Competency Focused Practice Questions

Biology (Volume 2) | Grade 12

Co-created by
CBSE Centre for Excellence in Assessment
and
Educational Initiatives

PREFACE

Assessments are an important tool that help gauge learning. They provide valuable feedback about the effectiveness of instructional methods; about what students have actually understood and also provide actionable insights. The National Education Policy, 2020 has outlined the importance of competency-based assessments in classrooms as a means to reform curriculum and pedagogical methodologies. The policy emphasizes on the development of higher order skills such as analysis, critical thinking and problem solving through classroom instructions and aligned assessments.

Central Board of Secondary Education (CBSE) has been collaborating with Educational Initiatives (Ei) in the area of assessment. Through resources like the Essential Concepts document and A- Question-A-Day (AQAD), high quality questions and concepts critical to learning have been shared with schools and teachers.

Continuing with the vision to ensure that every student is learning with understanding, Question Booklets have been created for subjects for Grade 10th and 12th. These booklets contain competency-based items, designed specifically to test conceptual understanding and application of concepts.

Process of creating competency-based items

All items in these booklets are aligned to the NCERT curriculum and have been created keeping in mind the learning outcomes that are important for students to understand and master. Items are a mix of Free Response Questions (FRQs) and Multiple-Choice Questions (MCQs). In case of MCQs, the options (correct answer and distractors) are specifically created to test for understanding and capturing specific errors/misconceptions that students may harbour. Each incorrect option can thereby inform teachers on specific gaps that may exist in student learning. In case of subjective questions, each question also has a detailed scoring rubric to guide evaluation of students' responses.

Each item has been reviewed by experts, to check for appropriateness of the item, validity of the item, conceptual correctness, language accuracy and other nuances.

How can these item booklets be used?

There are 123 questions in this booklet.

The purpose of these item booklets is to provide samples of high-quality competency-based items to teachers. The items can be used to–

- get an understanding of what good competency-based questions could look like
- give exposure to students to competency-based items
- assist in classroom teaching and learning
- get inspiration to create more such competency-based items

Students can also use this document to understand different kinds of questions and practice specific concepts and competencies. There will be further additions in the future to provide competency focused questions on all chapters.

The item booklets are aligned with the 2022-23 curriculum. However, a few questions from topic which got rationalized in 2023-24 syllabus are also there in the booklet which may be used as a reference for teachers and students.

Please write back to us to give your feedback.

Team CBSE

CONTENTS

1. BIODIVERSITY AND CONSERVATION

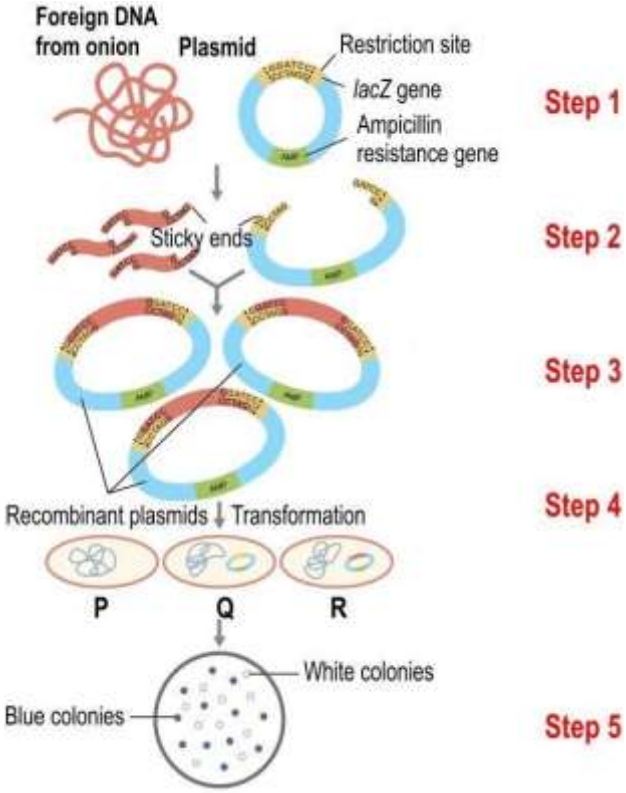
Q. No	Question	Marks
	Multiple Choice Question	
Q.1	Genetic diversity refers to the diversity in genetic makeup of organisms that are capable of interbreeding. What component of an ecosystem does genetic diversity DIRECTLY impact? A. ecosystem diversity B. species diversity C. species richness D. ecological niche	1
Q.2	Dr. Kirti has a patient who is diagnosed with an HIV infection. She has to test for HIV infection in the partner of the patient who has no symptoms of the infection. Which of these methods can be used to diagnose the infection in the partner? P) Urine analysis Q) Electroporation R) Polymerase Chain Reaction (PCR) S) Enzyme Linked Immuno-Sorbent Assay (ELISA) A. only S B. both Q and R C. both R and S D. all - P, R and S	1

Answer Key & Marking Scheme

Q. No	Answers	Marks
Q.1	B. species diversity	1
Q.2	C. both R and S	1

2. BIOTECHNOLOGY AND ITS APPLICATIONS

Q. No	Question	Marks
	Multiple Choice Questions	
Q.3	There are two statements given below marked as Assertion (A) and Reason (R). Read the statements and choose the correct option. Assertion: RNA interference (RNAi) is used to protect plants against nematode infestation. Reason: RNAi method involves silencing of a specific mRNA by a complementary dsRNA molecule that binds to and prevents translation of the mRNA. A. A is true but R is false. B. A is false but R is true. C. Both A and R are true and R is the correct explanation of A. D. Both A and R are true and R is not the correct explanation of A.	1
Q.4	Given below are steps involved in the gene therapy of a patient with adenosine deaminase (ADA) deficiency. P) Lymphocytes are grown in a culture outside the human body. Q) Lymphocytes are altered with a functional ADA cDNA. R) Lymphocytes are collected from the blood of the patients. S) The genetically modified lymphocytes are infused back into the patient. Which of the following show the correct order in which these steps must occur? A. Q --> P --> R --> S B. R --> S --> Q --> P C. R --> P --> Q --> S D. S --> R --> P --> Q	1
	Given below is an image of the process involved in recombinant DNA technology. LacZ is a gene that codes of β-galactosidase. When plated on an appropriate medium, cells that produce β-galactosidase form blue colonies whereas those that do not produce it form white colonies.	



Answer the Questions from Q5-Q8

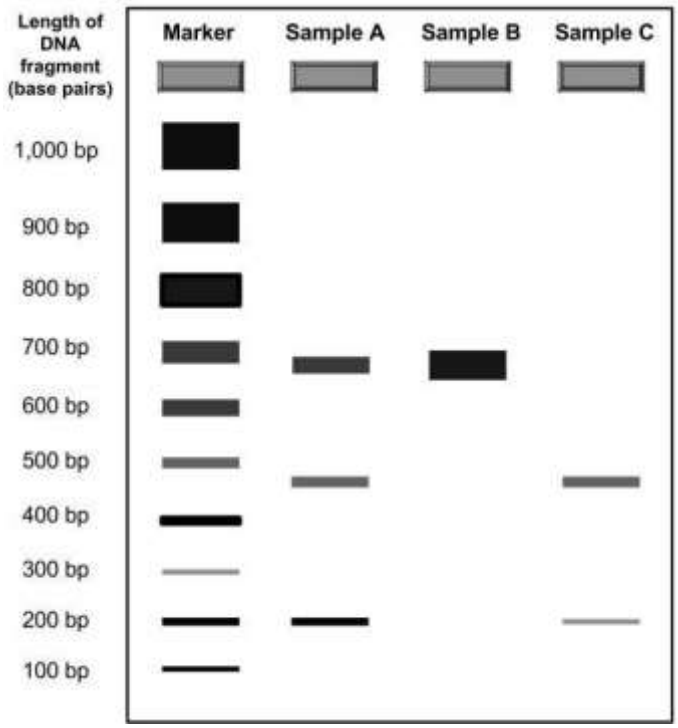
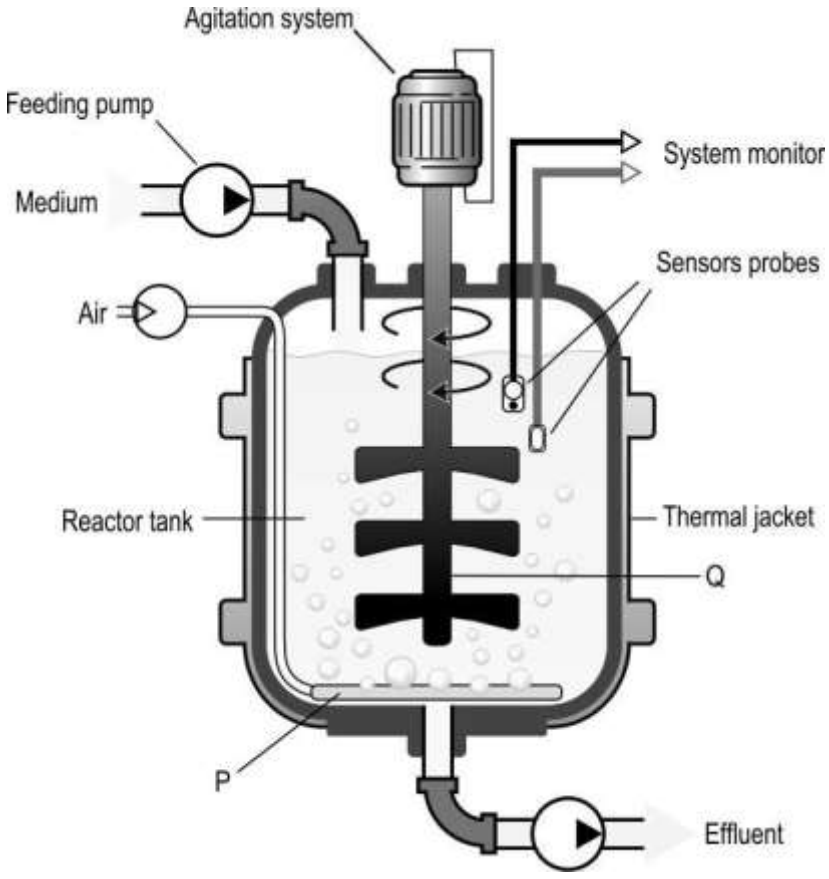
Q.5	Which of the following chemicals will be involved in a step that would come before step 1? lysozyme, ethanol, ribonuclease, cellulase, protease A. only lysozyme and ethanol B. only cellulase, lysozyme and ethanol C. only lysozyme, ribonuclease, protease, and ethanol D. all - lysozyme, ethanol, ribonuclease, cellulase, protease	1
Q.6	Which of the following will help one detect cells containing the recombinant DNA? A. A B. B C. C D. D	1
Q.7	At which step will DNA ligase be required? A. step 2	1

Option	Ampicillin in medium	colour of colonies formed
A	present	blue colonies
B	absent	blue colonies
C	present	white colonies
D	absent	white colonies

	B. step 3 C. step 4 D. (DNA ligase is not required in this process)	
Q.8	What would be the colour of the colonies formed by variant P? A. only blue colonies B. only white colonies C. a mix of blue and white colonies D. (They will not form any colonies.)	1
Q.9	Polymerase chain reaction (PCR) mimics which of the following natural processes? A. ligation B. translation C. replication D. transformation	1
Q.10	Which of the following correctly states the purpose of steam in a bio-processor? A. helps organisms grow faster B. adds to the water content C. maintains sterility D. (Steam is not required in a bio-processing unit.)	1
Q.11	Similar to sexual reproduction, rDNA technology contributes to_____. P) genetic mutation Q) faster replication R) genetic variation S) DNA ligation A. only R B. only P and R C. only P, Q and R D. all - P, Q, R and S	1
Q.12	In which of the following natural processes is recombinant DNA made? A. prophase in mitosis B. prophase 1 in meiosis C. prophase 2 in meiosis D. (Recombinant DNA cannot be made naturally).	1
Q.13	Two statements are given below - one labelled Assertion (A) and the other labelled Reason (R).	1

	Assertion (A): Sexual reproduction is similar to rDNA technology because it results in variations. Reason (R): Variation is impossible through asexual reproduction. Which of the following is correct? A. Both A and R are true, and R is the correct explanation for A. B. Both A and R are true, but R is not the correct explanation for A. C. A is true, but R is false. D. A is false, but R is true.	
Q.14	Two statements are given - one labelled Assertion (A) and the other labelled Reason (R). Assertion (A): Gene therapy is a method of treating a disorder but cannot cure it. Reason (R): In gene therapy, cells are drawn from a patient and the functional gene is introduced into these cells and transferred back to the patient. Which of the following is correct? A. Both A and R are true, and R is the correct explanation for A. B. Both A and R are true, but R is not the correct explanation for A. C. A is true, but R is false. D. A is false, but R is true.	1
Q.15	Given below are two statements about polymerase chain reactions. P) It mimics DNA replication that happens in a cell. Q) It cannot be used to amplify RNA molecules. Which of these is/are TRUE? A. only P B. only Q C. both P and Q D. neither P nor Q	1
Free Response Question/ Subjective Question		
Q.16	X is the first restriction enzyme isolated from strain H of Bacillus amyloliquefaciens. This enzyme cuts between two guanine bases of the following palindromic sequence: 5'-G G A T C C-3' 3'-C C T A G G-5' (a) Name the restriction enzyme X. Explain how you arrived at this name. (b) Draw the DNA fragments produced due to the action of enzyme X on the palindromic sequence shown above.	3

<table>
<tr><td>Q.17</td><td>In 1997, an American company obtained patent rights on Basmati rice, allowing them to market a 'new' strain of Basmati rice in the United States and overseas. This 'new' Basmati strain was really derived from Indian farmer's varieties.
(a) What is this unauthorised act called? Define it.
(b) State TWO ways in which Indian farmers are set to lose due to this unauthorised act.
(c) State TWO measures that different countries are taking to prevent such unauthorised exploitation of their bio-resources.</td><td>3</td></tr>
<tr><td>Q.18</td><td>(a) What are transgenic animals?
(b) To produce transgenic animals, the gene of interest is introduced into embryonic stem cells. These stem cells are undifferentiated and the preferred target in the process of developing any transgenic animal. Give a reason why.</td><td>2</td></tr>
<tr><td>Q.19</td><td>CRISPR is a gene editing technique for which the developers won the Nobel Prize. Indian scientists are in the process of developing resilient and high-yield varieties of rice using this technology and providing these to Indian farmers by 2024, once approved.
(a) Which organisation would be responsible for approving such varieties?
(b) What is the purpose of establishing the organisation identified in (a)?</td><td>2</td></tr>
<tr><td>Q.20</td><td>Kavya and David needed to cut out a 200 base-pair (bp) long DNA fragment from a 650 bp long vector. Enzyme A cuts at 350 bp and at 550 bp whereas enzyme B does not cut the vector. They followed the given steps to do this:
<table><tr><th>Step</th><th>David</th><th>Kavya</th></tr><tr><td>1</td><td>Take 3 micrograms of the vector</td><td>Take 3 micrograms of the vector</td></tr><tr><td>2</td><td>Add 2 microlitres of enzyme A</td><td>Add 2 microlitres of enzyme B</td></tr><tr><td>3</td><td>Incubate at 37°C for 2 hours</td><td>Incubate at 37°C for 2 hours</td></tr><tr><td>4</td><td>Run the sample on an agarose gel</td><td>Run the sample on an agarose gel</td></tr></table>Given below is an image of the gel that was run with the samples.</td><td>3</td></tr>
</table>

	 (a) What is the purpose of the marker? (b) Which of these shows the samples run by David and Kavya? Justify your answer.	
Q.21	Given below is a diagram of a bio-reactor with some of its parts labelled P and Q. 	3

	(a) Which type of organisms can MOST likely be used if part P is not made a part of the bio-reactor? Why? (b) Identify the name and purpose of part Q. (c) How does the thermal jacket help in the process?	
Q.22	(a) Give a reason why, although a toxin, Bt toxins are deadly for insects but not for plants producing them. (b) Describe the steps in which Bt toxins act on insects.	3
Q.23	Plants of a region in India are constantly infested by the corn borer. (a) What components are required in a recombinant plasmid that can produce modified plants which are resistant to the corn borer? State the purpose of each component. (b) Give an example of a plasmid that can be used for (a).	2
Q.24	Identify if the following statement is true or false. Between formation of the dsRNA and silencing of mRNA, the dsRNA needs to undergo an additional step. Justify if true, and rewrite the correct statement, if false.	2
Q.25	Hormones are broadly categorised as steroid hormones and protein hormones. Patients with type 2 diabetes, generally, have to take insulin externally. Researchers across the world believe that if insulin can be given orally it would be ideal as it would closely mimic the movement of natural insulin. Yet, injectable insulin is commonly prescribed by doctors. What type of a hormone is insulin and why can't it be administered orally?	2
Q.26	(a) What causes adenosine deaminase (ADA) deficiency? (b) What are the THREE methods that are currently used for the treatment of ADA? (c) What is the problem with the methods described in (b)? How can this problem be overcome?	3
Q.27	Give a reason why: (a) Transgenic animals are used for the production of biological components of medicines over synthetic industrial production. (b) In the process of testing for effects of chemicals, transgenic animals are used rather than non-transgenic ones.	2
Q.28	Naturally growing potatoes show bruises (black discolouration) when they get damaged. Bruising occurs when the tissue is crushed and cells rupture, releasing enzymes that produce a black discolouration. A gene has been	5

<table>
<tr><td></td><td>identified which codes for this enzyme. A company wants to produce potatoes that do not show these bruises.

