

CBSE Class 12 Biology Question Paper 2010 with Solution PDF-Set 57/1

Question Paper with Solutions

Conducted by the Central Board of Secondary Education (CBSE)



Time Allowed: 3 Hours

Maximum Marks: 70

General Instructions

- (i) This question paper contains 30 questions. All questions are compulsory.
- (ii) There is no overall choice. An internal choice is provided in 5 questions (Q14, Q26, Q28, Q29, Q30); attempt only one of the alternatives in such questions.
- (iii) Marks for each question are indicated against it.

1. Mention the site where syngamy occurs in amphibians and reptiles respectively.

[1 mark]

Solution:

Concept:

- Syngamy is the fusion of the male and female gametes to form a zygote. Its site depends on whether fertilisation is external or internal.
- In external fertilisation gametes unite outside the body; in internal fertilisation they unite within the female body.

Step 1: Identify the site in amphibians In the usual amphibian example, the frog, eggs and sperm are released into water. Their fusion therefore takes place outside the female body, in the surrounding water.

Step 2: Identify the site in reptiles Reptiles show internal fertilisation: sperm reaches the female reproductive tract, where it fuses with the egg before the egg is laid.

Step 3: Conclusion Syngamy occurs in water outside the body in amphibians, and inside the female reproductive tract in reptiles, respectively.

Quick Tip to Solve: Link amphibians with external fertilisation in water and reptiles with internal fertilisation before egg laying.

2. How is snow-blindness caused in humans?

[1 mark]

Solution:

Concept:

- Ultraviolet-B (UV-B) radiation can damage the cornea, the transparent surface at the front of the eye.
- Snow reflects sunlight strongly, increasing the ultraviolet radiation that can reach an unprotected eye.

Step 1: Identify the radiation involved Exposure to excessive UV-B radiation, including sunlight reflected from snow, injures the corneal surface. It is the ultraviolet component of sunlight that produces the injury.

Step 2: Relate the injury to snow-blindness The damaged cornea becomes inflamed. This inflammation, called photokeratitis or snow-blindness, causes painful, temporary impairment of vision.

Step 3: Conclusion Snow-blindness is caused by inflammation of the cornea due to excessive exposure to UV-B radiation, especially that reflected from snow.

Quick Tip to Solve: Remember the causal chain: reflected UV-B radiation, corneal inflammation, then temporary visual impairment.

3. Name one autosomal dominant and one autosomal recessive Mendelian disorder in humans.

[1 mark]

Solution:

Concept:

- An autosomal Mendelian disorder is caused by a mutation in a gene on an autosome rather than on a sex chromosome.
- A dominant disorder is expressed with one affected allele; a recessive disorder requires two affected alleles.

Step 1: Give an autosomal dominant example Myotonic dystrophy is an autosomal dominant disorder. A person with one copy of the disease-causing allele can express the disorder.

Step 2: Give an autosomal recessive example Sickle-cell anaemia is an autosomal recessive disorder. It is expressed in an individual homozygous for the sickle-cell allele; a heterozygous individual has the sickle-cell trait.

Step 3: Conclusion Autosomal dominant: myotonic dystrophy. Autosomal recessive: sickle-cell anaemia.

Quick Tip to Solve: Use myotonic dystrophy for dominant inheritance and sickle-cell anaemia for recessive inheritance; both are autosomal.

4. How is the action of exonuclease different from that of endonuclease?

[1 mark]

Solution:

Concept:

- Nucleases are enzymes that break phosphodiester bonds in nucleic acids. Their names distinguish the position at which they act.
- Exonucleases act at free ends, whereas endonucleases cleave at sites within a nucleic acid strand.

Step 1: Describe exonuclease action An exonuclease removes nucleotides successively from a free end of a DNA strand. Thus, its action shortens DNA starting at a terminus.

Step 2: Describe endonuclease action An endonuclease makes cuts at internal positions within DNA rather than removing nucleotides successively from its ends. Restriction endonucleases are a group that recognise specific DNA sequences.

Step 3: Conclusion Exonucleases remove nucleotides from DNA ends; endonucleases cut DNA at internal positions.

Quick Tip to Solve: Associate exo with an exposed end and endo with an internal site to distinguish the two nuclease actions.

5. India has more than 50,000 strains of rice. Mention the level of biodiversity it represents. [1 mark]

Solution:

Concept:

- Genetic diversity is variation in genetic characteristics among individuals or populations of the same species.
- Species diversity concerns different species, whereas ecological diversity concerns different ecosystems.

Step 1: Identify what the rice strains represent The many strains of rice are varieties within the same crop species. They differ in inherited features such as grain characteristics, yield and adaptation.

Step 2: Choose the appropriate biodiversity level Because the variation is among strains within a species, it represents variation in the gene pool. The number of strains is not a count of different ecosystems or of different species.

Step 3: Conclusion The more than 50,000 strains of rice represent genetic diversity.

Quick Tip to Solve: For varieties or strains of one species, choose genetic diversity; reserve species diversity for different species.

6. Mention the information that the health workers derive by measuring BOD of a water body. [1 mark]

Solution:

Concept:

- Biochemical oxygen demand (BOD) is the oxygen required by microorganisms to decompose biodegradable organic matter in a water sample.
- BOD therefore indicates the load of biodegradable organic pollutants and the consequent demand on dissolved oxygen.

Step 1: Interpret the BOD measurement Health workers use BOD to estimate the extent of organic pollution in a water body. More biodegradable organic matter supports greater microbial decomposition and oxygen consumption.

Step 2: Relate BOD to water quality A high BOD indicates a heavy biodegradable organic load and poorer water quality, with a risk of depletion of dissolved oxygen. A lower BOD generally indicates less biodegradable organic pollution.

Step 3: Conclusion BOD indicates the degree of biodegradable organic pollution in water: a higher BOD generally means greater organic pollution and poorer water quality.

Quick Tip to Solve: Read high BOD as high microbial oxygen demand due to organic waste, rather than as a high dissolved-oxygen level.

7. Name the enzyme involved in the continuous replication of DNA strand. Mention the polarity of the template strand. [1 mark]

Solution:

Concept:

- DNA-dependent DNA polymerase extends a new DNA strand only in the $5' \rightarrow 3'$ direction.
- The two DNA strands are antiparallel, so synthesis direction is opposite to template polarity.

Step 1: Identify the enzyme The enzyme is DNA-dependent DNA polymerase. It adds deoxyribonucleotides to the free $3' - OH$ end of the growing daughter strand, using the parental DNA strand as its template.

Step 2: Relate continuous synthesis to template polarity On the leading strand, DNA polymerase synthesises DNA continuously towards the advancing replication fork. The template is therefore read in the $3' \rightarrow 5'$ direction; the new strand grows in the opposite, $5' \rightarrow 3'$, direction.

Step 3: Conclusion DNA-dependent DNA polymerase carries out continuous replication on a template with $3' \rightarrow 5'$ polarity.

Quick Tip to Solve: Write the template polarity separately from the daughter-strand polarity: they are antiparallel.

8. Offsprings derived by asexual reproduction are called clones. Justify giving two reasons. [1 mark]

Solution:

Concept:

- A clone is a group of individuals that are morphologically and genetically similar.
- Asexual reproduction involves one parent and no fusion of gametes.

Step 1: Give the genetic reason Asexual offspring arise from a single parent without meiosis and fertilisation. Their genetic material is copied from that parent, generally through mitotic divisions, so they have the same genetic constitution as the parent and one another, apart from occasional mutations.

