In-Text Questions and Answers

Introduction to Gene Editing

1. **What doubt would have arisen in your mind after knowing about the Nobel Prize in Chemistry 2020 for the development of gene editing methodology?**
   Answer: A common doubt is, "How can genes, which are invisible, be edited?" This arises because genes are microscopic DNA segments, yet technologies like CRISPR-Cas9 allow precise modifications, which seems remarkable.

2. **What is the technology that helped in editing genes accurately?**
   Answer: CRISPR-Cas9 is the technology that enables accurate gene editing by targeting specific DNA sequences and altering them.

DNA: Location and Structure

3. **What are the components that give chromosomes a specific structure?**
   Answer: Chromosomes are composed of DNA and histone proteins. DNA wraps around histone octamers to form nucleosomes, which coil further to create the chromosome structure, consisting of chromatids joined by a centromere.

4. **Complete the illustration (Structure of DNA).**
   Answer:
   - **Number of strands**: Two (double helix)
   - **Molecules used to make strands**: Deoxyribose sugar, phosphate groups
   - **Molecules used to make rungs**: Nitrogenous bases (adenine, thymine, guanine, cytosine)
   - **Different types of nitrogen bases**: Adenine (A), Thymine (T), Guanine (G), Cytosine (C)
   - **Formation of rungs**: Hydrogen bonds between complementary bases (A-T, G-C)
   - **Mode of nitrogen base pairing**: Complementary pairing (A with T, G with C)
   - **Molecules in a nucleotide**: Deoxyribose sugar, phosphate group, nitrogenous base

5. **What is the length of DNA in a chromosome and in a cell?**
   Answer: The DNA in a single chromosome is about 5 cm long. In a human cell with 46 chromosomes, the total DNA length is approximately 2 meters.

Chromosomes

6. **What are the components of chromosomes?**
   Answer: Chromosomes consist of DNA and histone proteins. DNA carries genetic information, while histones form octamers around which DNA winds to form nucleosomes.

7. **Complete the table (Chromosome Structure).**
   Answer:

Component	Description

Histone proteins	Form octamers; DNA wraps around them
Nucleosome	DNA wound around histone octamer
Chromatid	One of two identical parts of a chromosome
Centromere	Region connecting chromatids

8. **Why do chromosomes appear in pairs?**
   Answer: Chromosomes appear in pairs because one chromosome is inherited from each parent, ensuring genetic diversity and stability in diploid organisms.

9. **Prepare a table including the number of chromosomes of organisms you know.**
   Answer:

Organism	Number of Chromosomes
Human	46
Dog	78
Cat	38
Rice	24
Pea	14

10. **What are the peculiarities of sex chromosomes?**
    Answer: Sex chromosomes determine an individual's sex. Females have two X chromosomes (XX), while males have one X and one Y (XY). The X chromosome is larger with more genes, while the Y chromosome is smaller, containing the SRY gene, which triggers male development.

11. **Complete the table (Chromosomal Variations).**
    Answer:

Genetic Constitution	Characteristics
44 + X0 (Turner)	Female, underdeveloped sexual characteristics
44 + XXX (Triple-X)	Female, often asymptomatic
44 + XXY (Klinefelter)	Male with some female traits
44 + XYY	Male, often taller, minimal effects

Genes

12. **What is a gene? Where are genes seen?**
    Answer: A gene is a specific sequence of nucleotides in DNA that codes for a protein, controlling traits and metabolic activities. Genes are located on chromosomes within the DNA.

13. **What is the role of the Y chromosome in sex determination?**
Answer: The Y chromosome contains the SRY gene, which triggers the development of testes in the embryo, leading to male characteristics.

Protein Synthesis

14. **What is the significance of protein synthesis?**
Answer: Protein synthesis is crucial as it produces proteins that determine physical traits (e.g., eye color) and regulate metabolic activities (e.g., enzyme functions) based on genetic instructions.

15. **Complete the flow chart (Protein Synthesis).**
Answer:

    1. **Transcription**: DNA unwinds, mRNA is synthesized in the nucleus.
    2. **mRNA Transport**: mRNA moves from nucleus to cytoplasm.
    3. **Translation**: mRNA binds to ribosome, tRNA delivers amino acids, rRNA links amino acids to form a protein.

16. **Complete the table (Types of RNA).**
Answer:

RNA Type	Function
mRNA	Carries genetic instructions for protein synthesis
tRNA	Transfers amino acids to ribosomes
rRNA	Forms part of ribosomes, aids in protein assembly

Heredity and Variation

17. **What are heredity and variation?**
Answer: Heredity is the transmission of characteristics from parents to offspring via genes. Variation refers to differences in traits between offspring and parents, caused by genetic recombination or mutations.

