

# INTRODUCTORY BIOLOGY

Written: Nov 22, 201

## FINAL EXAM

Scott Young

	SCORE	MAX
Q1	3	4
Q2	6	7
Q3	5	5
Q4	8	8
Q5	6	6
Q6	6	7
Q7	5	5
Q8	9	9
Q9	2	5

### SCOTT'S NOTES ON GRADING:

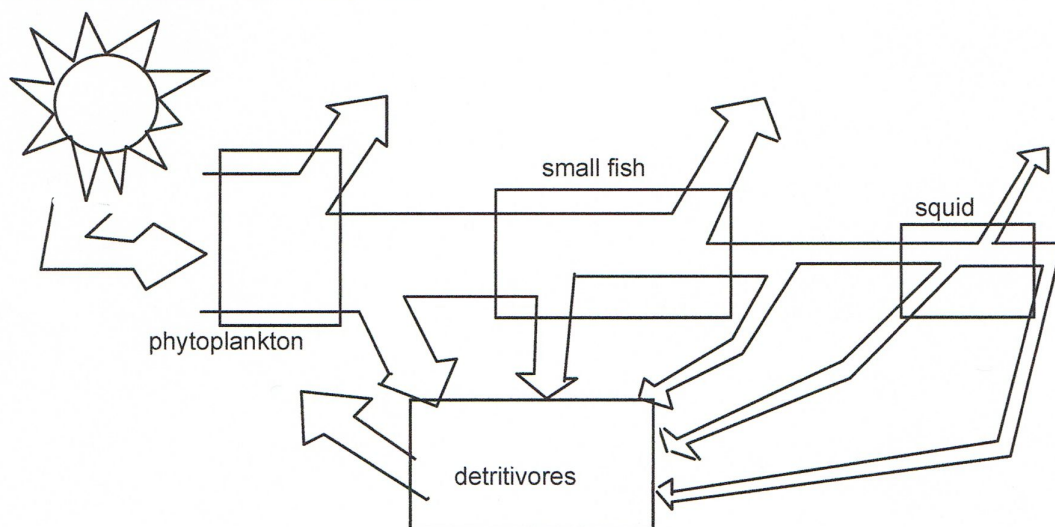
No rubric was provided so I marked the paper with points ranging from  $\frac{1}{2} \rightarrow 2$  for questions of different lengths.

TOTAL	50/56 = 89%
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## Question 1

Your ongoing interest in bioluminescent organisms has lead you to study the Hawaiian squid, *Euprymna scolopes*. Most nocturnal creatures cast shadows under the bright Hawaiian moonlight, and are easy prey to predatory fish. This type of squid can shine light downwards to match the moonlight and avoid casting a shadow thereby decreasing predation.

To provide squid for your studies, you maintain a large, self-supporting squid tank. The food web of the tank is shown below.



When your tank is at steady state, you can harvest 10 kg of squid carbon/week and all the other biomasses (phytoplankton, fish, squid, and detritivores) remain constant.

Given the following values:

- NPP of phytoplankton = 2.0 kilograms of organic carbon per gram of phytoplankton per day
- plant production efficiency = 60%
- fish exploitation efficiency = 50%
- fish assimilation efficiency = 20%
- fish net production efficiency = 5%
- squid exploitation efficiency = 50%
- squid assimilation efficiency = 80%
- squid net production efficiency = 40%

a) What NPP (in kilograms of carbon) is required to support a harvest of 10 kg of squid carbon per week at steady state? Show your work.

$$\underbrace{x}_{\text{amount of plankton}} \cdot \underbrace{(0.05)}_{\text{amount converted to fish}} \cdot \underbrace{(0.4)}_{\text{amount converted to squid}} = 10$$

$$\boxed{\text{NPP} = 500 \text{ kg/week}}$$



## Question 1, continued

b) Month after month, your squid harvest is 10 kg/week and all the biomasses remain constant. One month, you find that you can only harvest 5 kg of squid carbon/week and maintain steady state.

You suspect that something has contaminated your tank and reduced your yield. You propose two models to account for the reduction in yield. To test these models, you measure the respiration rate of the detritivores in the tank. You find that detritivore respiration has increased by 5 kg of carbon per week.

Model 1: Phytoplankton photosynthesis is inhibited so that they now only produce 1.0 kilogram of organic carbon per gram of phytoplankton per day, but at this new steady state, all other efficiencies remain constant.

i) Is this model consistent with your measurement? Explain.