Step 2: Give the morphological reason Because the offspring inherit the same genetic constitution, they are also morphologically similar to the parent and to one another. This similarity in form, together with genetic similarity, is why the term clone is used.

Step 3: Conclusion They are called clones because they are genetically similar and morphologically similar to the parent and to one another.

Quick Tip to Solve: For two reasons, state both genetic similarity and morphological similarity explicitly.

9. Mention the role of ribosomes in peptide-bond formation. How does ATP facilitate it? [2 marks]

Solution:

Concept:

- A ribosome positions aminoacyl-tRNAs so that adjacent amino acids can be joined during translation.
- Peptidyl transferase activity of ribosomal RNA catalyses peptide-bond formation.
- ATP supplies energy for amino-acid activation and attachment to tRNA before translation.

Step 1: Explain the catalytic role of ribosomes The ribosome brings the charged tRNAs into the correct positions at its P and A sites. Its large-subunit ribosomal RNA acts as a ribozyme, with peptidyl transferase activity. It catalyses formation of the peptide bond between the growing peptide on the P-site tRNA and the amino acid on the A-site tRNA, transferring the peptide to the latter.

Step 2: Explain how ATP facilitates the process Before an amino acid is delivered to the ribosome, an aminoacyl-tRNA synthetase uses ATP to activate the amino acid and attach it to its specific tRNA. ATP is converted to AMP and pyrophosphate during this charging process. Energy stored in the resulting aminoacyl-tRNA linkage drives peptide-bond formation; ATP thus facilitates the reaction through amino-acid activation, rather than being directly consumed by peptidyl transferase.

Step 3: Conclusion Ribosomal rRNA catalyses peptide-bond formation, while ATP enables amino-acid activation and tRNA charging, supplying energy indirectly for the bond-forming reaction.

Quick Tip to Solve: Link ATP to charging of tRNA, and link ribosomal rRNA to peptide-bond catalysis.

10. How do copper and hormone releasing IUDs act as contraceptives? Explain. [2 marks]

Solution:

Concept:

- Intrauterine devices (IUDs) are placed in the uterus and prevent conception mainly by interfering with sperm function and fertilisation.
- Copper-releasing and hormone-releasing IUDs have distinct additional contraceptive actions.

Step 1: Explain the action of copper-releasing IUDs IUDs increase phagocytosis of sperms within the uterus. Copper-releasing devices, such as CuT and Cu7, also release copper ions. These ions suppress sperm motility and reduce the fertilising capacity of sperms. Consequently, fewer functional sperms can reach and fertilise the ovum.

Step 2: Explain the action of hormone-releasing IUDs Hormone-releasing IUDs, such as Progestasert and LNG-20, release a progestational hormone locally. They make the uterus unsuitable for implantation and make the cervical mucus hostile to sperms. The cervical effect impedes sperm entry and passage, while the uterine changes further prevent establishment of a pregnancy.

Step 3: Conclusion Copper IUDs suppress sperm motility and fertilising ability; hormone IUDs make the cervix hostile to sperms and the uterus unsuitable for implantation.

Quick Tip to Solve: Remember copper for sperm motility and fertilising ability, and hormone IUDs for cervix and uterus.

11. If you squeeze a seed of orange you might observe many embryos of different sizes. How is it possible? Explain. [2 marks]

Solution:

Concept:

- Polyembryony is the occurrence of more than one embryo in a single seed.
- In Citrus, additional embryos can arise adventively from nucellar cells outside the embryo sac.

Step 1: Identify the phenomenon The presence of several embryos in one orange seed is called polyembryony. A seed need not contain only the embryo produced from the fertilised egg; in Citrus, maternal tissues can also give rise to embryos.

Step 2: Explain the origin of the additional embryos Some diploid nucellar cells surrounding the embryo sac begin to divide, protrude into the embryo sac and develop into embryos. These nucellar embryos develop alongside the normal embryo derived from the zygote. Their formation does not require fertilisation of the nucellar cells and is an example of adventive embryony, a form of apomixis.

Step 3: Account for the different sizes Several embryos therefore share one developing seed. They can be at different developmental stages and grow at different rates, so the embryos observed when the seed is opened may differ in size.

Step 4: Conclusion Orange exhibits polyembryony: several nucellar embryos can develop along with the normal zygotic embryo in the same seed, producing embryos of different sizes.

Quick Tip to Solve: For Citrus polyembryony, name the nucellus as the source of the additional embryos.

12. A recombinant DNA is formed when sticky ends of vector DNA and foreign DNA join. Explain how the sticky ends are formed and get joined. [2 marks]

Solution:

Concept:

- Restriction endonucleases recognise specific DNA sequences and can cut the two strands at different positions, producing single-stranded overhangs called sticky ends.
- Complementary bases pair by hydrogen bonds; DNA ligase seals breaks in the sugar-phosphate backbone.

Step 1: Form compatible sticky ends The vector DNA and the foreign DNA are cut with the same restriction endonuclease. The enzyme recognises its specific recognition sequence and makes staggered cuts in the two DNA strands. Short, exposed single-stranded ends are therefore left at the cut sites. Because the same enzyme is used, the vector and insert have compatible, complementary sticky ends.

Step 2: Join and seal the fragments When the cut vector and foreign DNA are mixed, their complementary sticky ends anneal through hydrogen bonding between complementary bases. DNA ligase then joins the adjacent nucleotides by forming phosphodiester bonds in the sugar-phosphate backbones. This converts the temporarily base-paired fragments into a stable recombinant DNA molecule.

Step 3: Conclusion Sticky ends arise from staggered restriction-enzyme cuts, pair by complementary base pairing, and are covalently joined by DNA ligase.

Quick Tip to Solve: Remember the sequence: restriction enzyme cuts, sticky ends pair, and DNA ligase seals.

13. (i) Mention the number of primers required in each cycle of polymerase chain reaction (PCR). Write the role of primers and DNA polymerase in PCR. (ii) Give the characteristic feature and source organism of the DNA polymerase used in PCR. [2 marks]

Solution:

Concept:

- A PCR reaction uses two types of short DNA primers, one complementary to each template strand at opposite ends of the target region.
- DNA polymerase extends a primer from its free 3'-OH end, synthesising DNA in the 5' to 3' direction.

Step 1: (i) State the primer requirement and enzyme roles Two primers, a forward primer and a reverse primer, are required in each PCR cycle. They anneal to complementary sequences on the separated template strands and define the ends of the DNA region to be amplified. Each primer supplies a free 3'-OH end from which synthesis can begin. DNA polymerase extends these primers by adding complementary deoxyribonucleotides, producing copies of the target DNA.

Step 2: (ii) Identify the polymerase and its special feature The enzyme commonly used is Taq DNA polymerase, obtained from the bacterium *Thermus aquaticus*. It is thermostable: it tolerates the high temperature used to separate DNA strands during PCR and remains functional for repeated extension cycles. Thus fresh polymerase need not be supplied after every denaturation step.

Step 3: Conclusion PCR uses two primers and a thermostable DNA polymerase; Taq polymerase comes from *Thermus aquaticus*.

Quick Tip to Solve: Link the two primers to the two template strands, and Taq thermostability to repeated heating.

14. Define the term 'health'. Mention any two ways of maintaining it. [2 marks]

Solution:

Concept:

- Health is a state of complete physical, mental and social well-being; freedom from disease alone is insufficient.
- Good nutrition and regular physical activity help maintain normal body functions and general well-being.

Step 1: Define health Health means a state of complete physical, mental and social well-being, rather than merely the absence of disease or physical infirmity. A healthy person should therefore be considered in terms of bodily condition, mental well-being and social functioning together.

