

CBSE 12 Biology (57/3/2) Question Paper with Solutions

Time Allowed :3 hours	Maximum Marks :70	Total Questions :33
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General Instructions

Read the following instructions very carefully and strictly follow them:

1. This question paper contains 33 questions. All questions are compulsory.
2. The question paper is divided into **FIVE sections**: Section A, B, C, D, and E.
3. **Section A:** Questions 1 to 16 are multiple-choice type questions. Each question carries 1 mark.
4. **Section B:** Questions 17 to 21 are very short answer-type questions. Each question carries 2 marks.
5. **Section C:** Questions 22 to 28 are short answer-type questions. Each question carries 3 marks.
6. **Section D:** Questions 29 and 30 are case-based questions. Each question carries 4 marks and has subparts with internal choice in one of the subparts.
7. **Section E:** Questions 31 to 33 are long answer-type questions. Each question carries 5 marks.
8. There is no overall choice. However, **internal choice** has been provided in some questions in Section B, Section C, and Section D. A candidate has to attempt only one of the alternatives in such questions.
9. A separate question paper is available for **Visually Impaired candidates**.
10. Wherever necessary, neat and properly labeled diagrams should be drawn.

SECTION A

Questions no. 1 to 16 are Multiple Choice Type Questions, carrying 1 mark each.

1. The ploidy of the apomictic embryos developing from the integument cells and synergids respectively would be:

- (A) $n, 2n$
- (B) $2n, n$
- (C) $3n, 2n$
- (D) $2n, 3n$

Correct Answer: (B) $2n, n$

Solution: Apomictic embryos arise without fertilization. When formed from integument cells, they retain the somatic ploidy level, which is $2n$, whereas synergids, being haploid structures, remain n .

This aligns with option (B) $2n, n$.

Quick Tip

Apomixis leads to clonal reproduction, maintaining genetic uniformity.

2. A DNA fragment has 2500 nucleotides, out of which 240 are Guanine. How many bases having double hydrogen bonds between them does this DNA fragment possess?

- (A) 480
- (B) 720
- (C) 1010
- (D) 2020

Correct Answer: (D) 2020

Solution: In DNA, Guanine (G) pairs with Cytosine (C) via triple hydrogen bonds, while Adenine (A) pairs with Thymine (T) via double hydrogen bonds.

Since there are 240 Guanine bases, there must be 240 Cytosine bases. This totals 480 nucleotides, leaving $2500 - 480 = 2020$ bases as Adenine and Thymine.

Since A-T pairs form double hydrogen bonds, the number of such bases forming double bonds is 2020.

Quick Tip

Adenine pairs with Thymine (A-T) via double bonds, while Guanine pairs with Cytosine (G-C) via triple bonds.

3. The mechanism to produce seeds without fertilization has evolved in the given family of the flowering plants:

- (A) Asteraceae
- (B) Solanaceae
- (C) Malvaceae
- (D) Liliaceae

Correct Answer: (A) Asteraceae

Solution: Apomixis is a special type of asexual reproduction in which plants can produce seeds without fertilization. It results in the formation of clonal progeny, ensuring genetic uniformity across generations.

This phenomenon is common in the Asteraceae family, which includes species such as *Taraxacum* (dandelions) and *Hieracium*.

Apomixis provides advantages such as bypassing meiotic recombination, producing genetically identical offspring, and ensuring stability in hybrid varieties.

Quick Tip

Apomixis is an evolutionary advantage that allows plants to reproduce without genetic variation, maintaining desirable traits in agriculture.

4. Louis Pasteur dismissed the theory of spontaneous generation by his experiments using pre-sterilized flasks and:

- (A) Live yeast
- (B) Killed yeast
- (C) Live bacteria
- (D) Killed bacteria

Correct Answer: (B) Killed yeast

Solution: The theory of spontaneous generation proposed that living organisms could arise from non-living matter. Louis Pasteur refuted this idea by designing an experiment using pre-sterilized swan-neck flasks containing nutrient broth.

When the flasks remained sealed, no microbial growth was observed, proving that microorganisms do not arise spontaneously.

However, when the flasks were exposed to air, microbial contamination occurred, confirming that microorganisms originate from pre-existing life forms in the environment.

Quick Tip

Louis Pasteur's experiment supported the biogenesis theory, which states that all life originates from pre-existing life.

5. After the 1850s in the post-industrialization era in England, the expected effect of natural selection on the number of white-winged moths as compared to the dark-winged moths was:

- (A) Less in number
- (B) More in number
- (C) Both were less in number
- (D) Both were more in number

Correct Answer: (A) Less in number

Solution: Before industrialization, white-winged moths were more common because they camouflaged well against lichen-covered tree trunks.

Industrial pollution darkened the tree bark due to soot deposition, making dark-winged moths less visible to predators and increasing their survival rate.

White-winged moths, now more visible, were predated more frequently, leading to a decline in their population. This is a classic example of natural selection known as industrial melanism.

Quick Tip

Natural selection favors traits that provide survival advantages in changing environments.

6. A Snapdragon plant bearing red color flowers was crossed with a Snapdragon plant bearing white color flowers. The F_1 progeny on selfing produced the progeny in the ratio of:

- (A) 50% Red : 50% White
- (B) 25% Pink : 50% White : 25% Red
- (C) 50% Red : 50% Pink
- (D) 25% Red : 50% Pink : 25% White

Correct Answer: (D) 25% Red : 50% Pink : 25% White

Solution: Snapdragon flower color follows incomplete dominance, where the heterozygous condition results in a pink phenotype instead of the dominant red.

Crossing a red flower (RR) with a white flower (rr) results in all pink (Rr) flowers in the F_1 generation.

Selfing the F_1 generation (Rr \times Rr) produces a 1:2:1 ratio in the F_2 generation: - 25% Red (RR) - 50% Pink (Rr) - 25% White (rr)

Quick Tip

Incomplete dominance results in intermediate traits rather than complete dominance.

7. In which of the following chromosomal disorders do individuals have short stature, underdeveloped feminine character, and sterile ovaries?

- (A) Down's syndrome
- (B) Turner's syndrome
- (C) Klinefelter's syndrome
- (D) Patau's syndrome

Correct Answer: (B) Turner's syndrome

Solution: Turner's syndrome is caused by monosomy of the X chromosome (45, X).

Individuals with this syndrome exhibit characteristics such as short stature, webbed neck, lack of secondary sexual development, and sterility due to ovarian dysgenesis. Unlike Klinefelter's syndrome (which affects males), Turner's syndrome only affects females.

Quick Tip

Turner's syndrome is a chromosomal disorder caused by the absence of one X chromosome in females.

