manner.	Drosophila sexual behavior	Drosophila melanogaster, otherwise known as the lowly fruit fly, has a lot more in common with us than you might think! Nearly 75% of disease-associated genes in humans are thought to have a functional equivalent in the fly. This is one reason that flies can be such a useful tool in the study of human diseases. The genetic similarities also lead to some interesting similarities in behavior between fruit flies and humans. Here's one example: in 2012, researchers at UCSF did an experiment to see how fruit flies reacted to rejection. They put some flies in tubes where they could mate with each other, and other flies in tubes where they couldn't mate. Then, they let the flies choose between drinking normal food, or food with alcohol. Surprisingly, the flies that had just experienced rejection drank an average of four times as much alcohol! Just like humans, it turns out that rejected flies also drown their sorrows.
Aneuploidy in humans	Discuss how errors in chromosome number can arise during meiosis, and why such	Klinefelter Syndrome medical advances	Klinefelter syndrome results from a nondisjunction event during meiosis where a male ends up with three sex chromosomes: two X chromosomes and a Y chromosome. This syndrome is one of the most common

Table S1 (Continued).

	alterations can be detrimental.		chromosomal disorders, affecting between 1:500 and 1:1000 males. Prior to the 21st century, individuals with Klinefelter syndrome were unable to father a child since only about half of males who have this condition produce sperm in the testicles. A newly developed treatment is capable of extracting sperm pockets in the testicles of men who have Klinefelter syndrome but still produce a small amount of sperm. This sperm is used for IVF treatments and in 45% of cases results in a live birth, giving hope to the men who have this condition today, many of whom will not be diagnosed unless they seek medical attention for suspected infertility.
Genetic mapping	Explain how genetic distance is different from physical distance. Calculate gene linkage and genetic map distances and interference from frequency of progeny with recombinant phenotypes from 2-factor and 3-factor genetic crosses.	23andMe, inclusivity in genetic studies	For a long time, genetic studies were done with fairly homogenous subject populations. Because of this, over 90% of the research we have on the genetics behind human diseases applies to individuals of European descent alone. These historic disparities in human genetics research can have important consequences for non-Europeans, who have not benefitted equally from the huge advances in genetics research. A relatively new company called 23andMe is aiming to correct this problem. 23andMe supplies affordable saliva collection kits to customers around the world. They use this saliva to collect DNA and determine single nucleotide variations between individuals at specific points in the genome. Using an approach called mapping by admixture linkage disequilibrium, 23andMe can identify single nucleotide variations that are associated with disease in a broader, less Eurocentric population. These new linkage

Table S1 (Continued).

			mapping techniques increasingly employed by 23andMe as well as other major research teams have the potential to expand our knowledge of human genetics and improve the efficacy of medical interventions in diverse populations.
Probability	Calculate the probability that an individual has a given phenotype.	The Mendelian paradox	Gregor Mendel was a friar, a scientist, and…a liar? When statisticians analyzed Mendel's data, they found that there was only a 0.2% chance that Mendel obtained the numbers he did. Why would he lie? At the time no one believed Mendel's hypotheses, and it's possible he felt the need to falsify the results to fit his hypotheses so closely that he would attract the attention of other scientists. His work actually didn't receive much attention until after he died, but his studies ultimately resulted in the formation of several scientific laws that are still observed today. Fortunately even if he *did* lie, his studies have been replicated and the resulting laws have been found to hold true.
The one gene, one enzyme hypothesis	Discuss Beadle and Tatum's "one gene, one enzyme" hypothesis.	Military funding of science in World War II	Many of Beadle's most important experiments with *Neurospora* were carried out during World War II. One reason for Beadle's success was his ability to convince the United States military that his research was relevant to the U.S. war effort. He argued that his *Neurospora* mutants that were unable to synthesize a particular vitamin could be used in determining the concentration of that vitamin in growth medium. Beadle proposed that this would lead to the more efficient manufacture of vitamins and amino acids by pharmaceutical and nutrition companies, thus producing more efficient food to supply the enormous nutritional needs of the

Table S1 (Continued).

