2025 SOAPS Invitational

Designer Genes C

Science Olympiad at Penn State Invitational

Saturday, January 17th, 2026

The Pennsylvania State University, University Park, PA

Team Name:_____

Participant Names:_____

Total Score:____/318 **Rank:_____**

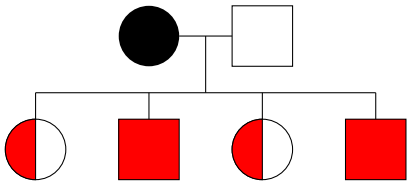
This test was written by Krish Shah (Carnegie Mellon University '29)

Please direct any questions to krishshah@cmu.edu

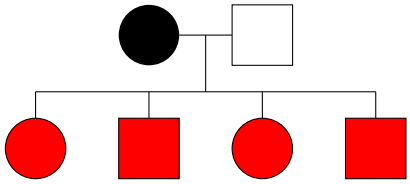
1.	B	11.	ABC	21.	A	31.	D	41.	B
2.	C	12.	C	22.	E	32.	C	42.	C
3.	B	13.	C	23.	A	33.	A	43.	A
4.	B	14.	A	24.	D	34.	C	44.	D
5.	A	15.	C	25.	E	35.	B	45.	C
6.	C	16.	D	26.	A	36.	A	46.	C
7.	C	17.	C	27.	C	37.	B	47.	C
8.	B	18.	B	28.	A	38.	B	48.	B
9.	A	19.	D	29.	A	39.	B	49.	A
10.	C	20.	A	30.	B	40.	A	50.	B

51. (a) (1 point) 1

(b) (2 points)



(c) (2 points)



Solution: 2 points, all or nothing for both pedigrees

(d) (4 points)

Solution: 9 black:3 brown:4 yellow (1 for each, 1 for getting all 3 right) (i.e. if the answer says 9 black, give a point regardless of what else they say). Fractions are also acceptable, in which case you just divide by 16 to get 9/16, 3/16, and 4/16.

(e) (4 points)

Solution: 9 pigmented:7 white (1 each, 2 for getting both right), also accept 9/16 pigmented, 7/16 white

(f) (2 points) Independent assortment

(g) (3 points)

Solution: 5.2 (accept ± 0.2), only give 2 points for 5.2%

52. (a) (2 points)

Solution: Denaturation, annealing, extension (1 point for getting 2 of them, 1 point for getting the third)

(b) (2 points)

Solution: Denaturation (1) to denature/split the strands of the DNA (1)

(c) (3 points)

Solution: bind stronger (1) because they form 3 hydrogen bonds (2)

(d) (3 points)

Solution: temperature at which 50% of primers are single stranded and other half is double stranded (2), increases with G/C (1)

(e) (2 points)

Solution: Accept anything 15-35 (2). If answer is a range and one endpoint is outside of this range while the other is inside, only give 1 point

(f) (4 points)

Solution: too long are slow/reduce efficiency (2), too short are not as specific (2)

(g) (2 points)

Solution: Self annealing/the primer binds to itself (2)

(h) (4 points)

Solution: Taq polymerase (1), Archaea (1), tolerates heat and doesn't denature (2 for anything about heat tolerance)

(i) (4 points)

Solution: dNTPs are monomers of DNA (nucleoside triphosphates with deoxyribose) (1 for either), rNTPs are monomers of RNA (nucleoside triphosphates with ribose) (1 for either), dNTPs only (2)

(j) (4 points)

Solution: nucleases would decrease amplification/cleave DNA (2 for either, also give full credit for saying that it's impossible to know if there are any DNases), gel would have no bands or multiple very light bands (2 for either)

(k) (4 points)

Solution: reverse transcriptase (1 for each word), amplifies starting with RNA (2 for anything talking about how it starts with RNA)

53. (a) (4 points)

Solution: large population/no inbreeding, no natural selection, no mutation, no gene flow/migration/immigration or emigration, random mating (1 point per condition, max 4)

(b) (3 points)

