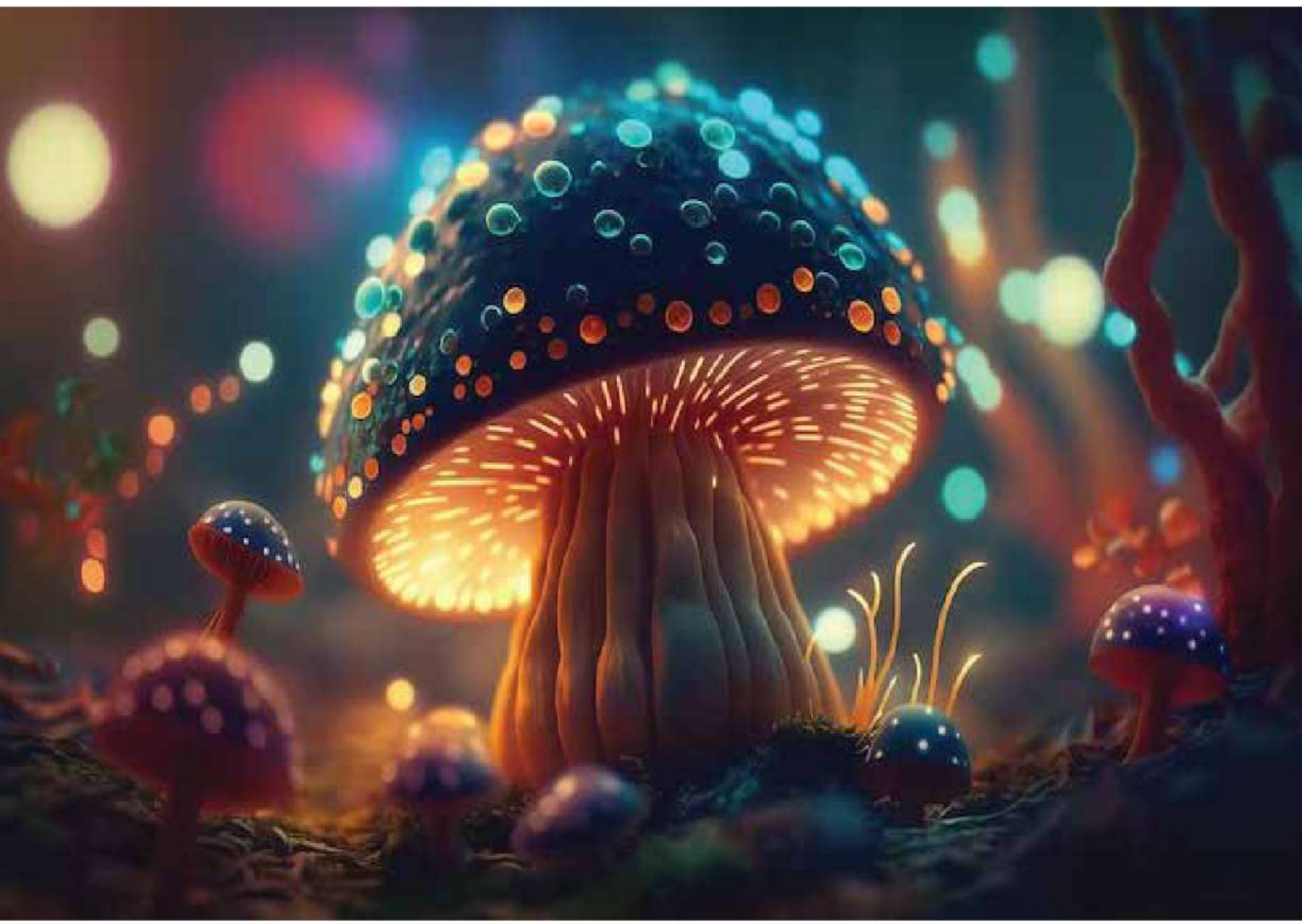
National Curriculum of Pakistan
2022-23

BIOLOGY

Grades 9-12



NATIONAL CURRICULUM COUNCIL SECRETARIAT
MINISTRY OF FEDERAL EDUCATION AND
PROFESSIONAL TRAINING, ISLAMABAD
GOVERNMENT OF PAKISTAN

بسم الله الرحمن الرحيم

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It is with great pride that we, at the National Curriculum Council Secretariat, present the first core curriculum in Pakistan's 75-year history. Consistent with the right to education guaranteed by Article 25-A of our Constitution, the National Curriculum of Pakistan (2022-23) aspires to equip every child with the necessary tools required to thrive in and adapt to an ever-evolving globalized world.

The National Curriculum is in line with international benchmarks, yet sensitive to the economic, religious, and social needs of young scholars across Pakistan. As such, the National Curriculum aims to shift classroom instruction from rote learning to concept-based learning.

Concept-based learning permeates all aspects of the National Curriculum, aligning textbooks, teaching, classroom practice, and assessments to ensure compliance with contemplated student learning outcomes. Drawing on a rich tapestry of critical thinking exercises, students will acquire the confidence to embark on a journey of lifelong learning. They will further be able to acknowledge their weaknesses and develop an eagerness to build upon their strengths.

