RUBRICS

BIOLOGY GRADE 12

Q1. Briefly explain how carbon dioxide is transported in human blood through bicarbonate ions and carbaminohemoglobin. (2+2)

Possible Answer:

Carbon dioxide produced in tissues is mainly transported in the blood in the form of bicarbonate ions. When CO_2 diffuses into red blood cells, it combines with water under the action of the enzyme carbonic anhydrase to form carbonic acid. This unstable compound quickly dissociates into hydrogen ions and bicarbonate ions. The bicarbonate ions then diffuse into the plasma and represent the major mode of CO_2 transport from tissues to the lungs.

A second important method of transport is through carbaminohemoglobin. In this process, a portion of the CO_2 binds reversibly with the globin part of hemoglobin to form carbaminohemoglobin(the reaction depends upon the partial pressure of CO2). This compound carries CO_2 in the blood until it reaches the lungs, where the partial pressure of CO2 is higher in blood than in tissue, so the gas is released

Rubric:

- **Bicarbonate ions (2 marks):** Award full marks if the student describes diffusion of CO_2 into RBCs, enzymatic action of carbonic anhydrase, formation of carbonic acid, dissociation into H^+ and HCO_3^-, and movement of bicarbonate into plasma as the major transport form. Award 1 mark if only a partial description is given (e.g., "CO_2 forms bicarbonate in blood").
- **Carbaminohemoglobin (2 marks):** Award full marks if the student explains that CO_2 binds to hemoglobin's globin part, forms carbaminohemoglobin, and is released in the lungs during exhalation where the partial pressure of CO2 is higher in blood than in lungs. Award 1 mark if only the binding of CO_2 to hemoglobin is mentioned without further detail.
- **Total = 4 marks**

2. Discuss ultrafiltration and tubular secretion as events in the excretory function of the nephron. (2+2)

Possible Answer:

Ultrafiltration occurs in Bowman's capsule of the nephron. Due to high blood pressure in the glomerulus, the diameter of efferent arteriole is half compared to afferent arteriole, therefore water and small solutes such as salts, glucose, urea, and amino acids are forced through the filtration barrier(endothelium and basement membrane of capillaries and endothelium of

bowman's capsule) into the nephron tubule. Larger molecules like proteins and blood cells are retained in the blood, ensuring that only the filtrate passes into the tubule called glomerular filtrate.

Tubular secretion, on the other hand, takes place mainly in the proximal and distal convoluted tubules and the collecting ducts. In this process, substances such as hydrogen ions, potassium ions and organic ions are actively transported from the peritubular capillaries into the tubular fluid. This process is vital for maintaining the acid–base balance of blood, eliminating wastes, and regulating the internal environment.

Rubric:

- **Ultrafiltration (2 marks):** Award full marks if the student states the site (Bowman's capsule), driving force (blood pressure), and substances filtered (small solutes, water), with exclusion of proteins and cells. Award 1 mark if only the site and general filtration are mentioned.
- **Tubular secretion (2 marks):** Award full marks if the student explains the site (PCT/DCT/collecting duct), gives examples of secreted substances, and mentions its role in pH regulation and waste removal. Award 1 mark if only examples or site are given without function.
- **Total = 4 marks**

Q3. State any four differences between tetanus and tetany as muscle disorders. (1+1+1+1)

Possible Answer:

Tetanus is caused by infection with *Clostridium tetani*, a bacterium that releases a toxin(tetanospasmin) leading to continuous and painful muscle spasms, often starting with lockjaw. Tetany, in contrast, is a metabolic disorder caused by low calcium levels in the blood, producing intermittent muscle cramps, twitching, and spasms. Tetanus is an infectious disease transmitted through contaminated wounds as this bacteria remain infectious more than 40 years in soil), while tetany is non-infectious. Furthermore, tetanus can be prevented by vaccination and treated with antitoxin and antibiotics, whereas tetany is managed by correcting calcium deficiency.

Rubric:

- Award 1 mark for a valid difference in **cause** (tetanus: bacterial infection; tetany: hypocalcemia).
- Award 1 mark for a valid difference in **nature** (infectious vs metabolic/non-infectious).