No, lower NPP would not increase detritivore respiration

Model 2: 5 kg of fish per week are dying with all other efficiencies remaining constant.

ii) Is this model consistent with your measurement? Explain.

Yes, extra fish dying would increase detritivore respiration and reduce sq population

c) In their native ocean environment, the squid feed on a wide variety of small fish and invertebrates. You suspect that the squid is the keystone species in this ecosystem. What experiment could you do to test this theory? What result do you predict?

You could overfish the squid in a patch of ocean and see if this causes an ecosystem collapse or loss of biodiversity

## Question 2

a) You want to build a larger squid facility. To make better use of your resources, you plan to construct a life table to determine the mortality rate, fecundity, and the net replacement value of your population. You follow 1000 squid eggs and collect the data below.

stage	number
unfertilized eggs	1000
eggs hatched into juveniles	840
juveniles at 2 month	210
juveniles at 4 months	100
juveniles at 6 months	33
juveniles at 8 months = adult	24
adult at 10 months	14
adults at 1 year	5
adults at 2 year	0

i) If you were to make a cohort life table using this data, how many squid would you initially have in your cohort?

840

ii) If the fecundity of squid at 8 months = 10, and the fecundity of squid at 10 months = 16, during which 2 month time period are more offspring produced?

$24 \cdot 10 = 240$  @ 8 months  
 $14 \cdot 16 = 224$  @ 10 months  
∴ more @ 8 months<sup>3</sup>

## Question 2, continued

b) Surprisingly, your tank-raised squid are not luminous. In fact, the glow seen in free living squid is due to a species of bacteria, *Vibrio fischeri* that live in a specialized light organ within the squid. When juvenile squid hatch, ambient water enters the light organ. *V. fischeri* and the many other bacterial species in this ambient water also enter the light organ and colonize it. All the bacteria initially flourish in this nutrient rich environment, but after 10 hours, only *V. fischeri* remain in the light organ.

i) The interaction between *V. fischeri* and the other bacterial species initially colonizing the light organ can best be described as competition.

ii) The interaction between the squid and *V. fischeri* can best be described as mutualism.

iii) Is the light organ of the squid the fundamental niche of *V. fischeri*.

Why? No. *V. fischeri* survive in other niches as well (otherwise none could colonize the light organ from seawater) but they are

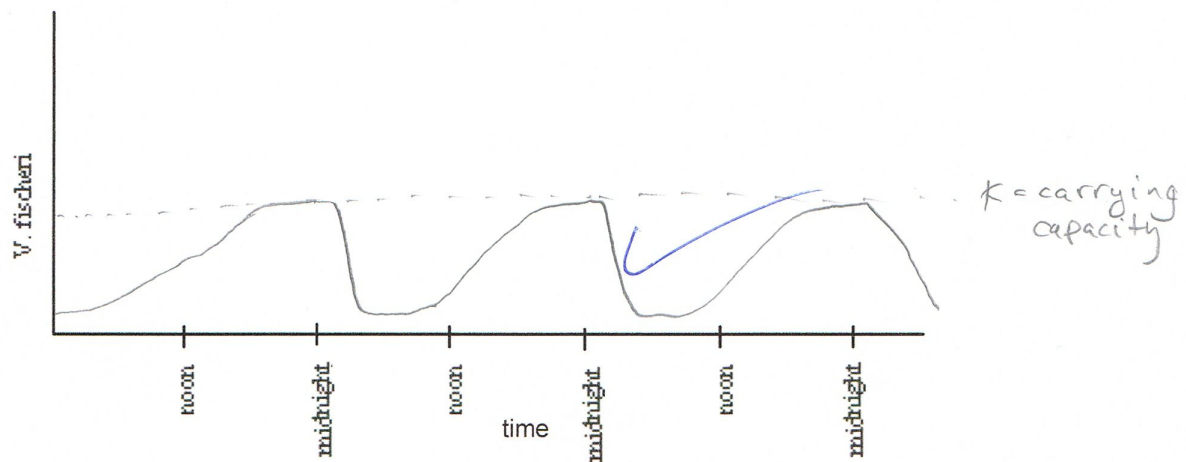
iv) Is the light organ of the squid the realized niche of *V. fischeri*. more limited because of competition

Why?

