# Supplemental Material

*CBE—Life Sciences Education*

**Avena and Knight**

**Supplemental Material**

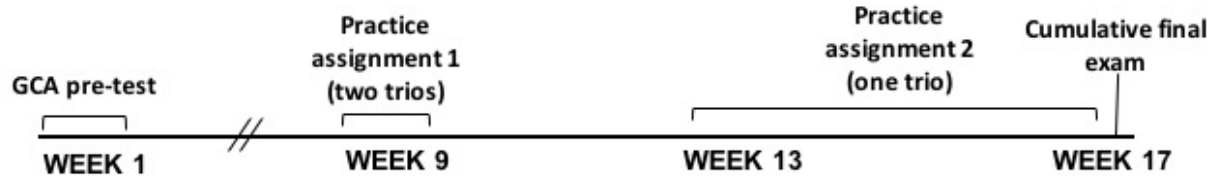



**Figure S1.** Study timeline. In practice assignment 1, each student completed two of three content area trios. In practice assignment 2, only recombination data was included since the questions from the other content area were not isomorphic. Students took the practice assignments 1 and 2 before a unit exam. Students who did not complete practice assignment 2 before the unit exam were allowed to complete it in preparation for the final exam.

**Table S1.** Percent of trios in which a hint was taken during practice

| **Content area** | **Hint option at Q2** | | **Hint option at Q3** | | **All** | |
|---|---|---|---|---|---|---|
| | n | % of trios in which hint taken | n | % of trios in which hint taken | n | % of trios in which hint taken |
| All content areas | 269 | 64 | 284 | 71 | 553 | 68 |
| Recombination | 87 | 72 | 92 | 77 | 179 | 75** |
| Probability | 59 | 63 | 63 | 67 | 122 | 65 |
| Gel/pedigree | 63 | 57 | 64 | 63 | 127 | 60** |
| Nondisjunction | 60 | 62 | 65 | 74 | 125 | 68 |

Percentage of trios in which a hint was taken in each condition reported. n represents total number of trios completed. There was no significant difference between the two conditions (hint option at Q2 versus Q3) within each content area or all content areas combined (Logistic regression, $p>0.05$). For all trios across both conditions, the likelihood of taking a hint for recombination was higher than for gel/pedigree (Logistic regression, OR=2.0, **$p<0.01$). There were no other significant differences between content areas (Logistic regression, $p>0.05$).

**Table S2.** Practice performance for answer trios in which a hint was taken vs. not taken

| Condition | n | Q1 % correct | Q2 % correct | Q3 % correct |
|---|---|---|---|---|
| **Hint taken** | | | | |
| All content areas | 374 | 48[ai] | 53[b] | 56[ci] |
| Recombination | 134 | 29[djk] | 41[j] | 44[k] |
| Probability | 79 | 46 | 47[e] | 51 |
| Gel/pedigree | 76 | 59 | 70 | 70[f] |
| Nondisjunction | 85 | 71[g] | 62[h] | 68 |
| **Hint not taken** | | | | |
| All content areas | 179 | 71[a] | 75[b] | 69[c] |
| Recombination | 45 | 64[d] | 58 | 58 |
| Probability | 43 | 58 | 70 [e] | 53 |
| Gel/pedigree | 51 | 75 | 84 | 86[f] |
| Nondisjunction | 40 | 88[g] | 90[h] | 78 |

n represents number of trios analyzed. For all content areas combined, for each Q1, Q2, and Q3, students scored lower for trios in which a hint was taken versus was not taken (Logistic regression, OR=0.38[a], p<0.001; OR=0.37, p<0.001[b]; OR=0.57, p<0.01[c], respectively). For individual content areas, students scored lower on trios in which they took a hint than on those in which they did not take a hint for recombination at Q1 (OR=0.23, p<0.001)[d], probability at Q2 (OR=0.38, p<0.05) [e], gel/pedigree at Q3 (OR=0.37, p<0.05)[f], and nondisjunction at Q1 (OR=0.34, p<0.05)[g] and Q2 (OR=0.18, p<0.01) [h]; all else was not significant (Logistic regressions, p>0.05). For all content areas combined, for trios in which a hint was taken, percentage correct in Q3 was significantly higher than Q1 (McNemar's test, p<0.01)[i], while there was no difference in pairwise comparisons between Q1 and Q2 or Q2 and Q3 (McNemar's test, p>0.05). For recombination, for trios in which students took a hint, the percentage correct in Q2[j] and Q3[k] was higher than Q1 (McNemar's test, p<0.01), but no other individual content area pairwise comparisons were significantly different (McNemar's test, p>0.05). For individual content areas as well as all content areas combined for trios in which a hint was not taken, there was no significant difference in percentage correct among Q1, Q2, and Q3 within each condition (McNemar's test; p>0.05).