The National Curriculum was developed through a nationwide consultative process involving a wide range of stakeholders, including curriculum experts from the public, private, and non-governmental sectors. Representatives from provincial education departments, textbook boards, assessment departments, teacher training departments, *deeni madaris*, public and private publishers, private schools, and private school associations all contributed their expertise to ensure that the National Curriculum could meet the needs of all Pakistani students.

The experiences and collective wisdom of these diverse stakeholders enrich the National Curriculum, fostering the core, nation-building values of inclusion, harmony, and peace, making the National Curriculum truly representative of our nation's educational aspirations and diversity.

I take this opportunity to thank all stakeholders, including students, teachers, and parents who contributed to developing the National Curriculum of Pakistan (2022-23)

Dr. Mariam Chughtai
Director
National Curriculum Council Secretariat
Ministry of Federal Education and Professional Training

Cross-Cutting Themes

Guidance for the Reader

The idea of Science, Technology, Engineering, The Arts and Mathematics (STEAM) is an overarching idea for how to break up the study of Biology into core disciplinary knowledge (that students need to learn in order to pass examination at each grade level) and cross-cutting themes (interdisciplinary connections and recurring ideas that are best reinforced in every chapter in order to promote student critical thinking and curiosity, but that is not expected to be assessed in standardized exams).

Cross-cutting themes must be appropriately included into every chapter of schools textbooks that are aligned with these standards. This does not mean that every subcomponent of every theme must be included in every chapter, rather that where connections are appropriate and would enhance the study of the core disciplinary knowledge these should be incorporated.

The themes presented below are adapted from the Next Generation Science Standards:

Science: theoretical understandings about science in general, experimental skills and their mutual overlaps in the methods of scientific inquiry

Engineering and Technology: applications of science to create solutions that improve standards of living, along with the design thinking approach of engineering applied to scientific problems and vice versa

Mathematics: the connections of mathematics with the natural world, and its interconnectedness with the methods of the natural sciences

The Arts: What can be understood about the nature of science from the fine arts, performing arts and the humanities

Theme	Components	Elaboration and Guidance
Science	**A) Scientific Knowledge (these themes are applied across the conceptual SLOs)** **1. Patterns** i) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. ii) Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. iii) Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. iv) Mathematical representations are needed to identify some patterns. v) Empirical evidence is needed to identify patterns **2. Cause and Effect: Mechanism and Prediction** i) Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. ii) Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. iii) Systems can be designed to cause a desired effect. iv) Changes in systems may have various causes that may not have equal effects. **3. Scale, Proportion, and Quantity** i) The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. ii) Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. iii) Patterns observable at one scale may not be observable or exist at other scales. iv) Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. v) Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). **4. Systems and System Models** i) Systems can be designed to do specific tasks. ii) When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.	**Elaborations on (A) Scientific Knowledge):** 1. Patterns: Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them. 2. Cause and Effect: Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering. 3. Scale, Proportion and Quantity: In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change. 4. Systems and System Models: A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems. 5. Energy and Matter: Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior 6. Structure and Function: The way an object is shaped or structured determines many of its properties and functions. 7. Stability and Change: For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand. **Elaborations on (B) Scientific Practices:** 1. Asking Questions and Defining Problems: A practice of science is to ask and refine

	iii) Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. iv) Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. **5. Energy and Matter: Flows, Cycles, and Conservation** i) The total amount of energy and matter in closed systems is conserved. ii) Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. iii) Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. iv) Energy drives the cycling of matter within and between systems. v) In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. **6. Structure and Function** i) Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. ii) The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. **7. Stability and Change** i) Much of science deals with constructing explanations of how things change and how they remain stable. ii) Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. iii) Feedback (negative or positive) can stabilize or destabilize a system. iv) Systems can be designed for greater or lesser stability. **B) Scientific Practices** **1. Asking Questions and Defining Problems** i) Ask questions:	questions that lead to descriptions and explanations of how the natural and designed world(s) works and which can be empirically tested. Engineering questions clarify problems to determine criteria for successful solutions and identify constraints to solve problems about the designed world. Both scientists and engineers also ask questions to clarify ideas. 2. Developing and Using Models: A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. Modeling tools are used to develop questions, predictions and explanations; analyze and identify flaws in systems; and communicate ideas. Models are used to build and revise scientific explanations and proposed engineered systems. Measurements and observations are used to revise models and designs. 3. Planning and Carrying Out Investigations: Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters. Engineering investigations identify the effectiveness, efficiency, and durability of designs under different conditions. 4. Analyzing and Interpreting Data: Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology

	- that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information - that arise from examining models or a theory, to clarify and/or seek additional information and relationships. - to determine relationships, including quantitative relationships, between independent and dependent variables. - to clarify and refine a model, an explanation, or an engineering problem. ii) Evaluate a question to determine if it is testable and relevant. iii) Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. iii) Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. iv) Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical and/or environmental considerations. **2. Developing and Using Models** i) Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria. ii) Design a test of a model to ascertain its reliability. iii) Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. iv) Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. v) Develop a complex model that allows for manipulation and testing of a proposed process or system. vi) Develop and/or use a model (including mathematical and	makes the collection of large data sets much easier, providing secondary sources for analysis. Engineering investigations include analysis of data collected in the tests of designs. This allows comparison of different solutions and determines how well each meets specific design criteria—that is, which design best solves the problem within given constraints. Like scientists, engineers require a range of tools to identify patterns within data and interpret the results. Advances in science make analysis of proposed solutions more efficient and effective. 5. Using Mathematics and Computational Thinking: In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; solving equations exactly or approximately; and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable scientists and engineers to predict the behavior of systems and test the validity of such predictions. 6. Constructing Explanations and Designing Solutions: The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories. The goal of engineering design is to find a systematic solution to problems that is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, technical feasibility, cost, safety, aesthetics, and compliance with legal requirements. The optimal choice depends on how well the proposed solutions meet criteria and constraints. 7. Engaging in Argument from Evidence: In

	computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. **3. Planning and Carrying Out Investigations** i) Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. ii) Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. iii) Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts. iv) Select appropriate tools to collect, record, analyze, and evaluate data. v) Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. vi) Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables. **4. Analyzing and Interpreting Data** i) Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. ii) Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. iii) Consider limitations of data analysis (e.g., measurement error,	science and engineering, reasoning and argument based on evidence are essential to identifying the best explanation for a natural phenomenon or the best solution to a design problem. Scientists and engineers use argumentation to listen to, compare, and evaluate competing ideas and methods based on merits. Scientists and engineers engage in argumentation when investigating a phenomenon, testing a design solution, resolving questions about measurements, building data models, and using evidence to evaluate claims. 8. Obtaining, Evaluating and Communicating Information: Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity. Communicating information and ideas can be done in multiple ways: using tables, diagrams, graphs, models, and equations as well as orally, in writing, and through extended discussions. Scientists and engineers employ multiple sources to obtain information that is used to evaluate the merit and validity of claims, methods, and designs.

	sample selection) when analyzing and interpreting data. iv) Compare and contrast various types of data sets (e.g., self generated, archival) to examine consistency of measurements and observations. v) Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. vi) Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success. **5. Using Mathematics and Computational Thinking** i) Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. ii) Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. iii) Apply techniques of algebra and functions to represent and solve scientific and engineering problems. iv) Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world. v) Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3 , acre-feet, etc.). **6. Constructing Explanations and Designing Solutions** i) Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. ii) Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	

	iii) Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. iv) Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. v) Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade off considerations. **7. Engaging in Argument from Evidence** i) Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. ii) Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. iii) Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions. iv) Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. v) Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence. vi) Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). **8. Obtaining, Evaluating and Communicating Information** i) Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific	

	and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. ii) Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. iii) Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. iv) Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. v) Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).	

Technology & Engineering

1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

i) Analyze complex real-world problems by specifying criteria and constraints for successful solutions.

ii) Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.

iii) Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

iv) All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment

v) New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

i) Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade off considerations.

ii) Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.

3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

i) Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence,

The Engineering Design cycle can be considered to consist of the below three iterative steps in a global problem solving context:

Define: Attend to a broad range of considerations in criteria and constraints for problems of social and global significance

Develop solutions: Break a major problem into smaller problems that can be solved separately

Optimize: Prioritize criteria, consider tradeoffs, and assess social and environmental impacts as a complex solution is tested and refined

	prioritized criteria, and trade off considerations. ii) When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. **4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.** i) Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. ii) Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. iii) Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales. **5. Interdependence of Science, Engineering, and Technology** i) Science and engineering complement each other in the cycle known as research and development (R&D). ii) Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. **6. Influence of Engineering, Technology, and Science on Society and the Natural World** i) Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. ii) Engineers continuously modify these systems to increase benefits while decreasing costs and risks.	

	iii) New technologies can have deep impacts on society and the environment, including some that were not anticipated. iv) Analysis of costs and benefits is a critical aspect of decisions about technology.	

The Arts and Mathematics	**A) Mathematical Knowledge in Science** (these are embedded into the conceptual SLOs, as well as is in the prerequisite mathematical knowledge requirements) **B) Nature of Science** **1. Scientific Investigations Use a Variety of Methods** i) Science investigations use diverse methods and do not always use the same set of procedures to obtain data. ii) New technologies advance scientific knowledge. iii) Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings. iv) The discourse practices of science are organized around disciplinary domains that share examples for making decisions regarding the values, instruments, methods, models, and evidence to adopt and use. v) Scientific investigations use a variety of methods, tools, and techniques to revise and produce new knowledge. **2. Science knowledge is based on empirical evidence.** i) Science disciplines share common rules of evidence used to evaluate explanations about natural systems. ii) Science includes the process of coordinating patterns of evidence with current theory. iii) Science arguments are strengthened by multiple lines of evidence supporting a single explanation. **3. Scientific Knowledge is Open to Revision in Light of New Evidence** i) Scientific explanations can be probabilistic. ii) Most scientific knowledge is quite durable but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. iii) Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation. **4. Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** i) Theories and laws provide explanations in science, but theories do	

not with time become laws or facts.
ii) A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that has been repeatedly confirmed through observation and experiment, and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.
iii) Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory.
iv) Laws are statements or descriptions of the relationships among observable phenomena.
v) Scientists often use hypotheses to develop and test theories and explanations.