- Award 1 mark for a valid difference in **symptoms** (continuous rigid spasms vs intermittent cramps).
- Award 1 mark for a valid difference in **treatment/prevention** (vaccination/antitoxin vs calcium therapy).
  Total = 4 marks

Q4. Define threshold and subthreshold stimuli. How does a threshold stimulus play a role in depolarization? (1+1+2)

Possible Answer:

A threshold stimulus is the minimum intensity of stimulation required to depolarize a neuron membrane to the critical level of about –55 mV, which is sufficient to generate an action potential. A subthreshold stimulus is weaker than this minimum level and, although it may cause slight depolarization, it does not trigger an action potential. When a threshold stimulus is applied, voltage-gated sodium channels open, allowing sodium ions to rapidly enter the neuron. This influx of sodium causes a sharp depolarization of the membrane, leading to the initiation of the all-or-none action potential.

Rubric:

- **Threshold stimulus (1 mark):** Award if the student defines it as the minimum intensity needed to generate an action potential.
- **Subthreshold stimulus (1 mark):** Award if the student defines it as a weaker stimulus that does not generate an action potential.
- **Role in depolarization (2 marks):** Award full marks if the student explains sodium channel opening, sodium influx, depolarization, and initiation of the all-or-none action potential. Award 1 mark if the explanation is general without mention of ion movement or the all-or-none principle.
  Total = 4 marks

Q5. Define insulin and glucagon. Discuss their roles in diabetes mellitus and during fasting. (1+1+1+1)

Possible Answer:

Insulin is a peptide hormone secreted by the β-cells of the pancreas. It lowers blood glucose levels by promoting uptake of glucose into body cells and stimulating its storage as glycogen or fat. Glucagon is a hormone secreted by the α-cells of the pancreas, and it raises blood glucose by breaking down glycogen and stimulating gluconeogenesis in the liver. In diabetes mellitus, a deficiency of insulin or resistance to its action results in abnormally high blood sugar(hyperglycemia)and disturbed carbohydrate metabolism. During fasting, glucagon becomes the

key hormone in maintaining blood glucose by mobilizing glycogen reserves and promoting glucose synthesis to supply energy to tissues.

Rubric:

- Definition of insulin with its source or role (1)
- Definition of glucagon with its source or role (1)
- Role in diabetes mellitus explained (insulin deficiency/resistance leading to hyperglycemia) (1)
- Role during fasting explained (glucagon maintains glucose through glycogenolysis/gluconeogenesis) (1)
- **Total = 4 marks**

Q6. State any four differences between classical conditioning and operant conditioning. (1+1+1+1)

Possible Answer:

Classical conditioning is a form of associative learning in which an involuntary or reflexive response becomes linked with a previously neutral stimulus; it was first demonstrated by Pavlov in his experiments with dogs. Operant conditioning, however, is based on voluntary behaviors that are influenced by rewards or punishments, and it was studied by Skinner. In classical conditioning, the stimulus comes before the response, while in operant conditioning, reinforcement follows the response. For example, salivation in dogs to the sound of a bell illustrates classical conditioning, while a rat pressing a lever to obtain food illustrates operant conditioning.

Rubric:

- 1 mark for valid difference in type of response (classical: involuntary vs operant: voluntary)
- 1 mark for valid difference in sequence (stimulus precedes response vs reinforcement follows response)
- 1 mark for researcher associated (Pavlov vs Skinner)
- 1 mark for example of each learning type (bell → salivation vs lever press → food) **Total = 4 marks**

Q7. What is miscarriage? State its causes and explain its conceptual distinction from induced abortion. (2+1+1)

Possible Answer:

A miscarriage is the spontaneous loss of pregnancy before the fetus is viable, usually before the twentieth week of gestation. It is also called spontaneous abortion. It occurs naturally without medical intervention and is one of the most common complications of early pregnancy. Causes of miscarriage include chromosomal abnormalities(genetic problem), maternal illnesses such as diabetes or infections, hormonal imbalances, trauma, obesity, problem with body's immune system and uterine defects. Miscarriage is distinct from induced abortion because miscarriage happens spontaneously, whereas induced abortion refers to the deliberate medical or surgical termination of pregnancy.