**Table S3.** Average Q1 practice performance based on the proportion of times a student chose to take a hint out of the times the student was offered the hint

| Student hint choice pattern | n | Practice Q1 correct (%) |
|---|---|---|
| Hints never taken | 14 | 74[a] |
| Hints sometimes taken | 56 | 61[b] |
| Hints always taken | 63 | 46[ab] |

n represents number of students. Data reported shows only students who completed both practice assignments, so Practice Q1 correct represents the average performance on Q1 for three content areas. Average Q1 performance was lower for students with hints always taken compared to hints never taken (OLS regression, $B$=-28, $SE\ B$=9, $p<0.01$)[a] and to hints sometimes taken (OLS regression, $B$=-13, $SE\ B$=9, $p<0.05$)[b]. There was no significant difference in average Q1 performance between students with hints sometimes taken and hints never taken (OLS regression, $p>0.05$).

**Table S4.** GCA, instructor-generated final exam, and practice performance for students that completed no or both practice assignments

| | Practice in both assignments mean (SD) (n=109) | No practice mean (SD) (n=35) |
|---|---|---|
| Entire assessment performance | | |
| GCA pre-test (%) | 36.37 (14.14) | 41.49 (14.59) |
| GCA post-test (%) | 74.68 (14.66) | 68.80 (18.45) |
| Instructor-generated final exam (%) | 73.55 (16.13) | 65.09 (18.93) |
| Practice-related questions performance | | |
| GCA post-test | 68.35 (25.83) | 58.57 (27.75) |
| Instructor-generated final exam | 72.32 (22.39) | 59.12 (27.11) |
| Practice-unrelated questions performance | | |
| GCA post-test | 75.88 (14.22) | 70.75 (18.30) |
| Instructor-generated final exam | 73.88 (16.28) | 66.67 (19.41) |
| Practice assignment performance | | |
| Practice Q1 correct (%) | 55.05 (31.87) | |
| Practice Q3 correct (%) | 59.94 (33.88) | |
| Practice questions correct (%) | 59.12 (28.52) | |

Students completed all assessments and either completed no or both practice assignments (nine practice questions). There is no significant difference on GCA pre-test performance between students with no practice versus students who completed both practice assignments (independent t-test, $t(142)=1.85$, $p>0.05$).

**Table S5.** OLS regression estimates of the association between the presence of practice and final exam performance

| | Practice-related *B* (*SE B*) | | Practice-unrelated *B* (*SE B*) | |
|---|---|---|---|---|
| | GCA post-test | Instructor-generated final exam | GCA post-test | Instructor-generated final exam |
| Model | (1) | (2) | (3) | (4) |
| Practice | 12.66*<br>(4.94) | 15.52**<br>(4.48) | 7.66**<br>(2.68) | 9.46**<br>(3.13) |
| GCA pre-test (%) | 0.56***<br>(0.15) | 0.45**<br>(0.13) | 0.49***<br>(0.08) | 0.44***<br>(0.09) |
| Adjusted $R^2$ | 0.1032 | 0.1128 | 0.2154 | 0.1509 |

All assessment performance is reported as % correct. Practice serves as a binary variable with 1=practice and 0=no practice. Data reported shows only students who completed all assessments and completed either no practice (n=35) or both practice assignments (n=109); total n=144. Standard error of *B* is shown in parentheses. *p<0.05, **p<0.01, ***p<0.001

## PRACTICE ASSIGNMENT INSTRUCTIONS AND EXAMPLE

**Instructions:** In this assignment, please document step-by-step how you are solving each of the problems as you do them. Include the steps you are taking and why, what you are thinking about as you solve the problem, and how you reached your final answer. Please number each of these steps.

**Example of how to Document your Problem Solving:**

**Question:** A point mutation in the DMD gene of Jared's DNA is found that changes the nucleotide A to a U and leads to a premature stop codon. What effect will this mutation have on mRNA size?

**Documented Problem Solving Answer Example:**

1. Read the problem.
2. Know that I am thinking about transcription because the question asks about mRNA.
3. Re-read the problem and note that this mutation is a nonsense mutation because it is a substitution (change in 1 nucleotide) that leads to a stop codon.
4. I know I need to think about the effect of the premature stop codon on length of the mRNA.
5. I draw a strand of DNA and write in the stop codon TAA in the middle so that I can visualize the mutation in the gene.
6. I draw how transcription will occur with an arrow making new mRNA 5' to 3', and I draw the new mRNA, which I realize will include the premature stop codon because I remember that translation will be affected by the codon, NOT transcription.
7. I now link my drawing of transcription to the concept of size of the mRNA and realize that the mRNA for this specific gene will be the same length with or without this specific mutation.
8. FINAL CONCLUSION: This mutation will NOT have any effect on mRNA size.