Yes, because in this niche *V. fischeri* exclude other competitors.

c) The interaction between the squid and *V. fischeri* is dynamic. *V. fischeri* are only luminescent when the density of cells is near carrying capacity, yet when nutrients become limiting, luminescence ceases. To overcome this problem, the squid expel 90-95% of the *V. fischeri* from the light organ as each new day begins. By the following evening, the bacteria that remained have repopulated the light organ and it is once again fully functional.

Using this information, graph the *V. fischeri* population within the light organ of a squid over several days. Indicate carrying capacity on the above graph.



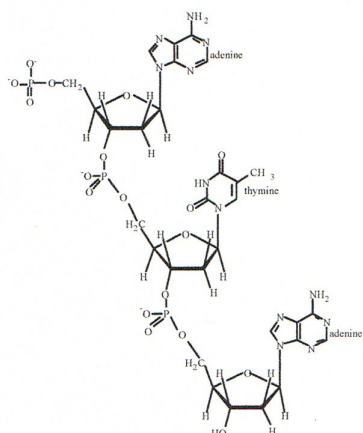
### Question 3

a) Match each of the following structures to the type of molecule it represents:

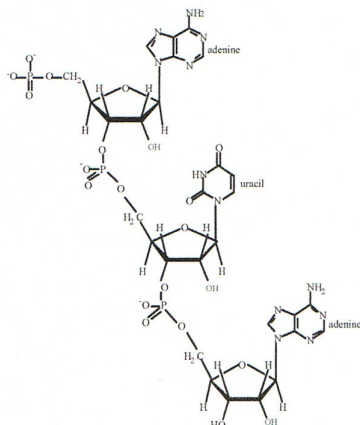
1) protein

2) RNA

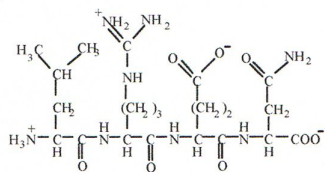
3) DNA



DNA



RNA



protein



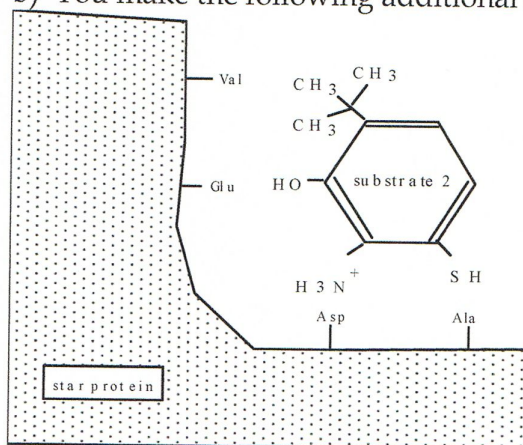


### Question 4, continued

a) Give the name for the strongest intermolecular interaction between the substrate and the following amino acids on the star protein. Choose from ionic bond, covalent bond, hydrogen bond, and van der Waals forces.

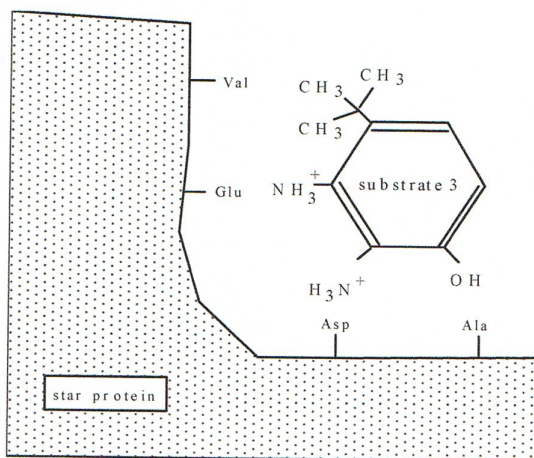
	Amino Acid	Strongest interaction
i)	Val	Van der Waals ✓ (hydrophobic)
ii)	Glu	Hydrogen Bonds ✓
iii)	Asp	Ionic ✓
iv)	Ala	Van der Waals ✓

b) You make the following additional substrates



Does the type of interaction between the Ala of the star protein and the substrate change with substrate 2 as compared to substrate 1?

No. ✓



Does the type of interaction between the Glu of the star protein and the substrate change with substrate 3 as compared to substrate 1?