Step 2: State two ways to maintain health First, eat a balanced diet that supplies adequate carbohydrates, proteins, fats, vitamins, minerals and water. It supports growth, repair and the normal functioning of the body. Second, take regular physical exercise appropriate to age and ability. Exercise maintains physical fitness and supports mental well-being. These are two distinct measures for maintaining health.

Step 3: Conclusion Health is complete physical, mental and social well-being. A balanced diet and regular exercise are two ways of maintaining it.

Quick Tip to Solve: Include all three dimensions in the definition, then name two clear practical health measures.

OR

14. Why does a doctor administer tetanus antitoxin and not a tetanus vaccine to a child injured in a roadside accident with a bleeding wound? Explain. [2 marks]

Solution:

Concept:

- Tetanus antitoxin contains ready-made antibodies that neutralise tetanus toxin and provide passive immunity.
- A vaccine induces active immunity by stimulating the patient to make antibodies and memory cells; this response takes time.

Step 1: Explain why immediate protection is needed A roadside wound may become contaminated with spores of *Clostridium tetani*. If infection develops, the bacterium can release a toxin that affects the nervous system. The child therefore needs rapid protection against the toxin following such a potentially contaminated injury.

Step 2: Compare antitoxin with vaccination Tetanus antitoxin supplies preformed antibodies, which can immediately neutralise circulating, unbound tetanus toxin. This is passive immunity and is relatively short-lived. A tetanus vaccine contains toxoid and stimulates the child's own immune system to produce antibodies and memory cells. That active response takes time, so vaccination alone does not provide the immediate antibody protection required in the situation described.

Step 3: Conclusion Antitoxin is used for immediate passive protection because it supplies ready-made antibodies; a vaccine needs time to induce active immunity.

Quick Tip to Solve: For immediate protection think ready-made antibodies; for lasting immune memory think vaccination.

15. Giving two reasons explain why there is more species biodiversity in tropical latitudes than in temperate ones. [2 marks]

Solution:

Concept:

- Species richness depends on the evolutionary time available for speciation and the stability of environmental conditions.
- Tropical regions have generally experienced fewer large climatic disturbances and less seasonal variation than temperate regions.

Step 1: Explain the longer evolutionary history Tropical latitudes have remained relatively undisturbed for millions of years. Their communities have therefore had a long, uninterrupted period in which new species could evolve and accumulate. Temperate regions underwent repeated glaciations, which disturbed habitats and eliminated many species, reducing the time available for uninterrupted diversification.

Step 2: Explain the effect of a stable climate Tropical environments are less seasonal, relatively constant and more predictable than temperate environments. Such conditions promote niche specialisation: different species become adapted to particular resources and ways of life. This allows more specialised species to coexist and consequently supports greater species richness.

Step 3: Conclusion Greater tropical species biodiversity is explained by a longer, relatively undisturbed evolutionary history and a more stable, less seasonal climate that favours niche specialisation.

Quick Tip to Solve: Link each reason to its consequence: uninterrupted time allows speciation; climatic stability allows niche specialisation.

16. Name an opioid drug and its source plant. How does the drug affect the human body? [2 marks]

Solution:

Concept:

- Opioids are drugs that bind to specific opioid receptors, present principally in the central nervous system and gastrointestinal tract.
- Heroin is an opioid derived from morphine obtained from the opium poppy, *Papaver somniferum*.

Step 1: Identify the drug and its plant source An example is heroin, commonly called smack. Chemically, it is diacetylmorphine and is prepared by acetylation of morphine. Morphine is extracted from the latex of the opium poppy, *Papaver somniferum*; this plant is therefore the source of the opioid.

Step 2: Describe its action on the body Heroin binds to opioid receptors and acts as a depressant. It slows down body functions, including nervous-system activity and breathing. It may produce a sense of euphoria and drowsiness, but repeated use can cause dependence. Thus, its characteristic effect is depression of body functions rather than stimulation of alertness.

Step 3: Conclusion Heroin is an opioid obtained from morphine of the opium poppy, *Papaver somniferum*. It acts on opioid receptors as a depressant and slows body functions.

Quick Tip to Solve: Remember the source chain: opium poppy latex gives morphine, whose acetylation gives heroin; heroin is a depressant.

17. Mention the major cause of air pollution in metro cities. Write any three ways by which it can be reduced. [2 marks]

Solution:

Concept:

- Automobile exhaust is a major cause of air pollution in metropolitan cities because of the large number of motor vehicles.
- Vehicular pollution can be reduced by using cleaner fuel, treating exhaust gases and reducing emissions through maintenance.

Step 1: Identify the major source The major cause is emissions from automobiles. Burning petrol or diesel releases pollutants such as carbon monoxide, nitrogen oxides, unburnt hydrocarbons and particulate matter. Heavy urban traffic makes these vehicular emissions a major contributor to polluted city air.

Step 2: State three measures to reduce pollution (i) Replace petrol or diesel with cleaner fuels such as compressed natural gas (CNG), especially in public transport. CNG burns more completely and releases fewer pollutants.

(ii) Fit vehicles with catalytic converters. These convert carbon monoxide and unburnt hydrocarbons into less harmful products and reduce nitrogen oxides to nitrogen. Vehicles with catalytic converters must use unleaded petrol.

(iii) Maintain engines regularly and carry out periodic emission checks. Proper engine tuning and servicing improve combustion and reduce the release of smoke and unburnt fuel.

Step 3: Conclusion Automobile exhaust is the major cause. Cleaner fuels such as CNG, catalytic converters, and regular vehicle maintenance with emission checks help reduce it.

Quick Tip to Solve: Organise the three controls by stage: cleaner fuel before combustion, a tuned engine during combustion, and catalytic treatment of exhaust.

18. How did Eli Lilly synthesise the human insulin? Mention one difference between this insulin and the one produced by the human pancreas. [2 marks]

Solution:

Concept:

- Mature human insulin contains an A chain and a B chain joined by disulphide bonds.
- Pancreatic beta cells first synthesise proinsulin, containing an additional connecting segment called the C-peptide, which is removed during maturation.

Step 1: Describe recombinant production by Eli Lilly In 1983, Eli Lilly prepared two DNA sequences corresponding to the A and B chains of human insulin. Each sequence was introduced into a plasmid of *Escherichia coli* so that the bacteria produced the corresponding insulin chain. The A and B chains were produced separately, extracted and combined by creating disulphide bonds to form mature human insulin.

Step 2: Compare the production forms Eli Lilly's method assembled the A and B chains directly and

the resulting insulin lacked C-peptide. In contrast, the human pancreas initially produces proinsulin, in which C-peptide connects the A and B portions. The C-peptide is removed when proinsulin matures. Thus, the difference concerns the precursor and production route; mature pancreatic insulin also lacks C-peptide and has the same A and B chain structure.

Step 3: Conclusion Eli Lilly expressed the A and B chains separately in *E. coli* and joined them through disulphide bonds. Its insulin lacked C-peptide, whereas the pancreatic precursor, proinsulin, contains C-peptide before maturation.

Quick Tip to Solve: Separate proinsulin from mature insulin: C-peptide occurs in the pancreatic precursor, but is absent from both mature pancreatic and recombinant insulin.

19. (i) Write the characteristic features of anther, pollen and stigma of wind pollinated flowers. (ii) How do flowers reward their insect pollinators? Explain. [3 marks]

Solution:

Concept:

- Wind pollination, or anemophily, depends on the release of pollen into moving air and its interception by a receptive stigma.
- Insect pollination, or entomophily, involves transfer of pollen by visiting insects; food and sometimes safe breeding sites attract these visitors.