(a) Describe the steps in which they can produce such potatoes that do not show bruises.

(b) What is the process called?</td><td></td></tr>
<tr><td>Q.29</td><td>(a) What is a disadvantage of the traditional hybridisation procedure?

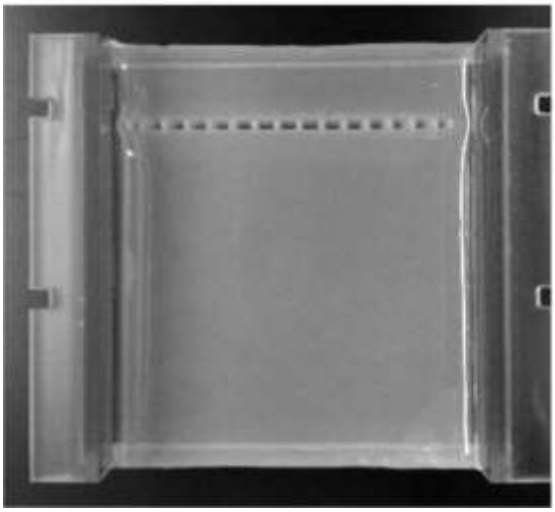
(b) How has rDNA technology overcome the disadvantage identified in (a)?</td><td>2</td></tr>
<tr><td>Q.30</td><td>Anita and Dipti followed the steps mentioned below to introduce their gene of interest into the target organism.

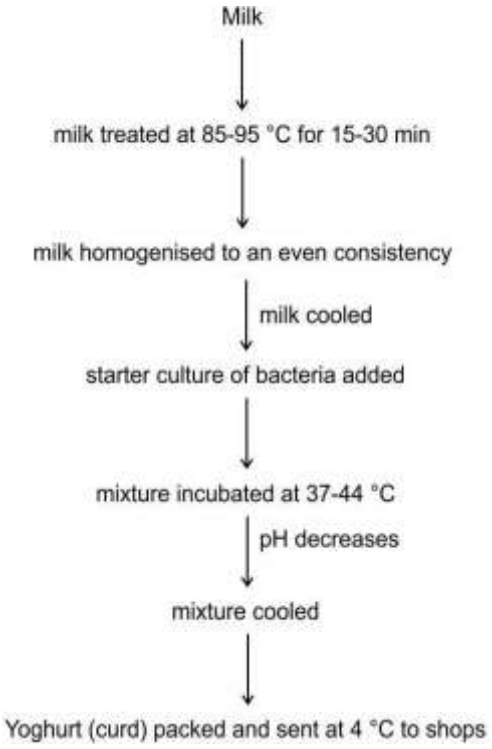
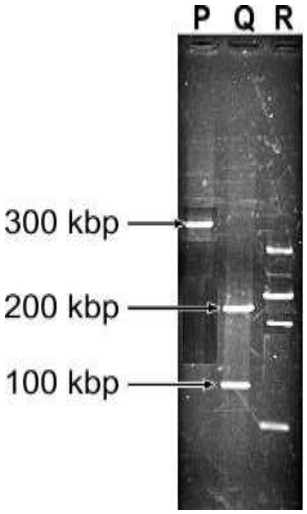
<table><tr><th>Step</th><th>Anita</th><th>Dipti</th></tr><tr><td>1</td><td>used a restriction enzyme to obtain gene of interest</td><td>used a restriction enzyme to obtain gene of interest</td></tr><tr><td>2</td><td>made multiple copies of the gene of interest using PCR</td><td>ligated the gene of interest with a cloning vector</td></tr><tr><td>3</td><td>introduced the amplified genes in the cell</td><td>introduced the vector prepared in step 2 in the cell</td></tr></table>
Of these, whose experiment is more likely to succeed and why?</td><td>2</td></tr>
<tr><td>Q.31</td><td>Golden rice is a variety of rice that has been genetically modified to produce a compound called β-carotene, which gets converted to Vitamin A when metabolised in the human body. This was done by introducing the genes coding for three enzymes - 'psy' and 'LCYB' from daffodil and 'crtI' from the soil bacterium Erwinia uredovora.

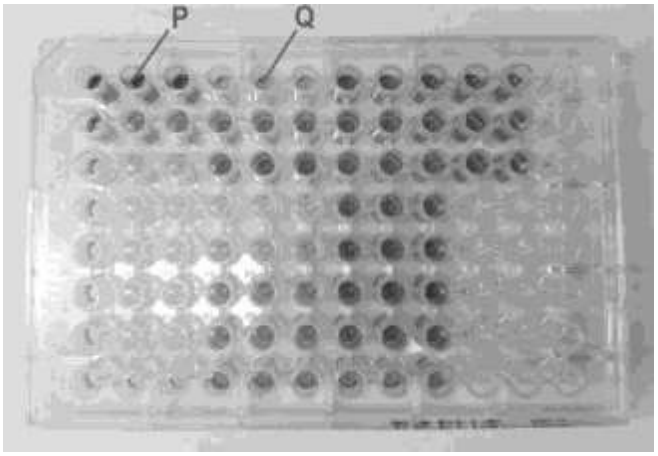
(a) With the help of a diagram, describe the process by which golden rice can be made.

(b) Name the vector used in the process.

(c) Give a reason why the vector identified in (b) should be used.</td><td>5</td></tr>
<tr><td>Q.32</td><td>Karan wanted to cut a DNA fragment which was 800 base-pairs long from a vector. He followed each step of the protocol correctly and ran the resultant sample on an agarose gel. In an earlier attempt in extracting DNA from onion cells, he had seen DNA form a thread like precipitate in ethanol. Given below is an image of the gel after he finished running his sample in it.</td><td>2</td></tr>
</table>

	 (a) Why does he not see the same thread like precipitate in the gel? (b) How can he ensure he has obtained the desired result?	
Q.33	Papaya is a widely cultivated crop in several regions. However, its production was limited by papaya ringspot disease which is caused by the Papaya ringspot virus (PRSV). Papaya plants infected by PRSV show symptoms of yellowing, discolouration of leaves and 'ringspots' on the fruit. PRSV belongs to the genus Potyvirus which has a single-stranded RNA as its genetic material. (a) Explain the step-by-step process to inhibit the viral RNA from surviving in the papaya plants thus creating disease-resistance varieties of papaya. (b) Name the biotechnological process described in (a) and give a reason why it is the appropriate process to be used in this case.	5
Q.34	Growth hormone injection treatment is prescribed for children who have been diagnosed with growth hormone (GH) deficiency and other conditions causing short stature and insufficient growth. This hormone is produced by the pituitary gland in humans so the gene for this hormone was isolated from the pituitary gland and introduced into phGH407 vectors for production. However, a problem with this was that the protein so produced was 26 amino acids longer than the active growth hormone (24 amino acids long) and so this method could not be used. (a) Given that the amino acid sequence of the active growth hormone was known, use a diagram to explain how human growth hormone could be produced outside the body. (b) The vector consists of a lac gene which codes for the enzyme β-galactosidase. Describe how this gene can help with the selection of colonies containing the transgene.	5
Q.35	Given below is the step-by-step process in the formation of yoghurt (curd) in a bioreactor.	3

	 (a) Why does the pH start decreasing a while after the mixture is incubated at 37-44 °C? (b) From the flowchart, identify two systems that the bioreactor would have. Give a reason to support your answer.	
Q.36	Nidhi performed gel electrophoresis after treating one vector with restriction enzymes. She added one mixture in well Q and another mixture in well R. Given below is an image of the results.  (a) What can be concluded about the mixtures loaded in wells P and Q? (b) What is the likely reason that the fragments in wells Q and R are different?	2
Q.37	ELISA is a test used for early detection of an infection.	3

	What components of a disease can be detected using ELISA? Describe the components that can be checked if one wants to identify whether an individual is allergic to pollen or not. Given below is an image of an ELISA test result with two of its cells marked P and Q. A coloured cell indicates a positive result whereas an uncoloured cell is a negative result.  (c) The colour of P is darker than the colour of Q. What could this possibly indicate?	
Q.38	Explain why vectors that have restriction site/s within a marker gene are preferred, for recombinant DNA technology.	2

Answer Key & Marking Scheme

Q.No	Answers	Marks
Q.3	C. Both A and R are true and R is the correct explanation of A.	1
Q.4	C. R --> P --> Q --> S	1
Q.5	D. all - lysozyme, ethanol, ribonuclease, cellulase, protease	1
Q.6	C. C	1
Q.7	B. step 3	1
Q.8	D. (They will not form any colonies.)	1
Q.9	C. replication	1
Q.10	C. maintains sterility	1
Q.11	B. only P and R	1
Q.12	B. prophase 1 in meiosis	1
Q.13	C. A is true, but R is false.	1
Q.14	A. Both A and R are true, and R is the correct explanation for A.	1
Q.15	A. only P	1
Q.16	(a) 0.5 marks for each of the following: - Name of the enzyme: BamHI - The convention used to name a restriction enzyme is the first letter comes from the genus (Bacillus) and next two letters from the species (amyloliquefaciens). - The fourth letter refers to the strain (strain H). - The roman number in the end indicating the order in which the enzyme was isolated from the strain (first enzyme). (b) 5'-G G A T C C-3' 3'-C C T A G-5'	3
Q.17	(a) 0.5 marks each for the correct name and its definition:	3

	- biopiracy - refers to the use of bio-resources by multinational companies and other organisations without proper authorisation from the countries and people concerned without compensatory payment. (b) 0.5 marks each for the following: - authorisation - compensation (c) 0.5 marks each for any two correct points such as: - Benefits of bio-resources should be shared between developed and developing countries. - Implementing laws for issues such as patent terms emergency provisions and research and development initiative. [Marks to be awarded for any other correct answer]	
Q.18	(a) Animals that have had their DNA manipulated to possess and express an extra (foreign) gene are transgenic animals. (b) Since embryonic stem cells are undifferentiated, they have the capability of forming all other cells of the body with their specialised functions and the inserted foreign gene.	2
Q.19	(a) GEAC (Genetic Engineering Approval Committee) OR GEAC (Genetic Engineering Appraisal Committee) [No marks to be awarded if the full form is not mentioned] (b) 0.5 marks each for the following: - Provide decisions regarding the validity of GM research. - Ensure the safety of introducing GM-organisms for public services [Accept any other valid point]	2
Q.20	(a) The marker acts as reference to identify the size of the fragments that are visible on the gel. (b) 0.5 marks each for identification and justification: - Sample C belonged to David. - David followed the procedure properly and so can see two correct bands (200 bp of the fragment and 450 bp of the remaining vector). - Sample B belonged to Kavya	3

	- Since enzyme B does not cut the vector, it remained intact when run on the gel.	
Q.21	(a) Anaerobic organisms Reason - since the aerator ensures supply of oxygen for aerobic organisms to respire and function, anaerobic organisms will not need this to carry out life processes. (b) Q - stirrer/agitator Purpose - The stirrer facilitates even mixing and oxygen availability throughout the bio-reactor. (c) to maintain temperature throughout the process	3
Q.22	(a) Bt toxins exists as inactive protoxins when produced by the plant and become active only when they are ingested by insects. (b) 0.5 marks for each of the following points: - A plant/part of plant producing bt toxins is ingested by an insect. - The inactive protoxin form of the bt toxin gets converted into an active form of toxin due to the alkaline pH of the gut which solubilises the crystals. - The activated toxin binds to the surface of midgut epithelial cells and create pores. - These pores cause cell swelling and lysis and eventually cause death of the insect.	3
Q.23	(a) 0.5 marks for each of the following components along with their purpose: - a cloning site with the cryIAb gene inserted in it to produce the toxin - a selectable marker such as an antibiotic resistance gene for selection of colonies with the recombinant plasmid - an origin of replication so that the plasmid can replicate and make copies [no marks to be awarded for component if purpose is not mentioned] (b) Ti plasmid from Agrobacterium tumifaciens	2
Q.24	- True [1 mark] - Justification: Since dsRNA is double stranded, it cannot automatically bind to the mRNA. So the two strands must be separated so that a single stranded RNA is obtained which can bind to the single stranded mRNA, silencing it. [1 mark]	2
Q.25	1 mark each for the following: - Insulin is a protein hormone.	2

	- If taken orally, they will get digested by pepsin and trypsin in the stomach and small intestine into their simpler forms, thereby losing their function.	
Q.26	(a) ADA is caused due to the deletion of the gene coding for adenosine deaminase. (b) 0.5 marks each for the following methods: - bone marrow transplantation - enzyme replacement therapy - gene therapy (c) 0.5 marks for each of the following: Problem - all three methods are not completely curative. Way to overcome - introducing the gene coding for ADA from marrow cells into early embryonic cells could permanently cure the disorder.	3
Q.27	(a) 1 mark for any one correct reason such as: - Industrial production is expensive when compared to production through transgenic animals. - The components produced by transgenic animals have the possibility of being as close to the natural product as possible. (b) Transgenic animals are made that carry genes which make them more sensitive to toxic substances than non-transgenic animals allowing for results in lesser time.	2
Q.28	(a) 1 mark each for the following points: - Creating a Ti plasmid which have the sense and anti-sense RNA, the latter complimentary to the mRNA coding for the enzyme. - Introducing these plasmids into the host plant. - The sense and anti-sense RNA would combine to form a dsRNA - The two strands split and the anti-sense RNA binds to the mRNA coding for the enzyme causing the black discolouration, silencing it. (b) RNA interference (RNAi)	5
Q.29	(a) Traditional hybridisation procedures very often lead to inclusion and multiplication of undesirable genes along with the desired genes. (b) Using rDNA technology, only the desired gene can be introduced into an organism without introducing other undesirable gene.	2
Q.30	- Dipti's experiment is more likely to succeed. [1 mark]	2

	- Since Anita introduce her gene as it is, it did not have an origin of replication to replicate on its own and would get degenerated over time. [1 mark]	
Q.31	(a) Correct illustration of the process - drawing 3 genes of interest from 2 sources, inserting them into a plasmid cut with the same restriction enzyme, introducing the plasmid into rice embryos/cells [2 marks] - Step by step description of the process with correct terminology [2 marks] (b) Ti plasmid (c) Ti plasmid can replicate well in the plant genome/Its genes can be expressed in the environment of the plant genome.	5
Q.32	(a) When DNA is extracted from several cells, it is much bigger in size than 800 base-pairs and is present in a larger volume and so can be seen with the naked eye. [Accept any other valid answer] (b) When stained with ethidium bromide and kept under UV light, the agarose gel should show a band of DNA corresponding to 800 base-pairs on the marker.	2
Q.33	(a) 0.5 marks each for the following: - The viral RNA is isolated and converted to a dsDNA structure. - The dsDNA so formed is inserted into an appropriate vector (Agrobacterium or viral vector). - The vectors are then introduced into the host plant where it transcribes the mRNA for this gene. - Whenever the virus infects the plant and injects its RNA into the host plant, the host plant transcribes the viral RNA. - The mRNA produced from the vector binds to the transcribed viral RNA. - This prevents the viral RNA from being transcribed and therefore survives in the host plant without infecting the plant. (b) 1 mark each for the following: - RNAi or RNA interference - RNAi helps in in-vitro silencing of a gene/set of genes so that they lose their function.	5
Q.34	(a) 1 mark each for each of the following step explained in a diagram: - From the amino acid sequence, the gene for growth hormone needs to be synthesized chemically. - The gene of interest is cut using a restriction enzyme and the same restriction enzyme is used to cut the vector within the lac gene.	5

	- The gene obtained is inserted into the vector using a ligase. - These are transformed into E.coli cells/host cells for production. (b) 0.5 marks each for the following: - In recombinants, since the lac gene is inactivated, after insertion of the gene of interest, it does not produce the β-galactosidase enzyme which results in colourless colonies when a chromogenic substrate is added. - In non-recombinants, since the lac gene is still active, it produced the enzyme β-galactosidase which results in blue colonies when a chromogenic substrate is added.	
Q.35	(a) 0.5 marks for each of the following: - As the bacteria starts to grow, it uses up the oxygen in the system. - After a while, the oxygen gets used up and anaerobic respiration begins which leads to the formation of lactic acid, causing a decrease in the pH. (b) 0.5 marks for identification and 0.5 marks for the reason for any TWO of the following: - Oxygen delivery system: After the starter culture is added, oxygen is also added which will need a delivery system. - Stirrer: Once oxygen is added, the system would need to be mixed thoroughly so that oxygen is available throughout the bioreactor. - Sterilization unit: Milk needs to be sterilised before addition of the starter culture to remove any other microorganisms already present in it. [Accept any other valid answer]	3
Q.36	(a) Well P contains the uncut vector whereas well Q contains the vector cut by a restriction enzyme. (b) The vector in well Q has been cut by a restriction enzyme that has two sites whereas the vector in well R has been cut either by different enzymes or by one enzyme that has more than two sites.	2
Q.37	Presence of antigen/antibodies to an antigen can be detected using ELISA. 0.5 marks for each of the following: antigen from pollen IgE antibodies (c) P may have more antigen/antibodies as compared to Q.	3
Q.38	1 mark each for the following: - When a target gene gets inserted into a marker gene which has a restriction site, it inactivates the production of the marker	2

