

**Roll Number:**

**NAME:**

**BB101: 2022 Autumn semester**

**Mid-sem exam (40 marks)**

You have 2 hours to answer this exam.

You must answer only within the space provided.

The questions are connected to each other so read them carefully.

If you are confused, make an assumption, clearly state your assumption and answer the question. Your confusion will NOT be clarified during the exam.

Try and enjoy the exam.

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**Table 1: Genetic Code Table**

UUU } Phe UUC } UUA } Leu UUG }	UCU } Ser UCC } UCA } UCG }	UAU } Tyr UAC } UAA } Stop UAG }	UGU } Cys UGC } UGA } Stop UGG } Trp
CUU } Leu CUC } CUA } CUG }	CCU } Pro CCC } CCA } CCG }	CAU } His CAC } CAA } Gln CAG }	CGU } Arg CGC } CGA } CGG }
AUU } Ile AUC } AUA } AUG } Met	ACU } Thr ACC } ACA } ACG }	AAU } Asn AAC } AAA } Lys AAG }	AGU } Ser AGC } AGA } Arg AGG }
GUU } Val GUC } GUA } GUG }	GCU } Ala GCC } GCA } GCG }	GAU } Asp GAC } GAA } Glu GAG }	GGU } Gly GGC } GGA } GGG }

**Table 2: 1 letter code for amino acids**

Amino Acid	3-Letter Code	1-Letter Code
Alanine	Ala	A
Cysteine	Cys	C
Aspartic acid or aspartate	Asp	D
Glutamic acid or glutamate	Glu	E
Phenylalanine	Phe	F
Glycine	Gly	G
Histidine	His	H
Isoleucine	Ile	I
Lysine	Lys	K
Leucine	Leu	L
Methionine	Met	M
Asparagine	Asn	N
Proline	Pro	P
Glutamine	Gln	Q
Arginine	Arg	R
Serine	Ser	S
Threonine	Thr	T
Valine	Val	V
Tryptophan	Trp	W
Tyrosine	Tyr	Y

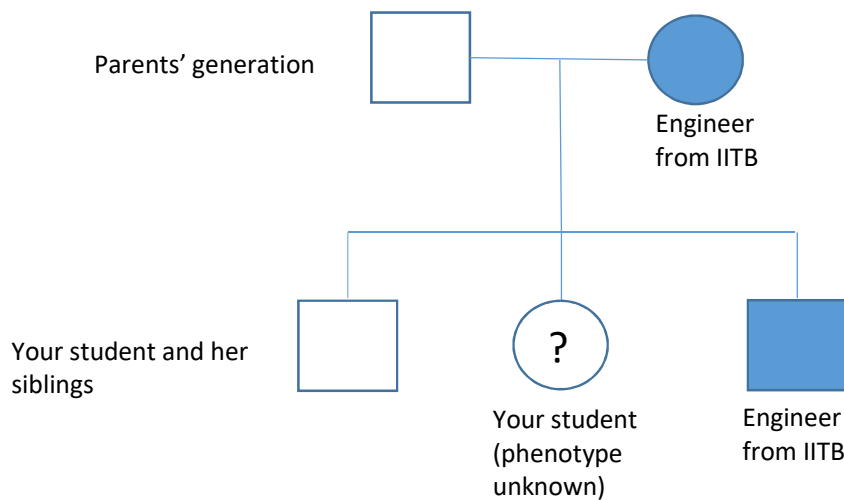
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After coming to IIT Bombay and being exposed to biology and the start-up business culture on campus, you decide that you can make a lot of money in your own company (Super 10) that will screen and prepare students to get into the IITs by cracking the JEE exam.

You use your new knowledge of biology to find a new gene that you believe can give the phenotype of cracking the JEE exam. You call this gene *jee1* and find that the gene is dominant (the student will be able to crack the JEE exam if there is a single copy of the dominant allele). For the rest of this exam, use *JEE1* to denote the dominant allele and *jee1* to denote the recessive allele.