			military. Because Beadle was successful in connecting his research to the U.S. war effort, his staff could remain in his lab to continue their research rather than being drafted into the military, which happened with some competing research groups. The funding Beadle received from an association of manufacturers of military rations was one of the earliest examples of military funding of biology research.
Replica plating	Design a screen for isolating antibiotic resistance mutants and auxotrophic revertants.	The history of biology in NASA	Replica plating was a technique developed by Joshua and Esther Lederberg, who are considered two of the pioneers of bacterial genetics. Joshua and Esther married after meeting at work in a Yale biology lab. The couple are credited with developing some of the most important tools used by bacterial geneticists. While Esther was known to make brilliant contributions to genetics, in particular coming up with the technique for replica plating, her husband had strong ideas about the biological impact of space exploration. He was concerned that extraterrestrial microbes might gain entry to the Earth onboard spacecraft, causing catastrophic diseases. He also argued that, conversely, microbial contamination of man-made satellites and probes may obscure the search for extraterrestrial life. He advised quarantine for returning astronauts and equipment. He led to biology having a larger role in NASA.
Bacterial conjugation	Diagram bacterial conjugation from mating through recombination.	Agrobacterium applications in agriculture	Conjugation is often thought of as bacterial 'sex'; that is, one bacterium exchanging genetic information with another bacterium. However, some bacteria undergo conjugation with plants as well! In

Table S1 (Continued).

			particular, one soil bacterium called Agrobacterium has been widely studied because of its extraordinary ability to transfer DNA between itself and plants, often causing tumor-like growths on infected plants. Luckily, scientists have discovered how to rewire pesky Agrobacterium so that instead of transferring genes that make plants sick, they can transfer genes that benefit the plant's growth, hardiness, or nutritional value. This discovery has made Agrobacterium an important tool for modern agricultural scientists. Over 90% of current genetically modified crops contain genes transferred into plant genomes using Agrobacterium's conjugation capabilities. These crops include soybeans, cotton, corn, sugar beets, wheat, rice, and more. Who knew that bacterial sex could be so appetizing?
Bacteriophage life cycle	Design a bacteriophage cross that will allow the calculation of genetic map distance between two genes.	Phage therapy for treating antibiotic resistant infections	Bacteriophages are found nearly everywhere you can look on Earth. You can find them in locations as diverse as the soil, the intestines of animals, and sea water. Almost as soon as phages were discovered in the early 1900's, researchers began to investigate how they could use the natural bacteria-killing activity of phages to combat bacterial infection in humans. During World War II, the Soviet Union used bacteriophages to treat soldiers with dysentery and gangrene. When antibiotics were discovered in the 1941, scientists in the U.S. and Europe lost interest in phage therapies, thinking antibiotics had made them irrelevant. However, since antibiotic resistance appeared in the 1950's and accelerated throughout the 20th and 21st century, the scientific community has found a renewed interest in phage therapy as an

Table S1 (Continued).

			alternative to antibiotics. Now, researchers are actively looking into using phage to combat food borne illnesses, cholera, and even acne!
Complementation tests using temperature sensitive mutations	Design a complementation test in phage that will determine whether two mutations are in the same gene.	Deep sea geothermal vents	In the lab, we often take advantage of certain mutations that make phage or bacteria more sensitive to high temperatures in order to solve important genetic questions. However, in nature some of the most fascinating bacteria are not very sensitive to high temperatures at all. In some of the deepest corners of the ocean where no sunlight reaches, cracks in the Earth's crust result in undersea volcanos spouting geothermally heated water that can reach up to 464 degrees Celsius. While you might think that these so-called "geothermal vents" would be inhospitable to life, they actually play host to complex biological communities which rely on hyperthermophilic, or heat-loving, bacteria. The protein molecules in these bacteria exhibit hyperthermostability, meaning that they can maintain their structure and function at extremely high temperatures. In March of 2017, researchers found fossilized evidence that some of these hardy bacteria may have been the oldest forms of life on Earth, living here as early as 4.3 billion years ago. So while temperature sensitive mutations may help us in the lab, you might want to take some time to appreciate the heat-tolerant bacteria at the bottom of the ocean; after all, they may be your ancestors.

Table S2. Examples of questions used in video quizzes. Questions are listed alongside the associated video lecture topic and course learning outcome most closely aligned to the associated topic.

