



Supporting Online Material for

Why Peer Discussion Improves Student Performance on In-Class Concept Questions

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This PDF file includes:

SOM Text

Fig. S1

Tables S1 to S3

Supporting Text

Supplemental material on limiting data analysis to students who answered all three questions (Q1, Q1_{ad}, and Q2).

Data analysis was limited to students who answered all three questions of an isomorphic pair of questions (Q1, Q1_{ad}, and Q2). Students were given participation points regardless of their answer, but they had to answer at least 75% of the questions asked in a given class to get their participation points for that day. Therefore there was an incentive to answer every question even if students were unsure of the correct answer. For students who answered at least one but not all of the clicker questions in the isomorphic question series, on average: 3% (SE 1%) did not answer Q1, 8% (SE 1%) did not answer Q1_{ad}, and 3% (SE 1%) did not answer Q2. We suspect that the proportion of missing data is higher for Q1_{ad} because during discussion students had trouble hearing when it was time to vote or forgot to vote.

Supplemental material on ranking the questions according to Q1 difficulty.

Ranking the questions by Q1 raises the possibility that regression to the mean could explain our results. To investigate this, we assessed the impact of ranking the pairs by Q1 and looked at anomalies in the ranking of Q2 (Table S2). There were only two anomalies.

The first anomaly is the maternal effect question pair shown in Figure S1. This question has a Q1 percent correct (20%) that ranks it as difficult (this question is the fourth most difficult Q1 asked), but a Q2 percent correct (72%) that is similar to the medium difficulty questions. Our observations of student discussion indicated that students answered individual Q1 as if it were asking about a normal Mendelian inheritance pattern [the most popular answer to Q1 was (c) 25%], but when given a chance to talk with their neighbors they quickly realized that the inheritance pattern would be different because they were dealing with a maternal effect. Therefore, student discussion had an abnormally large positive impact on the maternal effect isomorphic question pair.

The second anomaly is the two-point cross question pair shown in Supplemental Figure 1. This question has a Q1 percent correct (40%) that ranks it as medium (this question is the fifth most difficult Q1 asked), but a Q2 percent correct (37%) that is the lowest we observed for any Q2 in our study. Our observations of student discussion in class, as well as during independent one-on-one interviews, revealed that students have a persistent difficulty with the concept in this question pair. Students assume that the normal alleles or versions of two linked genes must be together on one chromosome and the mutant alleles must be together on the other copy of the chromosome. Consequently, for the two-point cross isomorphic question pair, student discussion only served to confirm this misconception. This was the only isomorphic question pair in our study where peer discussion was ineffective.

Supplemental material on statistical analyses

To determine whether all students who answered Q2 correctly for the difficult questions were instructed by students who correctly answered Q1 (Figure 1b), we used the following model. If the students who answered individual Q1 correctly (see Table S3) were randomly distributed throughout the classroom (binomial distribution), they

would be represented in less than half the peer discussion groups. Even if we make the best-case assumption that during peer discussion students who answered Q1 correctly were successful in teaching their group members such that all of them answered Q2 correctly, the predicted number of correct Q2 answers is significantly lower than the observed number of correct Q2 answers (ave. $\chi^2=27.3$, $df=1$, $p<0.05$) (Table S3).

Three-point Cross Question Q1/Q1_{ad} (ranked as easy): Phenotypically wild-type female flies heterozygous for each of three different mutations [purple eyes (pr), dumpy wings (dp), and hairy (h)] were crossed to male flies that have purple eyes, have dumpy wings, and are hairy. The number of progeny in eight different phenotypic classes is:

Wild-type = 298	Dumpy wings & Hairy = 30
Hairy = 8	Vision defects & Purple eyes = 165
Purple eyes = 28	Dumpy wings & Purple eyes = 10
Dumpy wings = 161	Dumpy wings, Purple eyes, & Hairy = 300

Which of the three genes is in the middle?