8. Which one of the following represents the correct annealing of primers to the DNA to be amplified in the PCR?

- (A)
- (B)
- (C)
- (D)

Correct Answer: (B)

Solution: Polymerase Chain Reaction (PCR) is a technique used to amplify DNA sequences using primers that anneal to the template strand.

Primers must bind in a complementary manner, with one primer annealing to the 3' end of one strand and the other primer annealing to the 3' end of the opposite strand.

Option (B) correctly represents the primers binding in an antiparallel orientation, ensuring successful amplification.

Quick Tip

In PCR, primers must be complementary to the template DNA and anneal in an antiparallel fashion to allow DNA polymerase to extend in the 5' to 3' direction.

9. A patient is suffering from fever, chills, cough, headache, and bluish fingernails and lips. These symptoms are of the disease:

- (A) Malaria
- (B) Typhoid
- (C) Common cold
- (D) Pneumonia

Correct Answer: (D) Pneumonia

Solution: Pneumonia is a respiratory infection that affects the lungs, leading to symptoms such as cough, chills, fever, and difficulty in breathing. The bluish discoloration of fingernails and lips is due to oxygen deprivation, a key symptom of severe pneumonia. Other diseases listed as options, such as malaria and typhoid, do not primarily cause respiratory distress or oxygen deprivation.

Quick Tip

Pneumonia is commonly caused by bacterial infections like *Streptococcus pneumoniae* and viral infections, requiring prompt medical attention.

10. In an experiment, *E. coli* is grown in a medium containing $^{14}\text{NH}_4\text{Cl}$ (^{14}N is the light isotope of nitrogen) followed by growing it for six generations in a medium having heavy isotope of nitrogen (^{15}N). After six generations, their DNA was extracted and subjected to CsCl density gradient centrifugation. Identify the correct density (Light/Hybrid/Heavy) and ratio of the bands of DNA in CsCl density gradient centrifugation.

- (A) Hybrid : Heavy, 1 : 16
- (B) Light : Heavy, 1 : 31
- (C) Hybrid : Heavy, 1 : 31
- (D) Light : Heavy, 1 : 05

Correct Answer: (C) Hybrid : Heavy, 1 : 31

Solution: Meselson and Stahl's experiment demonstrated semi-conservative replication, where parental DNA strands serve as templates for new strands. Initially, *E. coli* grown in ^{14}N medium contains only light DNA. When shifted to ^{15}N medium, new DNA incorporates ^{15}N , leading to a hybrid DNA fraction after the first round of replication. After six generations in ^{15}N medium, the majority of the DNA will be heavy (fully ^{15}N -incorporated), but a small proportion (1 in 31) will still exist in a hybrid form.

Quick Tip

Semi-conservative DNA replication ensures that each daughter strand consists of one parental and one newly synthesized strand.

11. For the replication of the first recombinant DNA, Stanley Cohen and Herbert Boyer used the DNA polymerase of:

- (A) *Thermus aquaticus*
- (B) *Salmonella typhimurium*
- (C) *Escherichia coli*
- (D) *Haemophilus influenzae*

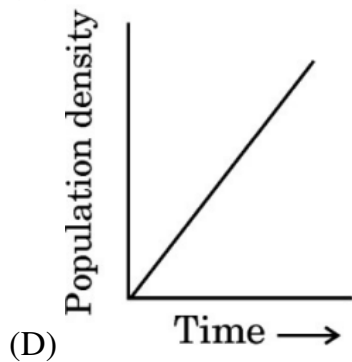
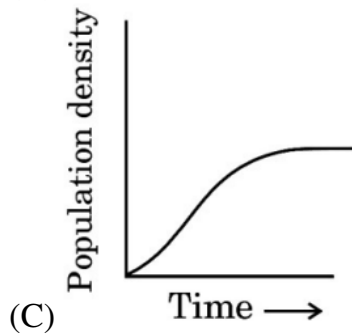
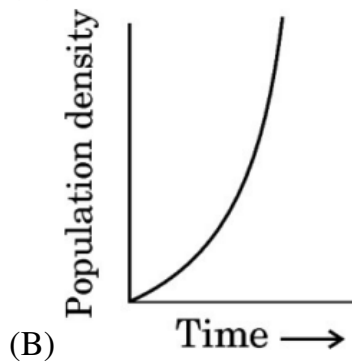
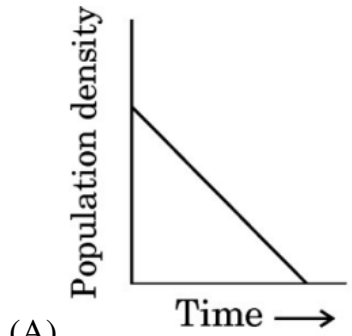
Correct Answer: (C) *Escherichia coli*

Solution: The first recombinant DNA was created by Stanley Cohen and Herbert Boyer using DNA from two different organisms. They used the DNA polymerase from *Escherichia coli* (*E. coli*), which played a critical role in amplifying the DNA during the process of recombinant DNA technology. The use of *E. coli* was vital because it is a model organism for genetic manipulation and is capable of rapid growth, facilitating easier cloning of recombinant DNA.

Quick Tip

Escherichia coli is a widely used organism in molecular biology for cloning and recombinant DNA experiments due to its fast replication and genetic versatility.

12. The population growth curve applicable for a population growing in nature with limited resources available to them will be:



Correct Answer: (C)

Solution: A population growing in nature with limited resources follows a logistic growth model, where the population size increases rapidly initially and then slows as the carrying capacity of the environment is reached.

This pattern is represented by a sigmoid curve (S-shaped curve), where the population density starts low, increases exponentially, and then levels off as resources become limited. Graph 3 depicts this logistic growth, showing the population density reaching a stable equilibrium at the carrying capacity.

Quick Tip

Logistic growth is a common model for population growth in nature, where resources limit further increases in population size.

For Questions number 13 to 16, two statements are given one labelled as Assertion (A) and the other labelled as Reason (R). Select the correct answer to these questions from the codes (A), (B), (C) and (D) as given below.

- (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A)
- (B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A)
- (C) Assertion (A) is true, but Reason (R) is false
- (D) Assertion (A) is false, but Reason (R) is true

13. Assertion (A): The zygote gives rise to a heart-shaped embryo and subsequently proembryo in most angiosperms.

Reason (R): The zygote is present at the micropylar end of the embryo sac and develops into an embryo.

Correct Answer: (D) Assertion (A) is false, but Reason (R) is true

Solution: The assertion about the zygote developing into a heart-shaped embryo is true, as it forms the proembryo in angiosperms.