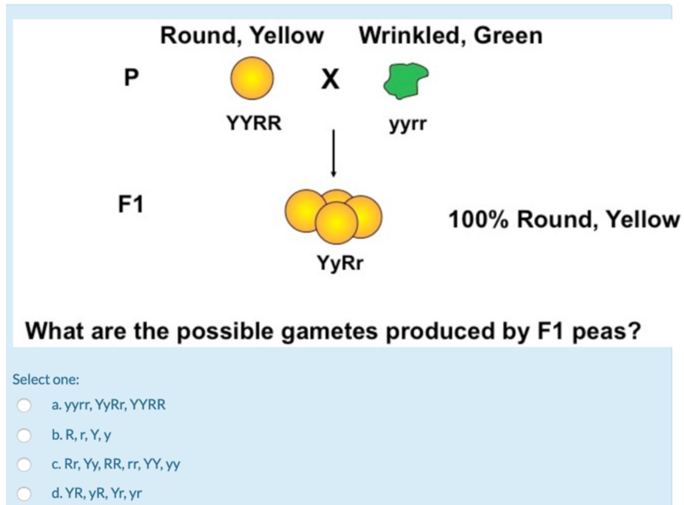
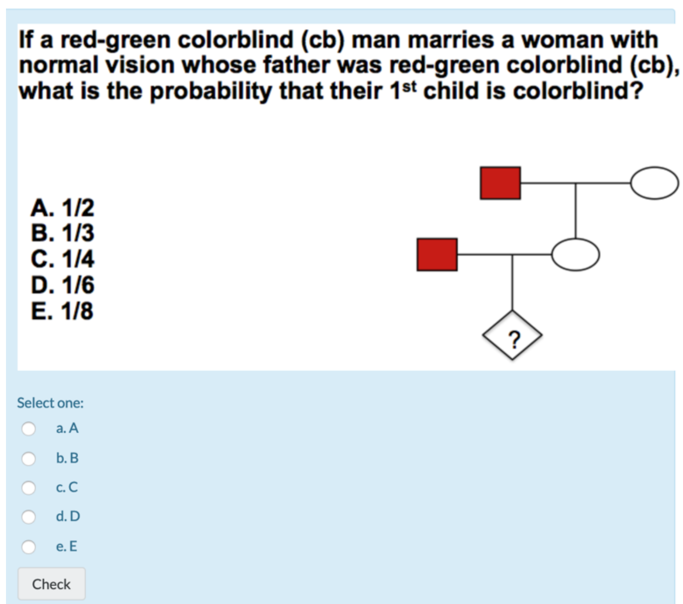
Associated topic	Associated learning outcome	Example video quiz question
Mendelian genetics and Independent assortment	Explain how independent assortment of alleles during meiosis can lead to new combinations of alleles of unlinked genes.	
Consanguinuity and pedigree analysis	Calculate the probability that an individual in a pedigree has a particular genotype.	

Table S2 (Continued).