Mendel's Experiments

18. **What are the reasons for the reappearance of recessive characters in the F2 generation?**
Answer: Recessive traits reappear in the F2 generation due to the law of segregation. In the F1 generation (Tt), the recessive allele (t) is masked by the dominant allele (T). In F2, when gametes combine, 25% of offspring inherit two recessive alleles (tt), expressing the recessive trait.

19. **Why are there no plants with intermediate height in the F2 generation?**
Answer: No intermediate height appears because of complete dominance. The tall allele (T) fully masks the dwarf allele (t), resulting in only tall (TT, Tt) or dwarf (tt) phenotypes, with no blending.

20. **What are the new characters formed in the F2 generation of a dihybrid cross? Why?**
Answer: New characters in the F2 generation include combinations like tall/wrinkled and dwarf/round. These arise due to independent assortment, where alleles for different traits (e.g., height and seed shape) segregate independently during gamete formation, creating new trait combinations.

21. **What is the phenotypic ratio in a dihybrid cross?**
Answer: The phenotypic ratio in the F2 generation of a dihybrid cross is 9:3:3:1 (9 tall/round, 3 tall/wrinkled, 3 dwarf/round, 1 dwarf/wrinkled).

Non-Mendelian Inheritance

22. **How do incomplete dominance and co-dominance differ from dominance?**
Answer: In complete dominance, one allele fully masks the other (e.g., tall over dwarf in peas). In incomplete dominance, neither allele is fully dominant, producing an intermediate phenotype (e.g., pink flowers in four o'clock plants). In co-dominance, both alleles are expressed simultaneously (e.g., roan coat in cattle with red and white hairs).

23. **What is multiple allelism?**
Answer: Multiple allelism is when a gene has more than two alleles. An example is the ABO blood group system, controlled by three alleles: IA, IB, and i.

24. **What are the factors that influence skin colour variation?**
Answer: Skin color variation is influenced by:
    - **Genetic Factors**: Multiple genes control melanin production.
    - **Environmental Factors**: Sunlight exposure, diet, and vitamin D levels.
    - **Geographical Factors**: Ancestral adaptations to sunlight intensity in different regions.

Genetic Processes for Variation

25. **What is crossing over? In which phase of cell division does it occur?**
Answer: Crossing over is the exchange of genetic material between homologous chromosomes at chiasmata, creating new allele combinations. It occurs during prophase I of meiosis.

26. **What is mutation?**
Answer: A mutation is a sudden, heritable change in the genetic constitution of an organism, such as point mutations or chromosomal alterations, which can introduce new traits or cause disorders.

Career Opportunities

27. **What are the career opportunities in genetics?**
Answer: Career opportunities in genetics include:
    - **Molecular Genetics**: Studying gene function and regulation.
    - **Population Genetics**: Analyzing genetic variation in populations.

- **Medical Genetics**: Diagnosing and treating genetic disorders.
- **Cytogenetics**: Examining chromosome abnormalities.
- **Behavioral Genetics**: Investigating genetic influences on behavior.
- **Genomics**: Analyzing entire genomes.
  Educational pathways include graduate programs in biotechnology, microbiology, or bioinformatics, postgraduate studies in genetic counseling or forensic science, and Ph.D. research in pharmaceuticals or agriculture.

Let Us Assess Questions and Answers

1. **Analyse the components that build up DNA and RNA, compare them, and prepare a note.**
   Answer:
   DNA and RNA Comparison:
   - **Similarities**: Both are nucleic acids made of nucleotides, each consisting of a sugar, a phosphate group, and a nitrogenous base. They store and transmit genetic information.
   - **Differences**:
     - **Sugar**: DNA has deoxyribose; RNA has ribose.
     - **Bases**: DNA contains adenine (A), thymine (T), guanine (G), and cytosine (C); RNA has uracil (U) instead of thymine.
     - **Structure**: DNA is double-stranded (double helix); RNA is single-stranded.
     - **Location**: DNA is primarily in the nucleus; RNA is synthesized in the nucleus but functions in the cytoplasm.
     - **Function**: DNA stores genetic information; RNA (mRNA, tRNA, rRNA) facilitates protein synthesis.
       Note: DNA's stable structure ensures long-term storage of genetic data, while RNA's single-stranded nature allows it to act as a temporary messenger and translator in protein synthesis.
2. **Analyse the given statements and find out the correct one.**
   a) i – Dominance, ii – Co-dominance, iii – Incomplete dominance
   b) i – Co-dominance, ii – Incomplete dominance, iii – Dominance
   c) i – Co-dominance, ii – Incomplete dominance, iii – Dominance
   d) i – Incomplete dominance, ii – Co-dominance, iii – Dominance
   Answer: c) i – Co-dominance, ii – Incomplete dominance, iii – Dominance
   Explanation: Co-dominance (e.g., ABO blood group AB type) shows both alleles expressed, incomplete dominance (e.g., pink flowers) produces an intermediate phenotype, and dominance (e.g., tall peas) has one allele masking the other.
3. **How many genes are contributed by each parent to their children during sexual reproduction?**