Yes → Ionic Bond ✓

c) Which substrate would you expect binds the most tightly to the star protein?

substrate 1  
Why?

substrate 2

substrate 3 ✓

Because there are two ionic bonds instead of just one, in the other cases. ✓

## Question 5

To investigate the yeast metabolic pathway for serine biosynthesis, you screen for serine auxotrophs (mutants which are unable to grow without serine supplied in their growth medium). You isolate four such mutants, and test them for growth on medium supplemented with several intermediates (A, B and C) known to be part of the pathway. The results are shown below ("+" represents growth, "-" represents no growth).

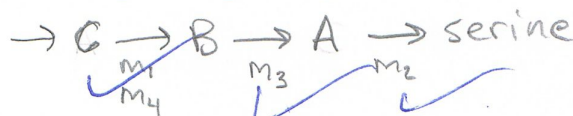
Strain	minimal medium	minimal + A	minimal + B	minimal + C	minimal + serine
wild type	+	+	+	+	+
m1	-	+	+	-	+
m2	-	-	-	-	+
m3	-	+	-	-	+
m4	-	+	+	-	+

You then mate the haploid m1 strain with the haploid m4 strain to create a diploid yeast carrying both the m1 and the m4 mutations. You test the diploid for growth on the same conditions as above and observe that the diploid exhibits the same growth requirements as m1 or m4 haploid.

a) Are the m1 and m4 mutations in the same gene or different genes? Briefly explain your reasoning.

Same gene, otherwise the complementation test would have produced *some* viable offspring

b) Draw the metabolic pathway for the synthesis of serine, consistent with the data given above. Include the intermediates (A, B, and C) and serine, and indicate which mutants (m1, m2, m3, m4) are defective at each step in the pathway.



c) You create a haploid strain that has both the m1 and m3 mutations.

i) This haploid mutant will grow on media supplemented with which of the following intermediate(s) (A, B and/or C)?

A. (also some B colonies if recombination occurs AND the mutations are not 100% linked)

ii) Which of the following intermediate(s) (A, B and/or C) will accumulate when this haploid mutant is grown on minimal medium?

C. (also some B if m1 & m3 are not 100% linked and recombination occurs)



## Question 6

a) Indicate whether the following statements are true or false. If false, correct the statement or provide a brief explanation for why the statement is false.

i) DNA replication is initiated at ~~promoter~~ sequences in the DNA.

origin of replication

False

ii) RNA polymerase requires ~~primers~~ to initiate RNA synthesis.

promoters

False

iii) Okazaki fragments are the short fragments of DNA that are produced on the ~~leading~~ strand at the DNA replication fork.

lagging

False

iv) The 5' to 3' direction of DNA synthesis implies that deoxyribonucleotides are added to the ~~5'~~ OH group on the growing strand.

3'

False

v) ~~Transcription~~ terminates at stop codons in the mRNA sequence.

translation

False

b) Shown below is the DNA sequence of a gene from a virus that encodes a short viral peptide, and also the sequence of the mRNA synthesized from this gene.

genomic DNA sequence:

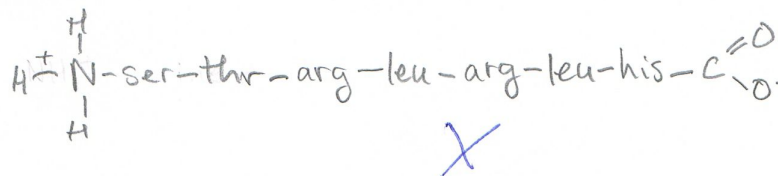
5' - AGCTCATGTGCGAGTCTCTGACGCTGACGTAGG - 3'  
3' - TCGAGTACACGCTCAGGACTGCGACTGCATCC - 5'

mature mRNA sequence:

5' - UCAUGUGCGAACGCGUGACGUAGG - 3'  
AGUACAAGCUGUGACUGCAUCC

i) In the genomic DNA sequence shown above, draw boxes around the exons.

ii) Write the sequence of the peptide encoded by this gene. Indicate the  $\text{NH}_3^+$  and the  $\text{COO}^-$  ends of the peptide.