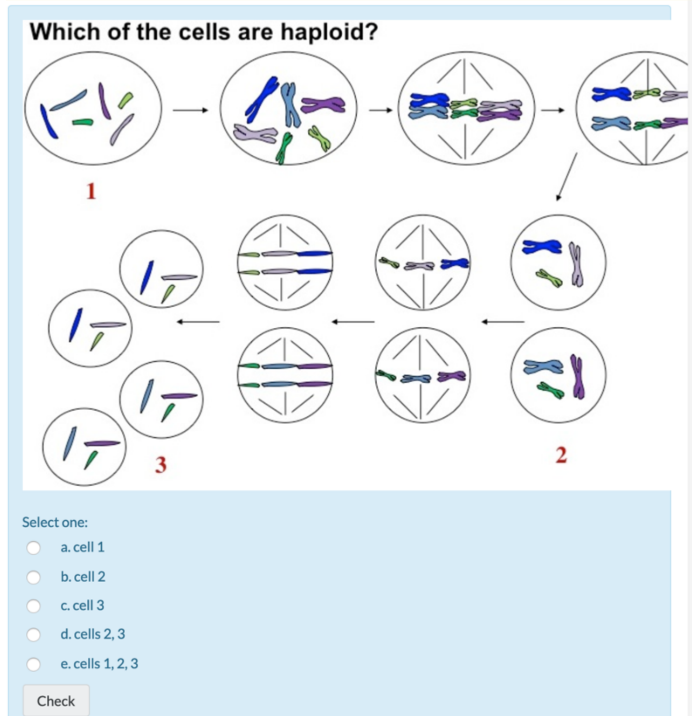
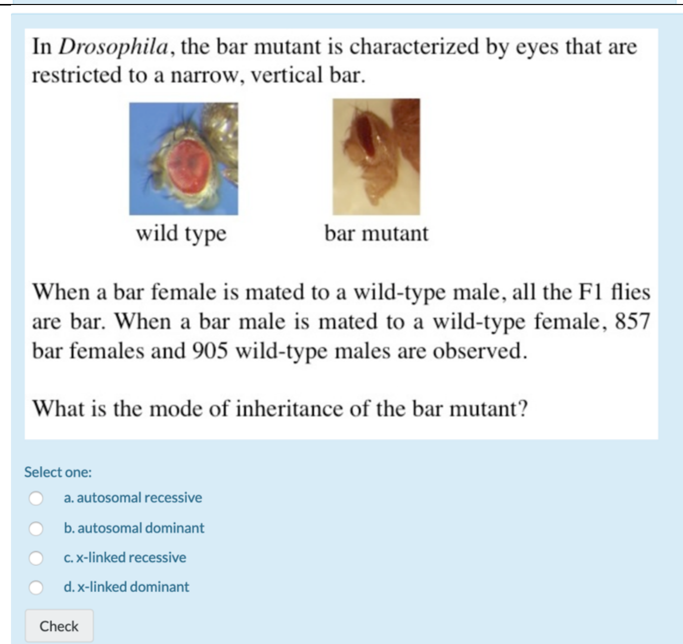
<table>
<tr>
<td>Chromosomes and ploidy</td>
<td>Explain the meaning of ploidy and how it relates to the number of homologues of each chromosome.</td>
<td>
</td>
</tr>
<tr>
<td>Thomas Hunt Morgan's chromosomal theory of heredity</td>
<td>Describe Morgan's experiment which shows that the white gene of Drosophila is inherited in a sex-linked manner.</td>
<td>
</td>
</tr>
</table>

Table S2 (Continued).

Genetic mapping	Explain how genetic distance is different from physical distance. Calculate gene linkage and genetic map distances and interference from frequency of progeny with recombinant phenotypes from 2-factor and 3-factor genetic crosses.	23andMe, inclusivity in genetic studies You do a test cross and get the following progeny. A and B are dominant, a and b are recessive. P AABB x aabb F1 AaBb x aabb F2 36 A_B_ 14 A_bb 16 aaB_ 34 aabb Are genes A and B linked? If so, how many m.u. separate them A. 5 m.u. B. 10 m.u. C. 20 m.u. D. 30 m.u. E. 40 m.u. F. They are not linked. Select one: a. A b. B c. C d. D e. E f. F
Probability	Calculate the probability that an individual has a given phenotype.	The Mendelian paradox P RR yy PP x rr YY pp F1 Rr Yy Pp (round, yellow, purple) If Rr Yy Pp were selfed, what proportion of the progeny would have dominant phenotype for all three genes? Select one: a. 1/8 b. 1/16 c. 3/16 d. 1/64 e. 3/64 f. 9/64 g. 27/64

Table S2 (Continued).