5. Science is a Way of Knowing

i) Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise, and extend this knowledge.
ii) Science is a unique way of knowing and there are other ways of knowing.
iii) Science distinguishes itself from other ways of knowing through use of empirical standards, logical arguments, and skeptical review.
iv) Science knowledge has a history that includes the refinement of, and changes to, theories, ideas, and beliefs over time.

6. Scientific Knowledge Assumes an Order and Consistency in Natural Systems

i) Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future.
ii) Science assumes the universe is a vast single system in which basic laws are consistent.

7. Science is a Human Endeavor

i) Scientific knowledge is a result of human endeavor, imagination, and creativity.
ii) Individuals and teams from many nations and cultures have contributed to science and to advances in engineering.
iii) Scientists' backgrounds, theoretical commitments, and fields of endeavor influence the nature of their findings.
iv) Technological advances have influenced the progress of science and science has influenced advances in technology.
v) Science and engineering are influenced by society and society is

	influenced by science and engineering. **8. Science Addresses Questions About the Natural and Material World** i) Not all questions can be answered by science. ii) Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. iii) Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. iv) Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues.	

Theoretical Concepts Progression Grid

Guidance for the Reader

Assumption of Prior Knowledge: It is assumed that students will already have knowledge (and be able to apply it as needed in their current class) of what they learned in their previous grades, so SLOs from previous grades are not repeated in the higher grades. In practice, teachers may want to refresh concepts with their students as appropriate.

Organization of the SLOs in the Progression Grid: Inside a grade, teachers are free to teach the content in any order of preference. Textbook publishers are also free to organize the contents of their books in any manner that they consider most effective, as long as all the SLOs in the Progression Grid and Cross-Cutting themes are covered. The SLOs inside a grade do not need to be taught in the order presented in a grade in this PG. The Nature of Science domain would, for example, be best taught by being integrated into the teaching of all the chapters of the curriculum.

Nature of Science Domain Guidance for the Reader: Nature of Science learning objectives have been added to the Progression Grid. The purpose of studying science at the high school level is not only to prepare students for further study in the sciences. Many students will in fact not go on to study further science or STEM fields. The science that they learn in school may well remain their understanding of the subject for the rest of their lives. Hence these curricula must consider what citizens in a democratic society ought to know about the nature of science. "Nature of Science" (NOS) means teaching about science's underlying assumptions, and its methodologies. This involves some integrated study of the history of science, and some of the broad concepts from the philosophy of science. It is important to study NOS because it helps students become critical thinkers about the scientific information they consume from the world around them. Teaching NOS in the study of Physics, Biology, Chemistry is a cutting-edge international trend.

- In the Nature of Science domain SLOs, unless explicitly stated, where the SLO begins with the phrase 'explain with examples' it is enough that students study 2-3 examples and can use them in their answers for examination questions. There is no need to extensively or comprehensively study the history of science or its applications in other fields. The purpose here is that students are able to develop an appreciation of these aspects of the field of chemistry with some rigor (hence these SLOs are expected to be assessed), but not to become so extensive that it take a lot of time out from building competence in rest of the domains on chemistry skills and knowledge.

- **Assessment** of Nature of Science in standardized board exams will be kept to objective knowledge; students will not be expected to write argumentative essays or express subjective perspectives. Rather assessment in the standardized exams will occur through multiple choice questions and/or through short answer questions that require two-three sentence responses. Sample questions are provided in the Curriculum Guidelines. In their regular

classroom study, teachers *are* encouraged to teach these topics through learner-centered activities that promote curiosity, inquiry, creativity, critical discussion and collaboration.

Optional SLOs: SLOs that are italicized are optional, as they may be advanced or too much to cover with the rest of the content in the grade.

Grade 9	Grade 10	Grade 11	Grade 12
Domain A: Nature of Science in Biology This field studies science's underlying assumptions, and its methodologies. This involves some integrated study of the history, philosophy and sociology of science. **Note:** In the Nature of Science domain SLOs, unless explicitly stated, where the SLO begins with the phrase 'explain with examples' it is enough that students study 2-3 examples and can use them in their answers for examination questions. There is no need to extensively or comprehensively study the history of science or its applications in other fields. The purpose here is that students are able to develop an appreciation of these aspects of the field of physics with some rigor (hence these SLOs are expected to be assessed), but not to become so extensive that it take a lot of time out from building competence in rest of the domains on physics skills and knowledge. Assessment of Nature of Science in standardized board exams will be kept to objective knowledge; students will not be expected to write argumentative essays or express subjective perspectives. Rather assessment in the standardized exams will occur through multiple choice questions and/or through short answer questions that require two-three sentence responses. Sample questions are provided in the Curriculum Guidelines. In their regular classroom study, teachers *are* encouraged to teach these topics through learner-centered activities that promote curiosity, inquiry, creativity, critical discussion and collaboration.			
Standard: Students should be able to explain and evaluate with examples that science operates in a historical context that affects its current practices and paradigms **Note:** In the Nature of Science domain SLOs, unless explicitly stated, where the SLO begins with the phrase 'explain with examples' it is enough that students study 2-3 examples and can use them in their answers for examination questions. There is no need to extensively or comprehensively study the history of science or its applications in other fields. The purpose here is that students are able to develop an appreciation of these aspects of the field of biology with some rigor (hence these SLOs are expected to be assessed), but not to become so extensive that it take a lot of time out from building competence in rest of the domains on biology skills and			