**PRACTICE ASSIGNMENT QUESTIONS**

**Recombination questions**

1. The aldose gene is 10 map units from the fructose gene. (A = dominant allele, can produce aldose; a = recessive allele, cannot produce aldose; F = dominant allele, can produce fructose; f = recessive allele, cannot produce fructose). You cross worms with the chromosomes shown below. What is the probability that offspring will be able to produce only aldose (and not fructose)?

$$\frac{A\ f}{a\ F} \times \frac{a\ f}{a\ f}$$

2. Two genes, Q/q and R/r, are 30 map units apart on a non-sex chromosome and are both inherited in an autosomal recessive manner, with q leading to PKU and r leading to Pendred syndrome.

Michele is the following genotype for two linked genes:

$$\frac{Q\ r}{q\ R}$$

Her husband is the following genotype:

$$\frac{q\ r}{q\ r}$$

What is the chance their child will be a carrier for PKU and have Pendred syndrome?

3. Kumar and Arya are about to have a child. They are worried about two traits that run in the family—fancomi anemia (inherited in an autosomal recessive manner) and polydactyly (inherited in an autosomal dominant manner). The two genes are 14 map units apart. Kumar has fancomi anemia (ff) but does not have polydactyly (dd). Arya is a carrier for fancomi anemia (Ff) and does have polydactyly (Dd).

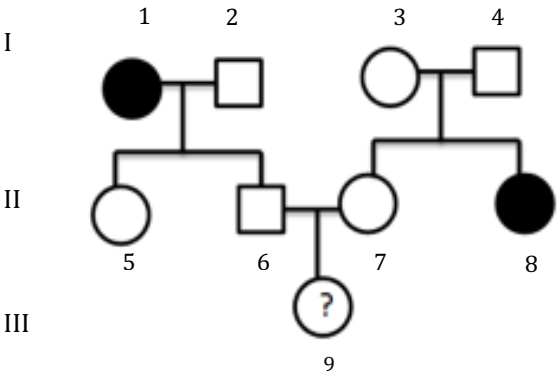
Kumar's genotype is as follows: $\frac{f\ d}{f\ d}$

Arya's genotype is: $\frac{F\ D}{f\ d}$

What is the chance that the child will have both Fancomi Anemia and polydactyly?

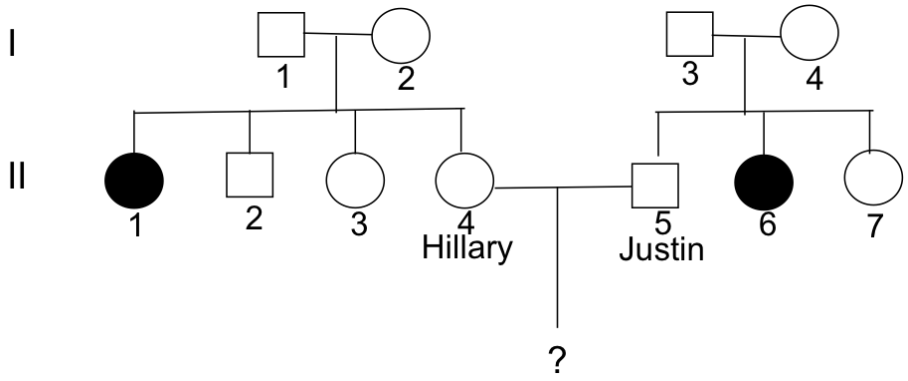
**Probability questions**

1. Normal giraffes have long necks. Below is a pedigree of a family of giraffes that has a history of an autosomal recessive disorder that causes giraffes to have short necks. What is the probability that the female giraffe with the question mark in the third generation will have the short neck phenotype?

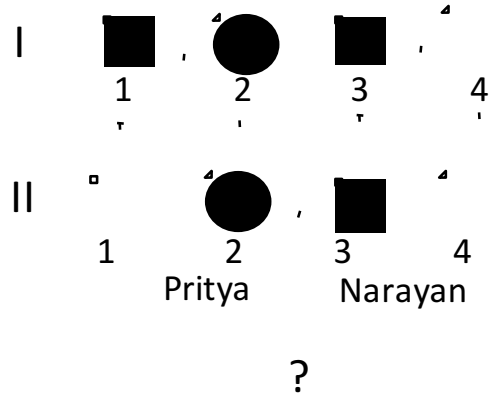



2. Wilson's disease is an inherited disorder in which there is too much copper in the body's tissue. It is inherited in an autosomal recessive manner.

Below are pedigrees from two families where some members of a family have Wilson's disease. Neither Hillary nor Justin have Wilson's disease. If they have a child, what is the chance this child will have Wilson's disease?