Step 1: (i) Adaptations for wind pollination Anthers are well exposed, often borne on long, projecting filaments, so that air currents can readily shake out and carry away their pollen. The pollen grains are light, dry and non-sticky, allowing them to travel in the wind rather than adhere to one another. They are produced in very large numbers because much of the pollen released into the air never reaches a compatible stigma. Stigmas are large, feathery and exposed; their extensive surface can efficiently intercept the airborne pollen grains. Together, exposed anthers facilitate dispersal, while feathery stigmas facilitate reception.

Step 2: (ii) Rewards for insect visitors Most insect-pollinated flowers offer nectar and pollen as food. An insect visiting to collect nectar or consume pollen contacts the anthers and stigma, thereby transferring pollen between flowers. Some flowers also provide a safe place for insects to lay eggs. For example, the association of *Yucca* and its moth provides an egg-laying site for the moth; the moth pollinates the flower, and its larvae obtain food from some developing seeds. Thus, the reward encourages visits that enable pollination.

Step 3: Conclusion Wind-pollinated flowers have exposed anthers, abundant light non-sticky pollen and large feathery stigmas. Flowers reward insect pollinators with nectar, pollen and, in some cases, safe egg-laying sites.

Quick Tip to Solve: Link each wind adaptation to its task: exposed anthers release, light pollen travels, and feathery stigmas trap.

20. (i) Why are grasshopper and Drosophila said to show male heterogamety? Explain. (ii) Explain female heterogamety with the help of an example. [3 marks]

Solution:

Concept:

- Heterogamety means production of two types of gametes differing in their sex-chromosome constitution. The sex producing these two gamete types is called heterogametic.
- In male heterogamety, males produce two kinds of sperm while females produce one kind of egg. In female heterogamety, females produce two kinds of eggs while males produce one kind of sperm.

Step 1: (i) Male heterogamety in grasshopper and Drosophila In grasshopper, the female has the sex-chromosome constitution XX and the male has XO; O denotes absence of a second sex chromosome, not a separate chromosome. During spermatogenesis the male produces two types of sperm: one carrying an X chromosome and the other carrying no sex chromosome. All eggs carry an X. Fertilisation by an X-bearing sperm forms an XX female, whereas fertilisation by a sperm without a sex chromosome forms an XO male.

In Drosophila, females are XX and males are XY. Males produce X-bearing and Y-bearing sperm, while all eggs carry an X. Union with an X-bearing sperm gives an XX female and union with a Y-bearing sperm gives an XY male. Both grasshopper and Drosophila therefore show male heterogamety, although their male sex-chromosome systems are XO and XY respectively.

Step 2: (ii) Female heterogamety in birds Birds, such as hens, show female heterogamety. The female is ZW and the male is ZZ. The female produces two kinds of eggs, Z-bearing and W-bearing, whereas the male produces only Z-bearing sperm. A Z-bearing egg fertilised by a Z-bearing sperm forms a ZZ male; a W-bearing egg fertilised by a Z-bearing sperm forms a ZW female. Thus, the female supplies the two alternative sex-chromosome types through her eggs.

Step 3: Conclusion Grasshopper males (XO) and Drosophila males (XY) are heterogametic because they produce two sex-chromosome types of sperm. In birds, ZW females are heterogametic and ZZ males are homogametic.

Quick Tip to Solve: Identify the sex producing two gamete types: XO or XY males give male heterogamety; ZW females give female heterogamety.

21. In a series of experiments with Streptococcus and mice F. Griffith concluded that R-strain bacteria had been transformed. Explain. [3 marks]

Solution:

Concept:

- Griffith studied Streptococcus pneumoniae. Its smooth (S) strain has a polysaccharide capsule and is virulent; the rough (R) strain lacks the capsule and is non-virulent in his mouse experiments.
- Transformation is a heritable change in a bacterium caused by acquisition of genetic material from another source. Griffith demonstrated the phenomenon without identifying the chemical nature of the transforming material.

Step 1: Establish the effects of S and R strains When Griffith injected live S-strain bacteria into mice, the mice died. The smooth colonies were associated with a protective capsule that helped the bacteria escape the host's defences. Mice injected with live R-strain bacteria survived because these non-capsulated bacteria were non-virulent. Mice injected with heat-killed S-strain bacteria also survived: heating had killed the bacteria, so the S strain could no longer multiply and cause disease.

Step 2: Combine live R bacteria with heat-killed S bacteria Griffith then injected a mixture of live R-strain bacteria and heat-killed S-strain bacteria. Unexpectedly, the mice died even though each component, when injected separately, had failed to kill them. Moreover, he recovered living S-strain bacteria from the dead mice. Thus, the mixture had produced viable, virulent, capsulated bacteria; the effect was not simply illness caused by dead S cells.

Step 3: Infer a heritable transformation Some substance from the dead S bacteria had converted the live R bacteria into S-type bacteria. The transformed bacteria acquired the capacity to form the capsule and cause disease, and could multiply as S bacteria. Griffith called this transfer of properties transformation and inferred the presence of a transforming principle. His experiments did not establish that the principle was DNA; that identification was made later by Avery, MacLeod and McCarty.

Step 4: Conclusion Live R bacteria mixed with heat-killed S bacteria killed mice, and living S bacteria were recovered. Griffith therefore concluded that material from dead S cells had transformed non-virulent R bacteria into virulent S bacteria.

Quick Tip to Solve: Remember the decisive combination: live R plus heat-killed S kills mice and yields live S; Griffith demonstrated transformation, not DNA's identity.

22. (a) How does the Hardy-Weinberg's expression $p^2 + 2pq + q^2 = 1$ explain that genetic equilibrium is maintained in a population? (b) List any two factors that can disturb the genetic equilibrium.

[3 marks]

Solution:

Concept:

- The Hardy-Weinberg principle states that allele frequencies remain constant from generation to generation in a large, randomly mating population when evolutionary forces do not act.
- For two alleles A and a , let their frequencies be p and q , respectively. Then $p + q = 1$, and the expected genotype frequencies are p^2 , $2pq$ and q^2 .

Step 1: (a) Interpret the expression Random union of gametes gives AA with frequency $p \times p = p^2$, aa with frequency $q \times q = q^2$, and Aa with frequency $pq + qp = 2pq$. Thus

$$p^2 + 2pq + q^2 = (p + q)^2 = 1.$$

The three terms account for all individuals in the population: homozygous dominant, heterozygous and homozygous recessive, respectively.

Step 2: Explain maintenance of equilibrium In the next generation, the frequency of A is $p^2 + \frac{1}{2}(2pq) = p$, and that of a is $q^2 + \frac{1}{2}(2pq) = q$. Therefore, random mating reproduces the same allele and genotype

frequencies in successive generations, provided mutation, migration, natural selection and genetic drift do not disturb the population. This constancy is genetic equilibrium; the equation describes its expected genotype proportions.

Step 3: (b) State two disturbing factors **Gene migration (gene flow):** individuals entering or leaving a population can add or remove alleles and change their frequencies. **Natural selection:** differential survival and reproduction of genotypes can increase favourable alleles and reduce others, changing allele frequencies over generations.

Step 4: Conclusion Genetic equilibrium is maintained when p and q , and hence $p^2 : 2pq : q^2$, remain unchanged across generations. Two factors that can disturb it are gene migration and natural selection.

Quick Tip to Solve: Define p and q as allele frequencies, then interpret all three genotype terms before naming two evolutionary forces.

