Chapter 1 - Nature of Science in Biology

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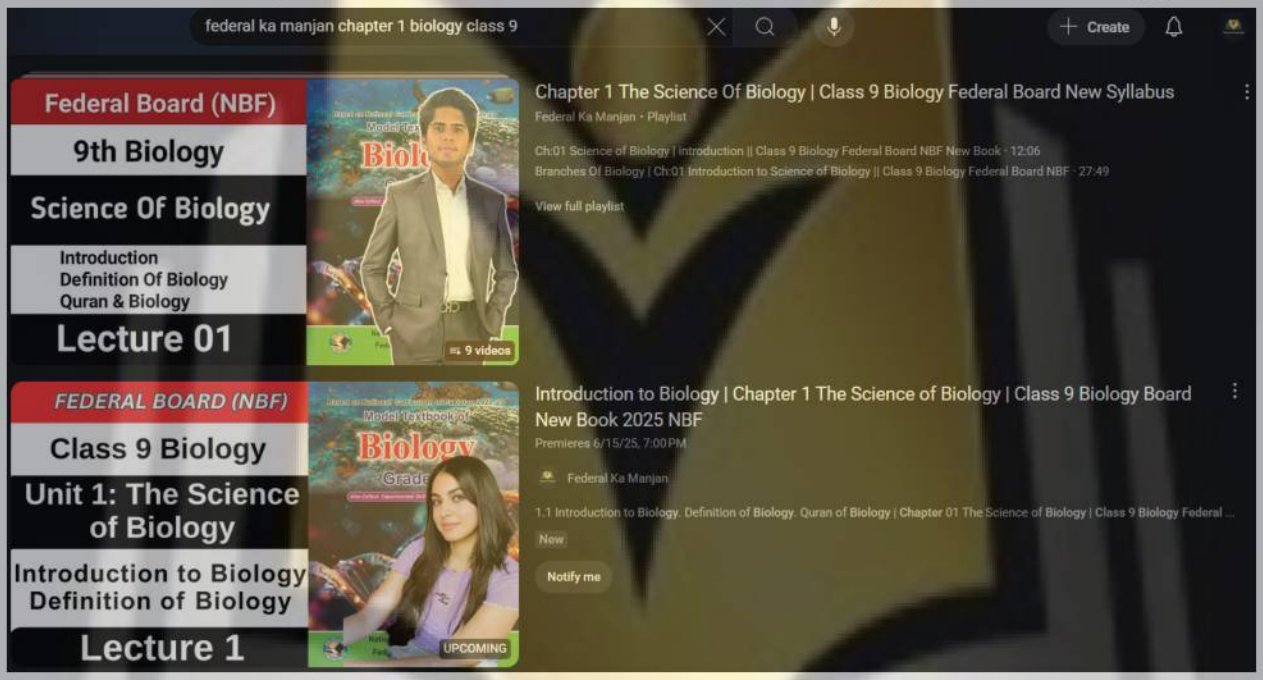

Biology- Bio and logos

Bio means life, and logos means study
Hence, it is the study of life

Major fields of Biology:
Main divisions of Biology: Botany, Zoology, Microbiology

Sub-fields of Biology:

1. Morphology- study of size, shape and structure of organisms (animals, plants and microorganisms)
2. Anatomy- study of internal structures of organisms
3. Physiology- study of the functions of various organs of living organisms

4. Histology- the microscopic study of tissues of organisms
5. Cytology- the study of the structure and function of the cell
6. Genetics- the study of genes and heredity
7. Molecular biology- the study of life at a molecular level
8. Embryology- the study of an embryo and its development
9. Paleontology- the study of history of life based on fossils
10. Taxonomy- the classification and naming of organisms based on species (e.g., homo sapiens)
11. Ecology- the study of relationships between organisms and their environment
12. Marine Biology- the study of organisms living in the sea
13. Pathology- the study of diseases and their diagnoses
14. Immunology- the ability of body to protect itself from pathogens and infectious substances/ the study of immunity of organisms
15. Pharmacology- the study of drugs

