1.

(a)

(i) The part labelled H is the cell membrane.

(ii) Part H (cell membrane) differs from I (cell wall) as follows:

- The cell membrane (H) is a semi-permeable membrane that controls the movement of substances in and out of the cell.
- The cell wall (I) is a rigid outer layer that provides structural support and protection to the cell, mainly found in plant cells.

(iii) The function of structure labelled J (vacuole) is to store nutrients, waste products, and help maintain turgor pressure in plant cells.

(iv) Cell F belongs to the group of living organisms known as animals.

(b)

(b) (i) Identify the parts labelled K and M.

- K: **Cells**
- M: **Organs**

(ii) State the level of cell organisation at which muscles would be found.

- **Tissues**

(iii) Give one example of a system in plants and in animals.

- Plants: **Vascular system**
- Animals: **Circulatory system**

2.

(a)

(i) Osmosis:

- Water

(ii) Active transport:

- Nitrates

- Potassium

(iii) Diffusion:

- Oxygen

(b)

(i) The term given to the parts labelled X and Y in the graph is **optimum pH**.

(ii) The reaction that is under acidic conditions is **N**.

(iii) The reaction that could only be for a protein food is:

- Reaction: **N**
- Reason: Protein-digesting enzymes, such as pepsin, typically function optimally in acidic conditions, which is shown by reaction N at a lower pH.

(c)

Explain the role of enzymes in metabolism.

- Enzymes act as biological catalysts that speed up chemical reactions in metabolic processes. They lower the activation energy required for reactions, thus increasing the rate of metabolic activities. This enables the efficient regulation and coordination of complex biochemical pathways necessary for life.

3.

(a)

P: **Esophagus**

Q: **Stomach**

(b)

The part labelled R is the **pancreas**. The pancreas has several key functions in digestion:

1. **Production of Digestive Enzymes**: The pancreas produces digestive enzymes, such as amylase, lipase, and proteases, which help in the breakdown of carbohydrates, fats, and proteins in the small intestine.

2. **Secretion of Bicarbonate**: The pancreas secretes bicarbonate ions into the small intestine, which neutralizes the acidic chyme from the stomach, creating an optimal pH environment for the digestive enzymes to function.
3. **Regulation of Blood Sugar**: The pancreas also produces hormones like insulin and glucagon that regulate blood sugar levels, which are crucial for maintaining overall metabolic balance.

(c)

The part labelled S is the liver.

1. **Production of Bile:** The liver produces bile, which is stored in the gallbladder and released into the small intestine. Bile helps in the emulsification and breakdown of fats, making them easier to digest.
2. **Metabolism and Detoxification:** The liver plays a crucial role in metabolizing nutrients absorbed from the digestive tract. It detoxifies harmful substances, metabolizes drugs, and processes nutrients for storage and use by the body.

(d)

1. **Jaundice:** A condition where there is a yellowing of the skin and eyes due to the accumulation of bilirubin in the body. This can result from liver diseases like hepatitis or cirrhosis, where the liver's ability to process and excrete bilirubin is impaired.
2. **Ascites:** The accumulation of fluid in the abdomen, which can occur due to liver cirrhosis. This condition results from increased pressure in the blood vessels of the liver (portal hypertension) and decreased production of albumin, a protein that helps maintain fluid balance in the body.

4.

(a)

(i) Identify the cells labelled T and U.

T: Sperm cell

U: Egg cell (ovum)

(ii) State one way in which cell T and cell U in Figure 4 are genetically similar.

- Both cell T (sperm cell) and cell U (egg cell) contain half the number of chromosomes (haploid), which combine during fertilization to form a complete set of chromosomes in the fertilized egg (diploid).

(iii) Mention three functions of the part labelled V (placenta).

1. **Nutrient Transfer:** The placenta transfers nutrients from the mother's blood to the developing fetus.
2. **Gas Exchange:** The placenta facilitates the exchange of oxygen and carbon dioxide between the mother and fetus.
3. **Waste Removal:** The placenta removes waste products from the fetal blood and transfers them to the mother's blood for excretion.

(b)

1. **Hormonal Imbalances:** Issues such as polycystic ovary syndrome (PCOS) or thyroid problems can disrupt hormone levels, affecting ovulation and sperm production.
2. **Tubal Blockages**: Blockages or damage to the fallopian tubes can prevent the sperm from reaching the egg or hinder the passage of the fertilized egg to the uterus.
3. **Low Sperm Count:** A low sperm count or poor sperm motility can significantly reduce the chances of fertilization. This can be caused by various factors including lifestyle, medical conditions, or genetic issues.

5.

(a)

Mother: Blood Group A (genotype AO)

- Since the mother has a child with blood group O, she must carry the O allele, making her genotype AO.