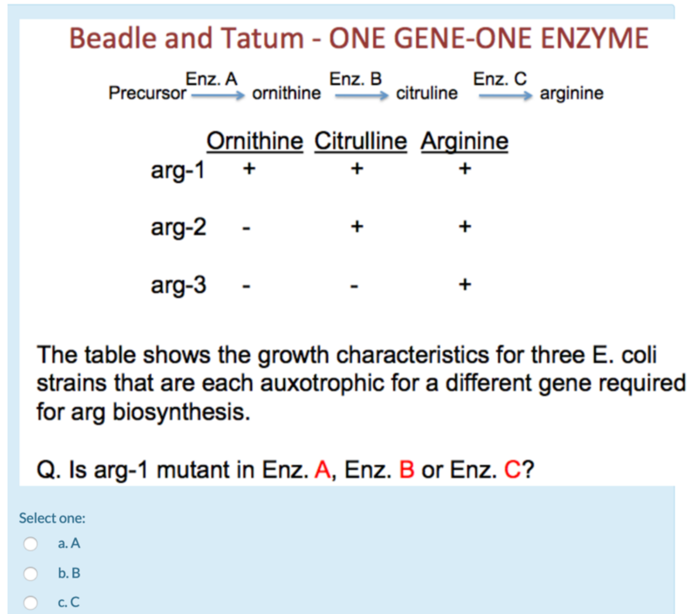
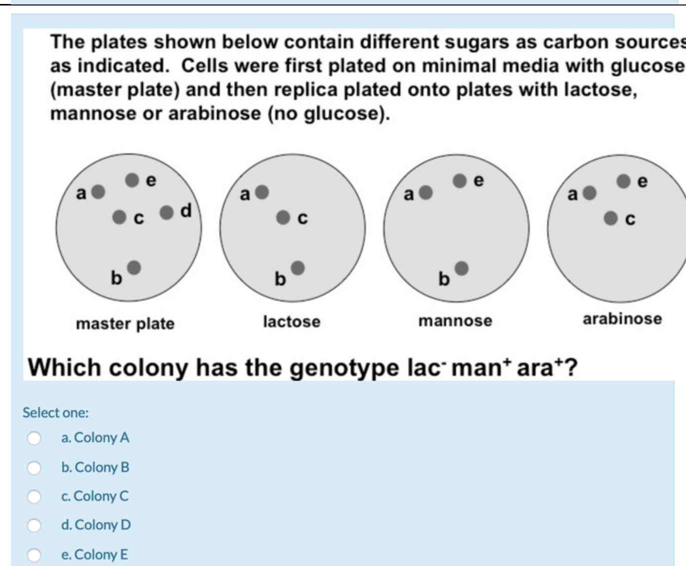
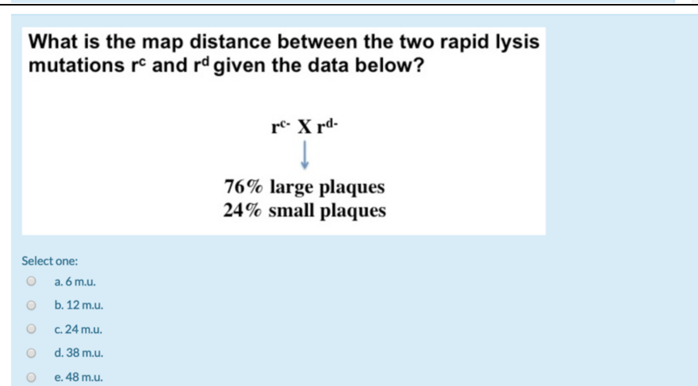
The one gene, one enzyme hypothesis	Discuss Beadle and Tatum's "one gene, one enzyme" hypothesis.	
Replica plating	Design a screen for isolating antibiotic resistance mutants and auxotrophic revertants.	
Bacteriophage life cycle	Design a bacteriophage cross that will allow the calculation of genetic map distance between two genes.	

Table S3. *Video quiz scores, interest, perceived relevance, perceived learning, and course outcomes by first-generation status and URM status.*

	Non-FG *(n=451)*		FG *(n=275)*		Non-URM *(n=592)*		URM *(n=145)*	
	Control	SD	Control	SD	Control	SD	Control	SD
Midterm 1	76.73	75.76	71.08	*75.48	76.80	78.78	66.11	63.11
Final Exam	166.54	165.71	160.75	163.64	167.93	170.38	150.22	143.67
Course Percentage	85.96	85.22	82.69	84.53	86.25	87.02	78.78	76.84

**p=0.037*

Table S4. *Course outcomes for students with low prior knowledge by first-generation status and URM status.*