knowledge. Assessment of Nature of Science in standardized board exams will be kept to objective knowledge; students will not be expected to write argumentative essays or express subjective perspectives. Rather assessment in the standardised exams will occur through multiple choice questions and/or through short answer questions that require two-three sentence responses. Sample questions are provided in the Curriculum Guidelines. In their regular classroom study, teachers *are* encouraged to teach these topics through learner-centered activities that promote curiosity, inquiry, creativity, critical discussion and collaboration.

Benchmark 1: Critically analyze claims made about the relationship of biology with society		**N/A**	
The Science of Biology: **[SLO: B-09-A-01]** Define biology **[SLO:B-09-A-02]** State Quran instructs to reveal the study of Life **[SLO:B-09-A-03]** Define major fields of biology as Botany, zoology and Microbiology **[SLO:B-09-A-04]** Define with examples that biology has many sub-fields. - Cytology - Embryology - Genetics - Molecular Biology - Pathology - Ecology - Marine Biology - Immunology			

-Morphology -Anatomy -Histology - Physiology -Taxonomy -Paleontology - Pharmacology **[SLO:B-09-A-05]** 3. Relate that biology connects with other natural sciences.Students should be able to distinguish in terms of the broad subject matter the below fields: - Biophysics - Biochemistry - Computational Biology -Biogeography - Biostatistics - Biotechnology -Bioeconomics **[SLO:B-09-A-06]** Identify the careers in Biology and Explain with examples how biology is a subset of the natural sciences and of the life sciences.			

[SLO: B-09-A-07] Justify with examples that science is a collaborative field that requires interdisciplinary researchers working together to share knowledge and critique ideas **[SLO: B-09-A-08]** Describe the steps of the scientific method that is: Recognition Observation Hypothesis Deduction Experiments Results **[SLO: B-09-A-09]** Evaluate the terms 'hypothesis', 'theory' and 'law' in the context of research in the natural sciences			

Domain B: Evolution and Biodiversity Classification			
Standard **Students should be able to:** **Define evolution and natural selection.** **Explain the mechanisms of genetic variation and inheritance.** **Describe how populations change over time and how speciation occurs.** **Explain the evidence for common ancestry and the history of life on Earth.** **Describe the major taxonomic categories and their characteristics, including the classification of organisms into species, genus, family, order, class, phylum, and kingdom.**			
Benchmark 1: Students will be able to explain the theory of evolution by natural selection and provide evidence for its occurrence.		**Benchmark 1: Students will be able to distinguish evolution from creationism and explain the factors that influence evolution and inheritance.**	
[SLO: B-09-B-01] Explain the theory of evolution by natural selection with examples **[SLO:B-09-B-02]** Define Species **[SLO: B-09-B-03]** Describe speciation.		**[SLO: B-11-B-01]** Explain that evolution happens due to variation in organisms and the selection pressures that organisms face. . **[SLO: B-11-B-02]** Discuss the evidence	

[SLO: B-09-B-04] Discuss briefly the observations Darwin made during his voyage on HMS Beagle. **[SLO: B-09-B-05]** Describe sources of variation which can lead to speciation and evolution. **[SLO: B-09-B-06]** Describe evidence of evolution with regards to the following - Paleontology (fossil record) - Comparative anatomy (homologous structures, vestigial structures) - Selective breeding		that is provided by biogeography **[SLO: B-11-B-03]** Analyze the evidence of evolution that comes from molecular biology. **[SLO: B-11-B-04]** Differentiate between convergent and divergent evolution on the basis of inheritance of the homologous and analogous structures. **[SLO: B-11-B-05]** Describe the Endosymbiotic theory about the mechanism of evolution of eukaryotes from prokaryotes **[SLO: B-11-B-06]** Describe the theory	

		of inheritance of acquired characters, as proposed by Lamarck with example of giraffe neck **[SLO: B-11-B-07]** State the drawbacks in Lamarckism.	
Benchmark 2: Students will be able to describe the process of classification and explain how taxonomy helps us understand the diversity of life on Earth.		**Benchmark 2: Students will be able to describe different ideas and models provided to understand and explain evolution and inheritance**	
[SLO:B-09-B-07] Define biodiversity and classification. **[SLO: B-09-B-08]** Describe advantages of classification. **[SLO: B-09-B-09]** Discuss the history of classification schemes. **[SLO: B-09-B-10]** List the three distinct domains into which living organisms are broadly classified into. **[SLO: B-09-B-11]** List the taxonomic ranks of classification.		**[SLO:B-11-B-08]** Describe non vascular plants (Bryophytes,) **[SLO:B-11-B-09]** Explain the life cycle of polytrichome **[SLO:B-11-B-10]** Describe the general features of vascular plants **[SLO:B-11-B-11]** Identify the division	

