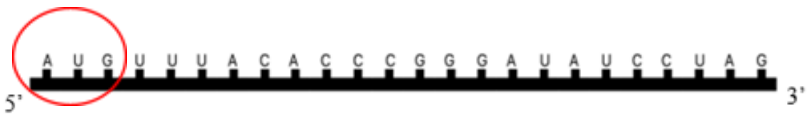
No	Answers	Marks
1. (a)	Cell X: Anaphase I Cell Y: Anaphase	1 1
(b)	Homologous chromosomes separate and move to the opposite poles in Cell X. Sister chromatids separate and move to the opposite poles in Cell Y.	1 1
(c) (i)	– 36 (in G_2 phase, there are still 18 chromosomes, but 36 molecules of DNA) – DNA replication/ synthesis happens during S phase // the amount of DNA is doubled after S phase	1 1
(ii)	● The cell is not large enough to proceed cell division ● The nutrient is not enough for energy supply// Nutrient deprivation // Lack nutrients and energy for cell division ● It does not receive molecule signal/growth factor from neighbouring cell ● DNA damage occur that need to be repaired first	1 1 1 1 Any 1
2 a)(i)	1 PP : 2 Pp : 1 pp	1
(ii)	F1 x F1 (self cross) : smooth pod, yellow seed × smooth pod, yellow seed PpGg × PpGg Gamete / G : (PG) (Pg) (pG) (pg) (PG) (Pg) (pG) (pg) F2 generation (/genotypes) : F2 phenotypic ratio : 9 smooth pod, yellow seed : 3 smooth pod, green seed : 3 constricted pod, yellow seed : 1 constricted pod, green seed	1 for **all** correct genetic diagram component 1 for correct gametes (**with circle**) 1 for **all** correct F_2 generations / genotypes 1 for **all** correct F_2 phenotypic ratio
(iii)		1 for **all** correct **linked gene** genetic diagram component 1 for correct gametes (with circle) 1 for **all** correct F_2

Gamete	(PG)	(Pg)	(pG)	(pg)
(PG)	PPGG	PPGg	PpGG	PpGg
(Pg)	PPGg	PPgg	PpGg	Ppgg
(pG)	PpGG	PpGg	ppGG	ppGg
(pg)	PpGg	Ppgg	ppGg	ppgg

	F1 test cross (linked gene) : smooth pod, yellow seed × constricted pod, green seed PG/pg × pg/pg Gamete / G : PG, Pg, pG, pg × pg F2 generation / genotypes : PG/pg, Pg/pg, pG/pg, pg/pg F2 phenotypes : smooth pod, yellow seed ; smooth pod, green seed ; constricted pod, yellow seed ; constricted pod, green seed	phenotypes (**use comma only**)
2 (b)(i)	P : $X^N Y$ (normal) x $X^N X^N$ (normal) G : X^N, Y ; X^N F_1 : Gamete: X^N, Y X^N: $X^N X^N$ (normal), $X^N Y$ (normal) **Probability = 0**	Correct gametes -1m Correct genotypes in Punnet square -1m Correct probability – 1m
(ii)	P : $X^n Y$ (M.D.) x $X^N X^n$ (carrier) G : X^n, Y ; X^N, X^n F_1 : Gamete: X^n, Y X^N: $X^N X^n$ (normal), $X^N Y$ (normal) X^n: $X^n X^n$ (M.D.), $X^N Y$ (M.D.) **Percentage of having a male child with M.D.** = 1/2 (to have a male) x 1/2 (male suffering from M.D.) x 100% = 1/4 x 100% = **25%**	1 1 } Any 1 1
3 a)	Frequency of homozygous recessive genotype, $q^2 = 4/100 = 0.04$ **Frequency of recessive allele, q = $\sqrt{0.04}$** **= 0.2** **p + q = 1, Frequency of dominant allele, p** **p = 1 – 0.2** **= 0.8**	1 1
b)	Number of homozygous recessive individuals in the original population = q^2 x 5000	