However, the reason incorrectly states that the zygote develops from the micropylar end. The

zygote actually forms from fertilization, and the assertion explains the general process rather than being directly related to the specific micropylar location.

Quick Tip

In angiosperms, the zygote develops into a heart-shaped proembryo, but the micropylar end refers to the fertilization site, not the development origin.

14. Assertion (A): Primary transcripts in eukaryotes are subjected to splicing to remove the introns.

Reason (R): Primary transcripts contain both exons and introns and the introns are non-functional in eukaryotes.

Correct Answer: (A)

Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

Solution: In eukaryotes, primary RNA transcripts indeed contain both exons (coding regions) and introns (non-coding regions).

The assertion that primary transcripts undergo splicing to remove the introns is true, and the reason correctly explains that the introns are removed because they are non-functional for protein coding.

Both the assertion and reason are true and the reason directly explains the assertion.

Quick Tip

In eukaryotic cells, splicing removes non-functional introns to ensure the correct formation of mature mRNA for translation.

15. Assertion (A): The stirrer facilitates the even mixing of oxygen availability in a bioreactor. **Reason (R):** Stirred-tank bioreactors generally have a flat base.

Correct Answer: (C) Assertion (A) is true, but Reason (R) is false

Solution: The assertion is correct as the stirrer in a bioreactor is used to mix the medium, ensuring an even distribution of oxygen for microbial growth.

However, the reason is incorrect as stirred-tank bioreactors typically have a cylindrical base

rather than a flat one. The base shape doesn't directly explain the stirrer's function. The assertion is true, but the reason does not properly explain the assertion.

Quick Tip

In bioreactors, efficient mixing is essential for uniform oxygen distribution, which supports optimal microbial growth.

16. Assertion (A): The chronic use of alcohol by a person leads to cirrhosis.

Reason (R): Alcohol addiction at times becomes the cause of mental and financial distress to the entire family of the addicted person.

Correct Answer: (B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A)

Solution: The assertion is true as chronic alcohol consumption can lead to cirrhosis, which is liver scarring caused by long-term damage.

The reason is also true, as alcohol addiction can have significant impacts on the family, causing both mental and financial distress.

However, the reason is not the direct cause of cirrhosis; it is an effect on the family, not the liver. Thus, the reason does not explain the assertion.

Quick Tip

Chronic alcohol use can cause irreversible liver damage leading to cirrhosis, but it also affects the emotional and financial well-being of the family.

SECTION B

17. (a) Write important features of 'humus' formed during the decomposition cycle in a terrestrial ecosystem.

Solution: Humus is the dark, organic material formed during the decomposition process in soil. The important features of humus are:

- Humus is a rich source of nutrients like nitrogen, phosphorus, and sulfur, which are essential for plant growth.
- It improves the soil's water-holding capacity and aeration, promoting root growth.
- Humus enhances the structure of soil, making it more porous and improving its drainage.
- It plays a critical role in maintaining soil fertility and pH levels by buffering against extreme changes.
- The decomposition process of humus is a slow process that recycles organic matter and helps in nutrient cycling.
- Humus increases the biological activity in the soil, supporting various microorganisms and beneficial soil fauna.

Quick Tip

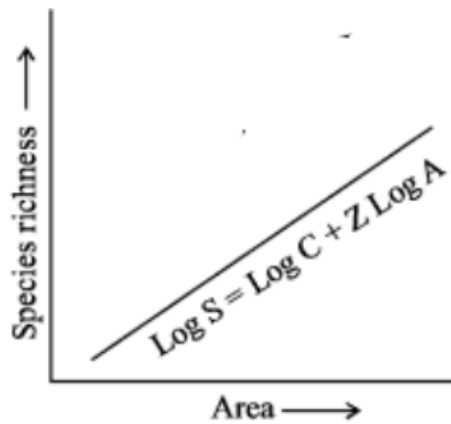
Humus is essential for maintaining soil health and fertility. It also aids in the long-term sustainability of terrestrial ecosystems by promoting nutrient cycling.

OR

(b) (i) Graphically represent the relationship between species richness and area on a log-log scale for bats and fishes.

Solution: On a log-log scale, the relationship between species richness and area can be represented by the following type of graph:

- The x-axis represents the area (log scale), and the y-axis represents species richness (log scale).
- The general trend is that as the area increases, the species richness also increases, following a power law.
- The curve typically shows a positive correlation with a steep slope in the early stages of area increase, then leveling off as the area increases further.



Quick Tip

On a log-log scale, the relationship between area and species richness generally follows a power law, where larger areas support more species.

(ii) Write the equation for the relationship as on a logarithmic scale.

Solution: The equation for the species-area relationship on a logarithmic scale is given by:

$$\log(S) = z \cdot \log(A) + c$$

where:

- S is the species richness,
- A is the area,
- z is the slope of the curve (species-area exponent), and
- c is a constant.

Quick Tip

The species-area relationship is important for understanding biodiversity patterns in ecosystems, and the equation helps quantify how species richness changes with area.

18. What is a vaccine? Write the basis on which it acts when administered in the body.

Solution: A vaccine is a biological preparation that provides active acquired immunity to a particular infectious disease. It typically contains weakened or killed forms of the microorganism or its toxins, or one of its surface proteins.

Basis of Action:

- When a vaccine is administered, it stimulates the body's immune system to recognize and fight off the pathogen in the future.
- The immune system produces antibodies in response to the vaccine, which "remember" the pathogen and allow for a quicker response if the body is exposed to the pathogen later.
- This process is known as immunization, and it helps to prevent future infections by providing "memory" immunity.

Quick Tip

Vaccines are an effective public health tool for preventing the spread of infectious diseases by "training" the immune system to recognize harmful pathogens.

19. State the procedure followed in the technique of amniocentesis. List any two advantages of this technique.

Solution: Amniocentesis is a medical procedure used to obtain a sample of amniotic fluid for testing during pregnancy. The procedure involves the following steps:

- A needle is inserted through the abdomen and into the uterus to collect a small amount of amniotic fluid, which contains fetal cells.
- The fluid is sent to a laboratory for analysis to detect genetic conditions or other abnormalities in the fetus.

Advantages:

- It helps in detecting genetic disorders like Down's syndrome, cystic fibrosis, and other chromosomal abnormalities.
- It can also detect infections, neural tube defects, and other conditions that may affect the fetus's health.

Quick Tip

Amniocentesis is a valuable diagnostic tool in prenatal care, although it carries some risk, such as miscarriage, and is typically performed when there is a medical indication.

20. Consider the given data of a hypothetical small portion of mRNA that codes for a functional polypeptide chain and answer the questions that follow:

mRNA 5'–UCAUUACACCGAUUCUUUUAAAAGA–3'

(a) How many amino acids will be formed from the given codons, if substitution of 'U' by 'C' takes place at the 5th codon? Explain your answer.