	- The absence of a characteristic that was coded for by the marker is useful in the detection of cells with the recombinant vectors. [Accept any other valid answer]	

3. ECOSYSTEM

Q. No	Question	Marks
	Free Response Question / Subjective Question	
Q.39	State ONE quality that a pioneer species must have. How can the process of succession be interrupted?	2

Answer Key & Marking Scheme

Q. No	Answers	Marks
Q.39	(a) They should be able to derive energy and produce organic matter from inorganic and non-living substances. *[Accept any other valid answer]* (b) Succession can be interrupted in the event of disturbances such as fire that convert a seral stage to an earlier stage or even lead to the elimination of species. *[Accept any other valid answer]*	2

4. ENVIRONMENTAL ISSUES

Q. No	Question	Marks
	Free Response Question / Subjective Question	
Q.40	In a research paper titled "Ecological Risk of DDT - A Case Study of Biomagnification Causing Extinction Risk of Herring Gull in Long Island" (Nakamaru *et a*l, 2001), it was cited that use of DDT causes immense risks of extinction of a bird named Herring Gull. There are severe implications of this. (a) The Herring Gull is a top predator in the food pyramid of the area. How will its extinction impact the food chain? (b) State ONE reason how can bio-magnification cause extinction of birds like the Herring Gull?	2
Q.41	(a) Recycling of e-waste is one of the most popular methods of e-waste management in developing countries. It benefits a sizeable proportion of the population by providing employment in such countries. What can be one of the biggest disadvantages of these recycling efforts? (b) Incineration, as a process of e-waste management, can destroy organic constituents in e-waste. What is the main advantage of using incineration in a landfill?	2
Q.42	Impurities in domestic sewage account for 0.1% of the total waste water. Such impurities include: A: suspended solids like sand, silt and clay B: colloidal material like faecal matter, bacteria C: dissolved materials like nutrients (nitrates, ammonia, phosphate, sodium, calcium etc). As a project manager for treatment of domestic sewage in a town, Shivam thought of recycling of the sewage water into other processes in the area. (a) How can Shivam remove the suspended solids from the sewage water? (b) How can the colloidal impurities be used in any other process in the town? (c) If the domestic sewage is allowed to enter a pond or a lake without being treated, what can be ONE impact it has on the quality of water in the water body?	3

Answer Key & Marking Scheme

Q. No	Answers	Marks
Q.40	(a) 0.5 marks for each correct answer: - increase in other predators, carnivores and herbivores in the area - imbalance in availability of food (b) 1 mark each for mentioning any one of the following: - decrease in fertility - early breakage of egg shells - thinning of eggshells	2
Q.41	(a) exposes workers to hazardous and toxic substances during manual participation (b) reduces volume of the waste	2
Q.42	(a) 1 mark for any correct answer such as: - sedimentation - filtration (b) in agricultural fields as organic manure (c) 1 mark for mentioning any one of the following: - increase of BOD - eutrophication	3

5. HUMAN HEALTH AND DISEASE

Q. No	Question	Marks
	Multiple Choice Question	
Q.43	In addition to being a vector, the female *Anopheles* mosquito also acts as a host for the malarial parasite - *Plasmodium*. Choose the option that supports the role of the female *Anopheles* mosquito as a host. A. Liver cells serve as the site for the multiplication of *Plasmodium*. B. *Plasmodium* completes part of its lifecycle in the female *Anopheles*. C. The female *Anopheles* mosquito lays eggs in stagnant pools of water. D. The female *Anopheles* mosquito transmits *Plasmodium* to humans by biting.	1
Q.44	Immuno-suppressants are administered to patients post-organ transplantation and also to those suffering from auto-immune disorders. In which of the following ways are immuno-suppressants helpful? A. They trigger allergic response. B. They eliminate unhealthy tissues. C. They control the cell-mediated response. D. They differentiate between self and non-self parts of the body.	1
	Free Response Questions/Subjective Question	
Q.45	Drug abuse is a common problem faced by countries around the world today due to its impact on the health and well-being of an individual. (a) How is the cocaine consumed? What impact it has on the body? (b) Some drugs make an individual sleepy while some other make them hyper-energetic. Using appropriate examples, explain this statement. (c) Why does a regular drug abuser have withdrawal symptoms when consumption of the drug is suddenly stopped?	5

Answer Key & Marking Scheme

Q. No	Answers	Marks
Q.43	B.	1
Q.44	C. They control the cell-mediated response.	1
Q.45	(a) 1 mark each for the following: - Cocaine is usually consumed by snorting/smoking. - Both these actions involve the respiratory system and so cocaine consumption can interfere with the regular functioning of the respiratory tract. (b) 1 marks each for naming the correct drug as an example and 0.5 marks each for the explanation: - Heroin is a drug that acts as a depressant to the functioning of the nervous system and so it slows down bodily functions and makes an individual sleepy. - Cocaine is a drug that stimulates the nervous system thereby making an individual feel very energetic. *[Accept any other valid answer]* (c) 0.5 marks each for the following: - Using drugs chronically makes the body used to functioning in the presence of the drug. - Sudden removal of the drug from the body leads to the body asking for the drug through improper functioning or withdrawal symptoms.	5

6. HUMAN REPRODUCTION

Q. No	Question	Marks
	Free Response Question/ Subjective Question	
Q.46	Meiotic arrest is a phenomenon noticed during oogenesis in human females where oocytes are arrested in the primary oocyte stage. (a) What is the chromosomal count of these primary oocytes? (b) How are these primary oocytes converted to ovum?	3

Answer Key & Marking Scheme

Q. No	Answers	Marks
Q.46	(a) 46 (b) 0.5 marks for each step: - each primary oocyte is converted to primary follicle - primary follicles further develop to form secondary and tertiary follicles - the tertiary follicles are converted to secondary oocytes - initiated by the action of FSH at puberty	3

7. MICROBES IN HUMAN WELFARE

Q. No	Question	Marks
	Multiple Choice Question	
Q.47	A scientist measured the BOD (biochemical oxygen demand) of water from the following sources. kitchen tap sewer pipe Choose the correct statement. A. The BOD of sample P will be lesser than sample Q. B. The BOD of sample P will be greater than sample Q. C. The BOD of sample P will be equal to that of sample Q. D. The BOD of the two samples cannot be compared without additional data.	1

Answer Key & Marking Scheme

Q. No	Answers	Marks
Q.47	A. The BOD of sample P will be lesser than sample Q.	1

8. MOLECULAR BASIS OF INHERITANCE

Q. No	Question	Marks
	Multiple Choice Question	
Q.48	Which of the following occurs as a result of DNA replication being semi-conservative? A. Chromosome number becomes half in the gametes. B. Each chromosome has half DNA and half RNA. C. Parental characters are found in each chromosome. D. Each new DNA strand has half the number of nucleotides compared to the parent DNA strand"	1
Q.49	An organism has 6 X 109 bp in its DNA. Which of the following is likely to be closest in height to the length of its DNA molecule? - A wardrobe: 2 m - A tall tree: 20 m - An A4 sheet: 20 cm - A eukaryotic nucleus: 10-10 m A. A wardrobe B. A tall tree C. An A4 sheet D. A eukaryotic nucleus	1
Q.50	Which of the following is true about the structure of DNA and RNA? P) The nitrogenous base is devoid of an OH group in DNA. Q) The nitrogenous base of RNA gains the OH group lost by DNA. R) The pentose sugar in RNA combines with an extra OH group. S) The pentose sugar in DNA loses an OH group to form deoxyribose. A. only P B. only S C. only R and S D. only P and Q	1
Q.51	Keratin is a common protein found in the human body with its gene on chromosome no. 12. Centromeres are constricted regions on the chromosome that help during cell division. In which of the following regions will the keratin gene and centromere be found?	1

	<table><tr><td>Option</td><td>Keratin</td><td>Centromere</td></tr><tr><td>P</td><td>euchromatin</td><td>euchromatin</td></tr><tr><td>Q</td><td>heterochromatin</td><td>heterochromatin</td></tr><tr><td>R</td><td>euchromatin</td><td>heterochromatin</td></tr><tr><td>S</td><td>heterochromatin</td><td>euchromatin</td></tr></table> A. P B. Q C. R D. S	
Q.52	In Griffith's experiment, when he injected a mixture of heat-killed S strain (virulent) and live R bacteria (non-virulent), the mice died. What type of colony/ies would he observe when the bacteria from the dead mice would be plated on a culture medium? A. Only rough colonies would be observed. B. Only smooth colonies would be observed. C. Both rough and smooth colonies would be seen. D. Each colony would have a mix of both rough and smooth textures.	1
Q.53	Given below are some statements about DNA replication. DNA replication is semiconservative. One of the DNA strands is replicated in a discontinuous fashion. Each strand of parental DNA acts as a template for the new strand. DNA replication shows a low level of accuracy. Based on the statements, pick the correct option. A. P and S are true and S is the reason for P B. P and Q are true and Q is the reason for P C. P and R are true and R is the reason for P D. S and Q are true and Q is the reason for S	1
Q54	Two statements are given below - one is an Assertion (A) and the other is a Reason (R). Assertion (A): DNA-dependent RNA polymerase catalyses polymerisation in the 5' to 3' direction. Reason (R): The strand with 5' to 3' polarity is called the coding strand. Which of the following is correct? A. Both A and R are true, and R is the correct explanation for A. B. Both A and R are true, but R is not the correct explanation for A. C. A is true, but R is false.	1

	D. A is false, but R is true.	
Q.55	Which of the following statement/s are correct example/s of the degenerate feature of the genetic code? UAA and UAG act as terminator codons. CUA codes for leucine in bacteria as well as humans. Valine is coded for by GUU and GUC. A. only Q B. only R C. only P and Q D. only P and R	1
Free Response Question/ Subjective Question		
Q.56	A DNA molecule is much longer than the length of nucleus of a cell. Describe the organization of DNA inside a nucleus.	2
Q.57	One strand of a DNA segment is made up of repeats of adenine and cytosine - 5' ACACACAC 3' Explain the formation of a dinucleotide (AC) and its base pair from nitrogenous bases.	5
Q.58	State TWO points of similarity between the process of replication and transcription in humans. Describe the fate of the products of replication and transcription with respect to the following: location of the product/s lifespan of the product/s In which phase/s of the cell cycle do these processes occur?	5
Q.59	Why is the enzyme ligase not required in DNA amplification using PCR? What will happen if DNA polymerase is used in PCR? Give a reason to support your answer. State one advantage of PCR over DNA replication. For any given sequence of nucleotides, DNA replication is faster than PCR. Justify.	5
Q.60	A DNA sequence consists of 35% cytosine nucleotides. What would be the percentage of adenine nucleotides in the same DNA sequence? Justify your answer.	2

Q.61	Although DNA replication by polymerases is an energetically expensive process, it still proves to be an efficient process. Justify the statement.	3
Q.62	What are the four properties needed in a molecule to function as genetic material? Compare these parameters between the DNA and RNA.	4
Q.63	Justify: RNA polymerase cannot transcribe a gene by itself. The terminator sequence can be used to define the template strand.	2
Q.64	Given below is a DNA sequence. 5' - TAACGATCGTACATGGAT - 3' Identify the mRNA sequence that is transcribed from this DNA sequence. Can this sequence be translated? Give a reason to support your answer. [Note: Assume no post-transcriptional and post-translational modifications will take place.]	3
Q.65	What does a translational unit comprise? If a codon CGA that codes for arginine is present on the mRNA after codon AUG, describe how the translation process will be done step-wise.	3
Q.66	The expressions of genes are regulated by metabolic, physiological and environmental factors/conditions. With the help of TWO examples, justify this statement in the case of eukaryotes.	2

Answer Key & Marking Scheme

Q. No	Answers	Marks
Q.48	C. Parental characters are found in each chromosome.	1
Q.49	A. A wardrobe	1
Q.50	B. only S	1
Q.51	C. R	1
Q.52	C. Both rough and smooth colonies would be seen.	1
Q.53	C. P and R are true and R is the reason for P	1
Q.54	B. Both A and R are true, but R is not the correct explanation for A.	1
Q.55	B. only R	1
Q.56	0.5 marks each for the following: - Positively charged basic histone proteins combine to form a unit of 8 molecules called the histone cluster. - DNA is wrapped around the histone cluster to form a nucleosome. - Many such nucleosomes repeat to form a bead-in-a-string structure called the chromatin which are thread like bodies. - The chromatin is further packaged with the help of non-histone chromosomal proteins to fit into the nucleus. [Key words mandatory in the complete answer are highlighted]	2
Q.57	1 mark for each correct step such as: - A nitrogenous base is linked to the OH of 1' C pentose sugar through a N-glycosidic linkage to form adenosine and cytidine nucleosides. - Next, a phosphate group is linked to OH of 5' C of a nucleoside through a phosphoester linkage, forming adenine and cytosine nucleotides. - The 3'C of adenine links to the 5'C of cytosine to form a 3'-5' phosphodiester linkage to form a dinucleotide. - In a similar manner, a dinucleotide is formed between thymine and guanine. - Finally, adenine forms two hydrogen bonds with thymine and cytosine forms three hydrogen bonds with guanine to form the dinucleotide base pairs.	5

Q.58	1 mark each for the following: Both processes involve the copying of a DNA molecule. Both processes take place in the nucleus of the cell. [Accept any other valid answer.] 1 mark each for the following: location: DNA strands formed after replication continue to stay in the nucleus whereas mRNA formed after transcription moves/is exported to the cytoplasm. lifespan: DNA strands formed after replication continue to remain in the nucleus as long as the cell is living whereas mRNA is degraded after translation. (c) 0.5 marks each for the following: DNA replication: S phase DNA transcription: throughout the cell cycle	5
Q.59	Since no Okazaki fragments are formed in PCR amplification, ligase is not required in the process. 1 mark each for the following: In PCR, heat is used to denature/separate the dsDNA. DNA polymerase cannot withstand this high temperature and will denature. PCR can be used to amplify any sequence of nucleotides - RNA or DNA whereas DNA replication is only for DNA sequences. PCR can be used to amplify just one gene as well unlike DNA replication which involves duplication of the entire genome. [Accept any other valid answer] For a given sequence, DNA replication is much faster as all three steps (denaturation, annealing and replication) happen simultaneously whereas in PCR it happens one by one which takes longer. [Accept any other valid answer]	5

Q.60	A possible complete answer: According to Chargaff's rule, If, C = 35%, then G = 35% If C and G make up 70% of the sequence then A and T will make up 30% So, A = T = 15% [0.5 marks for mentioning the rule 0.5 marks for calculating the percentage of guanine nucleotides 0.5 marks for calculating the percentage of A + T nucleotides 0.5 marks for finding the percentage of adenine nucleotides]	2
Q.61	1 mark for each correct point: It is considered efficient because they catalyse polymerisation of a large number of nucleotides in a very short time. They are highly accurate to avoid mutations. Even though the process needs a lot of energy the deoxyribose triphosphates act both as substrate and energy providers for the reaction as the two terminal phosphates are high-energy phosphates.	3
Q.62	(a) 0.5 marks for each of the following: can replicate should be stable allow for slow mutations ability to express itself (b) 0.5 marks for each comparison: Both, DNA and RNA can replicate. RNA is unstable when compared to DNA, due to the presence of the 2'-OH group at every nucleotide which makes it easily degradable. Both, DNA and RNA can mutate. Both can express themselves - RNA can do it directly by forming proteins whereas DNA can do it by forming an RNA first. [Award marks even if only the comparison between RNA and DNA is mentioned]	4
Q.63	RNA polymerase is only capable of catalysing the process of elongation. It associates transiently with the initiation factor and the termination factor to initiate and terminate the transcription, respectively.	2

	The terminator sequence is located at the 3' end of the coding strand and can help identify the coding strand, the opposite of which is the template strand.	
Q.64	(a) 1 mark each for the following: - Identify the complementary strand 3' - ATTGCTAGCATGTACCTA - 5' - Find the mRNA sequence: UAA CGA UCG UAC AUG GAU [Marks to be awarded if only the mRNA sequence is mentioned] (b) 0.5 marks each for the following: No The first codon of this sequence codes for a stop codon.	3
Q.65	A translation unit is the sequence of mRNA that codes for an amino acid sequence (polypeptide) with a start codon on one end and a stop codon on the other. [1 mark for mentioning all three parts. No marks are to be awarded for missing any of the parts of a unit] 0.5 marks for each step: Charging of tRNA: Arginine is charged in the presence of ATP and linked to its specific tRNA molecule. The small subunit encounters the mRNA. The large subunit, which has two sites for tRNAs to bind, which have the initiator tRNA and the arginine tRNA bound to it. Here, methionine and arginine form a peptide bond with each other in the presence of a catalyst before the ribosome moves ahead.	3
Q.66	1 mark each for the following: Glucose in the body is used by cells to produce energy, which causes glucose levels in the blood to reduce and signal the pancreas to produce less insulin, thereby reducing the transcription and translation of genes coding for insulin. The presence of mutagens in the environment impacts the expression of genes related to growth such that excessive uncontrolled growth begins in some cells, leading to cancer. [Accept any other valid answer]	2

9. ORGANISMS AND POPULATION

Q. No	Question	Marks
	Multiple Choice Question	
Q.67	The larvae of insects such as the African midge inhabit temporary pools in hollows of rocks when water evaporates in their arid environment. These larvae revive when immersed in water even after a few years. Which response to abiotic stress does the statement depict? A. regulation B. migration C. suspension D. conformation	1
Q.68	Trees in some regions have very thin barks, broad leaves placed at different angles to allow them to capture adequate sunlight and leaves with pointed tips that allow water to run off easily. In which biome are such trees likely to be found? A. arctic B. desert C. coastal D. rainforests	1

Answer Key & Marking Scheme

Q. No	Answers	Marks
Q.67	C. suspension	1
Q.68	D. rainforests	1

10. PRINCIPLES OF INHERITANCE AND VARIATION

<table>
<tr><th>Q. No</th><th>Question</th><th>Marks</th></tr>
<tr><td colspan="3">Multiple Choice Question</td></tr>
<tr><td>Q.69</td><td>In mice, brown fur is dominant and white fur is recessive. A biologist crossed a brown fur male with a white fur female and obtained two brown fur and two white fur offspring. Which of the following statements is MOST likely to be true?