You have 10 students enrolled in your company Super 10. They have all been selected based on their *jee1* gene. You start doing research on one of the students in the Super 10 group. You take DNA from the student's blood cells and also from the blood cells of the student's family. You find out the phenotypes of the student and her family members, shown below.



Qs. 1. On the family tree shown above, write the genotypes of all the family members, except your student. Use *JEE1* to denote the dominant allele and *jee1* to denote the recessive allele. (4 marks)

Qs. 2. Based on your student's family tree, you can predict that she could have two different genotypes. Write down these two genotypes. (2 marks)

Qs. 3. You want to find out which of the two genotypes is present in your student's genome. So you sequence the *jee1* gene using the DNA extracted from her blood cells. You also sequence the *jee1* gene from her father who is not an IITB engineer. The sequence of your student's alleles and her father's alleles for the *jee1* gene is given below. Circle the differences between the alleles. (2 marks)

Student's *jee1* allele 1: 5' ATGGAGTGTCTGGGCATGCAAAATAATTACCTGA 3'

Student's *jee1* allele 2: 5' ATGGAGTGTCTGGGCATGCAAAATGATTACCTGA 3'

Father's *jee1* alleles (both): 5' ATGGAGTGTCTGGGCATGCAAAATGATTACCTGA 3'

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Qs. 4. Why do humans (like your student and her father) have two alleles of each gene? (2 marks)

Qs. 5. Based on the results of the sequencing of the *jee1* alleles of the student and her father, what is her genotype of the two possibilities that you gave in your answer to Qs. 2? Explain briefly. (2 marks for genotype and 1 mark for explanation)

Qs. 6. You decide to further study the *jee1* gene and next you translate the gene sequence into the protein sequence that is encoded in the open reading frame. Using the genetic code table given to you (Table 1), translate both alleles of your student's *jee1* gene. (4 marks)

Student's *jee1* allele 1: 5' ATGGAGTGTCTGGGCATGCAAAATAATTACCTGA 3'

Student's *jee1* allele 2: 5' ATGGAGTGTCTGGGCATGCAAAATGATTACCTGA 3'

Qs. 7. You have a strange feeling that the sequence of the short protein made from the *jee1* gene (from your answer in Qs. 6) has some more information. For the two short proteins obtained from your student's alleles, use the information given in Table 2 to convert the 3-letter amino acid codes given above into 1-letter amino acid codes. This does not require any biology knowledge, just use the table to write the sequences. (1 mark)

Qs. 8. Although your student's father is not an IIT engineer, based on your results from Qs.7., which engineering institute might he have been able to get into? **HINT:** The answer is in the sequence you wrote for Qs. 7. (By the way, genes do not spell English words with meaning; this question is just for fun.) (2 marks)

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Qs. 9. It is clear that there is a single amino acid change in the JEE1 protein between the dominant and recessive alleles. Give another example of a single amino acid change causing a different phenotype that was discussed in class. (2 marks)

Based on all your research so far, you are convinced that the *jee1* gene encodes a protein that if expressed, can give a phenotype of cracking the JEE exam. So, you want to go beyond genetic testing of the *jee1* gene among your students. During the tutorials, you successfully had killed *Vibrio cholerae* using *E. coli* that expressed proteins that interfered with quorum sensing of *Vibrio cholerae*. You decide to use *E. coli* to express the dominant *JEE1* gene and release the JEE1 protein into the intestine of your students. This protein from the intestine will affect the brain and give the phenotype\*\*\*. This way, even the students who do not have the dominant gene, will be able to crack the JEE exam.

\*\*\* By the way, there is an effect of the bacteria in our intestines on our mental health, so this is not a crazy idea.

You decide to use the *lac* promoter and operator to express the dominant JEE1 gene and make protein. So, you introduce DNA containing the *lac* promoter and operator upstream of the dominant JEE1 gene into *E. coli*. Then you introduce these genetically modified *E. coli* into the intestine of your students whose genotype is *jee1/jee1*.