Solution: The given mRNA sequence has the following codons:

UCA UUA CAC GAA UCU UUU AAA GAA

If 'U' is substituted by 'C' at the 5th codon, the new sequence will be:

UCA UUA CAC GAAC(U)U UUU AAA GAA

From the above sequence, the number of amino acids will be 8 since there are 8 codons that code for amino acids.

(b) Write the number of amino acids that would be in the polypeptide synthesized by a similar mRNA as above, where in the fourth codon instead of 'C' there is 'U'. Justify your answer.

Solution: If in the fourth codon, 'C' is replaced with 'U', the new sequence becomes:

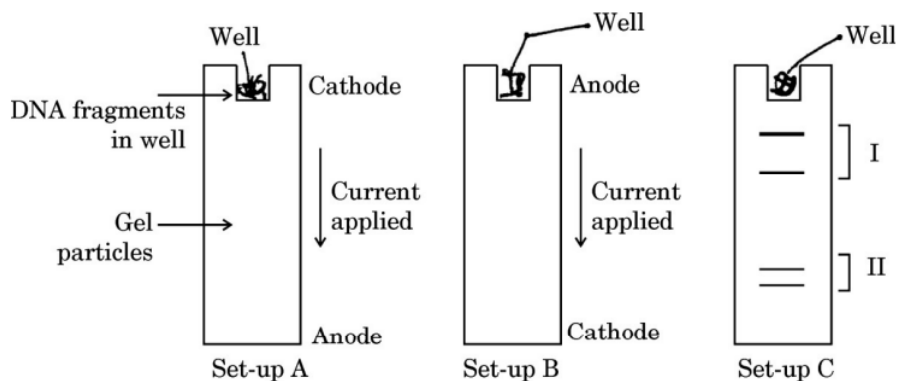
UCA UUA UUA GAA UCU UUU AAA GAA

The new codon is 'UUA', which still codes for an amino acid. The sequence will still produce 8 amino acids.

Quick Tip

The number of amino acids is determined by the number of codons, and a change in one codon (like substituting a 'C' for a 'U') can still code for an amino acid if the new codon is valid.

21. With reference to the set-ups (A, B, and C) given below, of the electrophoretic separation of a mixture of DNA fragments of varied lengths, answer the questions that follow:



(a) In which one of the two Set-ups, A or B, would you see the DNA fragments separated and why? Justify your answer.

Solution: In Set-up A, the DNA fragments will be separated. The gel matrix and the applied current create an electric field that separates the DNA fragments based on size. Smaller fragments move faster toward the anode, while larger ones move more slowly.

Quick Tip

Electrophoresis works by using an electric field to separate charged particles based on their size and charge. Smaller DNA fragments migrate faster through the gel.

(b) In Set-up C, which one of the two, I or II, are the bands of longer fragments of DNA? Justify your answer.

Solution: In Set-up C, the bands in position I represent longer DNA fragments, while the bands in position II represent shorter DNA fragments. Longer DNA fragments migrate slower through the gel matrix due to their larger size, so they form bands closer to the well in position I.

Quick Tip

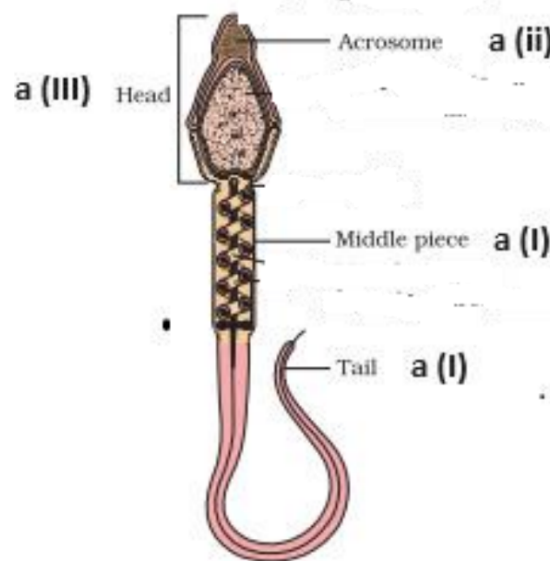
In gel electrophoresis, the longer DNA fragments move slower and thus appear closer to the starting point (well) compared to shorter fragments that migrate farther.

SECTION C

22. (a) Draw a diagram of a human sperm. Label the following parts:

- (i) Which helps in the motility of the sperm.
- (ii) Which helps in penetrating through the corona radiata and zona pellucida.
- (iii) Which enters into the cytoplasm of the human egg.

Solution:



Explanation of labeled parts:

- (i) Tail (Flagellum) - Responsible for motility
- The tail of the sperm, also called the flagellum, provides movement to propel the sperm forward.
- It generates a whip-like motion, allowing the sperm to travel through the female reproductive tract to reach the egg.
- (ii) Acrosome - Helps in penetration

- The acrosome is located at the tip of the sperm's head.
- It contains digestive enzymes such as hyaluronidase and acrosin, which help break down the protective barriers of the egg, including the corona radiata and zona pellucida, allowing fertilization to occur.
- (iii) Head - Enters the cytoplasm of the egg
- The sperm head contains the nucleus, which carries the genetic material (haploid set of chromosomes).
- During fertilization, the head fuses with the egg's plasma membrane and releases its genetic material, leading to the formation of a zygote.

Quick Tip

The acrosome contains enzymes like hyaluronidase that help the sperm penetrate the egg's protective layers during fertilization.

(b) Mention how polyspermy is prevented during the course of fertilization in humans.

Solution: Polyspermy, the fertilization of an egg by multiple sperm, is prevented by the following mechanisms:

- After the first sperm fuses with the egg, the egg's membrane undergoes a change that prevents other sperm from fusing with it.
- A cortical reaction occurs, which causes the release of enzymes that alter the zona pellucida, making it impenetrable to additional sperm.

Quick Tip

Polyspermy is prevented through mechanisms that modify the egg's membrane and zona pellucida to ensure only one sperm fertilizes the egg.

23. (a) (i) List two major reasons for using cow-dung in a biogas plant instead of using domestic sewage.

Solution:

- Cow-dung is rich in organic matter and microorganisms, making it more efficient for biogas production.
- It is easier to handle and process cow-dung as compared to domestic sewage, which may contain chemicals and other non-organic substances that could inhibit biogas production.

(ii) Mention one use of the unspent slurry of the biogas plant.

Solution: The unspent slurry from the biogas plant can be used as a high-nutrient fertilizer for crops, as it contains organic matter and nutrients that enhance soil fertility.