Father: Blood Group unknown

- The father's genotype must include the O allele since they have a child with blood group O. Therefore, the possible genotypes for the father could be BO (if he has blood group B) or OO (if he has blood group O).

(b)

The blood group phenotype of the husband must be either A or B.

Since the child has blood group AB, the daughter (who is blood group B, genotype BO) must have contributed the B allele. The husband must have contributed the A allele, which means he could have blood group A (genotype AA or AO) or blood group AB.

(c)

The father divorced the wife and married another woman with blood group B and their first child had blood group O. With the help of a genetic diagram, explain how this was possible.

Let's assume the father's genotype is BO, as he has a child with blood group O from his first marriage. The second wife has blood group B, so her genotype can be either BB or BO. For their child to have blood group O, both parents must carry the O allele. Therefore, the second wife's genotype must be BO.

Here is the genetic diagram:

	B	*O*
A	*AB*	*AO*
O	*BO*	*OO*

SECTION B

1.

(a)

1. Aerobic Respiration:
    - Process: Uses oxygen to convert glucose into energy, producing carbon dioxide and water as byproducts.

- Equation: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + Energy (ATP)
- Energy Yield: High (approximately 36-38 ATP molecules per glucose molecule).
- Location: Occurs in the mitochondria of cells.

2. Anaerobic Respiration:
   - Process: Occurs in the absence of oxygen, converting glucose into energy and producing lactic acid (in animals) or ethanol and carbon dioxide (in yeast and plants) as byproducts.
   - Equation (in animals): $C_6H_{12}O_6 \rightarrow 2C_3H_6O_3$ + Energy (ATP)
   - Energy Yield: Low (approximately 2 ATP molecules per glucose molecule).
   - Location: Occurs in the cytoplasm of cells

(b)

1. **Respiratory Issues:**
   - Chronic obstructive pulmonary disease (COPD) including chronic bronchitis and emphysema.
   - Increased risk of respiratory infections.
2. **Cardiovascular Problems:**
   - Increased risk of heart disease, stroke, and hypertension.
   - Reduced oxygen-carrying capacity of the blood due to carbon monoxide binding with hemoglobin.
3. **Cancer:**
   - Increased risk of various cancers including lung, mouth, throat, esophagus, bladder, and pancreas.
4. **Immune System Suppression:**
   - Weakened immune response, making the body more susceptible to infections.
5. **Pregnancy Complications:**

- Increased risk of miscarriages, premature births, and low birth weight.
- Higher likelihood of sudden infant death syndrome (SIDS).

6. **Reduced Sense of Taste and Smell:**
   - Damage to the olfactory and taste receptors.
7. **Poor Oral Health:**
   - Increased risk of gum disease, tooth decay, and oral cancer.
8. **Overall Reduced Life Expectancy:**
   - Smokers have a significantly reduced life expectancy compared to non-smokers due to the cumulative effects of smoking-related diseases.

2.

(a)

1. **Filtration**:
   - Blood enters the kidneys through the renal arteries.
   - In the glomerulus of each nephron, blood is filtered under high pressure.
   - Water, salts, glucose, amino acids, and urea pass into the Bowman's capsule, forming the filtrate.
2. **Reabsorption**:
   - As the filtrate moves through the proximal convoluted tubule, essential substances like glucose, amino acids, and most of the water and salts are reabsorbed back into the bloodstream.
   - This occurs through active and passive transport mechanisms.
3. **Secretion**:
   - In the distal convoluted tubule, additional waste products and excess ions are secreted from the blood into the filtrate.

- This fine-tuning helps maintain the body's chemical balance.

4. **Formation of Urine**:
   - The filtrate, now called urine, collects in the collecting ducts.
   - The urine flows through the renal pelvis into the ureters.
5. **Storage and Elimination**:
   - Urine is stored in the bladder until it is excreted.
   - When the bladder is full, urine is expelled from the body through the urethra.

(b)

1. **Osmoregulation**:
   - The kidneys regulate the concentration of water in the blood through the process of osmoregulation.
   - Antidiuretic hormone (ADH) controls the permeability of the collecting ducts. When water levels are low, ADH increases water reabsorption, producing concentrated urine.
2. **Salt Balance**:
   - The kidneys regulate salt balance by reabsorbing or excreting sodium, potassium, and chloride ions.
   - Aldosterone hormone stimulates the reabsorption of sodium and excretion of potassium in the distal convoluted tubule and collecting duct.
3. **Blood Pressure Regulation**:
   - By controlling the volume of blood (through water reabsorption) and the concentration of salts, the kidneys help regulate blood pressure.

- The renin-angiotensin-aldosterone system (RAAS) is activated when blood pressure drops, leading to increased reabsorption of sodium and water, thus increasing blood volume and pressure.

