1.   Regulation of expression of trp operon genes   (0.5 + 1.5) × 2 = 4.0 marks
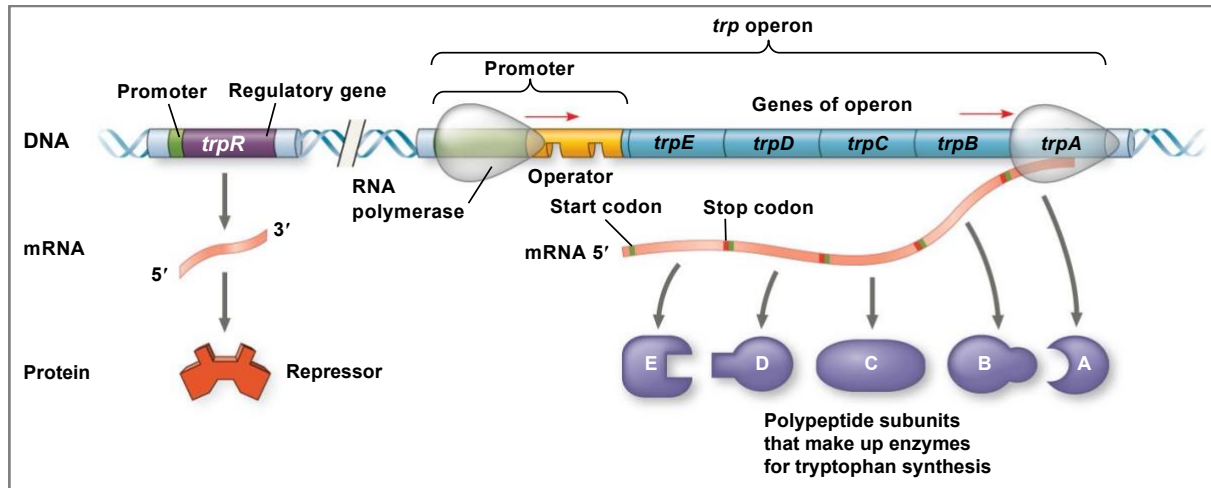
You may refer to the schematic shown below to specify whether *trp* operon genes are expressed or not under given conditions, and mention the reasons thereof.

(a) Condition #1:

    Tryptophan cannot bind to the repressor because of a mutation

    AND

    tryptophan is present in the growth medium

Answer: *trp* operon genes will be **EXPRESSED**.

Reason: Although tryptophan (co-repressor) is present in the growth medium, it cannot bind to the repressor because of mutation. As a result, the repressor cannot bind to the operator and thereby allows RNA Polymerase to transcribe the *trp* genes.

(b) Condition #2:

    Repressor, by itself, can bind to the operator because of a mutation

    AND

   tryptophan is absent in the growth medium

Answer: trp operon genes will **NOT BE EXPRESSED**.

Reason: A mutation causes the repressor to bind to the operator without the requirement of bound tryptophan. As a result, the operator-bound repressor inhibits the transcription of trp genes by the RNA Polymerase. Therefore, in this case, trp genes are **NOT EXPRESSED**.

2.   *Regulation of expression of lac operon genes*   (0.5 + 1.5) × 2 = 4.0 marks

You may refer to the schematic shown below to specify whether *lac* operon genes are expressed or not under given conditions, and mention the reasons thereof.
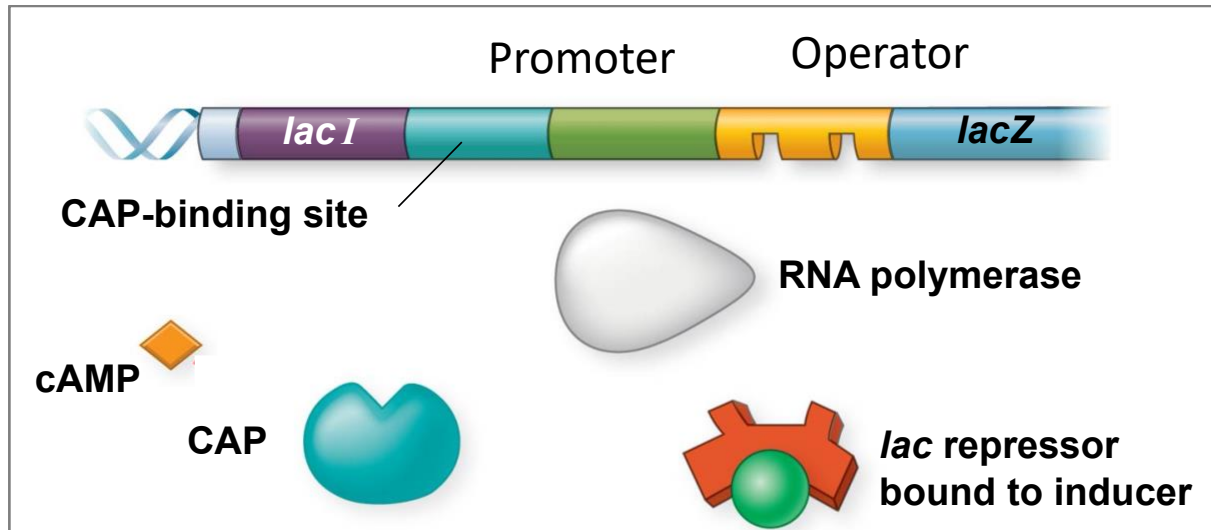
(a) Condition #1:

    Inducer cannot bind to repressor because of a mutation
    AND
    growth medium contains lactose but not glucose.

Answer: *lac* operon genes will **NOT BE EXPRESSED**.

Reason: Inducer cannot bind to the repressor because of a mutation. As a result, repressor remains bound to the operator region leading to the repression of transcription by RNA polymerase.

(b) Condition #2:

    Repressor cannot bind to operator, with or without bound inducer, because of a mutation
    AND
    growth medium contains glucose but not lactose.

Answer: *lac* operon genes will **NOT BE EXPRESSED.**

Reason: (i) Repressor cannot bind to the operator owing to a mutation.
        (ii) Because glucose is present in the medium, cAMP will not be present.
        (iii) Because cAMP is not present, CAP cannot bind to promoter and recruit RNA polymerase.

3. *Phenotype known but genotype unknown* (0.5 + 1.5) × 2 = 4.0 marks

Shown below is a cross between a purple-flower-bearing pea plant of unknown genotype and a white-flower-bearing pea plant.

(figure is part of the answer below)

Mentioned below are the two possible outcomes from the view point of flower color of progeny plants obtained by this cross:

Possible outcome #1:
 Suppose the genotype of the purple-flower-bearing parent pea plant is *PP*,
 then the progeny will bear <u>only purple flowers</u>, <u>only white flowers</u>, or <u>both purple and white flowers</u> (<u>choose any one</u>).
 Answer: The progeny will bear **ONLY PURPLE FLOWERS**.

Possible outcome #2:
 Suppose the genotype of the purple-flower-bearing parent pea plant is *Pp*,
 then the progeny will bear <u>only purple flowers</u>, <u>only white flowers</u>, or <u>both purple and white flowers</u> (<u>choose any one</u>).
 Answer: **The progeny will bear both PURPLE AND WHITE FLOWERS**

Reasons or the basis on which you arrived at the answer:
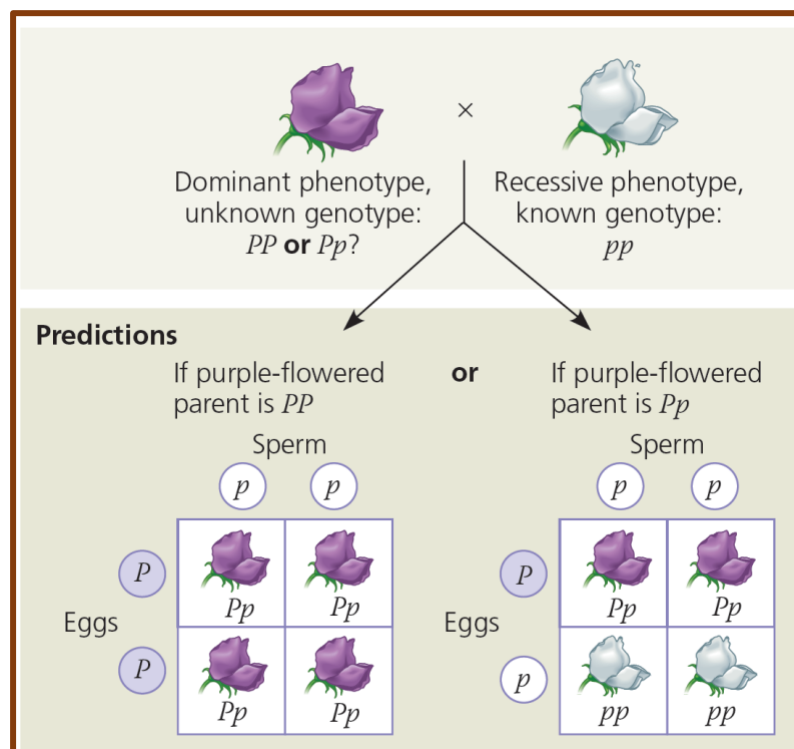
4.   Conceptual translation of DNA   1.0 × 4 = 4.0 marks

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

Conceptual translation of the sequence of 18-nucleotide long DNA fragment shown below:

5'-A G C T A G C C T A G C T T G A C A-3'

3'-T C G A T C G G A T C G A A C T G T-5'

First stand (spacing has been modified to group three nucleotides that form a codon):

5'-A G C T A G C C T A G C T T G A C A-3' 1st DNA strand
5'-A G C U A G C C U A G C U U G A C A-3' 1st mRNA sequence
(note: DNA alphabet has A, C, G, and T whereas RNA alphabet has A, C, G, and U).