Rubric:

- Accurate definition of miscarriage as spontaneous/natural pregnancy loss before viability (2)
- At least one valid cause such as chromosomal abnormality, infection, hormonal issue, or trauma (1)
- Conceptual distinction from induced abortion clearly stated (spontaneous vs deliberate) (1)
  Total = 4 marks

Q8. Define epistasis. How is it different from dominance? (2+2)

Possible Answer:

Epistasis is a genetic interaction in which one gene masks or alters the expression of another gene located at a different locus. An example is coat color in Labrador retrievers, where the presence of one gene can suppress the effect of another gene responsible for pigment. Dominance, in contrast, refers to the interaction between alleles of the same gene, in which the dominant allele expresses its trait over the recessive one in a heterozygous condition. Thus, epistasis involves the interaction of two different genes, whereas dominance involves only alleles of a single gene.

Rubric:

- Definition of epistasis given with a clear explanation and example (2)
- Explanation of dominance as an intra-allelic interaction contrasted with inter-genic epistasis (2)
  Total = 4 marks

Q9. Differentiate between the genetic code and a codon (any four points). (1+1+1+1)

Possible Answer:

The genetic code refers to the complete set of rules by which nucleotide sequences in DNA or RNA are translated into the amino acid sequence of proteins. It is universal, redundant, and governs the translation process in almost all organisms. A codon, on the other hand, is a specific sequence of three nucleotides that codes for a single amino acid or a stop signal. While the genetic code represents the entire system of translation, a codon is an individual unit of that system. The genetic code is described as redundant because several codons can specify the same amino acid, whereas each codon is unambiguous, coding only for one amino acid. Thus, the genetic code provides the overall framework, and codons serve as its working units.

Rubric:

- 1 mark for a valid difference in definition (genetic code = complete system vs codon = triplet unit)
- 1 mark for a valid difference in scope (broad set of rules vs individual sequence)
- 1 mark for a valid difference in property (redundancy/universality vs specificity/unambiguity)
- 1 mark for a valid example or functional distinction (e.g., AUG as codon for methionine vs code as overall language of translation)
  Total = 4 marks

Q10. Explain the role of endosymbiosis and membrane infolding in the origin of the eukaryotic cell. (2+2)

Possible Answer:

The endosymbiotic theory suggests that certain organelles in eukaryotic cells originated when ancestral eukaryotes engulfed free-living prokaryotes. Aerobic bacteria became mitochondria, while photosynthetic cyanobacteria became chloroplasts. Strong evidence for this includes their possession of circular DNA, 70S ribosomes, and double membranes. Alongside endosymbiosis, the membrane infolding hypothesis explains the origin of other internal organelles. In this process, the plasma membrane of early cells folded inward to form internal compartments such as the nuclear envelope, endoplasmic reticulum, and Golgi apparatus. It is also known that in modern day eukaryotes, the inner membrane of both the mitochondria and chloroplast contains structures more similar to prokaryotes whereas the outer membrane retains eukaryotic characteristic. These developments provided compartmentalization and efficiency, which are hallmarks of eukaryotic cells today.

Rubric:

- Endosymbiosis explained with example organelles (mitochondria/chloroplasts) and supporting evidence (2)

- Membrane infolding explained with reference to formation of nuclear envelope, ER, Golgi, and its role in compartmentalization (2)
  Total = 4 marks

11. Define succession. Which type of succession begins on a bare rock surface? (2+2)

Possible Answer:

Succession is the natural, orderly, and predictable process of change in the species composition of a community over time, where one group of organisms is gradually replaced by another until a stable climax community is established.

When succession begins on a bare rock surface with no soil present, and culminating in a mature climax forest, it is known as Xerarch succession. In this type, pioneer species such as lichens and mosses colonize the rock, break it down into smaller particles, and contribute organic matter to form soil. This soil then allows grasses, shrubs, and eventually trees to grow, leading to a mature community.