A. Both parents are heterozygous.
B. Only the male parent is homozygous.
C. Only the male parent is heterozygous.
D. Only the female parent is heterozygous.</td><td>1</td></tr>
<tr><td>Q.70</td><td>In which of the following process would genetic variation occur?

P) mutation in liver cells

Q) development of a zygote to an embryo

R) gene flow from one population to another

A. only P
B. only Q
C. only P and Q
D. only P and R</td><td>1</td></tr>
<tr><td>Q.71</td><td>Which of the following was a reason that Mendel's experiments showed reproducible results?

use of mathematical logic

use of large sample sizes

use of true breeding parental lines

use of pea plants that had a quick growth time

Kernel colour in wheat ranges from dark red to white depending on the number of dominant alleles in the genotype of the plant as shown below.

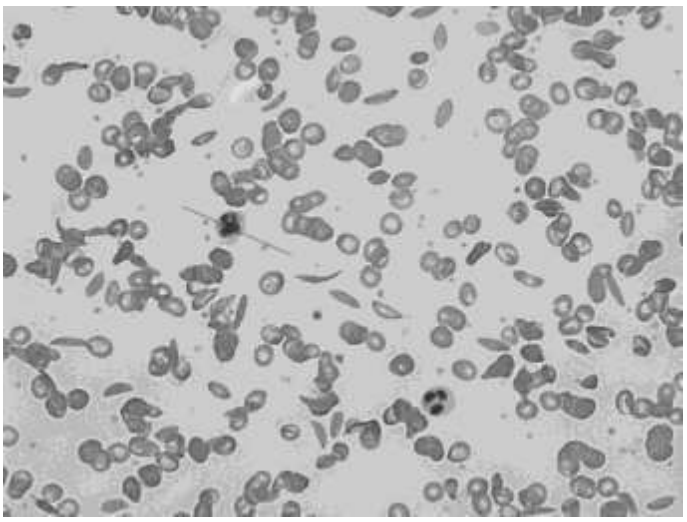
<table><tr><th>kernel colour</th><th>no. of dominant alleles</th></tr><tr><td>dark red</td><td>4</td></tr><tr><td>medium red</td><td>3</td></tr><tr><td>intermediate red</td><td>2</td></tr><tr><td>light red</td><td>1</td></tr><tr><td>white</td><td>0</td></tr></table></td><td>1</td></tr>
</table>

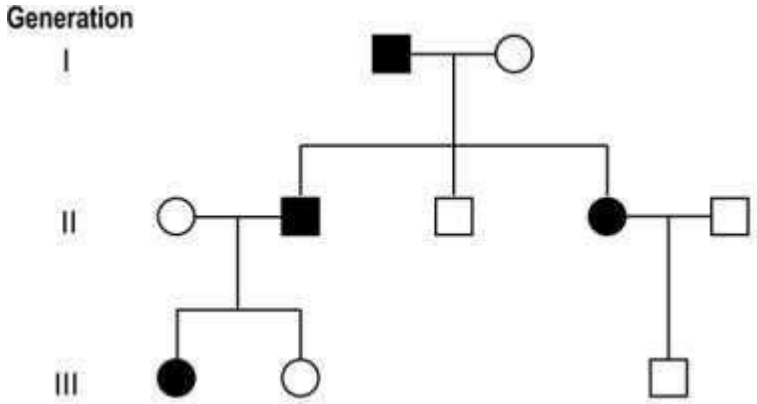
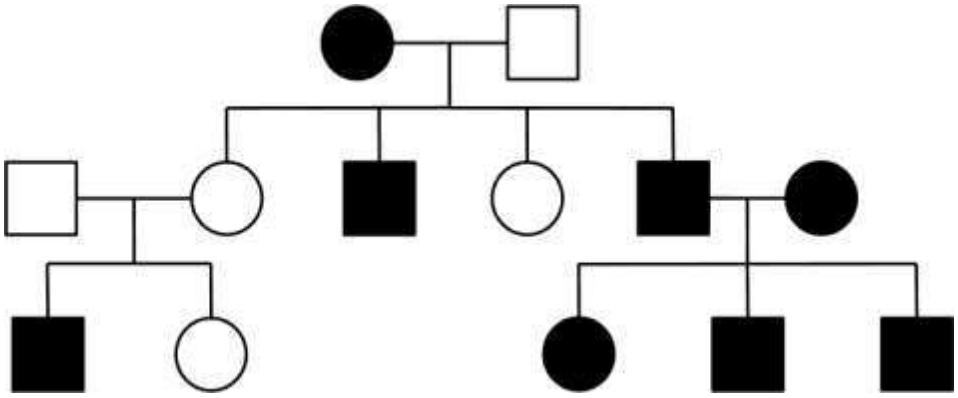
	Assuming that a cross is performed between a homozygous dominant male and a homozygous recessive female, answer the questions that follow. Answer the Questions from Q72-Q75.	
Q.72	What will be the kernel colour of offspring in the F1 generation? A. white B. dark red C. medium red D. intermediate red	1
Q.73	How many genes code for kernel colour in wheat? A. 1 B. 2 C. 4 D. (Cannot say from the information provided)	1
Q.74	What would be the ratio of kernel colours in the F2 generation? A. 1:2:1 B. 9:3:3:1 C. 1:4:6:4:1 D. 1:6:15:20:15:6:1	1
Q.75	Which of the following phenomenon is/are exhibited by alleles coding for kernel colour in wheat? P) co-dominance Q) incomplete dominance R) polygenic inheritance A. only P B. only R C. only P and R D. only Q and R	1
Q.76	In a cross between pea plants having round green seeds (RRGG) and wrinkled yellow seeds (rrgg), what percentage of eggs will carry both the round and green alleles for the F2 generation? A. 9% B. 93% C. 64% D. D. 25%	1
Q.77	Which of the following processes helped scientists corroborate Mendel's findings much after he had discovered them?	1

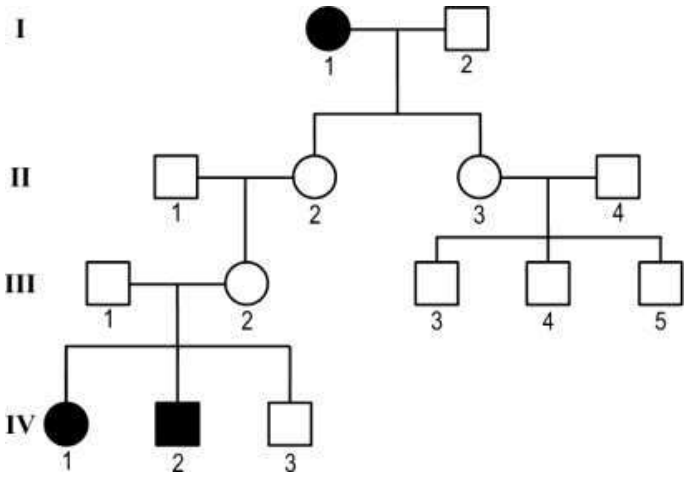
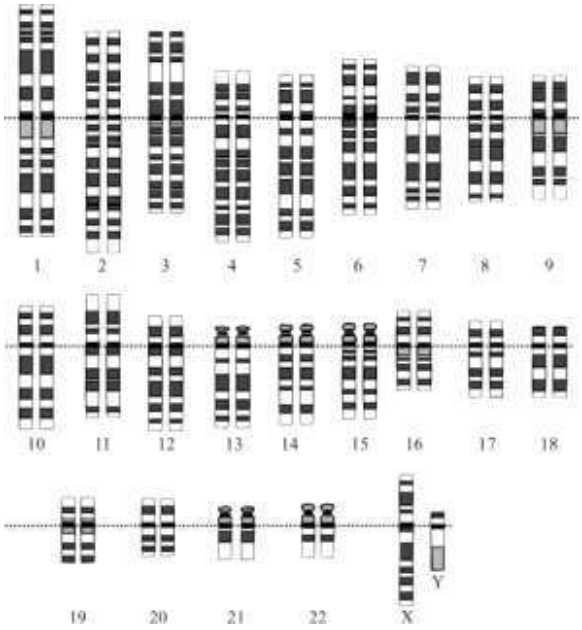
	A. recombinant DNA technology B. DNA transcription C. DNA replication D. cell division	
Q.78	Marfan syndrome is a connective tissue disorder in humans caused due to the mutation of the FBN1 gene coding for fibrillin-1. Some symptoms of this disease are abnormally long limbs, heart murmurs, and extreme nearsightedness. Marfan syndrome is an example of . A. a chromosomal disorder B. polygenic inheritance C. codominance D. pleiotropy	1
Free Response Question/ Subjective Question		
Q.79	Mendel crossed a pea plant having inflated pods with another pea plant having constricted pods. Both parents were pure-lines. Next, he crossed the progeny obtained in the F1 generation. (a) Depict the cross and observations using a Punnett square. (b) How did his findings lead to the inference of the law of segregation? (c) State two findings that Mendel would have made if there was no segregation.	5
Q.80	State two ways in which sex determination in humans is different from that in honeybees.	2
Q.81	The pea plant is a self-pollinating plant. (a) Why was this fact about the pea plant a concern in Mendel's experiments? (b) How did Mendel ensure that self-pollination was avoided in his experiments?	2
Q.82	The stem colour of a plant is characterised by a green (G) dominant allele and a yellow (g) recessive allele. (a) What would be the genotype/s of a plant with a green phenotype of the stem colour? (b) Using an illustration, explain how we can ascertain the correct genotype of the plant mentioned in (a). (c) Name and define the process followed in (b).	5

Q.83	In the process of sperm formation, a cell called the spermatogonium undergoes mitosis first to form the primary spermatocyte, which then undergoes meiosis to form the spermatozoa or the sperm cell. What percentages of the primary spermatocyte and the spermatozoa would have the X chromosome? Justify your answer.	2
Q.84	(a) What is the mode of inheritance of traits causing haemophilia? (b) What would be the possibility of a female and male child having haemophilia in the following scenarios? (i) the mother is a unaffected and the father is affected (ii) the mother is a carrier and the father is unaffected	3
Q.85	(a) State two points of difference between aneuploidy and polyploidy. (b) Failure in which phase of cell division can cause the conditions mentioned in (a)?	3
Q.86	In pea plants, inflated (A) and green (B) pods with round (C) seeds and the male with constricted (a) and yellow (b) pods with wrinkled (c) seeds. Mendel performed a cross to study the inheritance of these three traits. He performed a cross between two parents that were heterozygous for all the traits. Identify the: (a) Genotype of the gametes. (b) Number of offspring in the F1 generation. Give a reason to support your answer. (c) Number of offspring who are homozygous for all traits. State their phenotype.	5
Q.87	A colour-blind father will not have a colour-blind son. State if the above statement is true and justify your answer if the mother is homozygous for the: (a) colour blind trait (b) normal vision trait	2
Q.88	Rett syndrome is a rare X-linked dominant genetic neurological and developmental disorder that affects the way the brain develops. What would be the occurrence of the disease in their daughter and son, if: (a) a normal male marries a female with Rett syndrome (b) a normal female marries a male with Rett syndrome	2

Q.89	State TWO points of difference and TWO points of similarity between Klinefelter's syndrome and Turner's syndrome.	2
Q.90	Using a Punnett square, determine the genotype of the parents if their child can have any of the four blood groups.	2
Q.91	Duchenne muscular dystrophy is an X-linked recessive genetic disease that is also caused by mutations in the DMD gene. Predict the genotypic and phenotypic ratios of the possible offspring of a male with muscular dystrophy and a female who is a carrier using suitable symbols for the alleles in a Punnett grid.	3
Q.92	A gardener has been planting white flowers that grow on the terminal ends of the plant in a garden for several months. One day, a purple flower along the terminal end of the plant grows. The gardener wants to know if these flowers would give rise only to purple terminal flowers if pollinated. She knows that purple axial alleles are recessive over white terminal ones. (a) What are the possible genotypes of the new purple flower that sprouted? (b) If she wants to use only one generation to determine its genotype, what should she do? (c) With the help of a Punnett grid/s, help her make inferences to arrive to the conclusion she desires.	5
Q.93	Sickle cell anemia (allele a) is a disorder where the RBCs stretch out and become thin as opposed to the round normal (allele A) RBCs. A person who is homozygous for normal RBCs marries a person who is heterozygous for sickle cell RBCs. What is the probability of the off-springs to be homozygous for the sickle cell trait? Blood from one of the off-springs was checked and the microscopic image of its RBCs is shown below.	3

	 What is the genotype of this individual? (c) Based on the image shown, explain the type of dominance exhibited by the sickle cell allele?	
Q.94	Mia's family consists of her grandparents, brother, sister and parents. Her parents are the only off-springs of her paternal and maternal grandparents. She is the only one in her family who has thalassemia. Of her 4 grandparents, her maternal grandmother had thalassemia. Describe the method she can use to analyse the inheritance of thalassemia in her family. Draw an illustration to show the pattern of inheritance. What is the mode of inheritance? Justify your answer.	5
Q.95	A roan cattle is an animal that has both red (R) and white (R') hair on its coat. Consider that two cows - one pure line for white hair and one pure line for red hair are crossed. What would be the genotype and phenotype of the F1 and F2 generations? What kind of dominance does the gene for hair colour exhibit? Give a reason to support your answer.	3
Q.96	State THREE advantages of using Drosophila as the model organism for studying genetics as compared to Mendel's pea plant.	3
Q.97	Given below is a pedigree chart for an autosomal dominant disorder characterised by trait 'A'.	2

	 What evidence in the pedigree chart helps establish that the condition is caused by a dominant allele? What are the genotypes of the affected and unaffected individuals?	3
Q.98	Given below is the pedigree of a family for a trait.  Identify the mode of inheritance of the trait. Give a reason(s) to support your answer. Choose the correct answer to complete the following sentence: Colour blindness is a sex-linked condition. However, a (heterozygous/homozygous) (male/female) will always have normal vision.	3
Q.99	Cystic fibrosis is a condition in which a defective cf gene (consider allele c) produces faulty transport channels that causes mucus to build up in the ducts of different organs leading to vitamin deficiency diseases, respiratory infections and excessive loss of salt through sweat. Given below is a pedigree chart for a family. The great-grandmother, represented as I- 1, suffers from cystic fibrosis.	3

	 Identify the type of expression of the cystic fibrosis gene. Give a reason to support your answer. From the pedigree, deduce the pattern of inheritance exhibited by the gene. Justify your answer. Identify the genotypes of II-2 and III-2.	
Q.100	Given below is the karyotype of an individual.  What are the characteristic reproductive and physical features of such an individual? What is the category of such disorders called? How is it caused?	2

Answer Key & Marking Scheme

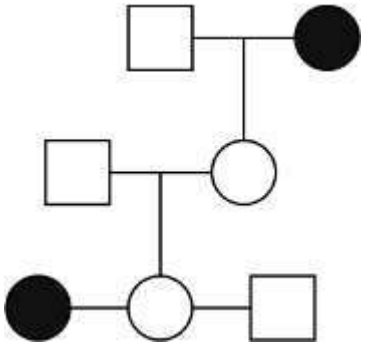
Q. No	Answers	Marks
Q.69	C. Only the male parent is heterozygous.	1
Q.70	D. only P and R	1
Q.71	C. use of true breeding parental lines	1
Q.72	D. intermediate red	1
Q.73	B. 2	1
Q.74	C. 1:4:6:4:1	1
Q.75	B. only R	1
Q.76	D. 25%	1
Q.77	D. cell division	1
Q.78	D. pleiotropy	1
Q.79	(a) Draws correct Punnett squares for F1 and F2 offsprings with the correct signs and ratios (b) Since the recessive parental trait is expressed without any blending in the F2 generation, the alleles from the parental pair separate or segregate from each other and only one allele is transmitted to the offspring. (c) 1 mark each for the following: - He would have arrived at a 1:1 ratio in the F1 generation - A trait would not disappear in F1 and reappear in F2.	5
Q.80	1 mark each for any two differences such as: - Sex determination in humans is of the XY type i.e the male has 2 different sex chromosomes (X and Y) and females have 2 copies of X chromosome whereas it is of the haplodiploid type in bees i.e, females are diploid and males are haploid (only one set of chromosomes) - Males in bees are produced by parthenogenesis and females by fertilization, whereas both male and female offspring in humans are produced by fertilization. - Sperm production by mitosis in bees and by meiosis in humans.	2