Quick Tip

Biogas plants not only provide renewable energy but also produce valuable by-products like fertilizer, contributing to sustainable agriculture.

OR

(b) Name the bioactive molecule and its microbial source generally used by physicians to treat the patients for:

- (i) Myocardial infarction
- (ii) High blood cholesterol level
- (iii) Organ transplantation

Solution:

- (i) **Streptokinase** is used to treat myocardial infarction (heart attack) and is derived from *Streptococcus bacteria*.
- (ii) **Statins** are used to lower high blood cholesterol levels and are produced by fungi like *Aspergillus terreus*.
- (iii) **Cyclosporine** is used in organ transplantation to prevent rejection and is derived from the fungus *Tolypocladium inflatum*.

Quick Tip

Bioactive molecules like Streptokinase, Statins, and Cyclosporine are important in treating critical conditions and have revolutionized medical treatments.

24. Three crosses were carried out in pea plants with respect to flower colour violet/white (V/v) and flower position axial/terminal (A/a). Study in the table the crosses 'a', 'b' and 'c' where parental phenotypes and their F_1 progeny phenotypes are given.

<i>Parental plants (Phenotypes)</i>	<i>F₁ Progeny (Phenotypes)</i>
(a) Violet, axial × white, axial	6/16 white, axial 2/16 white, terminal 6/16 violet, axial 2/16 violet, axial
(b) Violet, axial × white, terminal	1/4 violet, axial 1/4 violet, terminal 1/4 white, axial 1/4 white, terminal
(c) Violet, axial × violet, axial	3/4 violet, axial 1/4 white, axial

Find the genotypes of each of the parental pairs of crosses 'a', 'b' and 'c'.

Solution: For cross (a):

- Since both violet and white flowers are present in the offspring, the violet parent must be heterozygous (Vv) and the white parent must be homozygous recessive (vv).

- The axial flower phenotype indicates that both parents were either homozygous (AA) or heterozygous (Aa). Therefore, the parents' genotypes are:

- Violet, axial: VvAa

- White, axial: vvaa

For cross (b):

- The presence of both axial and terminal flowers suggests that the violet axial parent must be heterozygous for both traits (VvAa).

- The white terminal parent must be homozygous recessive for both traits (vvaa). Therefore, the parental genotypes are:

- Violet, axial: VvAa

- White, terminal: vvaa

For cross (c):

- The offspring consists of violet axial and white axial plants, which suggests that the violet axial parents must be heterozygous for both traits (VvAa).

- The parental genotypes for this cross are:

- Violet, axial: VvAa

- Violet, axial: VvAa

Quick Tip

In Mendelian genetics, understanding the phenotypic ratios and how they arise from parental genotypes helps in determining the genetic makeup of the parents.

25. (a) Mention the advantages of 'ART'.

Solution: Assisted Reproductive Technology (ART) has several advantages:

- It helps couples with infertility issues to conceive by using techniques such as in-vitro fertilization (IVF) and intrauterine insemination (IUI).
- ART allows for genetic testing of embryos, improving the chances of healthy pregnancies.
- It aids in preserving fertility for people with medical conditions that might affect their reproductive health, such as cancer or aging.

- ART provides options for single women and same-sex couples to have biological children.
- It helps to overcome reproductive challenges caused by male or female infertility.

Quick Tip

ART has revolutionized reproductive medicine by providing viable solutions to infertility and enabling many people to become parents.

(b) Explain the 'ICSI' and 'AI' methods of assisted reproductive technologies.

Solution: ICSI (Intracytoplasmic Sperm Injection): - ICSI is a type of in-vitro fertilization (IVF) in which a single sperm is injected directly into an egg to achieve fertilization. - This method is commonly used for male infertility, especially in cases of low sperm count or poor sperm motility.

AI (Artificial Insemination):

- Artificial insemination involves introducing sperm into a woman's reproductive system by means other than sexual intercourse.

- It is used when a male has low sperm count, motility issues, or other fertility problems.

Intrauterine insemination (IUI) is a common type of AI, where sperm is directly placed into the uterus.

Quick Tip

ICSI is particularly beneficial for men with severe male factor infertility, while AI helps couples with unexplained infertility or male fertility issues.

26. (a) Give the scientific name of the bacteria widely used in biotechnology to create a GM cotton crop resistant to bollworm attacks.

Solution: The scientific name of the bacterium widely used in biotechnology to create genetically modified (GM) cotton resistant to bollworm attacks is *Bacillus thuringiensis* (Bt).

- *Bacillus thuringiensis* produces a protein called Cry protein, which is toxic to specific insects like the cotton bollworm. The protein is harmless to humans, animals, and other

beneficial insects. - The use of *Bt* in GM crops like cotton helps in reducing the reliance on chemical pesticides, which benefits both the environment and farmers by reducing pesticide-related costs.

Quick Tip

Bacillus thuringiensis (Bt) is a natural insecticide used in genetically modified crops, providing sustainable pest control without the negative impacts of chemical pesticides.

(b) Explain how GM cotton crop is able to resist insect attacks.

Solution: GM cotton is engineered to produce *Bacillus thuringiensis* (Bt) proteins, specifically the Cry proteins, which are toxic to specific pests like the cotton bollworm.

Here's how the mechanism works:

- The cotton plants express the Bt protein in their tissues. When a bollworm feeds on the cotton, it ingests the Cry protein.
- The Cry protein is activated in the alkaline environment of the insect's gut and binds to receptors in the gut wall, causing a disruption in the digestive system.
- This leads to the insect's inability to digest food, causing it to stop feeding and ultimately die.
- This built-in protection reduces the need for chemical insecticides, providing an environmentally friendly and cost-effective solution to pest control.

Quick Tip

Bt cotton is an example of an environmentally sustainable solution to pest control, as it uses the plant's own defenses to protect against harmful insects, reducing pesticide use.