	U	C	A	G	
U	UUU phe (F) UUC phe UUA leu (L) UUG leu	UCU ser (S) UCC ser UCA ser UCG ser	UAU tyr (Y) UAC tyr UAA STOP UAG STOP	UGU cys (C) UGC cys UGA STOP UGG trp (W)	U C A G
C	CUU leu CUC leu CUA leu CUG leu	CCU pro (P) CCC pro CCA pro CCG pro	CAU his (H) CAC his CAA gln (Q) CAG gln	CGU arg (R) CGC arg CGA arg CGG arg	U C A G
A	AUU ile (L) AUC ile AUA ile AUG met (M)	ACU thr (T) ACC thr ACA thr ACG thr	AAU asn (N) AAC asn AAA lys (K) AAG lys	AGU ser (S) AGC ser AGA arg AGG arg	U C A G
G	GUU val (V) GUC val GUA val GUG val	GCU ala (A) GCC ala GCA ala GCG ala	GAU asp (D) GAC asp GAA glu (E) GAG glu	GGU gly (G) GGC gly GGA gly GGG gly	U C A G

### Question 7

a) Indicate whether the following statements are true or false. And if false, correct the statement or provide a brief explanation for why the statement is false.

i) Plasma B cells secrete antibody into the bloodstream.

True ✓

ii) T cells produce antibodies that neutralize antigen.

False, B cells do ✓

iii) Each B cell can make many different kinds of antibodies.

False, each can only make one type ✓

b) When a rabbit protein is injected into rabbits, no antibodies against this protein are generated. If, however, the same rabbit protein is injected into guinea pigs, the guinea pigs generate antibodies against the rabbit protein. Briefly (in one or two sentences) explain this observation.

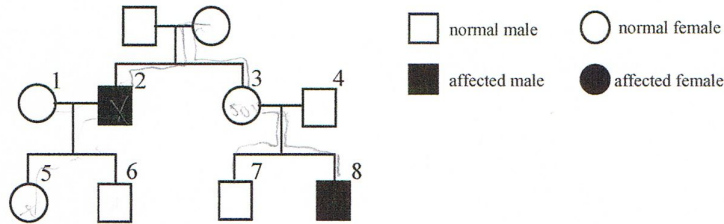
Because during embryogenesis, education occurs in the thymus of the rabbit, killing all B-cells which recognize rabbit proteins (self v. non-self) ✓

c) The genomes contained in almost all of the somatic cells in an adult human are identical. Name one (diploid) cell type that is an exception to this and name the primary mechanism by which this cell type arose.

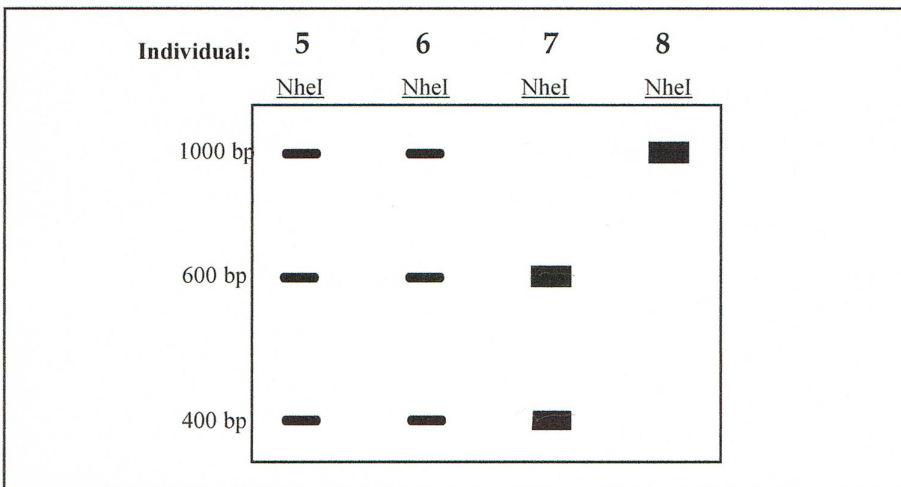
B-cells, deletion of <sup>random</sup> segments to create permutations of antibodies ✓

## Question 8

You are studying a common genetic condition. The mutant allele differs from the wild-type allele by a single base-pair (bp) substitution. This substitution eliminates a *NheI* restriction site that is present in the wild-type allele. (The mutant allele is not cut by *NheI*.) A pedigree of a family exhibiting this condition is shown below:



You isolate DNA from four individuals in the pedigree. Using PCR techniques, you amplify a 1000 bp portion of their DNA which includes the site affected by the mutation. You digest the PCR products with *NheI* and analyze the resulting DNA fragments on a gel:



a) Based on these data, is this gene located on an autosome or the X-chromosome? Briefly justify your reasoning.