	[Accept any other point of difference]	
Q.81	(a) In Mendel's experiment, self-pollination would have led to unknown and undesirable results as the experiment would not have been controlled. (b) by the removal of stamen or anther from the flower bud	2
Q.82	(a) 0.5 marks each for the following: - GG (homozygous) - Gg (heterozygous) (b) Punnett square for GG x gg with the correct result and interpretation [1.5 marks] Punnett square for Gg x gg with the correct result and interpretation [1.5 marks] (c) 0.5 marks each for the following: - test cross - A genetic cross between a homozygous recessive parent and a parent with unknown genotype to determine the genotype of the latter.	5
Q.83	100% of primary spermatocyte will have the X chromosome whereas 50% of the sperm cells will have the X chromosome. Since the spermatogonium undergoes mitosis the number of chromosomes remains the same in the daughter cell i.e all cells get all the chromosomes whereas when the primary spermatocyte undergoes meiosis, where the number of chromosomes divide, only half the cells get the X chromosome.	2
Q.84	(a) X-linked recessive transmission (b) 0.5 marks for each of the following: (i) male child: all will be unaffected female child: all will be carriers (ii) male child: half will be affected and half will be unaffected female child: half will be carriers and half will be unaffected	3
Q.85	(a) 1 mark each for the following: - Aneuploidy is the loss or gain of an extra chromosome whereas polyploidy is the gain of an entire chromosome set(s). - Aneuploidy is common in humans whereas polyploidy is common in plants. [Accept any other valid point of difference] (b) 0.5 marks each for the following: Aneuploidy - anaphase	3

	Polyploidy - anaphase/cytokinesis	
Q.86	(a) Genotype of gametes: ABC, ABc, AcB, aBC, Abc, abC, aBc, abc (b) Number of offsprings: 64 Reason: Since 8 gametes will be produced by each parent, the cross will result in 8x8 = 64 offsprings [1 mark each for the correct number of offsprings and the reason] (c) 2 offsprings will be homozygous for all traits [1 mark] 0.5 marks for each of the following: - inflated, green pods with round seeds - constricted, yellow pods with wrinkled seeds	5
Q.87	[marks to be given only if the mode of inheritance is mentioned] (a) Since colour blindness is an X-linked recessive disorder, a colour blind male will share the normal Y chromosome and the colour blind mother will share a chromosome with the colour blindness trait to the child, making him a carrier but having normal vision. (b) A colour blind male will transfer the normal Y chromosome and the mother with normal vision will transfer a chromosome with the normal vision trait to the child so the child will not be a carrier too.	2
Q.88	(a) 0.5 marks for each of the following: son: will have Rett syndrome daughter: will have Rett syndrome (b) 0.5 marks for each of the following: son: will not have Rett syndrome daughter: will have Rett syndrome	2
Q.89	0.5 marks each for any TWO points of difference such as: - Klinefelter's syndrome is caused due to the presence of an additional copy of the X chromosome whereas Turner's syndrome is caused due to the absence of an X chromosome. - Klinefelter's syndrome occurs in both genders whereas Turner's syndrome is found in females. [Accept any other valid point] 0.5 marks each for any TWO similarities such as: - Both are chromosomal disorders related to the sex chromosomes	2

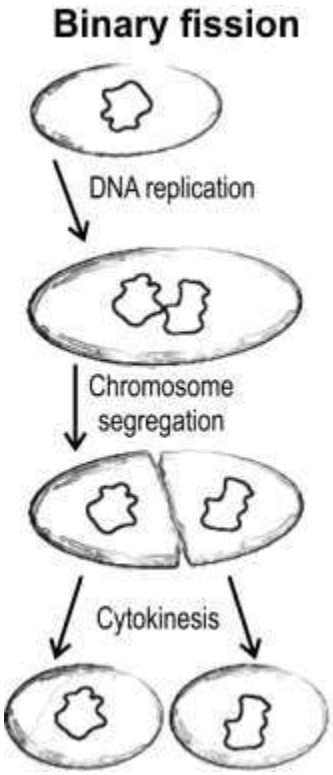
<table>
<tr><td></td><td>- In both disorders, the individuals are sterile.
[Accept any other valid point]</td><td></td></tr>
<tr><td>Q.90</td><td>1 mark for drawing the Punnett square and 1 mark for identifying both the parental genotypes correctly.
- Child can have any of the four blood groups - IAi, IBi, IAIB, ii
<table><tr><td></td><td>IB</td><td>i</td></tr><tr><td>IA</td><td>IAIB</td><td>IBi</td></tr><tr><td>i</td><td>IAi</td><td>Ii</td></tr></table>
- The parent genotypes would have to be IAi, IBi</td><td>2</td></tr>
<tr><td>Q.91</td><td>Punnett grid [1 mark]
<table><tr><td></td><td>XH</td><td>Xh</td></tr><tr><td>Xh</td><td>XHXh</td><td>XhXh</td></tr><tr><td>Y</td><td>XHY</td><td>XhY</td></tr></table>
Genotypic ratio [0.5 marks]
1 XHXh: 1XhXh: 1XHY: 1XhY
Phenotypic ratio [1.5 marks]
1 female with muscular dystrophy: 1 carrier female: 1 male with muscular dystrophy: 1 normal male
OR
50% offsprings with muscular dystrophy: 50% without muscular dystrophy
OR
50% offsprings with muscular dystrophy: 25% normal: 25% carriers</td><td>3</td></tr>
<tr><td>Q.92</td><td>(a) 0.5 marks for each of the following:
- wwTT
- wwTt
(b) She will need to perform a test cross with a purple axial flower that are homozygous for both alleles.
(c) 1 mark for each grid and 0.5 marks for each inference:</td><td>5</td></tr>
</table>

<table>
<tr><td></td><td>Possibility 1: wwTt x wwtt
<table><tr><td></td><td>wT</td><td>wt</td><td>wT</td><td>wt</td></tr><tr><td>wt</td><td>wwTt</td><td>wwtt</td><td>wwTt</td><td>wwtt</td></tr><tr><td>wt</td><td>wwTt</td><td>wwtt</td><td>wwTt</td><td>wwtt</td></tr><tr><td>wt</td><td>wwTt</td><td>wwtt</td><td>wwTt</td><td>wwtt</td></tr><tr><td>wt</td><td>wwTt</td><td>wwtt</td><td>wwTt</td><td>wwtt</td></tr></table>
- Inference: If the genotype of the unknown flower is wwTt then only 50% progeny will have purple terminal flowers.
Possibility 2: wwTT x wwtt
<table><tr><td></td><td>wT</td><td>wT</td><td>wT</td><td>wT</td></tr><tr><td>wt</td><td>wwTt</td><td>wwTt</td><td>wwTt</td><td>wwTt</td></tr><tr><td>wt</td><td>wwTt</td><td>wwTt</td><td>wwTt</td><td>wwTt</td></tr><tr><td>wt</td><td>wwTt</td><td>wwTt</td><td>wwTt</td><td>wwTt</td></tr><tr><td>wt</td><td>wwTt</td><td>wwTt</td><td>wwTt</td><td>wwTt</td></tr></table>
- Inference: If the genotype of the unknown flower is wwTT only then all progeny will have purple terminal flowers.</td><td></td></tr>
<tr><td>Q.93</td><td>Probability of offspring being homozygous for sickle cell anemia - 0%
Heterozygous (Aa) for sickle cell anemia.
co-dominance - as both parental alleles are expressed in the offspring</td><td>3</td></tr>
<tr><td>Q.94</td><td>(a) 0.5 marks each for the following:
Pedigree analysis can be done to analyse the inheritance of thalassemia in her family.
It is the study and representation of the family history with respect to inheritance of a particular trait.
1 mark for correct drawing of the pedigree and 1 mark for the correct symbols.</td><td>5</td></tr>
</table>

	 Autosome linked recessive trait [1 mark] Justification: This is an autosome-linked recessive blood disease transmitted from parents to the offspring when both the partners are unaffected carriers for the gene. [1 mark]	
Q.95	(a) 0.5 marks each for the following: F1 generation genotype: all RR' F1 generation phenotype: all roan cows F2 generation genotype: 1RR:2RR':1R'R' F2 generation phenotype: 1 red hair cow, 2 roan hair cows, 1 white hair cow. (b) 0.5 marks each for the following: codominance both alleles are equally expressed in the offsprings	3
Q.96	1 mark each for the following: Drosophila can be grown on a simple synthetic medium making growth faster and more controlled whereas pea plants were grown naturally, making growth slower and unpredictable. Drosophila complete their life cycle in about two weeks whereas pea plants take 10-12 weeks. In Drosophila, there is a clear differentiation of the sexes whereas pea plants are bisexual.	3
Q.97	1 mark for any one reason such as: In every generation, there is an affected individual. OR An affected offspring has an affected parent. 0.5 marks each for the following: Affected individual - heterozygous dominant OR Aa	2

	Unaffected individual - homozygous recessive OR aa	
Q.98	(a) 1 mark for each correct answer: X-linked recessive disorder The affected mother has all affected male children but female children are not affected. (b) 0.5 marks each for the following: heterozygous female	3
Q.99	(a) 0.5 marks each for the following: pleiotropy One gene is affecting multiple organs and therefore contributing to multiple phenotypes. [Accept any other valid answer] (b) 0.5 marks each for the following: recessive disorder Expression of the trait is skipping generations so it cannot be dominant. [Accept any other valid answer] (c) 0.5 marks each for the following: II-2 - Cc III-2 - Cc	3
Q.100	(a) 0.5 marks for each of the following: may or may not have an impact on reproductive features short stature with a small round head [Accept any other valid answer] (b) 0.5 marks each for the following: category: chromosomal disorders/aneuploidy cause: failure of segregation of chromatids during cell division	2

11. REPRODUCTION IN ORGANISMS

Q. No	Question	Marks
	Free Response Question / Subjective Question	
Q.101	Amoeba reproduce through a process called binary fission as shown in the diagram below:  (a) How is this different from mitosis with reference to: (i) types of cells where these processes take place? (ii) how the genetic material is divided? (b) In case of binary fission, are the daughter cells genetically similar to the parent cells? Justify.	2

Answer Key & Marking Scheme

Q. No	Answers	Marks
Q.101	(a) 0.5 marks for each correct answer: Mitosis occurs in eukaryotic cells while binary fission occurs in prokaryotic cells. In binary fission, the genetic material is simply cut into two halves / there is no spindle formation while in mitosis, spindle formation divides the nuclear material. (b) - Yes. [0.5 marks] - The parental genetic material is divided into two and passed on to the daughter cells formed by binary fission. [0.5 marks]	2

12. REPRODUCTIVE HEALTH

Q. No	Question	Marks
	Multiple Choice Question	
Q.102	Which of the following is an indicator of a reproductively unhealthy society? A. increase in infant mortality rate B. decline in maternal mortality rate C. widespread awareness of contraceptive methods D. detection and cure of sexually transmitted diseases	1
Q.103	Amniocentesis is a medical procedure where some of the amniotic fluid of the developing foetus is drawn to analyse the foetal cells and dissolved substances. It was banned in India around 1994 under the Pre-Conception and Prenatal Diagnostic Techniques Act in order to stop female foeticides. Which of the following highlight the importance of amniocentesis despite the ban? A. identification of a decline in sex ratio B. prevention of sexually transmitted diseases C. determination of biological sex of the unborn baby D. detection of genetic disorders	1
Q.104	Two statements are given below - one is an Assertion (A) and the other is a Reason (R). Assertion (A): Periodic abstinence is a natural method of birth control where couples avoid intercourse from day 10 to 17 of the menstrual cycle. Reason (R): Ovulation occurs around the middle of the menstrual cycle. Which of the following is correct? A. Both A and R are true, and R is a correct explanation of A. B. Both A and R are true, but R is not a correct explanation of A. C. A is true, but R is false. D. A is false, but R is true.	1
	Free Response Question / Subjective Question	
Q.105	The Medical Termination of Pregnancy (Amendment) Act, 2017 dictates that a pregnancy may be terminated on certain considered *grounds* within the first 12 weeks of pregnancy on the opinion of one registered medical practitioner. If the pregnancy has lasted more than 12 weeks, but fewer than 24 weeks, two	2

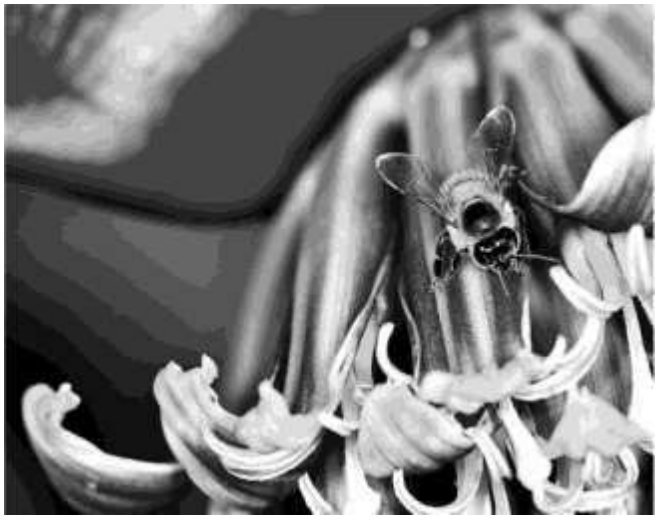
	registered medical practitioners must be of the opinion, formed in good faith, that the required *ground* exist. *[Note: Grounds refer to circumstances or conditions.]* Describe two grounds under which medical termination of pregnancy is permitted.	
Q.106	Given below are two statements. State whether each of them is true or false and justify, using examples. (a) All contraceptives have the added advantage of protection against sexually transmitted diseases. (b) Natural birth control methods have negligible side effects.	2
Q.107	As a volunteer for creating sexual health awareness in rural areas, you have been asked to create a poster highlighting birth control options available to males. State two contraceptive methods with negligible chances of failure available to males. For each method, mention the working principle briefly.	2

Answer Key & Marking Scheme

Q. No	Answers	Marks
Q.102	A. increase in infant mortality rate	1
Q.103	D. detection of genetic disorders	1
Q.104	A. Both A and R are true, and R is a correct explanation of A.	1
Q.105	1 mark each for any two of the following: If pregnancy is continued, it would threaten the mental, emotional, and physical well-being of the pregnant woman. There is possibility that the infant would suffer from physical or mental abnormalities as to be seriously handicapped. The pregnancy is unwanted by the pregnant woman. [Accept any other valid answer.]	2
Q.106	(a) 0.5 mark for each of the following: The statement is false. Contraceptives like IUDs and pills do NOT protect against STDs. (b) 0.5 mark for each of the following: The statement is true. No medicines or devices are used in natural birth control options such as periodic abstinence, lactational amenorrhea, and coitus interruptus.	2
Q.107	0.5 marks for each contraceptive method and 0.5 marks for each working principle: Method: condoms Working: act as a barrier between sperms and ovum Method: sterilisation/surgical method/vasectomy Working: blocks the transport of sperm to the urethra [Accept any other valid answer.]	2

13. SEXUAL REPRODUCTION IN FLOWERING PLANTS

Q. No	Question	Marks
	Multiple Choice Question	
Q.108	Consider three plants with the following modes of pollination: Plant P: autogamy Plant Q: xenogamy Plant R: geitonogamy Which of the above case/s is/are most likely to NOT show genetic variation in the offspring? A. only P B. only Q C. only P and R D. only Q and R	1
	Free Response Question/ Subjective Question	
Q.109	(a) Plants have two phases in their life cycle: sporophytic phase and gametophytic phase. The sporophytic phase is diploid and vegetative while the gametophytic phase is haploid and reproductive. From this information, identify the male gametophyte in angiosperms. (b) The megasporangium is the female spore-bearing structure which carries the megaspore mother cell. This gives rise to the megaspores. Name the megaspore in angiosperms.	1
Q.110	In angiosperms, the male gametophyte has a simple structure while the female gametophyte has a much more complex structure with multiple supporting cells in it. How does such a structural difference help each gametophyte perform their functions better?	2
Q.111	Emasculation is the process of removal of anthers from a flower and is practised in artificial hybridisation techniques. (a) Mention ONE case where emasculation is compulsory and ONE where it is not required during such hybridisation processes. (b) Why is bagging a compulsory technique even when emasculation is not required?	2
Q.112	Angiosperms undergo double fertilisation.	3

	(a) What is/are the product/s of double fertilisation? (b) If you are given a pea pod, how can you identify the product/s of double fertilisation in it?	
Q.113	Banana and many citrus fruits are formed without fertilisation. (a) Name the process of fruit/seed formation in both. (b) Mention ONE similarity and ONE difference between the two processes.	3
Q.114	The image below shows a bee visiting an inflorescence on a banana plant.  Considering the fact that banana is a parthenocarpic fruit, what would be MOST LIKELY the reason for the bee to visit the banana flowers?	1