27. Describe the mutualistic relationship that exists between the Mediterranean orchid *Ophrys* and a bee species.

Solution: The Mediterranean orchid *Ophrys* engages in a mutualistic relationship with male bees of certain species. Here's how the relationship works:

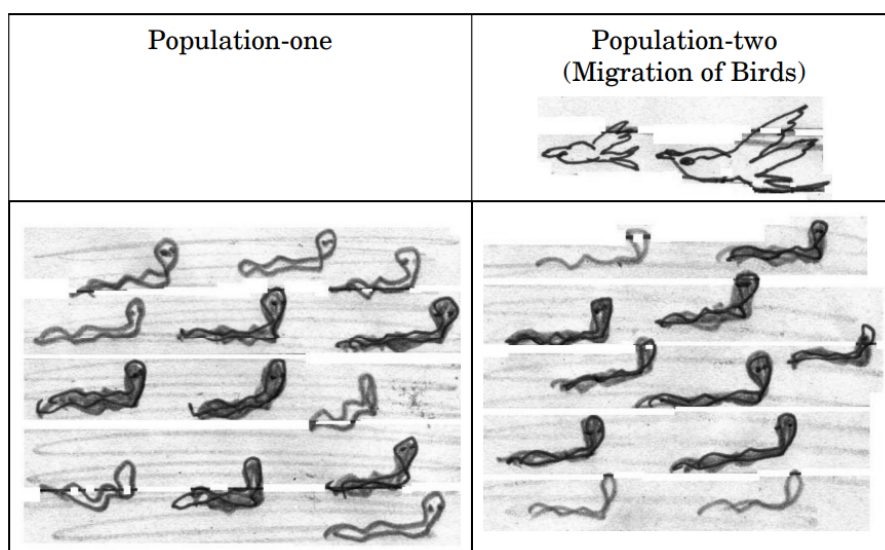
- The flower of *Ophrys* closely mimics the appearance and scent of a female bee, attracting male bees that mistake it for a mate.
- As the male bee tries to mate with the flower, it inadvertently brushes against the flower's anthers, picking up pollen.
- When the bee attempts to mate with another flower, it transfers the pollen to that flower, effectively pollinating the orchid.
- This benefits the orchid by enabling it to reproduce, while the bee gains no direct benefit, but the behavior is important for its reproductive strategy.

Thus, this relationship is mutualistic because the orchid gains pollination while the bee engages in mating behavior.

Quick Tip

Mutualism between orchids and pollinators like bees can drive evolutionary adaptations, where plants develop traits that attract specific pollinators for effective reproduction.

28. A population of snakes lived in a desert with brown sand. Study the drawings given below showing the change in the population from 'one' to 'two' over time and answer the question that follows. Brown snakes and Grey snakes are represented by alleles A/a (Dominant/recessive).



(a) If the frequency of the recessive trait is 9% in population-one, work out the frequency of homozygous dominant and heterozygous dominant snakes.

Solution: We are given the frequency of the recessive trait (aa) in population-one as 9%. Using Hardy-Weinberg equilibrium, we can calculate the frequency of the homozygous dominant (AA) and heterozygous dominant (Aa) genotypes.

- The frequency of the recessive allele (a) is given by $q = \sqrt{0.09} = 0.3$.
- The frequency of the dominant allele (A) is $p = 1 - q = 1 - 0.3 = 0.7$.
- The frequency of homozygous dominant (AA) is $p^2 = (0.7)^2 = 0.49$.
- The frequency of heterozygous dominant (Aa) is $2pq = 2(0.7)(0.3) = 0.42$.

Thus, the frequencies of the genotypes are: - Homozygous dominant (AA): 49-
Heterozygous dominant (Aa): 42

(b) Name the mechanism of evolution that must have operated so that population-two evolved from population-one.

Solution: The mechanism of evolution that must have operated is **natural selection**. The change in the snake population can be attributed to selective pressures in the environment. The brown sand likely provided camouflage for brown-colored snakes, offering them a survival advantage over grey snakes, leading to an increase in the frequency of brown-colored (dominant) snakes in the population. Additionally, migration and genetic drift might have contributed to the change in allele frequencies.

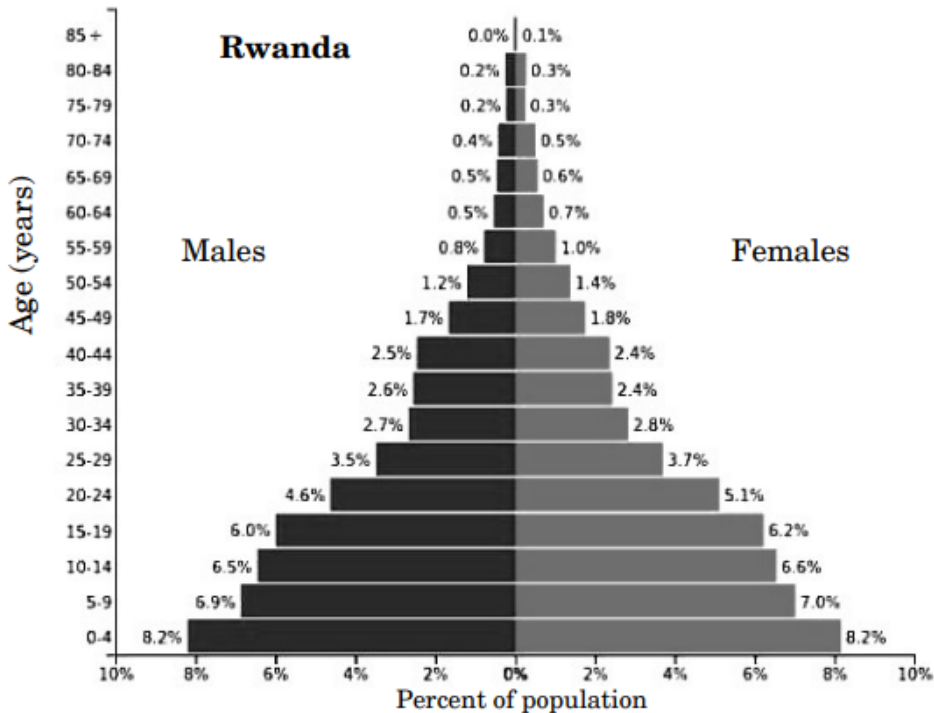
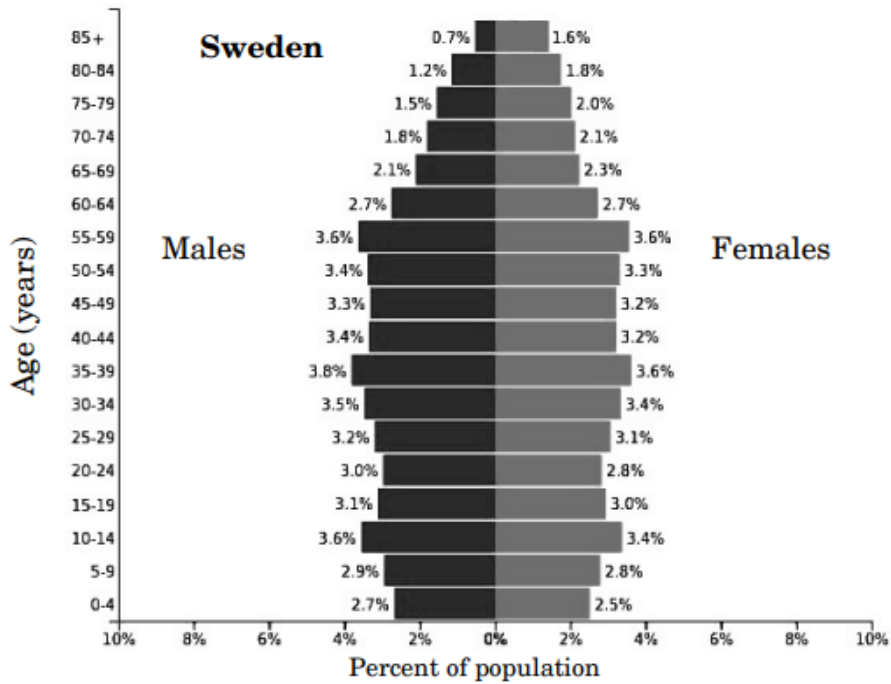
Quick Tip

Natural selection leads to the adaptation of populations over time as individuals with traits that are favorable for survival are more likely to reproduce and pass on those traits.