[SLO: B-09-B-12] Outline the binomial nomenclature system. **[SLO: B-09-B-13]** Describe the complications of classifying viruses.		between vascular plants (pteridophytes, gymnosperms, angiosperms) [**SLO:B-11-B-12]** Explain the general characteristics pteridophytes **[SLO:B-11-B-13]** Explain the life cycle of ferns **[SLO:B-11-B-14]** Describe the general characteristic of gymnosperms and classify them **[SLO:B-11-B-15]** Describe the life cycle of pinus **[SLO:B-11-B-16]** Describe the general characteristic of angiosperms and classify them **[SLO:B-11-B-17]**	

		Explain the life cycle of angiosperms **[SLO:B-11-B-18]** Describe general characteristics and economic importance of the following angiospermic families · Brassicacaeae · Solanaceae · Poaceae **[SLO: B-11-B-19]** Identify that animals are divided into two major groups as invertebrate and vertebrate **[SLO:B-11-B-20]** Describe the general characteristics, importance and example of sponges cnidarians, Platyhelminthes, Ascelminthes (vermatodes), mollusks, annelid, arthropods and echinoderms **[SLO:B-11-B-21]** Describe the general characteristics of chordates and vertebrates.	

		[SLO: B-11-B-22] Describe the general characteristics of amphibians, reptiles, birds and mammals.	

Domain C: Molecular Biology

Standard: Students should be able to:

Describe the structure and function of the four main biomolecules: carbohydrates, lipids, proteins, and nucleic acids.
Explain the role of DNA as the genetic material and its role in heredity.
Describe the structure of DNA, including the double helix and the four nitrogenous bases.
Explain the process of DNA replication and its importance in cell division.
Describe the process of transcription and translation, including the role of RNA and ribosomes.

Benchmark 1: Students will be able to describe the chemical structure, properties and roles of the four major classes of biomolecules (carbohydrates, lipids, proteins, and nucleic acids).		**Benchmark 1: Describe in detail the structure, chemistry and environment of the four major biomolecules, their types and reactions inside cells and tissues.**	
[SLO: B-09-C-01] Define Biochemistry/molecular biology **[SLO: B-09-C-02]** Outline the various types of common biomolecules (DNA, RNA, Proteins, Lipids, Carbohydrates) including their locations inside the cell and main roles. **[SLO: B-09-C-03]** 3. Outline the structure and function and		**[SLO: B-11-C-01]** Define biochemistry/molecular biology **[SLO: B-11-C-02]** Describe Briefly the different types of bonds found in biology (hydrogen	

sources of proteins with structure of amino acids **[SLO: B-09-C-04]** Outline the structure, function and sources of lipids **[SLO: B-09-C-05]** Define Carbohydrates and Outline the structure, function and sources of Carbohydrates. **[SLO:B-09-C-06]** Identify carbohydrates as monosaccharides, disaccharides and polysaccharides.		bonds, covalent bonds, interactions,Ionic, hydrophobic and hydrophilic interactions etc) **[SLO: B-11-C-03]** Distinguish carbohydrates, proteins, lipids and nucleic acids as the four fundamental kinds of biological molecules. **[SLO: B-11-C-04]** Describe and draw sketches of the condensation - synthesis and hydrolysis reactions for the making and breaking of macromolecule polymers. **[SLO: B-11-C-05]** State the properties of water (high polarity, hydrogen bonding, high specific heat, high heat of	

		vaporization, cohesion, hydrophobic exclusion, ionization and lower density of ice) allow it to be the medium of life. **[SLO: B-11-C-06]** Define carbohydrates and classify them. **[SLO: B-11-C-07]** Compare and contrast the properties and roles of monosaccharides and write their formula **[SLO: B-11-C-08]** Compare the isomers and stereoisomers of glucose. **[SLO: B-11-C-09]** Distinguish the properties and roles of disaccharides **[SLO: B-11-C-10]**	

		Describe glycosidic bonds in disaccharides. **[SLO: B-11-C-11]** Describe the structure properties and roles of polysaccharides starch, glycogen, cellulose and chitin. **[SLO: B-11-C-12]** Define protein, amino acid and recognized essential amino acid and structural formula of amino acid. **[SLO: B-11-C-13]** Outline the synthesis and breakage of peptide linkages. **[SLO: B-11-C-14]** Justify the significance of the sequence of amino acids through the example of sickle cell	

		hemoglobin. **[SLO: B-11-C-15]** Classify proteins as globular and fibrous proteins. **[SLO: B-11-C-16]** List the roles of structural proteins and functional proteins with 3 examples [**SLO: B-11-C-17]** • Define lipids **[SLO: B-11-C-18]** Describe the properties and roles of acylglycerols, phospholipids, terpenes and waxes. **[SLO: B-11-C-19]** Illustrate the molecular structure (making and breaking) of an acylglycerol, a phospholipid and a	