a) All their genes
b) Half of their genes
c) One-fourth of their genes
d) Three-fourth of their genes
Answer: b) Half of their genes
Explanation: During sexual reproduction, each parent contributes one chromosome per pair (via gametes), providing half of the offspring's genes.

4. **Answer the questions by observing the illustration of a dihybrid cross.**
a) **What is the phenotypic ratio obtained in the F2 generation?**
Answer: The phenotypic ratio is 9:3:3:1 (9 tall/round, 3 tall/wrinkled, 3 dwarf/round, 1 dwarf/wrinkled).
b) **Are there any new characters formed in the F2 generation? If yes, mention them.**
Answer: Yes, new characters include tall/wrinkled and dwarf/round, formed due to independent assortment of alleles.
c) **If the characters are not assorted independently, will there be any change in the phenotypic ratio? Why?**
Answer: Yes, the ratio would change. If genes are linked (not assorted independently), recombination is limited, altering the expected 9:3:3:1 ratio to favor parental combinations.

5. **How do dominance, co-dominance, and incomplete dominance differ from each other? Prepare a note.**
Answer:

   - **Dominance**: One allele completely masks the other in the heterozygous condition. Example: In pea plants, tall (T) masks dwarf (t), so Tt is tall.
   - **Co-dominance**: Both alleles are expressed simultaneously in the heterozygote. Example: In cattle, a roan coat (red and white hairs) results from red and white alleles.
   - **Incomplete Dominance**: Neither allele is fully dominant, producing an intermediate phenotype. Example: In four o'clock plants, red (RR) and white (WW) produce pink (RW) flowers.
     Note: Dominance follows Mendel's principles with clear dominant-recessive outcomes. Co-dominance and incomplete dominance, non-Mendelian patterns, show simultaneous expression or blending, respectively, explaining complex traits like blood types or flower colors.

6. **Analyse the phenotypic ratios obtained in the F2 generation of monohybrid and dihybrid crosses and prepare a note on your findings.**
Answer:

   - **Monohybrid Cross**: Involves one trait (e.g., height in peas). Crossing Tt × Tt yields a 3:1 phenotypic ratio in F2 (3 tall: 1 dwarf) due to complete dominance and segregation of alleles.
   - **Dihybrid Cross**: Involves two traits (e.g., height and seed shape). Crossing TtRr × TtRr yields a 9:3:3:1 ratio (9 tall/round, 3 tall/wrinkled, 3 dwarf/round, 1 dwarf/wrinkled) due to independent assortment.

Note: The monohybrid ratio reflects single-gene inheritance, while the dihybrid ratio shows how two genes assort independently, producing diverse combinations. These ratios indicate that traits are inherited as discrete units, supporting Mendel's laws.

7. **Each character is controlled by two alleles. Why?**
   Answer: Each character is controlled by two alleles because diploid organisms inherit one allele from each parent, forming a pair of homologous chromosomes. This ensures genetic diversity and stability in traits.

8. **DNA cannot move out of the nucleus, then how is protein synthesis taking place in the cytoplasm? Explain.**
   Answer: DNA remains in the nucleus, but protein synthesis occurs in the cytoplasm via transcription and translation. In transcription, DNA's gene sequence is copied into mRNA in the nucleus. mRNA exits the nucleus and travels to ribosomes in the cytoplasm. During translation, mRNA binds to ribosomes, where tRNA delivers amino acids matching mRNA codons, and rRNA links them to form proteins. Thus, mRNA acts as a messenger, carrying DNA's instructions to the cytoplasm.

9. **How do the alleles of the gene that controls the ABO blood group function?**
   Answer: The ABO blood group is controlled by three alleles: IA, IB, and i. IA and IB are co-dominant, meaning both are expressed in the heterozygote (IAIB results in type AB). The i allele is recessive, so ii produces type O. Genotypes IAIA or IAi yield type A, and IBIB or IBi yield type B. This demonstrates co-dominance (IA and IB) and multiple allelism (three alleles).

10. **All the ova formed in females contain only one type of sex chromosome. Why?**
    Answer: All ova in females contain an X chromosome because females have two X chromosomes (XX). During meiosis, each ovum receives one X chromosome, as homologous chromosomes segregate, ensuring only X is present in ova.