- A. hairy
- B. purple
- C. dumpy

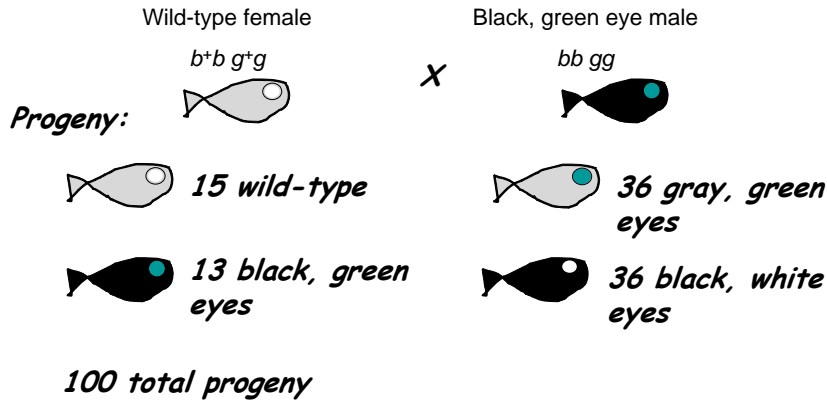
Three-point Cross Question Q2: Phenotypically wild-type female flies heterozygous for each of three different mutations [curly wings (c), short bristles (b), and sepia eyes (s)] were crossed to male flies that have curly wings, short bristles, and sepia eyes. The number of progeny in eight different phenotypic classes is:

Wild-type = 446	Sepia eyes & Curly wings = 10
Curly wings = 42	Sepia eyes & Short bristles = 40
Sepia eyes = 2	Short bristles & Curly wings = 1
Short bristles = 10	Sepia eyes, Curly Wings, & Short bristle = 449

Which of the three genes is in the middle?

- A. curly
- B. short bristle
- C. sepia

Two-point Cross Question Q1/Q1_{ad} (ranked as medium):

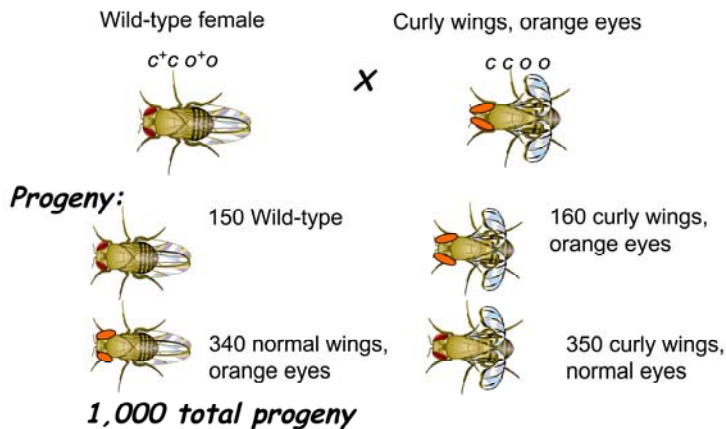


What is the recombination frequency between *black* and *green*?

- A) 0.13
- B) 0.15
- C) 0.28
- D) 0.49
- E) 0.72

b = mutant, black body
 b^+ = normal, gray body
 g = mutant, green eye
 g^+ = normal, white eye
Normal dominant over mutant for both

Two-point Cross Question Q2:



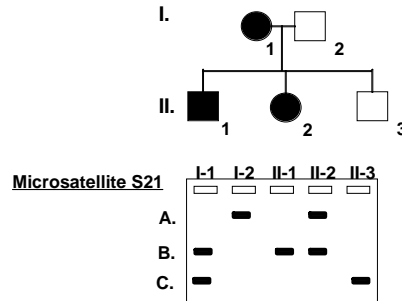
All fruit fly pictures from: http://www.exploratorium.edu/exhibits/mutant_flies/mutant_flies.html

What is the recombination frequency between *curly* and *orange*?