23. Mention the name of the causal organism, symptoms and the mode of transmission of the disease Amoebiasis. [3 marks]

Solution:

Concept:

- Amoebiasis, also called amoebic dysentery, is a protozoan infection of the human large intestine.
- Its infective cysts pass from contaminated food or drinking water into a new human host through the faecal-oral route.

Step 1: Identify the causal organism The causative organism is *Entamoeba histolytica*, a protozoan parasite that lives in the large intestine of humans. It can invade the intestinal wall and produce ulcers, causing the intestinal symptoms of amoebiasis.

Step 2: State the symptoms Typical symptoms are constipation, abdominal pain and cramps, and stools containing excess mucus and blood clots. The passage of mucus and blood is associated with damage to the intestinal lining. These intestinal disturbances are characteristic of amoebic dysentery.

Step 3: Explain the mode of transmission An infected person passes cysts of the parasite in faeces. Food and drinking water contaminated with such faecal matter carry the cysts, which enter another person when swallowed. Houseflies act as mechanical carriers: they transfer the parasite from infected faeces to uncovered food or other food products. Thus contaminated food or water is the immediate source of infection, while the housefly transfers the infective material without being a site of parasite multiplication.

Step 4: Conclusion Amoebiasis is caused by *Entamoeba histolytica*. It produces constipation, abdominal pain and cramps, and stools with excess mucus and blood clots; infection spreads through ingestion of faecally contaminated food or water, often contaminated mechanically by houseflies.

Quick Tip to Solve: Link the three requested facts: *Entamoeba histolytica*, intestinal symptoms, and ingestion of cysts in contaminated food or water.

24. (i) Mention the property that enables the explants to regenerate into a new plant. (ii) A banana herb is virus-infected. Describe the method that will help in obtaining healthy banana plants from this diseased plant. [3 marks]

Solution:

Concept:

- Totipotency is the capacity of a plant cell or explant to regenerate a complete plant under suitable tissue-culture conditions.
- Shoot apical and axillary meristems can remain free of viruses even when the rest of a plant is infected; culturing such meristems produces healthy plants.

Step 1: (i) Name the property of the explant The property is **totipotency**. Cells of an explant retain the genetic information needed to form the different tissues and organs of the plant. When supplied with suitable nutrients and growth regulators in sterile culture, they can regenerate a complete new plant.

Step 2: (ii) Select a virus-free meristem Use **meristem culture** to obtain healthy banana plants. Carefully excise a small shoot apical meristem or axillary meristem from the infected banana herb under aseptic conditions. These actively dividing meristematic regions are generally free of the virus despite infection elsewhere in the plant, so they provide the suitable starting material. An arbitrary piece of infected leaf or stem would not serve the same purpose.

Step 3: Culture and regenerate healthy plantlets Culture the isolated meristem on a sterile nutrient medium containing an appropriate carbon source, mineral nutrients, vitamins and suitable plant growth regulators. Maintain aseptic conditions and induce shoot multiplication followed by root development, forming complete plantlets. Harden the rooted plantlets gradually to external conditions and transfer them to soil. Meristem culture can therefore multiply healthy banana plants from the diseased parent; the source meristem must be virus-free for this result.

Step 4: Conclusion (i) The property is totipotency. (ii) Excise a virus-free apical or axillary meristem from the infected banana plant and culture it aseptically to regenerate rooted, healthy plantlets, which are hardened and transferred to soil.

Quick Tip to Solve: For a virus-infected plant, specify meristem culture and explain why the meristem is chosen before describing regeneration.

25. Mention the product and its use produced by each of the microbes listed below: (i) *Streptococcus* (ii) *Lactobacillus* (iii) *Saccharomyces cerevisiae*. [3 marks]

Solution:

Concept:

- Microorganisms produce useful enzymes, organic acids and alcohol during their growth or fermentation. The useful microbial product must be distinguished from the organism that produces it.
- *Streptococcus* provides a therapeutic enzyme, *Lactobacillus* carries out lactic acid fermentation,

and the yeast *Saccharomyces cerevisiae* carries out alcoholic fermentation.

Step 1: (i) Product and use of *Streptococcus* *Streptococcus* produces the enzyme streptokinase. After suitable modification by genetic engineering, it is used as a clot buster to remove blood clots from the blood vessels of patients who have suffered a myocardial infarction. Removing the clot helps restore blood flow to the affected heart muscle.

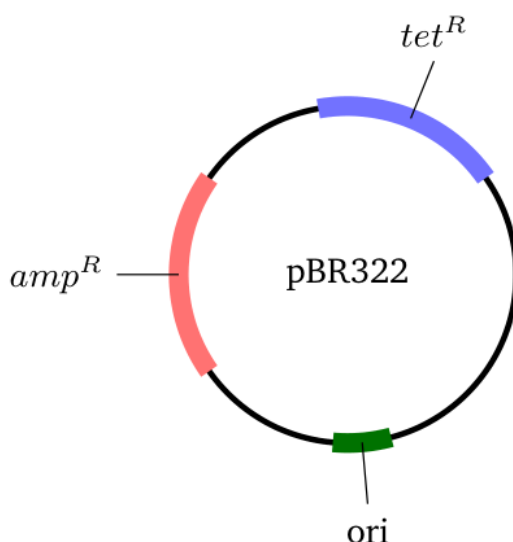
Step 2: (ii) Product and use of *Lactobacillus* *Lactobacillus* produces lactic acid by fermenting sugars. In milk, the acid lowers the pH and causes coagulation of milk proteins, converting milk into curd. Thus its lactic acid production is used in curd manufacture; lactic acid bacteria also improve the nutritional quality of curd.

Step 3: (iii) Product and use of *Saccharomyces cerevisiae* *Saccharomyces cerevisiae*, commonly called brewer's yeast, produces ethanol by alcoholic fermentation of sugars. Ethanol is used in the manufacture of alcoholic beverages such as beer and wine. Carbon dioxide is also released during this fermentation; this gas makes dough rise in bread making, another familiar use of the same yeast.

Step 4: Conclusion (i) *Streptococcus*: streptokinase, used to dissolve blood clots. (ii) *Lactobacillus*: lactic acid, used in making curd. (iii) *Saccharomyces cerevisiae*: ethanol, used in making alcoholic beverages.

Quick Tip to Solve: Pair each microbe with its product first: *Streptococcus*–streptokinase, *Lactobacillus*–lactic acid, and yeast–ethanol; then state the corresponding use.

26. (i) Name the organism in which the vector shown is inserted to get the copies of the desired gene. (ii) Mention the area labelled in the vector responsible for controlling the copy number of the inserted gene. (iii) Name and explain the role of a selectable marker in the vector shown. [3 marks]



Solution:

Concept:

- A cloning vector carries the desired DNA into a host. The plasmid pBR322 replicates in *Escherichia coli*, copying the inserted gene along with itself.
- The origin of replication, *ori*, controls copying and copy number. Selectable markers distinguish transformed cells from non-transformed cells.

Step 1: (i) Name the host The recombinant pBR322 vector is introduced into the bacterium *Escherichia coli*. Plasmid replication in this host produces copies of the inserted gene; multiplication of the transformed host cells amplifies this DNA further.

Step 2: (ii) Identify the copy-number region The region labelled *ori* is the origin of replication. Replication begins at this sequence, and DNA linked to it can replicate within the host. It also controls the copy number of the linked DNA, including the inserted gene.

Step 3: (iii) Explain a selectable marker The ampicillin-resistance gene, *amp^R*, is a selectable marker. On medium containing ampicillin, cells carrying this plasmid survive and form colonies, whereas susceptible non-transformed cells cannot grow. Thus it selects transformed cells. The tetracycline-resistance gene, *tet^R*, is another selectable marker. Further screening distinguishes recombinant plasmids from non-recombinant plasmids; antibiotic resistance alone shows uptake of the vector.