4. **pH Balance**:
   - The kidneys help maintain acid-base balance by excreting hydrogen ions and reabsorbing bicarbonate from urine.
   - This process helps neutralize the acids in the blood and maintains a stable pH.
5. **Excretion of Metabolic Waste**:
   - The kidneys filter out urea, creatinine, and other metabolic wastes, maintaining the chemical balance of the blood.
6. **Hormone Production**:
   - The kidneys produce erythropoietin, which stimulates red blood cell production in response to low oxygen levels, and calcitriol, which helps regulate calcium levels in the blood.

3.

(a)

1. **Spinal Reflex:**
   - **Example**: The knee-jerk reflex.
   - **Explanation**: When the patellar tendon is tapped, sensory neurons send a signal to the spinal cord, which immediately sends a response via motor neurons to the quadriceps muscle, causing it to contract and the leg to kick out. This reflex does not involve the brain and is a rapid, involuntary response.
2. **Cranial Reflex:**
   - **Example**: The pupillary light reflex.

- **Explanation**: When bright light is shone into the eyes, sensory neurons in the retina send signals to the brainstem. The brainstem processes these signals and sends motor responses to the muscles controlling the iris, causing the pupils to constrict. This reflex involves the brain (specifically the midbrain) and helps protect the eyes from excessive light.

3. **Conditioned Reflex:**
    - **Example**: Pavlov's dogs salivating in response to a bell.
    - **Explanation**: This type of reflex is learned through association. In Pavlov's experiment, dogs were conditioned to associate the sound of a bell with the presentation of food. After repeated associations, the dogs began to salivate (a reflexive response) whenever they heard the bell, even without the food being present. This type of reflex involves higher brain centers and is not innate.

(b)

1. **Cataracts**:
    - Clouding of the eye's lens leading to decreased vision.
    - Often age-related but can also result from trauma, certain medications, or diseases.
2. **Glaucoma**:
    - Increased pressure in the eye causing damage to the optic nerve.
    - Often has no symptoms in early stages but leads to vision loss if untreated.
3. **Diabetic Retinopathy**:
    - Damage to the blood vessels in the retina due to high blood sugar levels.
    - A complication of diabetes that can lead to blindness if not managed properly.
4. **Macular Degeneration**:

- Degeneration of the central part of the retina (macula).
- Leading cause of vision loss in older adults.

5. **Infections and Injuries**:
   - Infections like trachoma and injuries to the eye can cause blindness.
   - Proper hygiene and eye protection are essential.

Methods of Preventing Blindness:

1. **Regular Eye Examinations**:
   - Early detection and treatment of eye conditions can prevent vision loss.
   - Important for people with risk factors such as diabetes, high blood pressure, or a family history of eye diseases.
2. **Control of Chronic Conditions**:
   - Proper management of diabetes and hypertension to prevent complications like diabetic retinopathy and hypertensive retinopathy.
3. **Protection from UV Light**:
   - Wearing sunglasses that block UV rays to prevent cataracts and other UV-related eye damage.
4. **Healthy Diet**:
   - Consuming a diet rich in antioxidants, vitamins, and minerals to support eye health.
   - Foods like leafy greens, fish, and nuts are beneficial.
5. **Avoiding Smoking**:
   - Smoking is a risk factor for many eye diseases, including macular degeneration and cataracts.
   - Quitting smoking reduces the risk of developing these conditions.
6. **Vaccination and Hygiene**:

- Vaccinations against infections that can lead to blindness (e.g., measles).
- Maintaining good hygiene to prevent infections like trachoma.

4.

1. **Support**:
   - The skeleton provides a framework that supports the body and maintains its shape.
   - It gives structural support for the attachment of muscles and other tissues.
2. **Protection**:
   - The skeleton protects vital organs from injury.
   - For example, the skull protects the brain, the rib cage protects the heart and lungs, and the vertebral column protects the spinal cord.
3. **Movement**:
   - The skeleton allows movement by serving as points of attachment for muscles.
   - When muscles contract, they pull on bones, producing movement at the joints.
4. **Mineral Storage**:
   - Bones act as a reservoir for minerals, particularly calcium and phosphorus.
   - These minerals can be released into the bloodstream as needed for various bodily functions.
5. **Blood Cell Production**:
   - The bone marrow, found in certain bones, is responsible for the production of blood cells.
   - This includes red blood cells, white blood cells, and platelets.
6. **Energy Storage**:

- Yellow bone marrow stores lipids, which serve as an energy reserve.