	= $(0.2)^2$ x 5000 = 200 Number of homozygous dominant individuals in the original population = p^2 x 5000 = **$(0.8)^2$ x 5000 = 3200** Number of heterozygous individuals in the original population = 2pq x 5000 = **2(0.2)(0.8) x 5000 = 1600** Total number of individuals in the new population = 5000 – 120 = 4880 New number of homozygous recessive individuals **= 200 – 120 = 80** New frequency of recessive alleles = **[(80x2) + 1600] / (4880 x 2) = 0.180** New frequency of dominant alleles = **[(3200 x 2) + 1600] / (4880 x 2) = 0.820**	1 1 1
4 a) b) c) 3’ TAAGGCATCG 5’ // 5’ GCTACGGAAT 3’	• RNA primers/ nucleotides cannot be replaced with DNA nucleotides • This causes the synthesis of DNA molecules with mismatch base pairs // This causes the synthesis of new DNA strands with RNA nucleotides // This causes RNA primers to base pair with incorrect DNA nucleotides // DNA replication incomplete/ cannot complete • DNA polymerase III adds new nucleotides only in the 5’ to 3’ direction // New DNA strands are synthesized from 5’ to 3’ // New nucleotides are added only to the 3’ end of a growing DNA strand • (Thus) Replication of lagging strand occurs in a direction <u>away from</u> the replication fork / Lagging strand is synthesized in a direction <u>away from</u> the replication fork (by forming a series of short fragments called Okazaki fragments)	1 1 1 1 1

4 d) (i)
 	
(ii)
 	
(iii)
 	
(iv)
 	
(v)
	Strand A
	
	RNA polymerase separates/ unwinds the two DNA strands (by breaking hydrogen bond between complementary bases) // RNA polymerase binds to the promoter and unwinds the DNA double helix
	
	 
	
	Name of the stage: Translocation // Elongation
	
	Reason: tRNA holding the polypeptide chain is located on P site (of the large ribosomal subunit) // Empty tRNA is released from E site (of the large ribosomal subunit) // Ribosome moves (one codon ahead) from 5’ to 3’ along the mRNA
	**Dependent on the right stage*
	
	Stop codon <u>5’ UAG 3’</u> enters the **A site** causing **release factor** (bearing no amino acid) to bind to the stop codon // **Release factor** binds to the **stop codon**
		1
		
		1
		
		1
		
		1
		
		1
		
		1

<table>
<tr><td></td><td><u>5’ UAG 3’</u> at the A site (and breaks the bond between the tRNA in P site and the last amino acid of the polypeptide chain)</td><td></td></tr>
<tr><td>4 e) (i)</td><td>- Lactose is converted into allolactose <u>and</u> allolactose binds to the repressor protein
- Repressor protein changes its conformation <u>and</u> cannot bind to the operator
- RNA polymerase binds to the promoter (site)
- Transcription/ Expression of the structural genes occur// transcription <u>and</u> translation of structural gene occur // β-galactosidase, permease and transacetylase are produced</td><td>1
1
1
1
(Any 2)</td></tr>
<tr><td>(ii)
i.</td><td>Notes: No mark will be given if the answers are not written in the correct sequences.
● Cannot encode/ code for (enzyme) β-galactosidase
● Lactose cannot be hydrolyzed into glucose and galactose</td><td>1
1
(Any 1)</td></tr>
<tr><td>5 a)

b) i)

ii)

</td><td>− Due to base substitution // Due to missense mutation
− DNA base sequence CTC is changed to CAC // codons on mRNA is changed from GAG to GUG // glutamic acid / Glu is replaced with valine / Val
- Frameshift mutation (due to base deletion <u>or</u> base insertion)
- Amino acid sequence is changed (from the point of mutation)
- Nonsense mutation
- The polypeptide chain of species III is shorter/ more truncated than the polypeptide chain of species I
- Which shows/ indicates a premature stop/ termination of protein synthesis // Which shows/ indicates a mutation that changes a codon to a stop codon</td><td>1
1
<u>1</u>
1
<u>1</u>
1
1</td></tr>
<tr><td>5 c)(i)

ii)</td><td>− Chronic Myelogenous Leukemia / Chronic myeloid leukemia / CML
− (Reciprocal) translocation
<table><tr><th>Genetic disorder in (a)</th><th>Monosomy 21</th></tr><tr><td>Number of chromosome is 46</td><td>Number of chromosome is 45</td></tr><tr><td>Involves chromosomal aberration // Involves changes in chromosomal structure/ structure of chromosomes</td><td>Involves chromosomal number alteration // Involves changes in chromosomal number</td></tr><tr><td>Involves a segment of chromosome breaks and reattach to another part of other chromosome</td><td>Involves non-disjunction of chromosome (21)</td></tr></table></td><td>1
1