		terpene. **[SLO: B-11-C-20]** Evaluate steroids and prostaglandins as important groups of lipids **[SLO: B-11-C-21]** Describe nucleic acids and molecular structure of nucleotides. **[SLO: B-11-C-22]** Distinguish among the nitrogenous bases found in the nucleotides of nucleic acids. **[SLO: B-11-C-23]** Outline the examples of a mononucleotide (ATP) and a dinucleotide (NAD). **[SLO: B-11-C-24]** Illustrate the formation of phosphodiester	

		bond. **[SLO: B-11-C-25]** Explain the double helical structure of DNA as proposed by Watson and Crick. **[SLO: B-11-C-26]** Explain the general structure of RNA. **[SLO: B-11-C-27]** Distinguish in terms of functions and roles, the three types of RNA **[SLO: B-11-C-28]** Discuss the Central Dogma. **[SLO: B-11-C-29]** Define conjugated molecules and describe the roles of common conjugated molecules i.e. glycolipids, glycoproteins, lipoproteins and nucleoproteins.	

Benchmark 2: Students will be able to explain the role of DNA in genetic information storage and transfer, including the structure of DNA, DNA replication, and the central dogma of molecular biology.		**N/A**	
[SLO: B-09-C-07] Describe briefly the structure of DNA as a double helix macromolecule made of nucleotides with base pairing in between the two helices through complementary base pairing. **[SLO: B-09-C-08]** Outline function of DNA as carrier of hereditary information **[SLO: B-09-C-09]** Describe briefly the structure of RNA as single stranded macromolecule made of nucleotides with nitrogenous base overhangs. **[SLO: B-09-C-10]** Outline the function of RNA as aid in converting hereditary information into useful proteins. **[SLO: B-09-C-11]** Outline how information in the DNA is converted to information on RNA and then into proteins.			

Domain D: Cells and Subcellular Organelles

Standard: Students should be able to:

Describe the structure and function of cells, including prokaryotic and eukaryotic cells.
Identify and describe the main subcellular organelles, including the nucleus, mitochondria, ribosomes, endoplasmic reticulum, Golgi apparatus, lysosomes, and peroxisomes.
Explain the role of the cell membrane and describe its structure.
Explain the process of cellular respiration and its role in producing energy.
Describe the process of cellular division, including mitosis and meiosis.

Benchmark 1: Students will be able to describe the structure of animal and plant cells and the structure and roles of different organelles inside the cells.		**Benchmark 1: Students will be able to describe the function and draw the structure of cells and cell organelles, including the nucleus, mitochondria, ribosomes, and endoplasmic reticulum, and how they interact to maintain cellular homeostasis and communicate with each other.**	
[SLO: B-09-D-01] Describe cell as the basic unit of life **[SLO: B-09-D-02]** 2. Compare with diagrams the structure of animal and plant cells **[SLO:B-09-D-03]** Sketch different sub-cellular organelles (nucleus, mitochodria, cell membranes, etc) and outline their roles. **[SLO: B-09-D-04]** Outline structural advantages of plant and animal cells.		**[SLO: B-11-D-01]** Describe that cells are the basic unit of life with respect to 7 properties of Life. (Movement, Respiration, Homeostasis, Growth, Reproduction, Excretion, Nutrition)	

[SLO: B-09-D-05] Identify different types of cells (mesophyll cell, epidermal cell, neurons, muscle, red blood cell, liver cell) and sketch their structures **[SLO: B-09-D-06]** Describe the concept of division of labor and how it applies to - within cells (across sub-cellular organelles) - multicellular organisms (across cells) **[SLO: B-09-D-07]** Describe Cell Specialization.		**[SLO: B-11-D-02]** Identify the ultrastructure of animal and plant cells. **[SLO: B-11-D-03]** Describe the structure and functions of sub-cellular organelles. (mitochondria, nucleus -cell membrane, chloroplast, lysosomes, cell wall, centrioles, - Golgi apparatus, smooth endoplasmic reticulum, rough endoplasmic reticulum, vesicles, peroxisome, vacuoles, ribosomes	

		[SLO: B-11-D-04] Define cell signalling. **[SLO: B-11-D-05]** Discuss the pathway of a signal from outside the cell to the inside. (Protein signal and steroid signal)	
Benchmark 2: Students will be able to describe the different stages of cell division and the roles organelles have in this process.		**Benchmark 2: Students will be able to understand terms such as stem cells, the structure of cell membrane and its role in transport of material.**	
[SLO: B-09-D-08] Describe Cell cycle **[SLO: B-09-D-09]** Explain mitosis, meiosis and stages of mitosis, meiosis (by use of sketch and diagrams) **[SLO: B-09-D-11]** Compare the processes of mitosis and meiosis		**[SLO:B-11-D-06]** Define Stem cells and advantages of using stem cells **[SLO: B-11-D-07]** Categorize different types of stem cells **[SLO: B-11-D-08]** Evaluate the	

[SLO: B-09-D-12] Outline the significance of mitosis and meiosis. **[SLO: B-09-D-13]** Define Stem cells as unspecialized cell.		advantages and disadvantages of using induced Pluripotent Stem Cells. **[SLO: B-11-D-09]** Explain the structure of the cell membrane and the techniques that can be used to study it. **[SLO: B-11-D-10]** Explain the 4 membrane transport mechanisms with diagrams: (simple diffusion, Facilitated diffusion, Osmosis, Active transport) . **[SLO: B-11-D-11]** Differentiate between prokaryotic and eukaryotic cells with diagrams. **[SLO: B-11-D-12]** State cell theory (including how to validate it and exceptions to it.)	