Step 4: Conclusion (i) *Escherichia coli*. (ii) *ori*. (iii) *amp^R*, or *tet^R*, enables selection of transformed cells using the corresponding antibiotic.

Quick Tip to Solve: Keep the vector functions separate: *ori* controls copying, while antibiotic-resistance genes select cells carrying the plasmid.

OR

26. Name the insect pest that is killed by the products of *cryIAc* gene. Explain how the gene makes the plant resistant to the insect pest. [3 marks]

Solution:

Concept:

- *Bacillus thuringiensis* produces insecticidal proteins called Bt toxins, encoded by *cry* genes. Their action is specific to particular groups of insect pests.
- The *cryIAc* gene produces a toxin effective against cotton bollworms. Introducing and expressing this gene in cotton allows the plant itself to produce the insecticidal protein.

Step 1: Identify the insect pest and the source of resistance The product of the *cryIAc* gene kills cotton bollworms. The gene is obtained from *Bacillus thuringiensis* and introduced into cotton using genetic engineering. The transformed cotton plant expresses the gene and produces the Bt toxin protein in its tissues, so feeding larvae ingest it together with the plant material.

Step 2: Explain activation in the insect gut The Bt toxin is produced as an inactive protoxin. On ingestion by a susceptible bollworm larva, the alkaline pH of its gut solubilises the toxin crystals and

the protoxin is processed into its active form. Activation in the insect digestive system explains why the toxin can become harmful after the insect eats the plant tissue.

Step 3: Explain how the activated toxin kills the pest The activated toxin binds to specific receptors on the surface of midgut epithelial cells and forms pores in their membranes. These pores disturb normal membrane function, causing the cells to swell and lyse. Damage to the gut ultimately kills the larva, protecting the cotton plant from bollworm feeding and making the plant resistant to this pest.

Step 4: Conclusion cryI_{Ac} confers resistance to cotton bollworms. Its expressed Bt protoxin is activated in the alkaline insect gut, binds to midgut epithelial cells and forms pores, causing cell lysis and death of the insect.

Quick Tip to Solve: Explain Bt resistance in sequence: gene expression, ingestion, alkaline-gut activation, receptor binding, pore formation and larval death.

27. How do organisms like fungi, zooplanktons and bears overcome the temporary short-lived climatic stressful conditions? Explain. [3 marks]

Solution:

Concept:

- Organisms may survive a temporary unfavourable period by suspension of active life: growth, development and metabolic activity are reduced until suitable conditions return.
- Resistant spores, diapause and hibernation are different survival mechanisms; their names must be matched to the organisms concerned.

Step 1: Fungi survive through resistant spores Many fungi produce thick-walled spores that withstand unfavourable conditions such as extreme temperature or lack of moisture. The resistant covering protects the living contents while the spores remain dormant, with very low metabolic activity. When favourable temperature, moisture and other conditions return, the spores germinate and give rise to actively growing fungal individuals. Thus the fungus can bridge the stressful period without continuing normal growth throughout it.

Step 2: Zooplankton enter diapause Many zooplankton species in lakes and ponds enter diapause during unfavourable environmental conditions. Diapause is a stage of suspended development, accompanied by a substantial reduction in metabolic activity. Development is temporarily arrested rather than proceeding under conditions in which survival would be poor. When conditions again become suitable, normal development and activity resume.

Step 3: Bears undergo hibernation Bears escape the stress of winter by hibernating in a sheltered place. Their activity and metabolic rate decrease, so their energy requirement is reduced during the period when food is scarce. Stored body fat supplies energy during this inactive period. With the return of favourable seasonal conditions, the bears become active again. For the standard school-level answer, the winter dormancy of bears is termed hibernation.

Step 4: Conclusion Fungi persist as thick-walled resistant spores, many zooplankton suspend development by diapause, and bears undergo winter hibernation. All three mechanisms allow survival until favourable conditions return.

Quick Tip to Solve: Match the three examples in order: fungi-resistant spores; zooplankton-diapause; bears-hibernation.

28. Describe in sequence the events that lead to the development of a 3-celled pollen grain from microspore mother cell in angiosperms. [5 marks]

Solution:

Concept:

- Microsporogenesis is the meiotic formation of haploid microspores from a diploid microspore mother cell inside the microsporangium of an anther.
- Male gametophyte development follows microsporogenesis: a microspore divides mitotically into a vegetative cell and a generative cell; the generative cell subsequently produces two male gametes.
- A three-celled pollen grain contains one vegetative cell and two male gametes. All three cells are haploid; the two divisions following meiosis do not change chromosome number.

Step 1: Differentiate the microspore mother cell As a young anther develops, cells of the sporogenous tissue within its microsporangia differentiate into microspore mother cells, also called pollen mother cells. Each mother cell is diploid, with chromosome number $2n$, and can produce a tetrad of microspores. The surrounding tapetum supplies nourishment for developing microspores and contributes materials needed for pollen-wall formation.

Step 2: Form a tetrad by meiosis Each microspore mother cell undergoes meiosis. The first meiotic division reduces the chromosome number, and the second division separates sister chromatids. With cytokinesis, four haploid microspores are formed, initially arranged together as a microspore tetrad. Each microspore has chromosome number n . This conversion of a mother cell into a tetrad is microsporogenesis; it must be distinguished from the later mitotic development within each microspore.

Step 3: Release individual microspores and form the pollen wall As the anther matures, the microspores separate from the tetrad and develop as individual pollen grains. A microspore enlarges and develops a two-layered wall. The tough outer exine consists of sporopollenin and has germ pores where sporopollenin is absent. The inner intine is thin and is made of cellulose and pectin. These wall layers surround and protect the developing male gametophyte.

Step 4: Produce the two-celled pollen grain The nucleus of each haploid microspore undergoes mitosis. Unequal cytokinesis produces a large vegetative cell and a smaller generative cell. The vegetative cell contains abundant food reserves and a large, irregularly shaped nucleus; it subsequently forms the pollen tube. The spindle-shaped generative cell has dense cytoplasm and a nucleus and lies within the cytoplasm of the vegetative cell. At this stage the pollen grain is two-celled.

Step 5: Divide the generative cell to obtain three cells The generative cell undergoes one mitotic division to form two haploid male gametes. The vegetative cell does not divide during this event. Consequently, the pollen grain now contains three cells: one vegetative cell and two male gametes. In species that shed pollen at the three-celled stage, this generative-cell division occurs before pollen release. In the many angiosperms that shed two-celled pollen, the same division occurs later in the growing pollen tube.

Step 6: Conclusion The sequence is: diploid microspore mother cell $\xrightarrow{\text{meiosis}}$ four haploid microspores; each microspore $\xrightarrow{\text{mitosis}}$ one vegetative cell plus one generative cell; the generative cell $\xrightarrow{\text{mitosis}}$ two male gametes. Thus a three-celled pollen grain contains one vegetative cell and two male gametes.

Quick Tip to Solve: Keep the divisions distinct: meiosis produces four microspores, while two later mitotic events give the vegetative cell and two male gametes within each developing male gametophyte.