	Non-FG *(n=259)*		FG *(n=177)*		Non-URM *(n=349)*		URM *(n=94)*	
	Control	SD	Control	SD	Control	SD	Control	SD
Midterm 1	76.40	75.86	70.49	74.81	77.19	79.42	62.73	61.01
Final Exam	166.06	167.58	159.76	163.54	167.8	172.68	147.72	142.34
Course Percentage	85.89	85.65	82.47	84.31	86.43	87.63	77.53	76.17

Table S5. *Course outcomes for students with high prior knowledge by first-generation status and URM status.*

	Non-FG *(n=192)*		FG *(n=98)*		Non-URM *(n=242)*		URM *(n=61)*	
	Control	SD	Control	SD	Control	SD	Control	SD
Midterm 1	77.19	75.63	72.25	76.59	76.21	77.88	72.62	66.80
Final Exam	167.20	163.28	162.72	163.81	168.12	167.20	155.04	146.00
Course Percentage	86.06	84.67	83.13	84.89	85.98	86.16	81.18	78.01

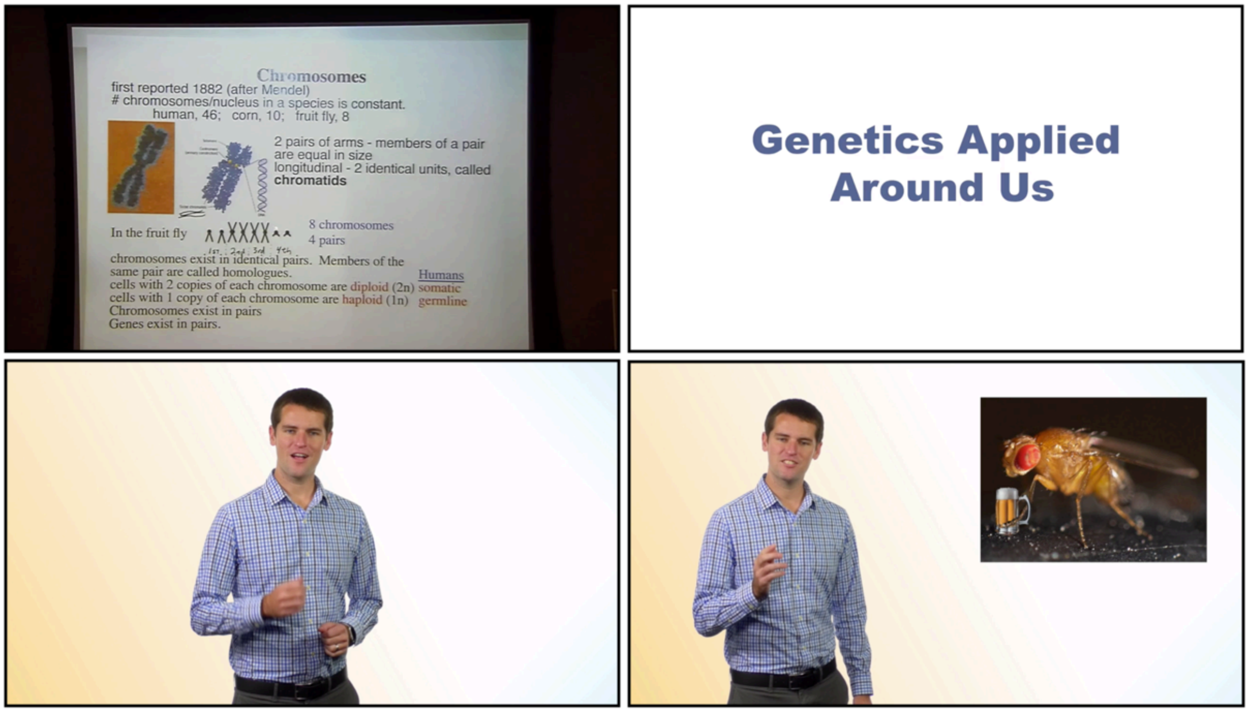


Figure S1. Seductive detail presentation. Seductive details were presented as visually abrupt interruptions to recorded video lectures. These clips were introduced each time with a "Genetics Applied Around Us" title slide followed by a video clip narrated by a different individual than the instructor of the course. Each seductive detail video clip also included pictures relevant to the real world examples being discussed to make them more visually interesting.