(b)

1. **Cellular Composition**:
   - Bones contain living cells, such as osteocytes, osteoblasts, and osteoclasts, which are involved in the formation, maintenance, and remodeling of bone tissue.
   - Osteoblasts build new bone, osteoclasts break down old bone, and osteocytes maintain the bone matrix.
2. **Blood Supply**:
   - Bones have a rich blood supply, which provides the necessary nutrients and oxygen for bone cells.
   - The blood vessels also remove waste products from bone cells.
3. **Growth and Repair**:
   - Bones have the ability to grow and repair themselves.
   - During childhood and adolescence, bones grow in length and width.
   - Bones can repair themselves after fractures through the process of bone remodeling.
4. **Metabolic Activity**:
   - Bones are metabolically active, continuously being broken down and rebuilt in response to mechanical stress and hormonal signals.
   - This dynamic process helps maintain the strength and integrity of the skeletal system.
5. **Communication with Other Tissues**:
   - Bone cells communicate with other tissues through signaling molecules.
   - This helps regulate calcium levels in the blood and coordinates bone growth and repair with other physiological processes.

6. **Presence of Marrow**:
    - Bone marrow, a soft tissue found within bones, is responsible for producing blood cells and storing fat.
    - The presence of active bone marrow indicates that bones are involved in essential bodily functions beyond mere structural support.

5.

(a)

Importance of a Rich Biodiversity:

1. **Ecosystem Stability:**
    - High biodiversity increases the resilience of ecosystems to environmental changes and disturbances, ensuring stability and continuity of ecosystem functions.
2. **Source of Food and Medicine:**
    - Biodiverse ecosystems provide a wide range of food resources and medicinal plants that are vital for human health and nutrition.
3. **Economic Value:**
    - Biodiversity contributes to economies through tourism, agriculture, and fisheries, providing livelihoods for millions of people worldwide.
4. **Ecosystem Services:**
    - Biodiverse ecosystems perform essential services such as pollination, water purification, climate regulation, and soil fertility, which are crucial for the survival of all living organisms.
5. **Cultural and Recreational Value:**

- Biodiversity has cultural, aesthetic, and recreational importance, enriching human life and well-being through activities like hiking, bird-watching, and nature appreciation.

6. **Genetic Diversity:**
    - High biodiversity ensures a pool of genetic variation, which is vital for the adaptation and survival of species in changing environmental conditions.

Human Activities Reducing Biodiversity:

1. **Habitat Destruction:**
    - Deforestation, urbanization, and agricultural expansion lead to the loss and fragmentation of habitats, making it difficult for species to survive and reproduce.
2. **Pollution:**
    - Air, water, and soil pollution from industrial, agricultural, and urban activities can poison ecosystems, leading to the decline or extinction of sensitive species.
3. **Overexploitation:**
    - Overfishing, hunting, and harvesting of plants and animals at unsustainable rates deplete populations faster than they can recover, leading to species decline and extinction.
4. **Climate Change:**
    - Human-induced climate change alters temperature and precipitation patterns, affecting the distribution and survival of species and ecosystems.
5. **Invasive Species:**
    - Introduction of non-native species by humans can outcompete, prey on, or bring diseases to native species, disrupting local ecosystems and reducing biodiversity.
6. **Land Use Change:**

- Conversion of natural landscapes into agricultural, industrial, or urban areas disrupts ecosystems and reduces the availability of habitats for wildlife.

(b)

Carbon Cycle:

1. **Photosynthesis:**
   - Plants, algae, and some bacteria absorb carbon dioxide (CO_2) from the atmosphere and use sunlight to convert it into organic molecules (glucose) through photosynthesis.
   - Equation: $6CO_2 + 6H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2$
2. **Respiration:**
   - Organisms (plants, animals, and microorganisms) break down organic molecules to release energy, producing CO_2 as a byproduct, which is returned to the atmosphere.
   - Equation: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$
3. **Decomposition:**
   - Decomposers (bacteria and fungi) break down dead plants and animals, releasing carbon stored in their bodies back into the soil and atmosphere as CO_2.
4. **Combustion:**
   - Burning of fossil fuels (coal, oil, and natural gas) and biomass releases stored carbon back into the atmosphere as CO_2.
5. **Ocean Uptake and Release:**
   - Oceans absorb CO_2 from the atmosphere. Marine organisms use it for photosynthesis and shell formation.
   - CO_2 is also released back into the atmosphere through respiration and decomposition of marine life.
6. **Sedimentation and Fossilization:**

- Over long periods, carbon from dead organisms can be buried and converted into fossil fuels (coal, oil, and natural gas) through geological processes.
- Carbon can also be stored in sedimentary rocks as carbonates.

7. **Human Impact:**
   - Human activities, such as deforestation and burning fossil fuels, increase CO_2 levels in the atmosphere, affecting the natural balance of the carbon cycle.

This recycling process ensures that carbon is continuously cycled through the ecosystem, maintaining a balance between carbon storage and release.