1

1

1</td></tr>
</table>

6 a)(i)	• (Restriction endonuclease / enzyme) recognizes <u>and</u> cuts/ cleaves DNA at restriction site/ **5' GAATTC 3'** (to break the phosphodiester bond/ linkage) • It produces complementary/ compatible sticky ends// It produces overhang 5'- AATT- 3' DNA segment // It makes staggered cuts	1 1
(ii)	Plasmid is able to replicate freely in the host cell // It has origin of replication (*ori*)	1
(iii)	(*E. coli*/ host cell) is able to receive recombinant DNA/ plasmid through <u>transformation</u>	1
(b)	i. mRNA is used as a template (and a short poly-dT as a DNA primer) ii. and enzyme reverse transcriptase is used to make/ synthesize the <u>first</u>/ <u>single</u> cDNA strand iii. mRNA is degraded by enzyme ribonuclease/ RNase/ mRNA degrading enzyme iv. The first/ single cDNA strand acts as a template v. And enzyme DNA polymerase is used to synthesize the second cDNA strand, vi. Resulting in a double-stranded cDNA/ complementary DNA, (carries the complete coding sequence of the gene but no introns// consists of exons only). **Notes: -1 mark if the answers are not written in the correct sequence**	1 1 1 1 1 1 (Any 5)
(c) (i)	(Enzyme in step I / Reverse transcriptase) synthesizes/ (catalyzes) the synthesis of the <u>first</u>/ <u>single</u> cDNA strand using the mRNA as a template // (DNA polymerase) synthesizes the second cDNA strand using <u>first</u>/ <u>single</u> cDNA strand as a template	1
(ii)	Bacteria cannot splice/ remove the introns (in mRNA)// No mRNA modification in bacteria/ RNA splicing/ RNA processing does not occur in bacteria// mRNA contains exons only // Nuclear DNA consists of both introns and exons	1
(iii)	- cDNA <u>and</u> cloning vector X / plasmid cannot be cut/ cleaved // - cDNA <u>and</u> cloning vector X / plasmid cannot be joined together (to form a recombinant plasmid)	1
(iv)	No allergic reactions/ No side effects/ No adverse reaction/ No rejection // Compatible to human insulin	1

7 (a)	- The phase is called luteal phase - After ovulation, luteinizing hormone (LH) released by anterior pituitary gland - Stimulates the development of corpus luteum from ruptured Graafian/ mature follicle // Stimulates the transformation of ruptured Graafian/ mature follicle to corpus luteum - LH stimulates corpus luteum to secrete (large amount/ high level of) progesterone and (small amount/ low level of) estrogen - Estrogen stimulates continued development of endometrium/ uterine lining/ endometrial wall - and progesterone maintain the thickness of endometrium/ uterine lining/ endometrial wall - High concentration/ levels of progesterone and estrogen has negative feedback on the hypothalamus and anterior pituitary (gland) - This inhibits the secretion of GnRH, FSH and LH - The importance is to prevent the growing/ development of new follicle// prepare for fertilization.	1 1 1 1 1 1 1 1 (Any 6)
(b)	- After sperm (penetrates the corona radiata and) reaches zona pellucida, the sperm head binds to (ZP3) receptors on zona pellucida - This triggers the acrosome to release hydrolytic enzymes/ hyaluronidase and protease/ acrosin to digest/ breakdown the zona pellucida of secondary oocyte	1 1
(c)(i)	Oxytocin and prostaglandin	1
(ii)	Both of the hormone level is low or insufficient (to stimulate and increase the frequency of contraction) (*Extra explanation: Low level of oxytocin decreases the intensity of uterine contraction, which will decrease the production of prostaglandin, hence less intensity and frequency of contraction occurs, thus longer labour (rhythmic contraction) duration. If high level of both hormones, there will be more uterine contractions = shorter labour duration*)	1
(iii)	Human chorionic gonadotropin / hCG	1
(iv)	- Estrogen and progesterone - Estrogen stimulates the thickening of endometrium - Progesterone maintains the thickness of the endometrium (to maintain the pregnancy) // prevents/ inhibits uterine contractions // inhibits the secretion of prolactin and oxytocin	1 1 1
7 (d) (i)	Allometric growth	1
(ii)	- The head grows at a faster rate at age of 0 to 4 compared to lymphoid organ. - The lymphoid organ grows at faster rate at age of 7 to 11/ 12 while the head stops growing at these age - The head stops growing at age of 6 while the lymphoid organ stops growing at age of 11/ 12.	1/0 1/0 1/0 (Any 1)