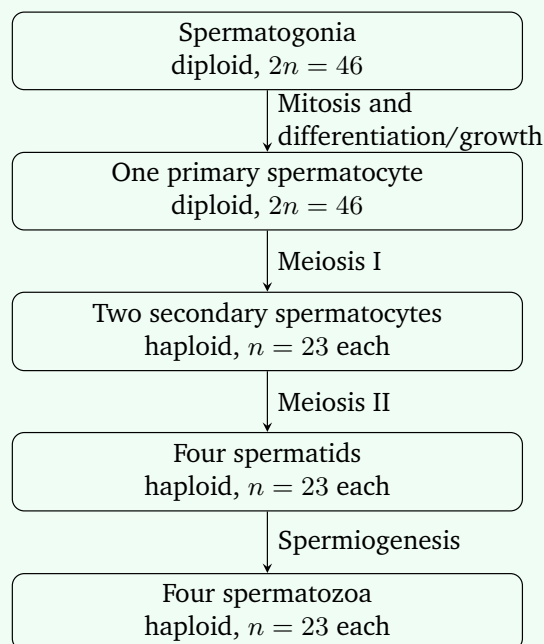
28. (a) Give a schematic representation showing the events of spermatogenesis in human male. (b) Describe the structure of a human sperm. [5 marks]

Solution:

Concept:

- Spermatogenesis produces haploid male gametes from diploid spermatogonia in the seminiferous tubules of the testes. In humans, diploid cells have $2n = 46$ chromosomes and haploid cells have $n = 23$.
- Meiosis reduces the chromosome number; spermiogenesis changes the shape of a spermatid into a spermatozoon without another cell division. The sperm is specialised to carry paternal genetic material to the ovum.

Step 1: (a) Multiplication, growth and meiotic divisions At puberty, spermatogonia on the inner wall of seminiferous tubules multiply by mitosis. Some continue as spermatogonia, maintaining the germ-cell population, while others grow and differentiate into diploid primary spermatocytes. Each primary spermatocyte undergoes the first meiotic division to form two equal-sized haploid secondary spermatocytes. Each secondary spermatocyte then undergoes meiosis II, producing two haploid spermatids. Thus, one primary spermatocyte produces four spermatids, each containing 23 chromosomes. The schematic below traces this sequence; the numbers of cells shown after meiosis refer to the descendants of one primary spermatocyte.



Schematic sequence of human spermatogenesis

Step 2: (a) Transformation and release During spermiogenesis, the four spermatids differentiate into spermatozoa: the nucleus becomes condensed, an acrosome develops, and the tail and mitochondrial middle piece are formed. Sertoli cells nourish the developing germ cells. The sperm heads remain embedded in Sertoli cells during development; release of the mature spermatozoa from these cells

into the lumen of the seminiferous tubule is called spermiation. Spermiogenesis is therefore a change in form, whereas spermiation is the subsequent release.

Step 3: (b) Structure of a human sperm A human sperm is a microscopic, motile cell enclosed by a plasma membrane and divided into a head, neck, middle piece and tail. The head contains an elongated, condensed haploid nucleus with 23 chromosomes. Its anterior portion is covered by a cap-like acrosome, derived from the Golgi apparatus. The acrosome contains enzymes that help the sperm penetrate the egg coverings during fertilisation. The short neck joins the head to the middle piece and contains centrioles; the distal centriole gives rise to the axial filament of the tail. The middle piece contains numerous mitochondria arranged around the axial filament. They provide energy for movement. The long tail produces the movements that propel the sperm through the female reproductive tract, helping it reach the ovum.

Step 4: Conclusion Spermatogonia give rise successively to primary spermatocytes, secondary spermatocytes, spermatids and spermatozoa. One primary spermatocyte yields four haploid spermatozoa. Each sperm has a nuclear and acrosomal head, a connecting neck, a mitochondrial middle piece and a motile tail.

Quick Tip to Solve: Keep the sequence separate from the cell counts: meiosis I gives two secondary spermatocytes, meiosis II gives four spermatids, and spermiogenesis changes their form without increasing their number.

29. (a) State the law of independent assortment. (b) Using Punnett Square demonstrate the law of independent assortment in a dihybrid cross involving two heterozygous parents. [5 marks]

Solution:

Concept:

- The law of independent assortment describes the inheritance of two pairs of contrasting traits when the genes assort independently during gamete formation.
- Let R denote round seed shape and r wrinkled shape, while Y denotes yellow seed colour and y green colour. Round and yellow are dominant over wrinkled and green, respectively.
- In a dihybrid, $RrYy$, segregation supplies one allele of each gene to a gamete. Independent assortment produces RY , Ry , rY and ry in equal proportions.

Step 1: (a) State the law When two pairs of contrasting traits are combined in a hybrid, the segregation of one pair of factors is independent of the segregation of the other pair. Thus, the allele received for seed shape does not determine the allele received for seed colour. This law applies to independently assorting genes, such as genes on different chromosomes; closely linked genes do not show this simple independent pattern.

Step 2: (b) Set up the cross and gametes Cross two plants heterozygous for both seed shape and seed colour:

$$RrYy \times RrYy.$$

Each parent produces four kinds of gametes, RY , Ry , rY , and ry , each with probability $1/4$. The occurrence of both parental combinations, RY and ry , and new combinations, Ry and rY , follows

from the independent distribution of the two allele pairs.

Step 3: Construct the Punnett square Place the gametes from one parent along the top and those from the other along the left. Each cell represents a possible offspring genotype with probability 1/16:

	<i>RY</i>	<i>Ry</i>	<i>rY</i>	<i>ry</i>
<i>RY</i>	<i>RRYY</i>	<i>RRYy</i>	<i>RrYY</i>	<i>RrYy</i>
<i>Ry</i>	<i>RRYy</i>	<i>RRyy</i>	<i>RrYy</i>	<i>Rryy</i>
<i>rY</i>	<i>RrYY</i>	<i>RrYy</i>	<i>rrYY</i>	<i>rrYy</i>
<i>ry</i>	<i>RrYy</i>	<i>Rryy</i>	<i>rrYy</i>	<i>rryy</i>

For example, combining *Ry* with *rY* gives *RrYy*, which has round, yellow seeds because each dominant allele is present.

Step 4: Group the offspring and demonstrate independence Of the sixteen equally likely combinations, nine have at least one *R* and one *Y* and are round yellow; three have at least one *R* with *yy* and are round green; three have *rr* with at least one *Y* and are wrinkled yellow; one is *rryy* and is wrinkled green. Thus the phenotypic ratio is

9 round yellow : 3 round green : 3 wrinkled yellow : 1 wrinkled green.

Each trait separately retains its monohybrid 3 : 1 ratio. For example, the probability of round yellow is $(3/4)(3/4) = 9/16$, while round green is $(3/4)(1/4) = 3/16$. The product probabilities and the recombinant phenotypes demonstrate that the two pairs of alleles assort independently.

Step 5: Conclusion Independent assortment means that segregation of one allele pair is independent of the other. The cross *RrYy* × *RrYy* produces four equally frequent gametes from each parent and the characteristic dihybrid phenotypic ratio 9 : 3 : 3 : 1.

Quick Tip to Solve: Write all four gametes in the same order across the top and down the side, then count phenotypes using the presence of at least one dominant allele for each trait.

OR

29. How did Alfred Hershey and Martha Chase arrive at the conclusion that DNA is the genetic material? [5 marks]

Solution:

Concept:

- A bacteriophage has a DNA core enclosed by a protein coat. During infection of a bacterium, the material that enters the cell and directs the production of new phages carries the genetic information.
- DNA contains phosphorus but no sulphur, whereas the phage proteins contain sulphur in sulphur-containing amino acids. Therefore radioactive phosphorus, ^{32}P , can trace phage DNA, and radioactive sulphur, ^{35}S , can trace phage protein.