Solution: $q = \sqrt{0.11} = \boxed{0.332}$ **for recessive (white flowers),** $p = 1 - q = \boxed{0.668}$ **for dominant (purple flowers)**

(c) (3 points)

Solution: $1 - 0.11 = \boxed{0.89}$ **(1),** $\frac{2pq}{1-0.11} = \boxed{0.498}$ **(2)**

(d) (2 points)

Solution: Negative frequency-dependent selection (2)

(e) (3 points)

Solution: diversity decreases (1) due to the bottleneck effect (2)

(f) (2 points)

Solution: heterozygous purple flowered (1, do not give credit for just purple, but do give credit for just heterozygous), Overdominance/heterozygote advantage (1)

(g) (4 points)

Solution: $\overline{w} = p^2 w_{PP} + 2pq w_{Pp} + q^2 w_{pp} = 0.4 \cdot (1 - \sqrt{0.11}^2 + 2 \cdot \sqrt{0.11} \cdot (1 - \sqrt{0.11}) + 0.6 \cdot 0.11 = \boxed{0.688}$ **(4 for correct answer, 2 partial for something with this formula)**

(h) (3 points)

Solution: $(2pqw_{Pp})/\overline{w} = \boxed{0.644}$

(i) (1 point)

Solution: heterozygous individuals would be most common

(j) (2 points)

Solution: this would require every individual to be heterozygous, but their children can't always be heterozygous (2)

54. (a) (2 points) **Karyogram (accept karyotype too)**

(b) (1 point) **bottom right or end (1)**

(c) (1 point) **5**

(d) (2 points) **Cri du chat syndrome**

(e) (3 points)

Solution: 18 (1), trisomy or aneuploidy (2)

(f) (2 points)

Solution: nondisjunction led to a gamete with an extra chromosome 18 and that was used in fertilization (2 for anything similar, more detail is fine but not needed)

(g) (3 points) **Edward's syndrome**

(h) (2 points)

Solution: one X chromosome is deactivated anyways in normal humans, which suggests that only one is needed (2 for mentioning X chromosome inactivation, give only 1 point for saying males only have 1 X chromosome)

(i) (2 points) Turner's syndrome

(j) (4 points) Philadelphia chromosome/translocation

(k) (3 points)

Solution: No (1), it's a balanced reciprocal translocation (2, give full credit for just reciprocal but only 1 point for unbalanced reciprocal)

55. (a) (2 points)

Solution: It increases transcription

(b) (2 points)

Solution: would be larger in the individual where it happened earlier

(c) (4 points)

Solution: uracil (2), leads to mutations because uracil binds to adenine and therefore if not corrected leads to the base being changed from guanine to adenine in one daughter strand (2 for something similar about changing the base in the daughter strand)

(d) (2 points)

Solution: many colonies/dots would appear on the dish

(e) (3 points)

Solution: Non homologous end joining (1), used for double stranded breaks (2)

56. (a) (1 point) deoxyribonucleic acid

(b) (5 points)

Solution: both cleave the phosphodiester bonds between nucleotides (1 for anything about splitting DNA or nucleotides), exonucleases can only take off nucleotides from the end (2), whereas endonucleases break bonds in the middle of the DNA strand (2)

(c) (2 points)

Solution: Impossible to know (1) because it's single stranded (1) - give 0 points for anything relating to Chargaff's rules

(d) (3 points)

Solution: 100 seconds (3) (since this is a plasmid and the replication fork travels both directions)

(e) (2 points) Okazaki fragments

(f) (3 points)

Solution: one band (1) in between where the original DNA and normal DNA would be (1), evidence for the semiconservative model (1)

(g) (2 points)

Solution: bind to the single strands (1) and keep them from binding to each other (1)

(h) (6 points)

Solution: DNA Polymerase (pol) I (2) for prokaryotes, flap endonuclease or DNA polymerase δ for eukaryotes (2 for either), DNA pol I does both the removal and the insertion of new nucleotides, while eukaryotes use two separate steps (removal and addition) with two enzymes (2 for anything similar about how eukaryotes are incremental or require more steps)

57. (a) (1 point) **transcription then translation**

(b) (2 points)