Qs. 10. What food will your student have to drink in order to turn on the switch for the *E. coli* to turn on the switch to make the JEE1 protein? Explain briefly. (2 marks for the right answer and 2 marks for explanation)

Qs. 11. You realize that having to keep drinking the food from your answer of Qs. 10 is a pain for your students. So you want to modify the *E. coli* that you created such that the *lac* promoter and operator are always ON and never OFF. Circle all the possible correct answers from the choices below. (2 marks)

- A) You make a mutation in the operator such that the repressor cannot bind
- B) You make a mutation in the promoter such that the RNA polymerase cannot bind
- C) You make a mutation in the repressor such that the inducer cannot bind
- D) You make a mutation in the Lac Z gene such that the beta-galactosidase activity is lost

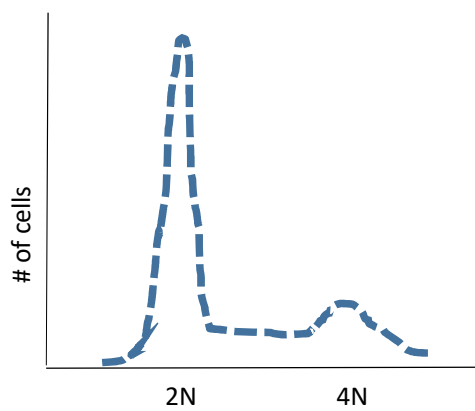
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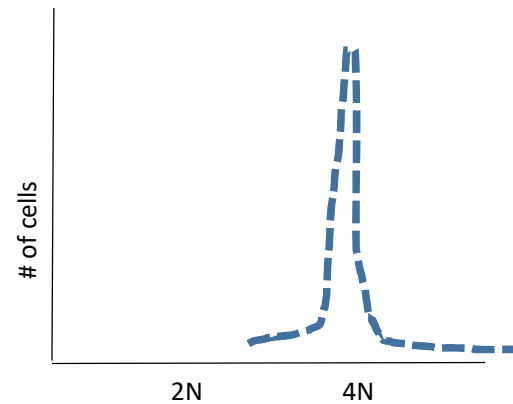
Another start up you have been working on is a company that is doing research on cancer. You know that cancer cells lose their regulation of the cell cycle by external and intrinsic signals.

Qs. 12. Name two external signals and two intrinsic signals that regulate the cell cycle. (4 marks)

Just to try something out, you put the JEE1 protein expressed in *E. coli* onto cancer cells grown in the laboratory. You then check the cell cycle of the untreated and treated cells using the FACS assay that gives quantity of the genome in cells of the population. You get the results shown below.



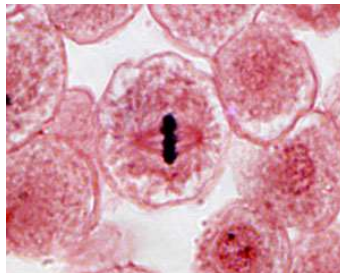
Untreated cancer cells



Cancer cells treated with JEE1

Qs. 13. The cancer cells treated with JEE1 protein are stuck in one or more stages of the cell cycle. Name the stage(s). (2 marks)

You want to figure out which precise stage of the cell cycle the JEE1 protein makes the cancer cells get stuck at. So you look at these cells under the microscope, after staining their DNA with a dye. The cells look like the image below. Grey: microtubules; Black: chromosomes



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Qs. 14. Which stage of the cell cycle has the JEE1 protein made the cancer cells get stuck at? (2 marks)

In addition to studying the cell cycle of the cancer cells, you also decide to study their metabolism.

Qs. 15. After glycolysis, cancer cells prefer to use one pathway for generating energy. Name this pathway. (2 marks)

Qs. 16. Why do they use this pathway? (2 marks)

Qs. 17. Based on our discussion of metabolism in class, if a cancer cell wanted to generate more ATP, what could it do? Circle all correct answers. (2 marks)

- A) Store more ATP
- B) Utilize more glucose
- C) Switch to oxidative phosphorylation
- D) Promote the growth of blood vessels to the tumor to deliver more oxygen

After successfully being able to run your two companies, using the miracle protein JEE1, you make a lot of money and do all the fun things you want in life. Thanks to your new knowledge of biology!

-----END OF EXAM-----