Answer Key & Marking Scheme

Q.No	Answers	Marks
Q.108	C. only P and R	1
Q.109	0.5 marks for each correct answer: (a) pollen grain (b) ovule	1
Q.110	1 mark each for mentioning the following: - The pollen grain needs to be transferred to the stigma. Hence, smaller size makes it easier for the movement. - The ovule develops into the seed and supports the growing embryo. The supporting cells provide nourishment to the growing embryo.	2
Q.111	(a) 0.5 marks for each correct answer: - compulsory for bisexual flowers - not required in case of unisexual flowers (b) to prevent unwanted cross pollination in unisexual flowers	2
Q.112	(a) 0.5 marks for each correct name: - embryo - endosperm (b) 1 mark for each correct answer: - The embryo is represented by the entire pea seed. - The endosperm is consumed by the developing embryo and cannot be identified as such.	3
Q.113	(a) 0.5 marks for each correct name: -banana: parthenocarpy - citrus fruits: apomixis (b) 1 mark for each correct similarity and difference respectively: Similarity: Both are asexual modes of reproduction. Difference: Apomixis is a process of seed formation while parthenocarpy creates seedless fruits.	3
Q.114	to collect nectar	1

14. STRATEGIES FOR ENHANCEMENT IN FOOD PRODUCTION

Q. No	Question	Marks
	Multiple Choice Question	
Q.115	Two statements are given below - one is an Assertion (A) and the other is Reasoning (R). Assertion (A): Continued inbreeding increases fertility and heterozygosity. Reasoning (R): Closely related individuals within the same breed who do not have a common ancestor for 4-6 generations are mated to develop pure lines. Which of the following is correct? A. Both A and R are true, and R is a correct explanation for A. B. Both A and R are true, but R is not a correct explanation for A. C. A is true, but R is false. D. A is false, but R is true.	1
Q.116	In Multiple Ovulation Embryo Transfer Technology (MOET), a sheep who acts as the genetic mother is artificially inseminated. The embroys are recovered non-surgically and transferred to surrogate mothers. What is the purpose of having separate genetic and surrogate mothers? A. The surrogate mother has a shorter pregnancy term. B. The genetic mother cannot mate with the bull naturally. C. The surrogate mother cannot produce multiple eggs per cycle. D. The genetic mother can undergo multiple rounds of super ovulation.	1
Q.117	A laboratory is developing a hybrid Basmati rice cultivar with the objective of increased grain length. Following are some details: Desired characteristics: require less water and mature early than traditional Basmati cultivars. Parent cultivars: Pusa 614–1-2 and Pusa 614–2–4-3 States grown in: Punjab, Haryana, and Uttarakhand A scientist outlined the steps for testing it before the release: growing the cultivar in research fields recording yield under ideal irrigation growing in farmers' fields for at least three growing seasons at several locations in the country representing all the agroclimatic zones where the crop is usually grown	1

	As a fellow scientist, you have to recommend another key aspect of testing that your colleague has missed. Select the appropriate recommendation from below. A. growing in coastal belts of India B. cultivating for atleast 4 growing seasons C. choosing parents with disease resistance D. comparing the yield against a reference cultivar	
Q.118	The Neelagiri breed of sheep are distributed in Tamil nadu. For a few generations, the animals have been producing poor quality of wool. To improve the wool quality, one Neelagiri sheep has been selected for out-crossing with another sheep. Select the statement that describes the relationship between the two sheep. A. They are animals of different breeds. B. They are animals of different species. C. They are related animals of the same breed. D. They are unrelated animals of the same breed.	1
Q.119	Consider two statements. The capacity to generate a whole plant from any cell is called totipotency. Any part of a diseased plant can be cultured in laboratory to recover healthy plants. Choose the correct option. A. Statement I is true, and II is the reason. B. Statement II is true, and I is the reason. C. Statement I is true, but statement II is false. D. Statement II is true, but statement I is false.	1
Q.120	Complete the following sentence by selecting the correct option. The tangelo is a fruit produced by crossing Citrus reticulata and Citrus maxima plants. It is an example of . A. inbreeding B. out-crossing C. cross-breeding D. interspecific hybridisation	1
Q.121	Somatic hybridisation is the artificial technique of creating a hybrid plant combining the desirable characteristics of two plants. Which of the following conditions MUST be satisfied by the two cells used for somatic hybridisation? A. They are gametes. B. They lack cell wall.	1

	C. They contain chlorophyll. D. They belong to same species.	
Free Response Question / Subjective Question		
Q.122	Sugarcane varieties that were earlier found in North India did not have enough sugar content. So, scientists decided to initiate a project to develop varieties of sugarcane which produce higher content of sugar. Given that the scientists had no prior information about sugarcane, describe the steps that they need to go through to create a high-sugar variety of sugarcane that can be tested.	4
Q.123	Two laboratories (Alpha and Bravo) executed different approaches to create a mustard plant variety that is resistant to aphids. Alpha laboratory followed the steps of conventional breeding technique as described below. germplasm collection evaluation and selection of parents cross-hybridisation among selected parents selection and testing of superior recombinant testing, release, and commercialisation of new cultivars Bravo laboratory followed mutation breeding to develop pest-resistant variety of mustard. Which step of Alpha's approach would be different from Bravo's approach? In the mutation breeding method, how is the step identified in (a) different? Name two ways by which Bravo laboratory could introduce variation in the mustard plant.	2

Answer Key & Marking Scheme

Q. No	Answers	Marks
Q.115	D. A is false, but R is true.	1
Q.116	D. The genetic mother can undergo multiple rounds of super ovulation.	1
Q.117	D. comparing the yield against a reference cultivar	1
Q.118	D. They are unrelated animals of the same breed.	1
Q.119	C. Statement I is true, but statement II is false.	1
Q.120	D. interspecific hybridisation	1
Q.121	B. They lack cell wall.	1
Q.122	1 mark for each of the following: Collection of variability: The team will need to collect and preserve all the different wild varieties, species and relatives of the cultivated species (followed by their evaluation of their characteristics) for effective exploitation of natural genes available in the populations. Evaluation and selection of parents: The germplasm is evaluated so as to identify plants with a desirable combination of characteristics. These parents are multiplied to create pure lines. Cross hybridisation among the selected parents: The parents are cross hybridized to produce variants with the desired characteristics. Selection and testing of the best recombinants: Since all offspring may not have the desired characteristics, it is important to select those that have the desired combination from among all the progeny. These are self-crossed for several generations till homozygous plants are obtained for testing.	4
Q.123	step I Genetic variability is introduced by artificial means. 0.5 marks for each of the following: exposure to chemicals exposure to radiation [Award marks for any other relevant answer.]	2

Central Board of Secondary Education
Shiksha Sadan, 17, Rouse Avenue,
New Delhi-110002

SUPPLEMENTARY MATERIAL
FOR
SENIOR SECONDARY BIOLOGY

National Curriculum for 2012 (Class XI & XII) has been revised under the aegis of COBSE in consensus with NCERT and CBSE.

In an effort to assist teachers to handle the revised curriculum, supplementary material has been prepared by experts at CBSE. The additional inputs have been proposed to motivate teachers to make conceptual linkages and create deeper interest in Biology.

CLASS XII-BIOLOGY

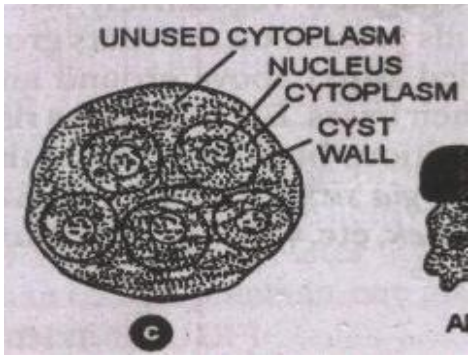
Unit VI

Chapter-1

Reproduction in organisms

Sporulation

When the products of multiple fission become individually surrounded by resistant coats, the cyst walls before their release from the parent, the processs is known as sporulation and the encysted products are termed spores. The spores remain inactive during unfavorable conditions such as dessication and extremes of temperature. When condition becomes favorable, the cyst hatches and gradually grows into an adult. Sporulation is thus not only a mean of reproduction, but also enables the organism to survive during unfavorable conditions and disperse to new localities with air. It occurs in amoeba.



Uniparental

It is the condition where a person receives two copies of a chromosome or part of a chromosome, from one parent and no copies from the other.

Fragmentation

Fragmentation is a form of asexual reproduction where an organism splits into fragments. Each of these fragments develops into mature fully grown individual followed by mitosis. it occurs in some algae (*Spirogyra*), fungi, some annelids and sea stars.

Regeneration

Regeneration is the process of renewal, restoration and growth. It can occur at the level of the cells, tissues and organs. It is common in Hydra, planarian flatworm and echinoderms. A lizard can discard a part of tail when in danger, and the tail can regenerate later. In humans too the liver can regenerate if partially damaged.

Unit VI- Reproduction

Chapter 2

Sexual Reproduction in Flowering Plants

Significance of seed and fruit formation

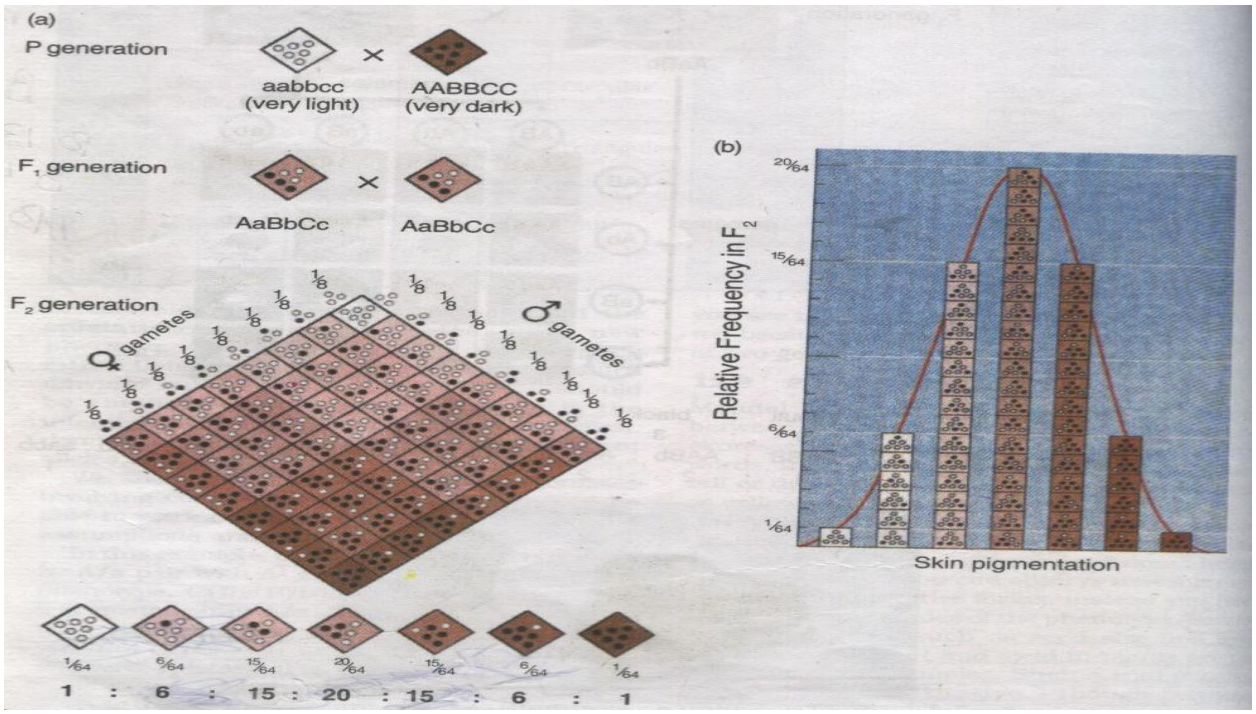
Significance of fruit formation

The fruits protect the seeds from unfavorable climatic conditions. Both fleshy and dry fruits help in the dispersal of seeds to distant places. They are a source of many chemicals like sugars, protein, oil, organic acids, vitamins and minerals. Some fruits may provide nutrition to the developing seedlings. Generally hard seeds are surrounded by soft fleshy fruit pericarp (for example guava) and soft seeds by a hard fruit shell (for example almond). The fleshy, edible parts of the fruit become the source of food and energy for the animals which often act as dispersal agents.

Polygenic Inheritance

Galton in 1883 suggested that many instances of continuous variation are heritable. He was impressed by the fact that taller human beings generally produce taller children. He suggested that characters such as height and mental capabilities in humans are heritable although these show a continuous range of variation in a population. Galton's postulate gained experimental support when it was found that at least in some instances the same

character can be determined by more than one gene, each with the same but cumulative phenotypic effect Quantitative characters like plant height, yield of crops (size, shape and number of seeds and fruits per plant), intelligence in human beings and milk yield in animals have been found to be determined by many genes and their effects have been found to be cumulative. Each gene has a certain amount of effect, and the more the number of dominant genes, the greater expression of the character. Quantitative inheritance is also known as polygenic inheritance or multiple factor inheritance. Though polygenic traits can be easily influenced by environment, these are generally controlled by three or more genes with phenotype reflecting the contribution of each allele (Quantitative). Let us discuss the polygenic trait by studying the inheritance of human skin colour. There are no contrasting phenotypes for this trait. Let us assume that this trait is controlled by three **genes A, B, and C. in this cross, there is a mating between dark-skinned and fair-skinned human beings and then the intermediate skin coloured individuals expected at F1 are mated to obtain F2 progeny.**



Polygenic inherence

(a) A cross depicting the inheritance of human skin colour controlled by polygenes.

(b) In the relative frequency of F_2 progeny in a polygenic cross is plotted against the extent of phenotypic expression – a typical inverted bell shaped curve is seen.

It is clear that:-

(i) Few individuals fall into parental categories;

(ii) The expression level of the phenotype is dependent upon the number of contributive alleles and is hence more quantitative.

If the F_2 data are plotted graphically, a bell-shaped curve results.
In this example, we have assumed the involvement of three gene pairs, However if higher number of genes are involved in determining a phenotype, greater variety would be expected in F_2generation.
Other examples that can be studied are the kernel colour in wheat and inheritance of cob length in maize. It is generally believed that during evolution there was duplication of chromosome or chromosome parts thereby leading to multiple copies of the same gene. A large number of characters are controlled by polygenes in which alleles contribute additively to a phenotype. This results in polygenic inheritance.

Unit VII

Chapter 5

Principles of Inheritance and Variation

Pleiotropy

Pleiotropism is defined as a phenomenon when single gene may produce more than one effect (the multiple effect of a gene) or control several phenotypes depending on its position.

The basis of Pleiotropy is the interrelationship between the metabolic pathways that may contribute towards different phenotypes. In phenylketonuria, mutation of a gene that codes for the enzyme phenyl alanine hydroxylase.

This results in a phenotypic expression characterized by mental retardation and a reduction in hair and skin pigmentation.

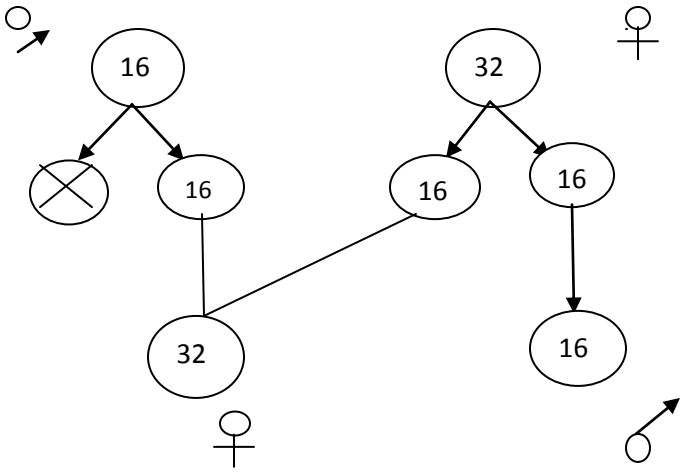
In drosophila white eye mutation leads to depigmentation in many other parts of the body, giving a pleitropic effect.

In transgenic organisms, the introduced gene can produce different effects depending on where the gene has introgressed.

Sex-determination in honey bee

The brood cells in a hive reveal two distinct sizes. The smaller of the two are reserved for the development of the workers, which are females, whereas the larger ones are for drones which are males. During the queen's nuptial flight, she is pursued by many drones. She finally allows herself to be inseminated by a drone. Sperms are stored in a seminal receptacle within her body. When she lays an egg in a worker cell, sperms are emitted from the seminal receptacle to fertilise the egg which will develop into a female, as all fertilised eggs form females (Incidentally, the workers can make this egg into a queen by enlarging the cell and feeding the developing larva on a rich diet, but both workers and queens are females.)

When the queen comes to a drone cell she exerts some sort of pressure on the ducts leading from the seminal receptacles so that the sperm cannot pass out and fertilise the egg as it passes down the oviduct. Thus an unfertilised egg is laid, which later hatches and produces a male. All unfertilized eggs produce males.