- A) 0.16
- B) 0.31
- C) 0.49
- D) 0.50
- E) 0.69

c = mutant version of *curly*
 c^+ = normal version of *curly*
 o = mutant version of *orange*
 o^+ = normal version of *orange*
Normal dominant over mutant for both

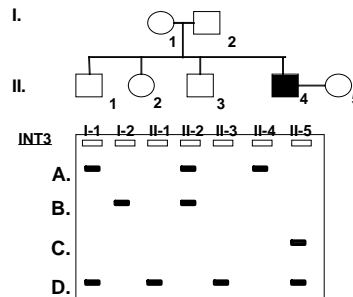
Mode of inheritance Question Q1/Q1_{ad} (ranked as difficult): Here is a pedigree of a family with Charcot Marie-Tooth (CMT) disease and a gel with the results of PCR amplification of the S21 microsatellite. S21 is tightly linked to the gene that causes CMT when mutated.



Considering both the pedigree and the microsatellite data, what is the mode of inheritance for CMT?

- A. Autosomal dominant
- B. Autosomal recessive
- C. X-linked dominant
- D. X-linked recessive
- E. More than one of the above is possible

Mode of inheritance Question Q2: Here is a pedigree of a family with Cardiac Valvular Dysplasia (CVD) and a gel with the results of PCR amplification of the INT3 microsatellite. INT3 is tightly linked to the gene that causes CVD when mutated.



Considering both the pedigree and the microsatellite data, what is the mode of inheritance for CVD?

- A. Autosomal dominant
- B. Autosomal recessive
- C. X-linked dominant
- D. X-linked recessive
- E. More than one of the above is possible

Maternal Effect Question Q1/Q1_{ad} (ranked as difficult): You are studying *Drosophila mulleri* and you discover a maternal effect gene you call *nanu*. *nanu* mRNA is localized to the anterior end of the embryo and promotes the formation of anterior structures.

Mutations in the *nanu* gene are recessive.

In a cross between two *nanu* heterozygotes, how many of the embryos will have defects in their anterior structures?

- A. 100%
- B. 50%
- C. 25%
- D. 0%

Maternal Effect Q2: You are studying *Drosophila mulleri* and you discover a maternal effect gene you call *nanu*. *nanu* mRNA is localized to the anterior end of the embryo and promotes the formation of anterior structures. Mutations in the *nanu* gene are recessive.

In a cross between a *nanu/nanu* mutant female and a *+/+* male, how many of the embryos will have defects in their anterior structures?

- A. 100%
- B. 50%
- C. 25%
- D. 0%

Figure S1. Examples of isomorphic question pairs used to assess gains in conceptual understanding following peer discussion. Correct responses are underlined.

Table S1. Demographic information on students in the undergraduate genetics class (n=350 students from a single one-semester class) who participated in this study.

Category	Demographic Information
Gender	63% female, 37% male
Year in college	34% freshman, 33% sophomore, 16% junior, 16% senior, 1% other
Major	63% biology
Ave. GPA	3.09 +/- 0.03 beginning of course, 3.04 +/- 0.03 end of course
Grade distribution in genetics course	19% A, 29% B, 28% C, 16% D, 8% F

Table S2. A comparison of Q1 and Q2 correct for the 16 isomorphic question pairs. Results in bold font indicate an anomaly.

Q1 Difficulty Rank	Q1 Percent Correct	Q2 Percent Correct
1 (most difficult)	11%	50%
2	16%	53%
3	18%	51%
4	20%	72%
5	40%	37%
6	44%	74%
7	51%	74%
8	52%	72%
9	54%	76%
10	61%	78%
11	63%	74%
12	73%	84%
13	74%	90%
14	78%	85%
15	79%	96%
16 (least difficult)	93%	96%

Table S3. Chi-square statistic comparing the number of students predicted to answer Q2 correctly based on our model versus the number observed on the four most difficult questions. All χ^2 values are significant at the $p < 0.05$ level, $df=1$.

Percent correct on Q1	Predicted correct Q2 (n)	Observed correct Q2 (n)	Total (n)	χ^2	p values
11%	63	100	201	31.8	$p < 0.01$
16%	114	147	277	15.9	$p < 0.01$
18%	122	141	275	5.1	$p = 0.02$
20%	125	185	258	56.3	$p < 0.01$