SECTION D

Questions no. 29 and 30 are case-based questions. Each question has 3 sub-questions with internal choice in one sub-question

29. Study the figures given below that depict the comparative age distribution of human populations in Sweden and Rwanda. (International Data Base 2003) and answer the questions that follow :



(a) What can be inferred from the very broad base of Rwanda's age pyramid? Support your answer with the data provided in the figure.

Solution: The very broad base of Rwanda's age pyramid indicates that there is a high birth rate, which is typical of developing countries. This suggests a larger proportion of the population is in the younger age groups (0-14 years), with a gradually decreasing number as age increases. - From the pyramid data, we see that the percentage of people in the younger age groups (e.g., 0-4 years and 5-9 years) is significantly larger than the older age groups. For example, in Rwanda, the age group 0-4 years makes up 8.2- This broad base suggests that Rwanda has a youthful population with a high fertility rate.

Quick Tip

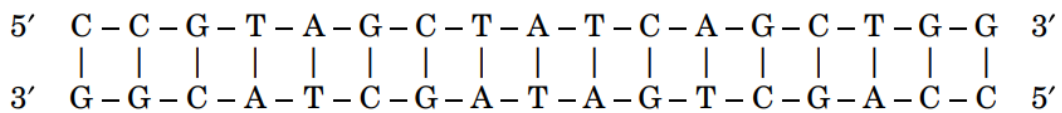
A broad base in an age pyramid indicates a high birth rate and a large proportion of the population in younger age groups, which typically suggests rapid population growth.

(b) Sweden has an age distribution that is approximately the same width near its base as at the apex. What does this indicate?

Solution: The fact that Sweden's age pyramid has a similar width near its base as at the apex suggests that Sweden has a stable population with low growth. This is characteristic of a developed country with low birth and death rates, where the population is more evenly distributed across age groups. - In Sweden, the percentage of the population in the younger age groups (e.g., 0-4 years, 5-9 years) is relatively lower compared to Rwanda, and the older age groups (60-64 years and 65+ years) also have a comparable percentage. - This type of distribution indicates that Sweden's population is aging with a steady replacement rate of younger individuals, contributing to a stable, non-expanding population.

Quick Tip

An age distribution that is similar at both the base and the apex of the pyramid indicates a stable population, typical of developed countries with low birth and death rates.



When Alu I cuts this sequence at the recognition sequence 5' A-G-C-T 3', the DNA strand is cleaved between G and C on each strand. The cuts will result in two fragments. The sequence of each fragment is as follows:

First fragment:



Second fragment:



Thus, 2 DNA fragments would be formed.

Quick Tip

Restriction enzymes like Alu I cut the DNA at specific sequences, creating fragments with sticky ends that can be used for cloning or recombinant DNA technologies.

(b) Which one of the two restriction enzymes BamH I or Alu I will preferably be used on the same given DNA strand to make a recombinant DNA molecule and why?

Solution: BamH I would preferably be used on the given DNA strand to make a recombinant DNA molecule. The reason is that BamH I creates sticky ends by cutting between G and G, which can facilitate the insertion of foreign DNA into a vector. - Sticky ends are useful in recombinant DNA technology as they allow for the ligation of complementary DNA fragments with high specificity. - In contrast, Alu I produces blunt ends, which are less efficient for ligating DNA into vectors compared to sticky ends.

Quick Tip

Sticky ends created by BamH I are ideal for the ligation of foreign DNA into vectors, while blunt ends created by Alu I are less efficient for recombination.

(c) After binding to the two strands of the double helix DNA, where specifically does the

restriction enzyme act to cut the two strands of DNA? Write the specific term used for the specific nucleotide sequences of DNA recognized by a restriction endonuclease.

Solution: Restriction enzymes act at specific sequences of nucleotides called **restriction sites**. The restriction enzyme binds to these sequences and cuts both strands of the DNA, usually between specific nucleotides. For example, the restriction enzyme BamH I recognizes the sequence



and cuts between the G and G on each strand. Similarly, Alu I recognizes the sequence



and cuts between G and C on each strand.

The process is called **restriction digestion** or **restriction enzyme cleavage**.

Quick Tip

Restriction enzymes recognize specific DNA sequences, and by cutting the DNA at these sites, they allow for precise manipulation of DNA in molecular biology experiments.

OR

(c) Write the specific sequence of DNA segment recognized by the restriction endonuclease EcoRI.

Solution: EcoRI is a widely used restriction endonuclease that recognizes the palindromic DNA sequence:



This sequence is cut between the G and A on each strand. The cut results in sticky ends with overhanging bases that can easily anneal with complementary DNA fragments during the process of cloning or recombinant DNA technology.

- The recognition site of EcoRI is specific, and only DNA fragments containing this sequence will be cleaved by this enzyme. - The sticky ends produced by EcoRI are particularly useful in molecular cloning, as they facilitate the ligation of DNA fragments with complementary sticky ends.

Quick Tip

EcoRI is one of the most widely used restriction enzymes in molecular biology. Its ability to create sticky ends enables efficient recombination of DNA fragments in genetic engineering applications.

SECTION E

31. (a) (i) Describe the life cycle of *Plasmodium* from the time it enters the human body till a female *Anopheles* mosquito bites an infected person.

Solution: The life cycle of *Plasmodium* involves both humans and *Anopheles* mosquitoes.