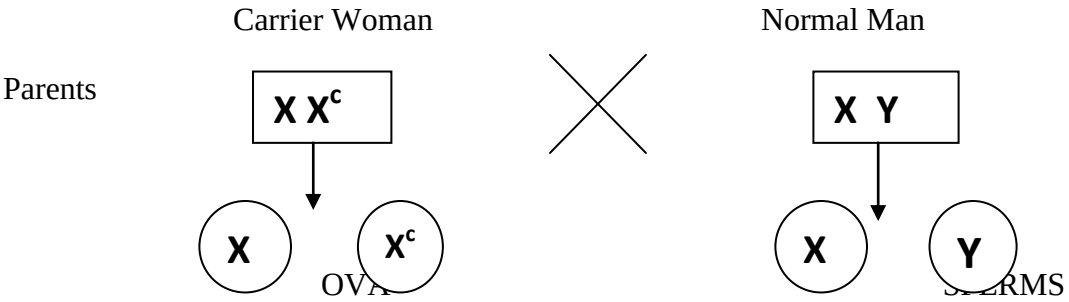


A diploid male could be obtained in the following manner. Suppose, there is a hetero zygous female X^a and X^z. When crossed with a male X^m,the females would be X^a/X^m and X^z/X^m. If the male with X^m is crossed with either of the females i.e. X^a/X^mor X^z/X^m then diploid male X^m/X^m. At the same time, the females would lay some infertile eggs which would hatch into normal, fertile, haploid males.

COLOUR BLINDNESS

Colour blindness is a recessive sex-linked trait in which the eye fails to distinguish red and green colours. The gene for normal vision is dominant. The normal gene and its recessive allele are carried by X-chromosome. In female colour blindness appears only when both the sex chromosomes carry the recessive gene (X^c X^c). The females have normal vision

but function as carrier if a single recessive gene for colour blindness is present (XX^c). However, in human males the defect appears in the presence of a single recessive gene (X^c Y) because Y chromosomes of males do not carry any gene for colour vision. Colour blindness, like any other sex-linked trait, shows criss-cross inheritance.



OFFSPRING

	X	Y
X	Normal Girl	Normal Boy
X^c	X X^C Carrier Girl	X^c Y Colour Blind Boy

1 Normal Girl: 1 Carrier girl
1 Normal Boy: 1 Colour Blind Boy

Colour blindness

Colourblindness does not mean not seeing any colour at all, it means that those who are colourblind have trouble in seeing the differences between certain colours.
Most colourblind people can't tell the difference between red or green. That does not mean that they can not do their normal work - Infact they can also drive – they learn to respond to the way the traffic signal lights up-the red light is generally on the top and green is on the bottom.

THALASSAEMIA

Thalassaemia is a genetic defect, originated in Mediterranean region – by their mutation or deletion. In thalassaemia too few globins are synthesised whereas in sickle cell anaemia there is a synthesis of incorrectly functioning globin.

Thalassemias are a group of disorders caused by defects in the synthesis of globin polypeptide. Absence or reduced synthesis of one of the globin chains results in an excess of the other. In this situation free globin chains, which are insoluble, accumulate inside the red

cells and form precipitates which damage the cell, causing cell lysis and resulting in anemia. There are two main types of Thalassemias in which synthesis of $\propto$ or β globin is defective. It is common in Mediterranean, Middle East, Indian subcontinent and in south east Africa.

Alpha (α) Thalassaemia

The α Thalassaemias involve the genes HBA1 and HBA2, inherited in a Mendelian recessive fashion. There are two gene loci and so four alleles. It is also connected to the deletion of the 16p chromosome. α Thalassaemias result in decreased alpha-globin production, therefore fewer alpha-globin chains are produced, resulting in an excess of β chains in adults and excess γ chains in newborns. The excess β chains form unstable tetramers (called Hemoglobin H or HbH of 4 beta chains) which have abnormal oxygen dissociation curves.

Beta (β) Thalassaemia

Beta Thalassaemias are due to mutations in the HBB gene on chromosome 11 , also inherited in an autosomal-recessive fashion. The severity of the disease depends on the nature of the mutation. Mutations are characterized as (β^o or β Thalassaemia major) if they prevent any formation of β chains (which is the most severe form of β Thalassaemia); they are characterized as (β^+ or β Thalassaemia intermedia) if they allow some β chain formation to occur. In either case there is a relative excess of α chains, but these do not form tetramers: rather, they bind to the red blood cell membranes, producing membrane damage, and at high concentrations they form toxic aggregates.

Delta (δ) Thalassaemia

As well as alpha and beta chains being present in hemoglobin about 3% of adult hemoglobin is made of alpha and delta chains. Just as with beta Thalassaemia, mutations can occur which affect the ability of this gene to produce delta chains.

Unit VII

Chapter 7

Evolution

Evidence from embryology

Embryos of the vertebrate series exhibit many features that are not seen in adults. For example, all embryos of vertebrates develop a row of vestigial gill slits just behind the head. Since these

gill slits are functional only in fishes, why do these structures appear in the land vertebrates? It could mean that land vertebrates descended from fishes that had gill slits to help in aquatic respiration. Generalized features such as brain, spinal cord, axial skeleton and aortic arches are common to all vertebrates. Organisms that share common descent show embryological patterns on which they later build their adult patterns. This was first observed by von Baer Ernst Haeckel reinterpreted Baer's law in the light of evolution. This law held that ontogeny (development of the embryo) is recapitulation of phylogeny (development of race). This is summarized as biogenetic law which states that ontogeny recapitulates phylogeny. However, this proposal was disapprover on careful studies by von Baer as it was noted that the embryos do not pass through the adult stages of other animals. There are stages that related embryo to share.

Embryological evidence of evolution (adapted from NCERT)

Examples of this phenomenon are also seen in plants.

For example-

(i) The Protonema, an early stage in the development of moss or fern gametophyte, resembles the filamentous green algae in structure, physiology and growth pattern. This suggests an algal ancestry of bryophytes and pteridophytes.

(ii) The gymnosperms have normally become independent of water in fertilisation. However, the primitive gymnosperms such as Cycas and Ginkgo have flagellated sperms and need water for fertilization just like the pteridophytes, their most likely ancestors.

(iii) The seedlings of acacia tree initially develop simple leaves, but the leaves that develop later are compound.

Molecular evidence in Evolution

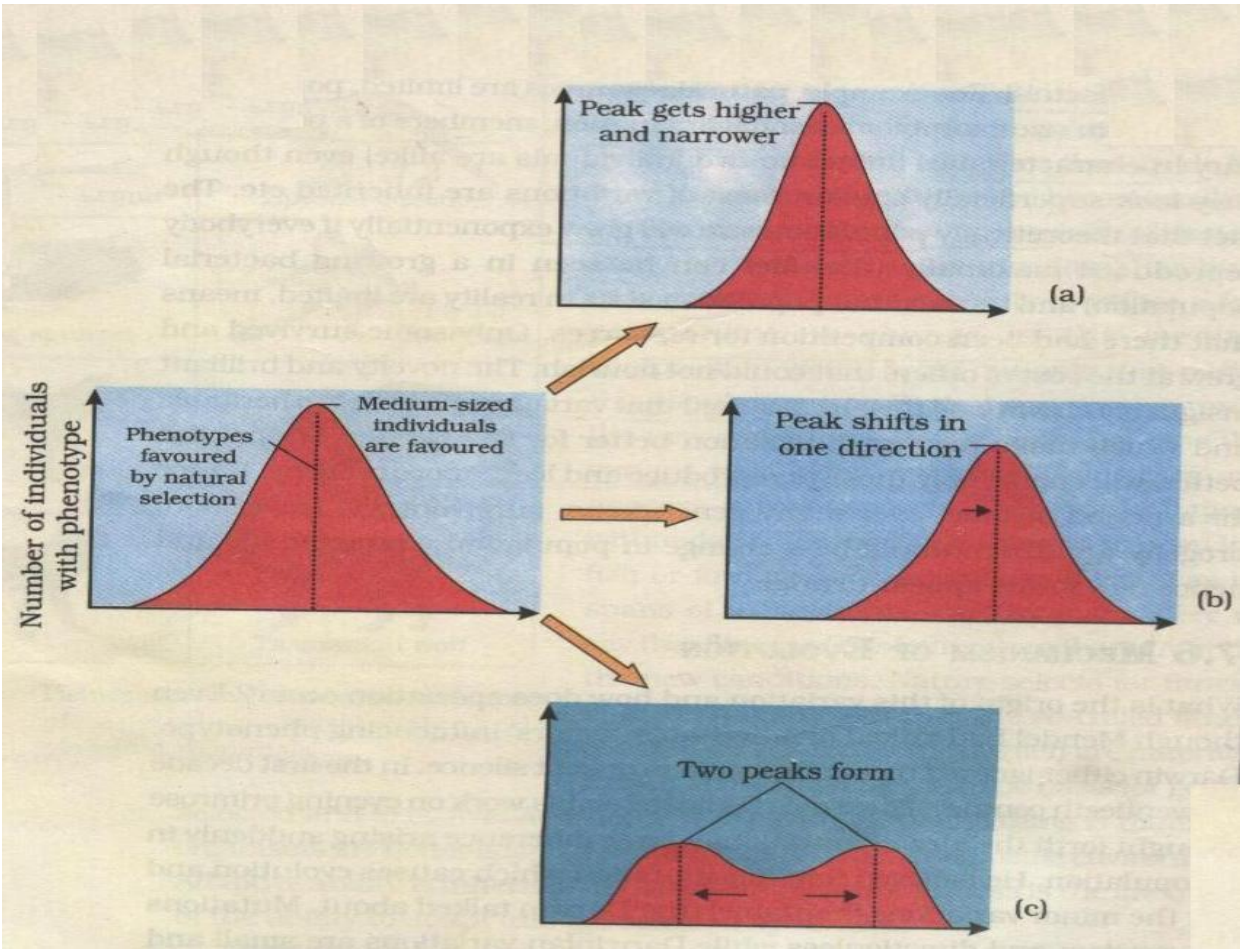
Similarity of organisms at the molecular level indicates phylogenetic relationship. The degree of similarity in the base sequence in their nucleic acids, and amino acid sequence in their proteins are indicated. Human DNA differs in only 1.8% of its base pairs from chimpanzee DNA, and there is no difference between the two in the amino acid sequence for the protein cytochrome C. Similarity in the molecular structure of actin and tubulin proteins in all animals point to their common ancestry.

A common genetic code is overwhelming evidence that all organisms are related.

MODERN SYNTHETIC THEORY OF EVOLUTION

Darwinism, the theory of natural selection has a wide acceptance. However, it has been criticised too, on the ground it could not explain how the variations arise. With progress in genetics, the sources of variation were explained and Darwin's theory was modified. Now, the most accepted theory of evolution is known as **SYNTHETIC THEORY OF EVOLUTION**, in which the origin of species is based on the interaction of genetic variation and natural selection.

Types of Natural Selection



Diagrmatic representation of the operation of natural selection on different traits (a)Stabilising (b)Directional (c)Disruptive - adapted from NCERT

Natural selection causes allele frequencies of a population to change. Depending upon which traits are favoured in a population it can produce three different results.

(1) Stabilizing selection - If both the smallest and largest individuals contribute relatively fewer offspring to the next generation than those closer to average size do, then stabilizing selection is operating. It reduces the variation but does not change mean value.
(2) Directional selection – If individuals at one extreme of the size distribution e.g. (the larger ones) contribute more offspring to the next generation then the other individuals do, then the mean size of individuals in the population will increase. In this case directional population is operating. If directional selection operates for many generations, an evolutionary trend within the population results.
(3) Disruptive selection- When natural selection simultaneously favours individuals at both extremes of the distribution, disruptive selection is operating. As a result we can see two peaks in the distribution of a trait.

UNIT - IX

CHAPTER 12

BIOTECHNOLOGY AND ITS APPLICATIONS

Patent

A set of exclusive rights granted by a state (national government) to an inventors or their assignee for a limited period of time in exchange for a public disclosure of an invention.

Patents are supposed to satisfy three criteria of : Novelty, non-obviousness, and Utility.

Novelty implies that the innovation must be new. It cannot be part of 'prior art' or existing knowledge. Non-obviousness implies that it may not be documented but is otherwise well known. The discored fact or product should be of a particular use for the human beings.

Controversies in India regarding patent and biopiracy

Turmeric: In May, 1995 the US Patent Office granted to the University of Mississippi Medical Center a patent for "Use of Turmeric in Wound Healing."

Consider the implication of 'turmeric patent'. If an Indian in America sprinkles turmeric powder – just as her ancestors in India have done for centuries – on her child's scrape, she would in fact be infringing US patent laws and would be open to prosecution.

The patent was promptly challenged by Dr. R A Mashelkar, an Indian scientist who has done much to awaken India to Intellectual property Rights issues. After four months of submissions it was established that the use of turmeric as a healing agent was well-known in India for centuries. The patent was revoked.

Neem: In 1996, Vandana Shiva challenged the patent ranted to the firm of W.R. Grace & Co. by the European Patent Office, Munich for 'fungicidal uses of neem oil'. Although the patent has been granted on an extraction technique, the Indian press described it as a patent on the neem tree itself: the result was widespread public outcry, which was echoed throughout the developing world. Vandana Shiva and Ajay phadke, who had researched neem in India, flagged ancient Indian texts to point out that there was on 'novelty' factor in neem's magical properties that Grace & Co. had unveiled – Indians had known them for long. Legal action by the Indian government followed, with the patent eventually being overturned in 2005.

Basmati Rice: In September 1997, a Texas company called Rice Tec won a patent on "basmati rice lines and grains." The patent secured lines of basmati and basmati-like rice and ways of selecting that rice for breeding. Rice Tec, owned by Prince Hans-Adam of Liechtenstein, international outrage over allegations of biopiracy. It has also caused a brief diplomatic crisis between India and United States with India threatening to take the matter to WTO (World Trade Organization) as a violation of TRIPS (trade-related aspects of intellectual property rights) which could have resulted in a major embarrassment for the United States. Both voluntarily, and due to review decisions by the United States patent Office, Rice Tec lost most of the claims of the patent.

UNIT – X

CHAPTER 13

ORGNISMS AND POPULATION

Niche

A habitat can contain many ecological niches and support a variety of species. The ecological niche of an organism represents the range of conditions that it can tolerate, the resources it utilizes, and its functional role in the ecological system. Each species occupies a distinct niche, and no two species are believed to occupy the same niche.

CLASS XI- BIOLOGY

UNIT - I

Chapter -2

Biological Classification

Five kingdom classification is based on complexity of organism and type of nutrition. The five kingdoms are:

Monera, Protista, Mycota, Plantae and animalia.

Six kingdom classification: proposed by Carl Woese who has suggested a separate kingdom for Arachaebacteria that are included in Monera in Whittaker's five - kingdom classification in addition to the five kingdom classification of R.H.Whittaker.

Three domains of life: These are Archaea, Bacteria and Eukarya. Archaea has kingdom Archaebacteria,

Bacteria has kingdom Eubacteria and Eukaryota has kingdoms -Protista, Mycota, Plantae and Animalia.

Unit IV-Plant Physiology

Chapter 15

Plant Growth and Development

Seed Germination

The first step is the process of plant growth is seed germination. The seeds germinate under favourable conditions of the environment. Some seeds undergo a period of dormancy and can germinate only after dormancy period gets over.

Seed germinates to from seeding which grows into a plant. After the dormancy of the seed is over or is broken, and the necessary conditions for germination are available the dormant embryo becomes metabolically active and starts growing. This process is known as seed germination. The conditions necessary for seed germination are availability of water and oxygen. The imbibitions or the uptake of water is the first step towards the germination of seed. It causes swelling of seed that ruptures the seed coat to enable the radical to emerge from one end of embryonic axis the metabolic activities require oxygen for breaking down the food reserves. The mobilization of food reserves involves the hydrolysis of stored polysaccharides, proteins, and lipids with the help of enzymes.

The emergence of radical which gives rise to root system is considered the first step towards seed germination. As radical emerges from one end of the embryonic axis, plumule which forms the shoot arises from the other end. The rate of respiration increases rapidly during seed germination. The growth of radical and plumule is due to the cell extension, cell division and initiation of several biochemical processes. The seed also needs a suitable temperature (optimum between 25 to35).

Some plants such as Rhizophora and Sonneratia show special type of germination known as vivipary. These plants grow in marshy lands. Vivipary is the germination of a seed while it is still attached to the parent plant and is nourished by it. As the germinating seed forms a seedling, its weight increases and the seedling separates and falls down into the mud. The lateral roots then develop to help proper anchorage of the seedling.

Seed Dormancy

The development of embryo stops once the seed matures. It sheds most of its water content, the metabolic activities become extremely low, the seed coat becomes impermeable to oxygen and moisture and it usually hardens.

In manyplants, the seed undergoes a period of suspended growth and does not germinate as soon as it is formed. The suspension of growth is referred to as quiescence when it is due to exogenous factors, such as the environmental conditions. The seeds may be in a state of dormancy or rest due to endogenous control during which metabolic activity of the seed is greatly reduced. While quiescence is the condition of a seed when it is unable to germinate because the conditions for germination are not available, dormancy is the condition of seed when it is unable to germinate in spite of the availability of all environments conditions suitable for germination.