Rubric:

- Definition of succession as a gradual and orderly replacement of species leading to a climax community (2)
- Identification and explanation of Xerarch succession on bare rocks (2)
  Total = 4 marks

Q12. What is PCR? Predict the outcome if Taq polymerase loses its thermostability during the process. (2+2)

Possible Answer:

Polymerase chain reaction (PCR) is a molecular biology technique which can create millions of copies of a single gene or a specific part of DNA quickly in a test tube. This technique takes its name from DNA polymerase, the enzyme which is responsible for DNA replication in a cell used to amplify a specific DNA sequence into millions of copies. The components of PCR includes template DNA, deoxyribonucleoside trichosphate, primers and Taq polymerase. A thermostable enzyme such as Taq polymerase is essential for extension at high temperatures. If Taq polymerase loses its thermostability, it will denature during the heating step, and DNA synthesis cannot continue. As a result, PCR amplification would fail because the enzyme could no longer function in repeated thermal cycles.

Rubric:

- Definition of PCR with purpose and basic components (2)

- Explanation of outcome: enzyme denatures at high temperature, preventing DNA synthesis and stopping amplification (2)
  Total = 4 marks

Q13. What are microbes? Describe their role in the pharmaceutical industry. (2+2)

Possible Answer:

Microbes are microscopic organisms that include bacteria, fungi, protozoa, and viruses, many of which play important roles in human health and industry. In the pharmaceutical industry, microbes are widely used to produce useful substances. For example, fungi such as *Penicillium* are used in the production of antibiotics like penicillin, and bacteria such as *Streptomyces* produce streptomycin. Recombinant bacteria are engineered to produce human insulin and other hormones. Cyclosporine, an immuno suppressive agent used in organ transplantations, is produced by a fungus trichoderma polysporum. The lovastatin produced by the yeast monascus perpureus is a blood cholesterol lowering agent. Microbes are also used in the manufacture of vaccines, enzymes, and bioactive compounds that are essential for modern medicine.

Rubric:

- Definition of microbes with at least two examples of types (2)
- Explanation of role in pharmaceutical industry with at least two valid applications (antibiotics, vaccines, hormones, enzymes) (2)
  Total = 4 marks

SECTION C

Q.3 (a) Differentiate between haemoglobin and myoglobin on the basis of structure, location, function, oxygen affinity, and physiological importance. (1+1+1+1+1)

Possible Answer:

Haemoglobin is a large, tetrameric protein found in red blood cells, composed of four polypeptide chains, each with a heme group that binds oxygen. In contrast, myoglobin is a smaller, monomeric protein located in the skeletal and cardiac muscles, containing a single polypeptide chain with one heme group. Functionally, haemoglobin transports oxygen from the lungs to tissues and also helps in the transport of carbon dioxide and buffering of blood pH, while myoglobin serves primarily as an oxygen reservoir within muscles, releasing oxygen during periods of high metabolic demand. Haemoglobin shows a sigmoidal oxygen dissociation curve due to cooperative binding, whereas myoglobin has a hyperbolic dissociation curve with much higher affinity for

oxygen. Physiologically, haemoglobin is critical for systemic oxygen delivery, while myoglobin ensures oxygen availability in muscles during exercise and oxygen scarcity.

Rubric (5 marks):

- **Structure (1 mark):** Haemoglobin described as tetramer with four chains vs myoglobin as monomer with one chain.
- **Location (1 mark):** Haemoglobin located in red blood cells vs myoglobin located in muscles.
- **Function (1 mark):** Haemoglobin transports O_2/CO_2 and buffers blood, while myoglobin stores O_2 for muscle use.
- **Oxygen affinity (1 mark):** Haemoglobin with cooperative binding and sigmoidal curve vs myoglobin with higher affinity and hyperbolic curve.
- **Physiological importance (1 mark):** Haemoglobin's role in systemic oxygen supply vs myoglobin's role in oxygen availability during muscular activity.
  Total = 5 marks