The key steps in the life cycle are:

1. Infection of the human host: When a female *Anopheles* mosquito bites an infected person, it injects *Plasmodium* sporozoites into the bloodstream. These sporozoites travel to the liver where they mature and reproduce.
2. Liver stage: In the liver, the sporozoites undergo asexual reproduction and form merozoites. These merozoites are released into the bloodstream.
3. Blood stage: The merozoites invade red blood cells, where they continue to reproduce asexually, causing the cells to rupture and release more merozoites into the bloodstream, which infect other red blood cells.
4. Transmission to mosquito: Some merozoites differentiate into gametocytes, which are then ingested by another *Anopheles* mosquito when it bites an infected person. Inside the mosquito's gut, the gametocytes fuse to form zygotes, which mature into sporozoites that travel to the salivary glands, ready to be transmitted to a new human host.

Quick Tip

The life cycle of *Plasmodium* alternates between human and mosquito hosts, involving both asexual and sexual reproduction phases, which contribute to its complexity and transmission.

(a) (ii) Mention the two events of *Plasmodium* life cycle that occur within the female

***Anopheles* body.**

Solution: The two key events of the *Plasmodium* life cycle that occur within the female *Anopheles* body are:

1. The fusion of male and female gametocytes to form a zygote, which develops into an ookinete.
2. The ookinete penetrates the mosquito's gut lining and forms an oocyst, where it undergoes division to produce sporozoites. These sporozoites travel to the salivary glands of the mosquito, ready to infect a new human host.

Quick Tip

The sexual cycle of *Plasmodium* occurs in the mosquito host, leading to the production of sporozoites that are essential for transmission to the human host.

OR

(b) (i) Write two differences between malignant tumor and benign tumor.

Solution: The two main differences between malignant and benign tumors are:

1. Malignant tumors are cancerous and can invade nearby tissues and spread to other parts of the body through the blood or lymphatic system, whereas benign tumors are non-cancerous and do not spread to other parts of the body.
2. Malignant tumors grow uncontrollably and can metastasize, while benign tumors grow slowly and are generally encapsulated, making them easier to remove surgically.

Quick Tip

Malignant tumors are more dangerous because they spread and invade other tissues, while benign tumors are typically localized and non-threatening.

(b) (ii) Explain any three diagnostic techniques for the detection of cancer.

Solution: Three common diagnostic techniques for detecting cancer are:

1. Biopsy: A sample of tissue is removed from the suspected tumor and examined under a microscope to check for cancer cells.
2. Imaging techniques: Methods such as X-rays, CT scans, and MRIs are used to visualize tumors inside the body.
3. Blood tests: Some cancers

produce specific markers that can be detected in the blood, helping in diagnosis and monitoring the progress of treatment.

Quick Tip

Early detection through various diagnostic techniques improves the chances of successful cancer treatment.

32. (a) (i) Explain any four devices that flowering plants have developed to encourage cross-pollination.

Solution: Four devices that flowering plants have developed to encourage cross-pollination include:

1. Colorful flowers: Brightly colored flowers attract pollinators such as bees, butterflies, and birds. 2. Scent: Flowers often release scents that attract pollinators, ensuring they visit and transfer pollen between flowers. 3. Nectar: The presence of nectar in flowers encourages pollinators to visit flowers and aids in the transfer of pollen. 4. Specialized floral structures: Some plants have specialized mechanisms, like long tubes or sticky pollen, which ensure that pollen is transferred effectively from one flower to another.

Quick Tip

Cross-pollination helps maintain genetic diversity, which is important for the health and survival of plant species.

(a) (ii) Why do plants discourage self-pollination? State any one reason.

Solution: Plants discourage self-pollination to promote genetic diversity. Cross-pollination allows for the mixing of genetic material, which helps in producing offspring with a broader genetic pool, making them more resilient to diseases and environmental changes.

Quick Tip

Self-pollination can limit genetic diversity, while cross-pollination promotes healthier and more adaptable offspring.

OR

(b) Explain the ovarian and uterine events taking place along with the role of pituitary and ovarian hormones, during menstrual cycle in a normal human female under the following phases:

(i) Follicular phase/proliferative phase

(ii) Luteal phase/secretory phase

(iii) Menstrual phase

Solution: The menstrual cycle involves several phases that are regulated by hormones from the pituitary and ovaries. The phases are:

1. Follicular phase (Proliferative phase):

- During this phase, the pituitary hormone FSH (follicle-stimulating hormone) stimulates the growth of ovarian follicles.

- The growing follicles release estrogen, which thickens the endometrium in preparation for implantation.

2. Luteal phase (Secretory phase):

- After ovulation, the ruptured follicle forms the corpus luteum, which secretes progesterone.

- Progesterone further thickens the endometrium and prepares it for potential pregnancy.

3. Menstrual phase:

- If fertilization does not occur, the corpus luteum degenerates, leading to a drop in progesterone levels.

- This causes the endometrial lining to break down and shed, leading to menstruation.

Quick Tip

The menstrual cycle is regulated by the interplay between pituitary and ovarian hormones, ensuring proper reproductive function.

33. (a) “The influence of both the alleles in a heterozygous state is clearly expressed in codominance.” Explain with the help of inheritance of ABO blood group in humans.

Solution: In the case of ABO blood groups, the alleles A and B exhibit codominance. This

means that when both alleles are present in a heterozygous individual, both are fully expressed.

For example:

- Genotype AB results in a person having both A and B antigens on the surface of their red blood cells.
- This is in contrast to dominant-recessive inheritance, where one allele is completely dominant over the other.

The ABO blood group system is controlled by three alleles: A, B, and O.

- A and B alleles are dominant, while O is recessive.
- Individuals with genotype AO or AA have blood group A, BO or BB have blood group B, AB has blood group AB, and OO has blood group O.

Quick Tip

Codominance results in both alleles being expressed simultaneously in a heterozygous individual, as seen in the ABO blood group inheritance pattern.

(b) A group of genes are regulated and expressed together as a unit in *lac operon*.

(i) Explain the mechanism of switching 'on' of the structural genes of *lac operon*.

Solution: The *lac operon* is regulated by the presence of lactose. When lactose is available, it binds to the repressor protein, causing a conformational change that prevents the repressor from binding to the operator. This allows RNA polymerase to bind to the promoter region and transcribe the structural genes, which are involved in the breakdown of lactose.

Quick Tip

The presence of lactose induces the transcription of the *lac operon* genes by inactivating the repressor protein, allowing the production of enzymes for lactose metabolism.

(ii) "Regulation of *lac operon* is referred to be negatively regulated." Justify giving a reason.

Solution: The regulation of the *lac operon* is considered negatively regulated because the

repressor protein normally binds to the operator region of the operon and prevents transcription. The presence of lactose inactivates the repressor, thus allowing transcription to occur. Without lactose, the repressor remains bound to the operator, blocking the operon.

Quick Tip

In negative regulation, the default state of the operon is "off," and the presence of an inducer like lactose removes the repression to allow gene expression.