3. The family below has the autosomal dominant trait of dimples. In this family, I-1 and I-2 are known to be heterozygous. It is not known whether any other individuals in this family are heterozygotes. If Narayan and Pritya have a child, what is the chance it will NOT have dimples?



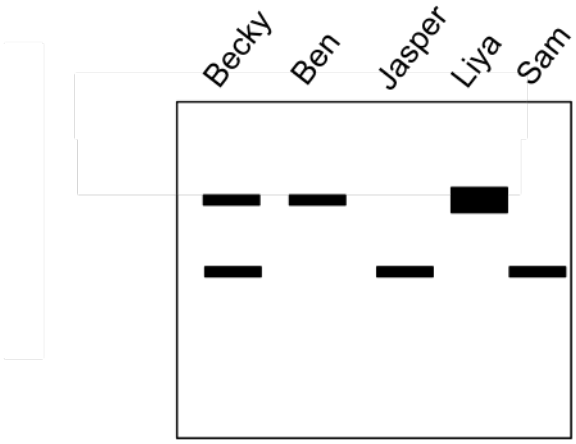

**Gel/pedigree questions**

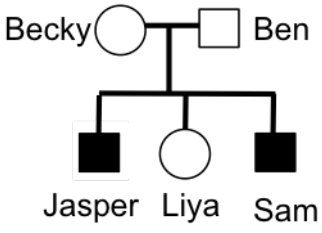
(Note: Students were taught in class that the thickness of a band on a gel indicates relative amount of DNA.)

1. The Clarke family shown below has a genetically inherited disease caused by a 300 bp insertion mutation in an exon of a single gene. DNA for this gene was amplified from each member of the family and run on the gel shown below. Using the pedigree and the gel, what is the most likely mode of inheritance for this disease?

2. The Bustamante family shown below has a genetically inherited disease caused by a 117 bp deletion mutation in an exon of a single gene. DNA for this gene was amplified from each member of the family and run on the gel shown below. Using the pedigree and the gel, what is the most likely mode of inheritance for this disease?

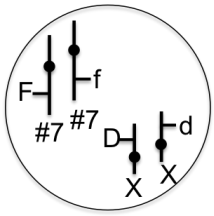
3. The Hale family has a genetically inherited trait called ocular albinism (lack of pigment in the eye) caused by a 516 bp deletion in an exon of a single gene. DNA for this gene was amplified from each member of the family and run on the gel shown below. Using the pedigree and the gel, what is the most likely mode of inheritance for this disease?



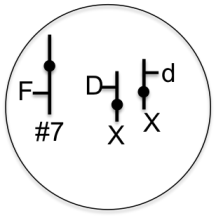



**Nondisjunction questions**

1. Jill is a carrier for the autosomal recessive disease cystic fibrosis (Ff on chromosome 7). She is also a carrier for the X-linked trait muscular dystrophy ($X^D X^d$). These chromosomes (unreplicated) are shown below in one of Jill's normal cells.

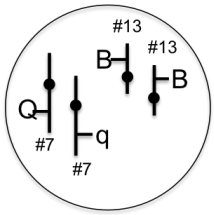



For this problem, assume no crossing over occurs during meiosis. Jill produces an egg with the genotype F $X^D$ $X^d$, as shown below.

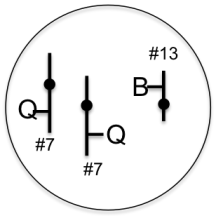



Just considering the steps of meiosis, what has occurred to produce this egg? Specify the phase of meiosis that was affected, if any.

2. Daryl is genotype Qq for a gene on chromosome 7. He is genotype BB for a gene on chromosome 13. These chromosomes (unreplicated) are shown below in one of Daryl's normal cells.

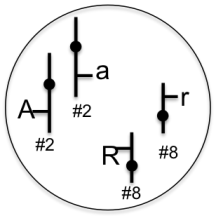



For this problem, assume no crossing over occurs during meiosis. Daryl produces a sperm with genotype BQQ, as shown below.

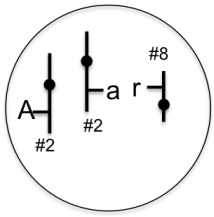



Just considering the steps of meiosis, what has occurred to produce this sperm? Specify the phase of meiosis that was affected, if any.

3. Maria is a carrier for two disorders, with genotype Aa on chromosome 2 and genotype Rr on chromosome 8. These chromosomes (unreplicated) are shown below in one of Maria's normal cells.




For this problem, assume no crossing over occurs during meiosis. Maria produces an egg with genotype Aar, as shown below.




Just considering the steps of meiosis, what has occurred to produce this egg? Specify the phase of meiosis that was affected, if any.