Relationship of Biology with Other Sciences

- Biology is related to many other fields of science in various ways
- This integration with other sciences can be studied further;
    a. Biophysics
    b. Biochemistry
    c. Biostatistics
    d. Computational biology
    e. Biogeography
    f. Biotechnology
    g. Bio-economics

Biological Method/ The Scientific Method

1. Recognition of a problem
    - A question or problem related to any living organism
2. Observation and identification
    - Observation- made by the 5 senses (sight, smell, touch, taste, hearing)
    - Types of observations: quantitative and qualitative

- Quantitative observation: (quantity) based on measurable or factual value
- Qualitative observation: based on some quality

3. Hypothesis generation (Hypothesis- an educated guess/ 'tukka')
   - A statement which you can test or is a tentative explanation of something
4. Drawing deductions (specific)
   - Logical conclusions of the hypothesis
   - For **example**, 'If you drink cold water, you will fall sick'
5. Conducting an experiment
   - To prove if the hypothesis is right or wrong
   - Deductions are tested to see how valid they are
6. Results
   - Gather the actual data from experiments which, when analysed/interpreted, gives you the results

Hypothesis, Theory and Law:

1. **Hypothesis:**

- A **hypothesis** is a temporary or tentative answer to a question or a problem.
- It is based on **past experiences** and **available data**.
- A scientific hypothesis **predicts outcomes** that can be tested through further experiments and observations.
- **Deductions** are logical outcomes of the hypothesis.
- They usually follow **"if... then..."** logic.
- Example: *If* a hypothesis is true, *then* a specific result should be observed in experiments.
- Experiments are performed to test if deductions (based on the hypothesis) are correct.
- If results match predictions, the hypothesis is supported.

2. **Theory:**

- A **theory** is a well-tested explanation supported by a lot of evidence and data.

- Theories are **broader** than hypotheses and explain a larger range of phenomena.
- A theory is more **general and reliable** than a hypothesis.
- Even well-supported theories can be **changed or rejected** if new evidence appears.

3. **Law:**

- A theory with **wide application** and verification may become a **biological law**.
- Example: The sun rises in the east and sets in the west

Data analysis:

- **Data** is the collection of facts and observations
- Data is first collected and then organized using graphs and tables.
- **Analysis** involves making sense of data using **ratios and proportions** to make predictions.

Malaria (Example of Biological Method)

- Symptoms: feeling cold, nausea, temperature rises, headaches, body feels better, then gets symptoms after every 24, 48 and 72 hours
- Recognition of problem: malaria exists, but the cause is unknown
- Observation:
- Hypothesis: 'Plasmodium is the cause of malaria'
- Deduction
- Experiment: the blood of **100 malaria patients (experimental condition)** was examined under the microscope. **Control group:** a group in an experiment used to compare results of the tested/experimental condition. (healthy people)
- Results: all malarial patients had plasmodium in their blood. 7 healthy people had plasmodium in their blood as it was in the **incubation period.**
- Hence, the hypothesis is proven right- plasmodium is indeed the cause of malaria

Multiple Choice Questions

1. C
2. B
3. C
4. A
5. D
6. C
7. C
8. B
9. A
10. A
11. D
12. B
13. B
14. C

Short Answer Questions

Q.1)

Molecular Biology

- **Definition:** Molecular biology is the study of biological activity at a molecular level. It focuses on the interactions and relationships between the various systems of a cell.
- **Significance:** Molecular biology has revolutionised our understanding of life processes. It has led to significant advancements in fields like medicine, agriculture, and biotechnology. For example, it has enabled the development of gene therapies, the creation of genetically modified organisms, and the understanding of genetic diseases.

B. Physiology

- **Definition:** Physiology is the study of the **functions of living organisms and their parts**. It deals with the mechanical, physical, and biochemical functions of organisms, as well as the ways in which these functions are maintained.
- **Significance:** Physiology is crucial for understanding how organisms function, adapt to their environments, and maintain homeostasis. It has applications in various fields, including medicine, where it helps us understand how diseases affect the body and develop treatments. It also plays a vital role in fields like sports science and exercise physiology.