Q.3 (b) List any four differences between osmoregulators and osmoconformers. (1+1+1+1)

Possible Answer:

Osmoregulators are organisms that actively maintain a constant internal osmotic environment regardless of external changes, whereas osmoconformers allow their internal osmotic concentration to vary with the surrounding environment. Osmoregulators, such as freshwater fishes, expend considerable energy through mechanisms like excretion and active transport of ions to maintain homeostasis, while osmoconformers, like most marine invertebrates, expend little energy because their internal fluids are isotonic with seawater. Osmoregulators can survive in diverse environments due to their regulatory mechanisms, while osmoconformers are restricted mainly to stable marine habitats.

Rubric (4 marks):

- 1 mark for difference in **basic definition** (active regulation vs conformity to external medium).
- 1 mark for difference in **examples** (e.g., freshwater fish vs marine invertebrates).
- 1 mark for difference in **energy requirement** (high in regulators vs low in conformers).
- 1 mark for difference in **habitat adaptability** (broad environments vs restricted to stable seas).
  Total = 4 marks

Q.4 (a) Explain joint dislocation with reference to definition, causes, symptoms, common sites, and treatment. (1+1+1+1+1)

Possible Answer:

A joint dislocation is a condition in which the bones forming a joint are displaced from their normal position, leading to loss of joint alignment. It is most often caused by trauma such as a fall, accident, or sports injury, but can also result from congenital weakness or diseases that affect ligaments. The major symptoms include intense pain, swelling, deformity, and loss of joint movement. Common sites of dislocation include the shoulder, fingers, knee, and jaw. Treatment involves immediate immobilization of the joint, medical reduction to restore bone alignment, followed by rest, physiotherapy, and in some cases surgery if ligaments are severely damaged.

Rubric (5 marks):

- Definition of joint dislocation as displacement of bones at a joint (1)
- Causes explained such as trauma, accidents, or congenital weakness (1)
- Symptoms described: pain, swelling, deformity, restricted movement (1)
- Common sites listed correctly (shoulder, fingers, knee, jaw) (1)
- Treatment outlined: immobilization, reduction, rest/therapy/surgery (1) **Total = 5 marks**

Q.4 (b) Differentiate between agonistic behaviour and altruistic behaviour (any four points). (1+1+1+1)

Possible Answer:

Agonistic behaviour refers to social behaviour related to fighting, including aggression, threats, displays, or submission, often seen when animals compete for territory, dominance, or mates. Altruistic behaviour, in contrast, involves actions that benefit other members of the species at the expense of the individual performing the act, such as warning calls or cooperative care. Agonistic behaviour is usually selfish in nature, aimed at increasing the individual's survival or reproductive success, while altruistic behaviour is selfless and increases the survival chances of relatives or the group. Examples of agonistic behaviour include two male deer locking antlers, while altruistic behaviour can be observed in honeybees sacrificing themselves to defend the colony.

Rubric (4 marks):

- 1 mark for difference in **definition** (agonistic = aggression/competition vs altruistic = selfless/helpful to others).

- 1 mark for difference in **purpose** (self-survival and dominance vs benefit to group/relatives).
- 1 mark for **nature** (selfish vs selfless).
- 1 mark for **example** (e.g., fighting deer vs honeybee sacrifice or warning call).
  Total = 4 marks

Q.5 (a) Describe the structure and function of gustatory and olfactory receptors. (2.5+2.5)

Possible Answer:

Gustatory receptors are specialized chemoreceptor cells located within taste buds on the tongue, soft palate, and epiglottis.

Structure of taste receptors:

The tongue contains many ridges and valleys called papillae . 1. Filiform papillae: cone shaped and found all over the tongue which is why tongue looks rough. 2.Fungiform papillae: mushroom shape and found at the tip and sides of the tongue. 3 Foliate papillae : a series of folds along the sides of tongue. 4. Circumvallate papillae: shaped like flat mounds surrounded by a trench and found at back of the tongue. All papillae except filiform contain taste buds. Each taste bud contains 50–100 receptor cells with microvilli projecting into a taste pore. These microvilli contain receptor proteins that detect dissolved chemicals in saliva. The receptors are sensitive to the five primary tastes: sweet, salty, sour, bitter, and umami.