Solution: ρ dependent takes energy, while ρ independent does not (also give credit for just saying that ρ dependent takes more energy)

(c) (3 points)

Solution: mRNA encodes multiple proteins (2), more common in bacteria (1)

(d) (2 points) **Shine–Dalgarno sequence**

(e) (2 points)

Solution: inability to initiate transcription (2, 1 point for just saying decrease in transcription)

(f) (2 points)

Solution: the third nucleotide in a codon is matched less strongly and can sometimes be mismatched

58. (a) (1 point) **Lactose**

(b) (3 points)

Solution: inducible (1), useful because lactose is not always in the environment and it would be wasteful to always produce lactose (2)

(c) (3 points)

Solution: no (1), decreased expression (2)

(d) (1 point) **Allolactose (1, also accept lactose)**

(e) (2 points) **Operator**

(f) (4 points)

Solution: Increase expression when both lactose and glucose are present (2, give 1 point for only increase expression) because excessive cAMP is produced (1) which means CAP would always be bound (1)

(g) (3 points)

Solution: repressible (1), useful because it's wasteful to synthesize extra tryptophan when there's already enough, but it is always needed so production should be the default (2 for anything similar)

(h) (2 points)

Solution: Tryptophan (1), negative feedback (1)

59. (a) (5 points)

Solution:

(b) (2 points)

Solution: Illumina is way better/faster (2) since it sequences in parallel

(c) (1 point) **No**

(d) (2 points)

Solution: X-gal (1), turns blue (1)

60. (a) (2 points) **0**

(b) (2 points) 1/64

(c) (2 points) 1/16

(d) (2 points)

Solution: Polygenic inheritance (multiple-gene inheritance, multigenic inheritance, quantitative inheritance, additive alleles, additive genetic effects also work)

(e) (2 points) **6**

(f) (3 points)

Solution: $\binom{5}{3} \cdot 2^{-3}2^{-2} = \boxed{10/32}$ **(1 partial for mentioning or trying to use a binomial distribution)**

(g) (5 points)

Solution: $1/4 \cdot 1/4 \cdot 1/2 \cdot 1/2 = \boxed{1/64}$ **(3), minimum height is 1 (2)**

(h) (3 points) $2^5 = \boxed{32}$

(i) (2 points) **11**

(j) (4 points)

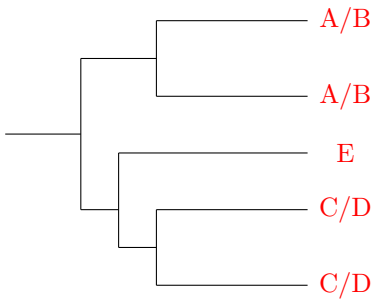
Solution: min 2 (2), max 8 (2) (from aabbccddEE and AABBCcDdEE)

(k) (6 points)

Solution: 1 unit - 0.0 (1), 3 units - 4 cases - allele is from first gene, second, third, or fourth, so $\frac{1}{2} \cdot \frac{1}{4} \cdot \frac{1}{2} \cdot \frac{1}{2}$ **[first gene]** $+ \frac{1}{4} \cdot \frac{1}{2} \cdot \frac{1}{2} \cdot \frac{1}{2}$ **[second gene]** $+ \frac{1}{4} \cdot \frac{1}{4} \cdot \frac{1}{2} \cdot \frac{1}{2}$ **[third gene]** $+ \frac{1}{4} \cdot \frac{1}{4} \cdot \frac{1}{2} \cdot \frac{1}{2}$ **[fourth gene]** $= \boxed{\frac{3}{32}}$ **(5, give 1 partial for anyone who tries to split it into multiple cases, 2 partial for someone who gets close (correct setup but wrong answer or missing exactly one case))**

61. (a) (1 point) **C and D**

(b) (5 points)



Solution: 1 point per correct letter.
If a letter has a slash, then the letter can go in either one of the two possible locations. However, the other must go in the other spot. For example, the first two can be A and B or B and A.

(c) (3 points)

Solution: time between A and B is smaller/shorter (1) because there are fewer differences (2)