C. Paleontology

- **Definition:** Paleontology is the scientific study of prehistoric life forms on Earth through the **examination of fossils**. It provides insights into the history of life on Earth, including the evolution of organisms and the changes in Earth's environment over time.

- **Significance:** Palaeontology is essential for understanding the history of life on Earth and the processes of evolution and extinction. It helps us to reconstruct past ecosystems, understand the impact of climate change on life, and predict future environmental changes.

D. Pharmacology

- **Definition:** Pharmacology is the study of **drugs and their interactions with living systems**. It encompasses various aspects, including drug discovery, design, action, and safety.
- **Significance:** Pharmacology is crucial for the development and use of medicines. It helps us to understand how drugs work, their side effects, and how to use them safely and effectively. Pharmacology plays a vital role in improving human health and well-being.

Q.2)

a. **Anatomy vs Morphology**
Anatomy focuses on the internal structures of organisms, their arrangement, and their relationships. Meanwhile, morphology studies the external and internal structures of organisms as a whole, including their form, shape, and size.

b. **Cytology and Genetics**
Cytology studies **cells**, their structure, function, and organisation and examines cellular components like organelles, membranes, and the cell cycle. Whereas, genetics is the study of **genes, heredity and genetic variation** in organisms. It focuses on DNA, RNA and chromosomes and how genetic information is passed down from generations

c. **Biotechnology and Immunology:**
Biotechnology is the use of living organisms and their components to develop products for various purposes, including genetic engineering etc. Immunology, on the other hand, is the study of the immune system, which protects the body from diseases.

d. **Marine Biology and Ecology**
Marine Biology is the scientific study of organisms that live in the **ocean** and their **interactions with the marine environment**. Ecology, however, examines how **organisms interact with each other** (e.g., predation, competition) and how they are influenced by abiotic factors (e.g., temperature, sunlight, water).

Q.3)

Biology empowers us to live healthier lives by providing crucial knowledge about the human body, disease prevention, and the impact of our environment on our well-being. Understanding how our bodies function, the importance of nutrition and exercise, and the causes and spread of diseases allows us to make informed choices about our health and take proactive steps towards a healthier lifestyle.

Q.4)

A.F.A. King worked on mosquitoes and malaria

Ronald Ross discovered the transmission of malaria

Laveran discovered that a single-celled organism causes malaria

Q.5)

Colour of cat– qualitative,

Height of giraffe– quantitative

Weight of mango– quantitative

Body temperature of birds– quantitative

Volume of blood– quantitative

Shape of leaves– qualitative

The climate of the desert– qualitative

Speed of tiger– quantitative

Song of a Bird— qualitative

Q.6) Yes, the hypothesis given by a Nobel prize winner can be wrong since the hypotheses are made on **limited evidence and without investigation.** The reasons it may be wrong are; **incomplete or insufficient data** as then the hypothesis would not be generalisable in broader contexts. The methodologies could also be wrong or have errors in sampling and data collection. The deductions that can be made from this hypothesis are: 1) Reducing the severity of disease is one of the outcomes of a successful immune response. 2) Clinical trials have shown that COVID-19 vaccines reduce hospitalisation and severe cases.

Q.7)

Eradicating malaria would be incredibly challenging and near to impossible. The Plasmodium parasite that causes malaria has a complex life cycle, involving both human and mosquito hosts. This makes it difficult to target and eliminate all stages of the parasite. Mosquitoes have developed resistance to many insecticides and anti-malarial drugs, making it harder to

control their populations. In many malaria-endemic regions, access to healthcare and effective malaria prevention and treatment tools is limited. Moreover, any vaccine hasn't yet been found 100% effective for it to work with complete efficacy

Q.8)

(i) The term "vector" is used for mosquitoes because they are organisms that **transmit pathogens from one host to another**. In the case of malaria, mosquitoes (*Anopheles*) act as vectors by carrying the *Plasmodium* parasite from an infected individual to a healthy one, facilitating the spread of the disease.