Olfactory receptors are specialized sensory neurons located in the olfactory epithelium of the nasal cavity. Each receptor cell has cilia with membrane-bound receptor proteins that bind odorant molecules dissolved in the mucus. When activated, they generate nerve impulses that travel through the olfactory nerve (cranial nerve I) to the olfactory bulb and then to higher brain centers. This system enables the detection of thousands of odorants, contributing to the sense of smell and also influencing taste perception.

Rubric (5 marks):

- Gustatory receptors described: location in taste buds, papillae types microvilli/taste pore, five primary tastes, (2.5)
- Olfactory receptors described: location in nasal epithelium, cilia with receptor proteins, transmission via olfactory nerve to brain (2.5)
  Total = 5 marks

Q.5 (b) What is embryonic induction? List the three mechanisms by which signals pass between cells to induce development. (1+3)

Possible Answer:

Embryonic induction is the process by which one group of embryonic cells influences the development and differentiation of a neighboring group of cells through signaling interactions. This ensures the proper formation of tissues and organs during development. The three main mechanisms of signaling involved in embryonic induction are: (1) **Diffusion**, where signaling molecules are released and diffuse across short distances to affect nearby cells; (2) **Direct contact**, where cell-surface molecules interact directly with receptors on adjacent cells; and (3) **Gap junctions**, where small signaling molecules pass directly between cells through intercellular connections.

Rubric (4 marks):

- Clear definition of embryonic induction as interaction between cell groups directing differentiation (1)
- Mechanism 1: Diffusion of signaling molecules (1)
- Mechanism 2: Direct contact between cell-surface molecules (1)
- Mechanism 3: Communication via gap junctions (1)
  Total = 4 marks

Q.6 (a) What is the Human Genome Project (HGP)? Enumerate its goals and any four benefits. (1+2+2)

Possible Answer:

The Human Genome Project (HGP) was a global scientific effort launched in 1990 and completed in 2003 to determine the complete sequence of human DNA. James D Watson was appointed as the first director of the institute but at the time of completion of the project the institute was being led by doctor Francis Collin .Its primary aim was to identify all genes(20000-25000) present in the human genome and analyze their sequences.

The goals of the project included mapping the entire human genome, sequencing three billion base pairs, developing tools for data analysis, transfer related technology to the private sector and addressing ethical, legal, and social implications of genome research.

Among the major benefits of the HGP are the improved diagnosis of genetic disorders, early detection of predisposition to certain diseases, advancement of gene therapy techniques control system for drugs, rational drug design and the development of pharmacogenomics to design drugs according to individual genetic profiles.

Rubric (5 marks):

- Definition of HGP (1 mark): Award if the student defines it as a project to sequence/map the entire human genome.
- Goals of HGP (2 marks): Award if at least two goals are mentioned, such as mapping, sequencing base pairs, developing analysis tools, or addressing ethical issues.
- One benefit (0.5 mark): Award for any single correct benefit, e.g., improved diagnosis of genetic disorders.(0.5*4=02)
- Total = 5 marks

Q.6 (b) What is a polygenic trait? Discuss human skin colour as an example of polygenic inheritance. (2+2)

Possible Answer:

A polygenic trait is a characteristic that is controlled by two or more genes, each contributing additively to the phenotype. Unlike single-gene traits, polygenic traits show continuous variation within a population. Human skin colour is a classic example of polygenic inheritance. It is determined by the combined effect of several genes(AaBbCc) that control the amount and type of melanin pigment produced in the skin. Each dominant allele(ABC) contributes to a darker shade, while recessive alleles(abc) contribute to lighter shades. As a result, skin colour varies along a gradient in the population, producing a wide range of phenotypes instead of discrete categories.

Rubric (4 marks):

- Definition of polygenic trait as controlled by multiple genes showing continuous variation (2)
- Explanation of human skin colour as polygenic inheritance with role of multiple alleles and additive effect (2)
  Total = 4 marks