Step 1: Prepare two differently labelled batches of bacteriophages In 1952, Alfred Hershey and Martha Chase grew bacteriophages in two separate cultures of *Escherichia coli*. One culture contained radioactive phosphorus, ^{32}P , so phages produced in it had radioactive DNA. The other contained radioactive sulphur, ^{35}S , so the resulting phages had radioactive protein coats. Thus the DNA and protein components could be followed independently.

Step 2: Allow the labelled phages to infect fresh bacteria The two labelled phage preparations were separately allowed to infect fresh, non-radioactive *E. coli* cells. The phages attached to the bacterial surface and initiated infection. Using separate preparations ensured that radioactivity detected inside the bacteria could be identified as originating from either DNA or protein.

Step 3: Separate the bacterial cells from the phage coats After infection had begun, each mixture was agitated in a blender to detach the phage protein coats from the bacterial surface. The mixtures were then centrifuged. The heavier bacterial cells formed the pellet, while the detached phage coats remained in the supernatant. Radioactivity was tested in these separated fractions.

Step 4: Compare the radioactive tracers In the ^{32}P -labelled DNA experiment, radioactivity was found in the bacterial pellet, showing that phage DNA had entered the bacteria. In the ^{35}S -labelled protein experiment, radioactivity remained mainly in the supernatant with the detached protein coats; the infected bacterial cells were not radioactively labelled with sulphur. Thus the protein coat stayed outside while DNA entered the host cell.

Step 5: Interpret the evidence from infection and multiplication The infected bacteria subsequently produced new bacteriophages. The DNA that had entered the bacterial cells therefore provided the information required to direct phage multiplication. The protein coat, which remained outside, could not be the material transmitting these instructions into the host. Following the two components separately established the role of DNA in carrying hereditary information.

Step 6: Conclusion Hershey and Chase concluded that DNA is the genetic material of bacteriophages: the ^{32}P -labelled DNA entered the bacteria and directed phage multiplication, whereas the ^{35}S -labelled protein coats remained outside the cells.

Quick Tip to Solve: Remember the sequence: label, infect, blend, centrifuge. Phosphorus traces DNA into the bacterial pellet; sulphur traces protein coats into the supernatant.

30. (a) Why are herbivores considered similar to predators in the ecological context? Explain. (b) Differentiate between the following interspecific interactions in a population: (i) Mutualism and Competition (ii) Commensalism and Amensalism. [5 marks]

Solution:

Concept:

- In an interspecific interaction, + denotes a benefit, – denotes harm and 0 denotes no significant effect on the species concerned.
- Predation transfers energy from a producer or prey to a consumer. In the broad ecological sense, feeding by herbivores on plants is also predation.
- Mutualism, competition, commensalism and amensalism differ in the effects that the two interacting

species have on each other.

Step 1: (a) Explain herbivory as an ecological form of predation Herbivores obtain food and energy by consuming living plants or their parts. The herbivore benefits, while the plant suffers loss of tissue, reduced growth or reduced reproductive output. Thus the interaction has the same benefit-harm pattern (+, -) as predation by a carnivore on animal prey. For example, a caterpillar feeding on leaves benefits at the expense of the plant.

Herbivores therefore act as conduits for the transfer of energy fixed by plants to higher trophic levels. Like other predators, they can also regulate the abundance of the organisms on which they feed. An herbivore need not kill the whole plant for the interaction to qualify as predation in this broad ecological context; consumption and harm to the plant are sufficient.

Step 2: (b)(i) Differentiate mutualism and competition **Mutualism** (+, +): Both interacting species benefit. In a lichen, the algal partner prepares food by photosynthesis, while the fungal partner provides shelter and helps absorb water and mineral nutrients. Each partner gains from the association.

Competition (-, -): Both species are adversely affected because they use a common resource, such as food, light or space, whose availability is limited. For example, weeds and crop plants competing for light, water and mineral nutrients reduce the resources available to each other. Their growth or reproductive success is lower than it would be without the competitor. The two species need not be equally affected.

Step 3: (b)(ii) Differentiate commensalism and amensalism **Commensalism** (+, 0): One species benefits while the other is neither significantly benefited nor harmed. For example, an epiphytic orchid growing on a mango tree obtains support and better access to light; the tree is unaffected. The orchid does not draw food from the tree.

Amensalism (-, 0): One species is harmed while the other is unaffected. For example, the antibiotic released by *Penicillium* inhibits susceptible bacteria, while the fungus is considered unaffected in this interaction. Unlike commensalism, there is no beneficiary in the interaction as classified.

Step 4: Conclusion Herbivores resemble predators because they gain energy by feeding on and harming plants (+, -). The interaction signatures are mutualism (+, +), competition (-, -), commensalism (+, 0) and amensalism (-, 0).

Quick Tip to Solve: Write the effect on both species before naming an interaction: mutualism has two plus signs, competition two minus signs, and commensalism and amensalism each have one zero.

OR

30. (a) Trace the succession of plants on a dry bare rock. (b) How does phosphorus cycle differ from carbon cycle? [5 marks]

Solution:

Concept:

- Primary succession on bare rock is a xerarch succession: pioneer organisms gradually alter a dry, soil-free habitat and allow successive plant communities to establish.

- Nutrients circulate between organisms and their environment. Phosphorus has a sedimentary cycle with rocks as its main reservoir, whereas carbon has a gaseous component involving atmospheric carbon dioxide.

Step 1: (a) Establishment of pioneers on bare rock Lichens are the pioneer community on dry, bare rock. They can colonise a surface where soil is initially absent. Lichens secrete acids that help weather the rock; the rock particles mix with dead and decomposing organic matter to begin soil formation. This improves moisture retention.

Step 2: (a) Replacement by successive plant communities The thin soil permits small plants such as mosses (bryophytes) to grow. Mosses further weather the substrate and add organic matter as they die and decompose. As soil depth, water-holding capacity and nutrient availability increase, herbs and grasses become established, followed by shrubs and finally trees. Each community modifies the environment and is gradually replaced. The broad sequence is:

Bare rock → lichens → mosses
→ herbs and grasses → shrubs → trees.

The habitat becomes mesic and a relatively stable climax forest develops, governed by the regional climate.

Step 3: (b) Compare the reservoirs and atmospheric exchange The principal reservoir of phosphorus is phosphate-bearing rock. Weathering releases inorganic phosphates into soil and water, from which plants absorb them. Carbon circulates through atmospheric carbon dioxide and reservoirs such as oceans. Phosphorus lacks a significant gaseous phase in its normal biogeochemical cycle, whereas carbon has a major gaseous phase: photosynthesis removes carbon dioxide from the atmosphere, while respiration, decomposition and combustion return it.

Step 4: (b) Compare transfer through organisms and return to the environment Both nutrients pass from producers to consumers through food chains. Decomposition returns phosphorus as inorganic phosphate to soil or water; some enters sediments and rock. Carbon returns prominently as carbon dioxide. Atmospheric inputs of phosphorus through rainfall are much smaller than those of carbon, and gaseous exchange between organisms and their surroundings is negligible in the phosphorus cycle. Consequently phosphorus is classified as a sedimentary cycle, while carbon is classified as a gaseous cycle.

Step 5: Conclusion (a) Lichens initiate xerarch succession; soil formation allows mosses, herbs, shrubs and trees to follow. (b) Phosphorus has a sedimentary cycle with negligible gaseous exchange; carbon has a major atmospheric gaseous phase.

Quick Tip to Solve: Recall the bare-rock sequence as lichens, mosses, herbs, shrubs, trees; compare the two nutrient cycles using reservoir, gaseous phase and atmospheric exchange.