Extended Activities and Answers

1. **Prepare a model of transcription and translation using locally available materials.**
   Answer:
   Materials: Colored beads (for nucleotides and amino acids), strings (for DNA/mRNA strands), paper clips (for ribosomes), and cards (for tRNA).
   Procedure:
   - **Transcription**: Use two strings with beads to represent DNA strands (e.g., blue for A, red for T). Create a complementary mRNA strand (replace T with U beads) to show mRNA synthesis.
   - **Translation**: Move the mRNA string to a paper clip "ribosome." Use cards labeled with tRNA anticodons and attached beads (amino acids) to match mRNA codons. Link beads to form a "protein."
     Outcome: The model demonstrates how DNA's code is transcribed into mRNA and translated into a protein, using visual aids to clarify molecular interactions.

2. **Prepare an animation on the timeline of genetics based on the discoveries in genetics.**
   Answer:
   Timeline Animation:
   - **1822**: Gregor Mendel born, later known as the father of genetics.
   - **1856–1863**: Mendel conducts pea plant experiments, formulating Laws of Inheritance.
   - **1866**: Mendel publishes findings, largely unnoticed.
   - **1900**: Mendel's work rediscovered by Hugo de Vries, Carl Correns, and Erich von Tschermak.
   - **1953**: Watson and Crick propose DNA double helix model, using Franklin's data.
   - **1962**: Watson, Crick, and Wilkins win Nobel Prize for DNA structure.
   - **2020**: Charpentier and Doudna win Nobel Prize for CRISPR-Cas9.
     Animation Plan: Use software like PowerPoint or Canva to create slides with visuals (e.g., pea plants, DNA helix, CRISPR). Add text captions and transitions to show progression. Narrate key contributions, emphasizing their impact on modern genetics.
3. **Conduct a simulation of Mendel's experiments using locally available materials.**
   Answer:
   Materials: Colored beads (e.g., red for dominant T, blue for recessive t), cups (for plants), and dice (for random gamete pairing).
   Procedure:
   - **Monohybrid Cross**: Assign red beads (T) to tall and blue (t) to dwarf. Simulate P generation (TT × tt) by pairing beads. For F1, pair T and t (Tt, all tall). For F2, use dice to randomly pair gametes from Tt × Tt, recording TT, Tt, or tt (expect 3:1 ratio).
   - **Dihybrid Cross**: Add yellow (R, round) and green (r, wrinkled) beads. Simulate TtRr × TtRr, pairing beads randomly to observe 9:3:3:1 ratio.
     Outcome: The simulation mimics Mendel's results, showing segregation and independent assortment, reinforcing genetic principles.
4. **Conduct a study on sex determination in different organisms and prepare a note on how environmental factors influence it.**
   Answer:
   Study:
   - **Humans**: XX/XY system; SRY gene on Y determines male sex.
   - **Birds**: ZW/ZZ system; females (ZW) determine sex.
   - **Reptiles (e.g., turtles)**: Temperature-dependent sex determination (TSD); egg incubation temperature influences sex (e.g., warmer for females).
   - **Fish (e.g., clownfish)**: Sequential hermaphroditism; environmental cues like social hierarchy trigger sex change.

Environmental Influence: In TSD species, temperature affects gene expression (e.g., aromatase activity), determining sex. In fish, social factors like dominant individual absence can alter sex.
Note: Sex determination varies across species, with genetic systems (XX/XY, ZW/ZZ) or environmental factors like temperature or social cues playing roles. Understanding these mechanisms aids conservation, as climate change may skew sex ratios in TSD species.

5. **Organise a discussion in your class on the topic 'The Science behind Skin Colour Variation and its Social Impacts.' Prepare a report.**
Answer:
Discussion Report:
Topic: The Science behind Skin Colour Variation and its Social Impacts
Participants: Class students, guided by the teacher.
Scientific Basis: Skin color is determined by melanin, controlled by multiple genes (polygenic inheritance). Environmental factors like sunlight and diet, and geographical ancestry, influence melanin levels, leading to diverse skin tones. For example, populations in high-UV regions evolved darker skin for protection.
Social Impacts: Skin color has historically influenced social perceptions, leading to discrimination or privilege in some societies. Students shared examples of colorism in media and personal experiences, noting its emotional impact. The discussion emphasized that skin color is a minor genetic variation, not a measure of worth.
Solutions: Education on genetics can reduce prejudice. Promoting inclusivity in media and policies fosters equality.
Conclusion: The discussion highlighted that skin color is a biological adaptation, not a basis for division. Understanding its science promotes empathy and challenges stereotypes, building a more inclusive society.