Frame 1	5'-AGC UAG CCU AGC UUG ACA-3' Ser Stop
Frame 2	5'-A GCU AGC CUA GCU UGA CA-3' Ala Ser Leu Ala Stop
Frame 3	5'-AG CUA GCC UAG CUU GAC A-3' Leu Ala Stop

Second strand
5'-T G T C A A G C T A G G C T A G C T -3' 2nd DNA strand
5'-U G U C A A G C U A G G C U A G C U -3' 2nd mRNA

Frame 4	5'-UGU CAA GCU AGG CUA GCU -3' Cys Gln Ala Arg Leu Ala
Frame 5	5'-U GUC AAG CUA GGC UAG CU -3' Val Lys Leu Gly Stop
Frame 6	5'- UG UCA AGC UAG GCU AGC U -3' Ser Ser Stop

5.   *Evolution: unity and diversity*   (1.0 + 1.0) + (0.5 + 1.5) = 4.0 marks

(a) How is adaptation different from evolution?
Answer: Adaptations are inherited characteristics of organisms that enhance their survival and reproduction in specific environments.

Evolution: (i) Change in the properties of a population over time (spanning generations)
(ii) Descent with modification
(iii) Change in the genetic composition of a population from one generation to another.

(b) While on a field visit, Mr. Wardin Larches discovered a fossil of an extinct mammal that lived **high in the Andes**. Which one of the following two does this extinct mammal resemble more closely (choose any one of the two options):

Note: one can reason that both options are possible. Hence, both (a) and (b) are correct answers as long as one justifies the choice.

(a) Present-day mammals from **South American jungles**

Certain descendants of the ancestral species inhabited high mountains whereas others inhabited jungles. During the course of evolution, in each of these two ecosystems, descendants from successive generations inherited characteristics that enhanced their survival and reproduction in the respective ecosystems (adaptation).

(b) Present-day mammals that live **high in African mountains**

It is possible that South American and African mammals share a common ancestor that existed in Pangea (https://en.wikipedia.org/wiki/Pangaea). Descendants that inhabit high mountains thereby accumulate similar characteristics in the two continents.
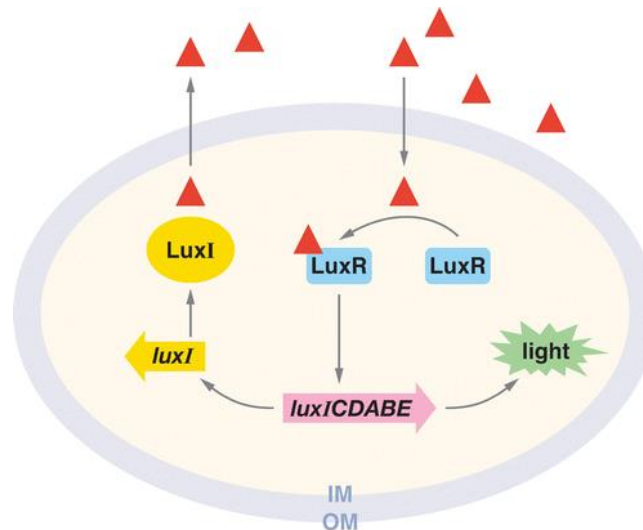

Note: Andes is a very long mountain range located on the west coast of the South American continent.

As can be seen from the map inset on the left, South America and Africa are separated by the South Atlantic Ocean.

6.   *Quorum sensing*   1.0 + 1.0 + 2.0 = 4.0 marks

Shown below is the schematic that was used to discuss quorum sensing in the lecture:

(a) What is the function of the protein LuxI?
Answer: LuxI is the enzyme responsible for the synthesis of "auto-inducer".

(b) What is the function of the protein LuxR?
Answer: LuxR is the intracellular receptor for the auto-inducer.

(c) The triangle in the schematic above depicts a molecule. One arrow shows that the molecule is moving from inside the cell to the outside, whereas another arrow shows the molecule to be moving from outside the cell to inside. What do these two arrows convey in the context of quorum sensing?

Answer:
The arrow pointing outwards indicates that the auto-inducer moves out of the cell. This happens only when quorum is NOT met i.e., the extra-cellular concentration of the auto-inducer is less than the intra-cellular concentration.

The arrow pointing inwards indicates that the auto-inducer enters into the cell. This happens only when quorum is met i.e., the extra-cellular concentration of the auto-inducer is higher than the intra-cellular concentration.

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