(ii) The *Plasmodium* species is the parasite responsible for malaria. In humans, the main species are *Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium malariae*, and *Plasmodium ovale*. In birds, *Plasmodium relictum* is a common species that causes avian malaria.

(iii) Ronald Ross aimed to demonstrate the **role of mosquitoes in the transmission of malaria**. His experiments were designed to prove that mosquitoes are the vectors that carry the *Plasmodium* parasites, completing the parasite's life cycle and transmitting it to humans.

Q.9)

Ross did not allow infected mosquitoes to bite healthy person to prevent the transmission of malaria to humans and to **ethically conduct** the experiment by **avoiding harm to humans**. His goal was to study the transmission of malaria, and he conducted his research with strict scientific and moral responsibility. Letting an infected mosquito bite a healthy human could have led to **serious illness or death**, especially since there were no

effective treatments for malaria at the time. Instead, Ross used bird models and experimental controls to prove that malarial parasites are transmitted through the bite of female Anopheles mosquitoes, making a major breakthrough in medical science without putting human lives at unnecessary risk.

Q.10)

Hepatitis B virus (HBV) was found in the blood of 10 persons, but only 6 of them were suffering from the disease because the presence of the virus does not always mean active illness. Some individuals may be carriers of the virus—they have the virus in their blood but do not show symptoms or suffer from the disease because their immune system is keeping the virus under control. Others may be in the **incubation period** (infected but not yet showing symptoms) or may have developed immunity after a past infection or vaccination. This shows that infection and disease are not always the same—a person can be infected (virus present) without being diseased (no symptoms or organ damage).

Extensive Answer Questions

Q.1) Biology is deeply interconnected with other branches of science, making it an interdisciplinary field. It links with **chemistry** through biochemistry, where understanding the chemical composition of cells, enzymes, and hormones is essential for explaining biological processes. It relates to **physics** through biophysics, as concepts like energy, pressure, and motion are vital in understanding blood circulation, nerve impulses, and muscle contractions. Biology also connects with **mathematics** in biostatistics, which helps analyse experimental data and predict outcomes in genetics and ecology. In **geography and environmental sciences**, biology aids in studying ecosystems, climate impact on biodiversity, and conservation efforts. Moreover, biology merges with **computer science** in bioinformatics/computational biology, helping decode genetic information and understand diseases at the molecular level. Thus, biology doesn't work in isolation but rather integrates principles from other sciences to build a deeper understanding of life.

Q.2) Biology provides the foundational knowledge required for a wide range of careers in health, environment, and industry. In **medicine and surgery**, biological studies of human anatomy, physiology, and pathology help diagnose and treat diseases. **Fisheries** biology helps improve fish breeding, sustainability, and disease control in aquatic environments. In **agriculture**, knowledge of plant biology and genetics aids in developing disease-resistant, high-yield crops. **Animal husbandry** relies on biology to improve livestock health and breeding. **Biotechnology** uses biological techniques for innovations in medicine, food, and the environment, such as producing insulin or genetically modified crops. **Horticulture** applies biology to the cultivation of fruits, vegetables, and ornamental plants, while **farming** benefits from biological methods to maintain soil health and crop productivity. In **forestry**, biology helps manage forest resources, preserve biodiversity, and prevent deforestation. Each of these fields applies biological principles to solve real-world problems, making biology a gateway to diverse and impactful careers.

Q.3) Science is inherently a collaborative field where researchers, scientists, and experts from various disciplines work together to solve complex problems. No single person can master all the knowledge needed in modern science, so collaboration is essential. For example, in medicine, biologists, chemists, and physicists work with engineers and computer scientists to develop diagnostic machines, prosthetics, or treatments. Global challenges like **climate change**, pandemics, or cancer research require international cooperation, shared data, and collective expertise. Collaborative science encourages peer review, increases the accuracy of findings, and allows for more diverse perspectives. By combining different areas of expertise, scientists can innovate faster, test hypotheses more thoroughly, and develop solutions that are practical and sustainable. Whether in laboratories, universities, or global networks, science thrives when knowledge is shared and teamwork is encouraged.