Autosome because if it were X-linked #6 wouldn't be able to inherit it from #2 and, as such, would have no DNA left uncut by the *NheI* restriction enzyme (resembles #7).

b) Based on these data, is the mutant phenotype dominant or recessive to wild-type and why?

Recessive because the restriction enzyme data shows #5, #6, and #8 all carry a copy of the gene, but only #8 is affected (who has 2 copies of the mutant allele).

c) If individuals 3 and 4 have a daughter, what is the probability that she will be affected? Justify your reasoning.

25% because both #3 & #4 have one wild type and one mutant allele, so the chance of getting two copies of the mutant allele is  $\frac{1}{4}$  ( $50\% \cdot 50\%$ ).



### Question 8, continued

d) You sequence the region around the *NheI* site in the wild-type PCR product. You then sequence the corresponding region in the mutant PCR product and discover that not only did the mutation eliminate the *NheI* site in the mutant allele but it has created a new *PvuII* restriction site. The recognition sites for the two enzymes are indicated below.

*NheI* cuts: 5' GCTAGC 3'  
3' CGATCG 5'

*PvuII* cuts: 5' CAGCTG 3'  
3' GTCGAC 5'

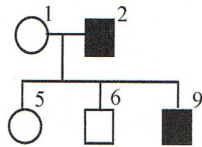
A portion of one strand of the wild-type DNA sequence is shown below:

5'...GCTAGCTG...3'

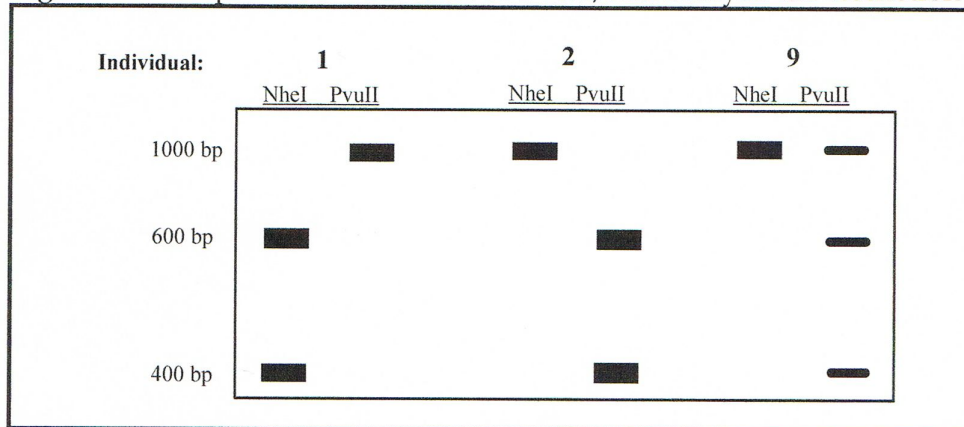
What is the sequence of this same region in the mutant allele? Indicate the 5' and the 3' ends of the DNA sequence.

5'GCCACTG3'

e) Individuals 1 and 2 have another child, 9, who is affected by the genetic condition.



You PCR amplify the 1000 bp region affected by the mutation from individuals 1, 2, and 9, digest the PCR products with *NheI* or *PvuII*, and analyze the restriction fragments on a gel:



What event occurred and how does this explain the data shown above?

A mutation occurred in the good copy of the mother's gene (given to son) which prevented it from working (thus activating the condition) but not the same mutation as the father's otherwise both sets would have been cut by *PvuII*.



### Question 9

Consider the following hypothetical chromosomal region containing two genes, *fadA* and *fadB*, necessary for the breakdown of oleic acid in a bacterium.



P = Promoter  
O = Operator

The FadX protein, which is continuously produced, binds to the operator in the presence of oleic acid.

a) Is the FadX protein a repressor or an activator of the *fadA* and the *fadB* genes? Briefly justify your reasoning.

repressor, because it prevents *fadA* and *fadB* from being produced.

b) For each of the following mutants (m1 - m4), predict the level of FadA in the presence of oleic acid. Circle either "Low" or "High".

Level of FadA with oleic acid present

m1	O is deleted	Low	High
m2	Loss-of-function mutation in <i>fadX</i>	Low	High
m3	P is deleted	Low	High
m4	FadX is always bound to O	Low	High