Dormancy in seeds may be due to impermeable or mechanically resistant seed coats, rudimentary or physiologically immature embryos and even due to the presence of germination inhibitors such as abscisic acid, phenolic acid, short chain fatty acids and coumarin. Dormancy of the seed can be broken, or its duration can be reduced to initiate germination, by mechanical or chemical scarification of the seed coat, stratification of seeds or changing environmental conditions such as temperature, light and pressure.

Scarification of seed involves scratching of seed coat to help break the dormancy caused by hard and impermeable seed coat. Stratification of seeds is subjecting the moist seeds to oxygen for variable periods of low or high temperatures.

Unit V- Human Physiology

Chapter 16

Digestion and Absorption

Calorific value of carbohydrate, protein and fat: We all recognize the vital importance of food for life. A certain part of the nutrients that we take is used for building cell structures, synthesize functional molecules or replace worn-out parts. However most of the foods are used as sources of metabolic fuels. Carbohydrates, proteins and fats serve as the chief sources of energy in humans. These are oxidized and transformed into ATP, the chemical energy form used by cells to drive their multitudes of activities.

Since heat is the ultimate form of all energy, the energy value of food (or any fuel) is expressed in terms of a measure of heat energy it produces on combustion. The heat energy released by combustion of one gram of food is usually known as its gross **calorific value**. It is defined as the amount of heat produced in calories (cal) or in joules (J) from complete combustion of 1 gram food in a bomb calorimeter (a closed metal chamber filled with O_2). The calorific value is usually expressed in terms of kcal per gram or kilojoules per gram. (1kcal = 4.184kJ) One kilocalorie is the amount of heat energy needed to raise the temperature of one kilogram of water through 1^0C (1.8^0F). Nutritionists traditionally refer to kcal as the **Calorie** or to kJ as **Joules** (always capitalized).The calorific values of carbohydrates, proteins and fats are 4.1 kcal /g, 5.65 kcal /g and 9.45 kcal /g, respectively. The actual amounts of energy liberated in the body by these nutrients, referred to as the physiologic value of the food, and are 4.0 kcal /g, 4.0 kcal /g and 9.0 kcal /g respectively.

DEFICIENCY DISEASES

Humans require a wide range of nutrients to perform various functions in the body and to lead a healthy life. You have already learnt about the functions of various nutrients in previous classes. Inadequate nutrients in the diet cause various deficiency disorders, particularly among the children and the poor.

The important deficiency disorders include protein energy malnutrition (PEM) and disorders due to deficiencies of Vitamin A ,iron and iodine. Deficiency of protein and energy or both, called PEM, has been identified as major health and nutritional problems in India. Protein and energy intake are difficult to separate because diets adequate in energy are adequate in protein. Young children (0-6 years) require more protein for each kilogram of body weight than adults. So they are more vulnerable to malnutrition. Malnutrition is not only an important cause of childhood mortality and morbidity, but it also leads to permanent impairment of physical and mental growth of those who survive. The details of the disorders are given below.

PEM: it is an important nutritional problem among pre-school children.

It leads to various degrees of growth retardation. This is due to lack of adequate quantity of protein or carbohydrate or both.

PEM is of 2 types: Kwashiorkor and marasmus

Deficient Nutrient	**Name of Deficiency**	**Deficiency Symptoms**
Protein (PEM)	Kwashiorkor (usually observed in children in the age group of 1-5 years)	Wasted muscles, thin Limbs, retarded growth of body and brain, swelling of legs due to retention of water (oedema), reddish hair, pot belly and diarrhea.
Protein and Calorie (PEM)	Marasmus (it usually affects infants below the age of one year)	Impaired growth and replacement of tissue proteins, thin limbs and prominent ribs (emaciated body), dry, wrinkled and thin skin, diarrhea.

The child suffering from PEM can recover if adequate quantities of protein and carbohydrate rich food are given.

Chapter 19

Excretory Products and their elimination

Diabetes Insipidus

Antidiuretic hormone (ADH) is one of the hormones that efficiently monitors and regulates the functioning of the kidneys. Can you recall the other hormones involved? Why is ADH so called? (Diuresis is urine production). Antidiuretic hormone released from the posterior pituitary, prevents wide swings in water balance, helping to avoid dehydration or water overload. Try to recollect how ADH facilitates reabsorption of water by the distal parts of the kidney tubules and thereby prevents diuresis. Deficiency of ADH leads to *diabetes insipedus*, a condition marked by the output of huge amounts of urine and intense thirst. The name itself *(diabetes* =overflow; *insipidus* = tasteless) distinguishes it from diabetes mellitus (*mel* = honey), in which insulin deficiency causes large amounts of blood sugar to be lost in the urine.

Artificial kidney

You have studied about various disorders of the excretory system. Hemodialysis is an artificial process of removing toxic substances from the blood in patients of kidney failure. The hemodialysis machine is therefore also known as the artificial kidney.

Chapter 20

Locomotion and Movement

Types of movements: Flagellar movement.

Movement is most basic characteristic of living organisms. There are three main types of movements shown by the cells of the human body, viz amoeboid, ciliary and muscular. Human sperms (typical example of flagellated cells) exhibit yet another type of movement, the flagellar movement. The flagellum is the propulsion equipment for the movement of sperm towards the ovum. This propulsion is brought about by the whip like movement of the tail and the middle piece of the sperm.

Chapter 21

Neural control and coordination

Sense organs

We humans are responsive organisms. Aroma of a freshly cooked dish makes our mouth water, loud thunder makes us jump in our seat and stepping on a nail causes intense pain. We sense the changes in our environment (both internal and external) with the help of special sensory receptors. These environmental changes, called stimuli, once detected by the special sensory cells, are conveyed to the brain in the form of nerve impulses. The meaning of each stimulus is interpreted in the brain and appropriate order is sent to the body parts for its appropriate response to ensure well being.

Traditionally, there are five senses: touch, vision, hearing, smell and taste. While touch is a complex **general sense**, the other four are **special senses**. The general sensory receptors are **simple receptors** that are mostly modified dendritic ends of sensory neurons. Such receptors are present throughout the body ─ in the skin, mucous membranes, connective tissues and muscles. These monitor most of the types of general sensory information such as tactile sensation (a mix of touch, pressure, stretch and vibration), heat, cold, pain and muscle sense (proception).

In contrast, special sensory receptors are distinct receptor cells that are actually confined to the head region and are highly localized within complex sensory organs like eyes and ears and tissues of the taste buds and olfactory epithelium .These sensory organs and tissues are collection of cells of many different types (receptor and non receptor cells}, working together to accomplish a specific receptive process. Recall the structure of eye and ear that you have studied. Which type of sensory receptor are these made of? Yes, the special sensory receptors called the photoreceptors and the auditory receptors respectively.

Though the complex sense organs are more familiar to us, the simple sensory receptors associated with general senses are no less important. These keep the central nervous system well informed about what is happening, both deep within the body and on its surface. In this lesson you will learn about a few of these simple receptors present in the skin. You will also learn about the special senses of taste and smell.

The chemical senses: the taste and smell

The receptors for taste and smell are classified as chemoreceptors as these respond to special chemicals in aqueous solution. In each case, the chemicals must go into solution in the film of liquid coating the membranes of the receptor cells before these can be detected. The taste receptors are specialized cells that detect chemicals present in quantity in the mouth itself, while smell receptors are modified sensory neurons in the nasal passage which detect the volatile chemicals that get wafted up the nostrils from distant sources. These two types of receptors complement each other and often respond to the same stimulus. You can now guess why a very strong perfume leaves a peculiar taste in your mouth. The smell receptors can be as much as 3,400 times more sensitive than the taste receptors.

Sense of smell (olfaction): Nose contains the receptors of smell, in the mucous coated thin, yellowish patch (about 5 cm^2) of modified pseudo stratified epithelium called **olfactory epithelium**. It is located way up at the roof of the nasal cavity on either sides of the nasal septum.

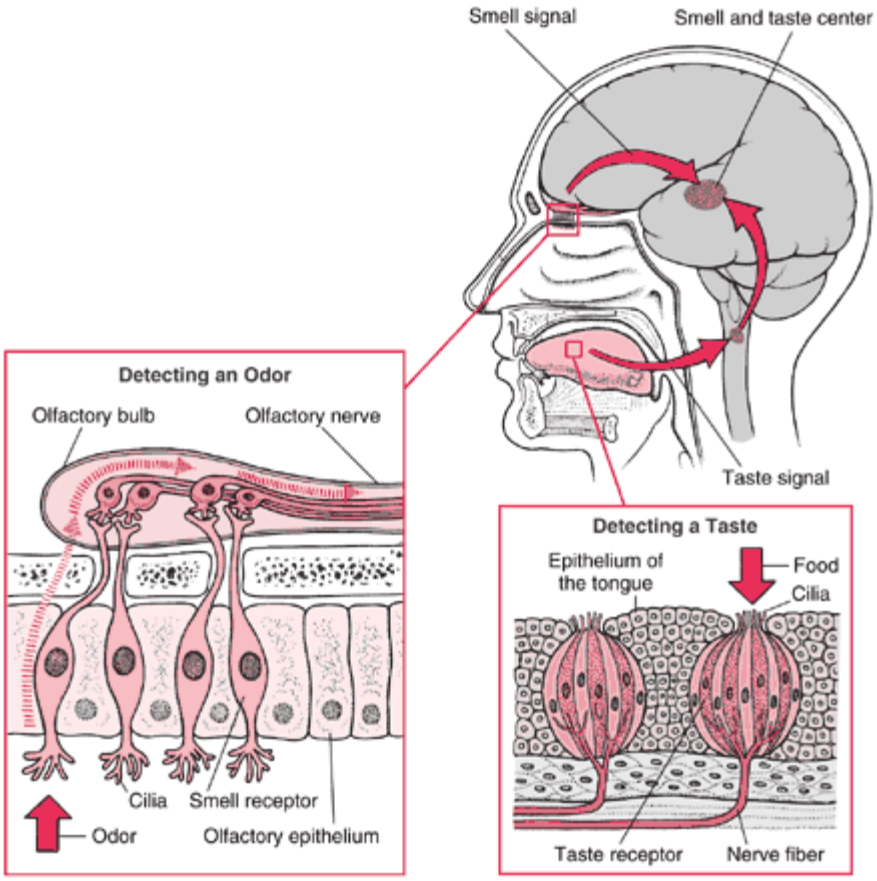


Figure 1 Human nose showing olfactory bulb and magnified view of olfactory epithelium

smsm2a2012.weebly.com/reading-site.html

The olfactory epithelium contains three types of cells: (a) millions of olfactory receptor cells; (b) columnar supportive cells; (c) short basal cells. Olfactory receptors are unusual bipolar sensory neurons. The thin dendrites of each of these neurons run to the surface of the epithelium where these bear a cluster of about 20 modified cilia which function as receptor sites. These cilia extend from the olfactory epithelium into the thin coat of nasal mucous secreted by the supportive cells and olfactory glands. This mucous is a solvent that captures and dissolves the air borne odour molecules. Once dissolved, the chemicals bind to the specific receptors on the cilia stimulating the receptor cells. This causes depolarization and ultimately action potential in the receptor cell. The axons of the olfactory receptors unite to form the olfactory nerve which transmits the information directly to the overlying olfactory bulb, a relay station in the brain. Unlike receptor ends of other senses, the axons of the olfactory receptors directly extend from the outside environment (the nasal cavity) into the olfactory bulb, a part of the brain. The number of receptors stimulated indicates the strength of the stimulus.

As with taste, some of what we call smell, can be really painful. The nasal cavity contains pain receptors that respond to irritants such as ammonia, vinegar or hot chilly pepper. Impulses from these pain receptors reach the brain. The brain combines these sensations with those of smell to identify the odours. Although humans do have a good sense of smell - we can detect about 10,000 different odours - our olfactory capability is not as good as those of many vertebrates, especially fish and mammals such as a dog.

Sense of taste (gustation)

The sense of taste and smell work closely together. If we cannot smell some thing we cannot taste it either. When we speak of taste sensations we are often referring to the combined sensation produced by both taste and smell receptors. One reason why we cannot taste (or smell) food well with a common cold is that with the nasal passages inflamed and coated with thick mucus layer the smell receptors are practically non functional. The receptor cells for taste are located in **taste buds**. Humans have about 10,000 taste buds. The majority of taste buds are located in pockets around the papillae (peg-like projections of the mucous membrane) on the surface and sides of the tongue, but there are some on the surface of the pharynx and the larynx. Each taste bud contains about 40 specialized receptor cells or **gustatory cells**, many more supporting cells and some basal cells that replace the worn out cells of the taste buds. Unlike the receptors for smell, that are modified sensory neurons, the receptor cells for taste are not neurons, but rather specialized cells with slender microvilli on their outer ends. The microvilli protrude into the surrounding fluids through a narrow opening called the **taste pore**. Dissolved chemicals contacting the microvilli bind to specific receptor proteins on the microvilli, thereby depolarizing the cell. The dendrites of the associated sensory neurons coil intimately around the receptor cells and synapse with them so that, when a receptor cell is stimulated and depolarized, it releases neurotransmitter which leads to the generation of an action potential in the associated sensory neuron. Each dendrite receives signals from several receptor cells within the taste bud. Nerve fibers emerging from the taste buds pass to the brain stem. From here the nerve impulse is relayed to the taste centre in the cerebral cortex of the brain that perceives the taste sensation.

Normally our taste sensations are complicated mixture of qualities. In humans there are four basic taste senses: sweet, sour, salt, and bitter. The receptors for these four basic tastes have their areas of greatest concentration on different parts of the tongue – sweet and salty on the front, bitter on the back, and sour on the sides. A few substances stimulate only one of the four types of receptors, but most stimulate two, three, or all four types to varying degrees. The sensation and flavour of the food we experience are thus produced by a combination of these four basic sensations, modified by accompanying sensations of smell, texture and temperature.

Sense of touch

Skin is the sensory organ for touch and is also the largest sense organ. Our sense of touch allows us to feel light sensation like the touch of a feather as well as a heavy sensation like a stone falling on the toe. These sensations come from millions of microscopic simple sensory receptors

located all over the skin and associated with the general sensations of contact or pressure, heat, cold, and pain. The receptors are located at different levels within the skin and distributed unevenly. Some parts of the body have a large number of these such as the finger tips, making them more sensitive. Can you name the parts of your body that are less sensitive and why?

Structurally, these touch receptors are either free dendritic endings or encapsulated dendritic endings present in the skin (and other parts of the body). When stimulated, these transmit the sensation to the brain. Given below is a list of some of these receptors present in the skin.

Free or bare dendritic nerve endings are present throughout the epidermis taking an extensive branching or "zigzag" form .These respond chiefly to pain and temperature but some respond to pressure as well. The root hair plexuses, net work of free nerve endings that surround hair follicles, are light touch receptors that detect bending of hairs. These report on wind blowing through your hair.

Meissner's corpuscles are small receptors in which a few spiraling dendrites are surrounded by specialized capsule (Schawann) cells. These are found just beneath the skin epidermis in dermal papillae and are especially abundant in finger tips and soles of the feet. These are light pressure receptors that allow us to become aware of a caress or feel of our shirt against our skin.

Pacinian corpuscles are the large egg shaped bodies .In each a single dendrite is surrounded by multilayers of capsule cells. These are scattered deep in the dermis and in the subcutaneous tissue of the skin .These are stimulated by deep pressure and respond only when pressure is firs applied. Thus, these receptors are best suited to monitor vibrations (on-off pressure stimulus the sense of touch allows us to detect different textures, temperatures, hardness and pain. Pain serves as a warning or alert system for the body. Whenever one or more of these sensory receptors are stimulated (by heat, cold, vibrations, pressure or pain) an impulse or action potential is generated. This impulse is then taken to the spinal cord and from there to the brain which analyses the stimulus and then generates appropriate response .The way brain interprets the sensation is our lives is also shaped by our personal experience in the past .Try to recollect your experience of touching a sharp object/ a hot plate by accident.

Chapter 22

Chemical coordination and integration

Exophthalmic goitre, also called Grave's disease: It is an endocrine disorder that is the most common cause of hyperthyroidism. In Grave's disease excessive secretion of thyroxine hormone is accompanied by diffuse enlargement of the thyroid glands. It is an autoimmune disease where patients produce antibodies that act on the thyroid glands to increase thyroxine hormone production and thyroid size. Patients suffering from cancer of thyroid glands or those with

nodules in the thyroid glands suffer from very high levels of thyroid hormones leading to hyperthyroidism**.** Such patients show some typical symptoms that include elevated metabolic rate, sweating, rapid and irregular heartbeat, weight loss despite increased appetite, frequent bowel movement and nervousness. Some patients may also experience *exophthalmos* (or protrusion of the eye balls). Thus this condition is also known as *exophthalmic goitre* .Do you recollect another condition that may also lead to goitre (enlargement of the thyroid glands)? Lack of iodine in our diet also results in goitre which, however, is associated with hypothyroidism and not hyperthyroidism.

Addison's' disease:

The cortex of the adrenal glands secretes many hormones, commonly called as corticoids. Hyposecretory disorder of the adrenal cortex or destruction of adrenal cortex in diseases such as tuberculosis leads to deficit of both glucocorticoids and mineralocorticoids. This condition is known as Addison's disease. Persons with Addison's disease tend to loose weight, their blood glucose and sodium levels drop and potassium levels rise. Can you explain why? Severe dehydration is also common in them.