Q.4) Biology plays a crucial role in ensuring the welfare of human beings because it helps us understand how our bodies work, how to prevent and treat diseases, and how to live healthier lives. It provides the foundation for advancements in **medicine**, **pharmacology**, and **public health**, leading to vaccines, antibiotics, and life-saving surgeries. Biology also contributes to **food security** through improved agricultural practices and genetically modified crops that grow faster and resist pests. It informs **sanitation and hygiene**, helping prevent the spread of infectious diseases. **Environmental biology** helps us conserve natural resources and manage waste responsibly, ensuring a sustainable future. In essence, biology equips us with the knowledge and tools to improve our quality of life, protect our planet, and make informed decisions for the betterment of individuals and communities.

Q.5)

Cattle Farming – Provides milk, meat, leather; supports dairy industry and exports.

Poultry Farming – Supplies eggs and chicken; creates jobs and meets protein needs.

Goat Farming – Gives meat and milk; suitable for rural areas with low investment.

Sheep Farming – Provides wool and meat; wool used in textile industry.

Fish Farming – Produces fresh fish; boosts food supply and reduces overfishing.

Camel Farming – Offers milk and meat; camels are also used in transportation.

Bee Keeping – Produces honey, beeswax; promotes pollination and eco-health.

Duck Farming – Provides eggs and meat; easy to manage in wetlands and rice fields.

Rabbit Farming – Provides lean meat and fur; has export potential.

Silkworm Farming – Produces silk; supports textile and clothing industry. These animal farming industries not only meet local demands for food and products but also contribute significantly to **exports**, **employment**, and **rural development**, helping strengthen Pakistan's economy.

Q.6) The biological method is a systematic approach used by scientists to investigate living organisms and life processes. It begins with **observation**, where a natural event or phenomenon is noticed, followed by the formation of a **hypothesis**, which is a testable explanation. Next, **experiments** are conducted under controlled conditions to test the hypothesis. The results are then **recorded and analyzed**, leading to a **conclusion** that either supports or rejects the hypothesis. If consistent results are observed, the findings may contribute to the development of a **theory or law**. This method ensures that biological knowledge is based on evidence and repeatable processes. Applications of this method are seen in disease research, genetic studies, agricultural innovations, and environmental conservation, making it a cornerstone of modern biology.

Q.7) The biological method was crucial in discovering the cause of malaria. Scientists observed patterns of the disease in certain regions and suspected mosquitoes played a role. Sir Ronald Ross used the biological method by making careful **observations** and forming a **hypothesis** that mosquitoes transmit malaria. He conducted **experiments** on birds infected with malaria and found that when mosquitoes bit these birds and then bit healthy ones, the disease spread. His **data** confirmed the presence of the malaria parasite in the mosquito's body. From these observations and experiments, it was **concluded** that malaria is caused by a parasite called *Plasmodium*, which is transmitted by the female *Anopheles* mosquito. This discovery was a major milestone made possible through the biological method.

Q.8) The biological method helped scientists understand how malaria spreads. After observing that malaria outbreaks were common in areas with stagnant water and mosquitoes, scientists proposed the **hypothesis** that mosquitoes might be the vector. Experiments were designed to test whether the mosquito bite transferred something infectious. Ronald Ross's research involved dissecting mosquitoes and examining their organs, where he found the malaria parasite (*Plasmodium*). Through controlled **experiments** with birds and mosquitoes, and careful **data collection**, he proved that malaria spreads through the bite of an infected female *Anopheles* mosquito. This **conclusion** helped in planning control strategies like *mosquito nets, insect repellents, and eliminating breeding grounds*—thereby controlling the spread of malaria. This entire process reflects the importance of the biological method in scientific discovery and public health.

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