		[SLO: B-11-D-13] Compare and constrast the workings of a light microscope and electron microscope with focus on resolution and magnificatiton and live vs dead samples. **[SLO: B-11-D-14]** Write the chemical structure of a single phospholipid (Glycerol as a three carbon molecule, phosphate group, one unsaturated fatty acid tail and one saturated fatty acid tail) . **[SLO: B-11-D-15]** Describe endocytosis and exocytosis with diagrams. **[SLO: B-11-D-16]** Compare and contrast simple and	

		facilitated diffusion. **[SLO: B-11-D-17]** Explain the steps of mitosis and meiosis with diagrams.	
Domain E: Tissue, Organs and Systems			
Standard: Students should be able to: **Describe the structure and function of tissues, including epithelial, connective, muscle, and nervous tissue.** **Explain the role of organs in maintaining homeostasis.** **Describe the structure and function of the major organ systems, including the circulatory, digestive, respiratory, nervous, endocrine, muscular, and skeletal systems.** **Explain how the different organ systems interact to maintain homeostasis in the body.** **Describe how diseases can affect the functioning of organ systems.**			
Benchmark 1: Students will be able to describe the four basic types of tissues (epithelial, connective, muscle, and nervous), their constituent cells and explain their structure and functions.		**N/A**	
[SLO: B-09-E-01] Distinguish between tissues, organs and systems with examples from animals and plants. **[SLO: B-09-E-02]** Describe the concept of emergent properties as gain in functionalities and how it applies to the following:			

- going from sub-cellular organelles to cells - going from cells to tissues - going from tissues to organs - going from organs to systems - going from systems to living organisms **[SLO: B-09-E-03]** Enlist the different types of tissue come together to form the stomach organ in the human body. **[SLO:B-09-E-04]** Discuss the different types of tissue come together to form the leaf			
Benchmark 2: Students will be able to explain the structure and function of major organ systems in animals, including the digestive, respiratory, cardiovascular, nervous, endocrine, and reproductive systems and their disorders		**N/A**	
[SLO: B-09-E-05] Discuss the organ systems come together to form the human body.			

Benchmark 3: Understand what homeostasis means and describe major plant organs.		**N/A**	
[SLO: B-09-E-06] Describe the advantages of homeostasis. **[SLO: B-09-E-07]** Discuss the various organs and systems of the human body work to maintain homeostasis. **[SLO: B-09-E-08]** Explain plant physiology in terms of structures and roles of various plant organs.			
Domain F: Metabolism			
Standard: Define metabolism and describe how it is related to cellular respiration and photosynthesis. **Explain the role of enzymes in metabolic reactions and describe the process of enzyme-catalyzed reactions.** **Define enzymes and explain their role in metabolic reactions.** **Describe the factors that affect enzyme activity, including temperature, pH, and substrate concentration.** **Explain the importance of enzymes in maintaining homeostasis and how disturbances can lead to disease.**			
Benchmark 1: Students will be able to describe the concepts of metabolism, anabolism and catabolism, and explain how enzymes help in metabolism.		**Benchmark 1: Students will be able to explain the role of enzymes in biological systems, including the facilitation of chemical reactions and regulation of metabolic pathways.**	
[SLO: B-09-F-01] Define metabolism, catabolism and anabolism with examples. **[SLO:B-09-F-02]**		**[SLO: B-11-F-01]** • Identify the role and component parts of the active site of an enzyme. **[SLO: B-11-F-02]**	

Define Enzymes and describe their characteristics **[SLO: B:09-F-03]** Show the mechanism of enzyme action **[SLO: B-09-F-04]** Assess the factors which could influence enzyme activity. **[SLO: B-09-F-05]** Describe competitive, and non-competitive inhibition.		Differentiate among the three types of co-factors i.e. in organic ions, prosthetic group and co-enzymes, with examples. **[SLO: B-11-F-03]** Explain the mechanism of enzyme action through the Induced Fit Model, including comparing it with Lock and Key Model. **[SLO: B-11-F-04]** Explain enzyme catalysis with example of specific reactions **[SLO: B-11-F-05]** Define energy of activation and discuss through graph how an enzyme speeds up a reaction by lowering	

		the energy of activation.	
N/A		**Benchmark2: Students will be able to describe the factors that affect enzyme activity, including temperature, pH, substrate concentration, and inhibitors, and explain how these factors can be used to control enzyme activity.**	
		[SLO: B-11-F-06] Explain the effect of temperature on the rate of enzyme action with example of human and thermophilic bacteria **[SLO: B-11-F-07]** Investigate the effect of pH on enzyme activity Compare the optimum pH of different enzymes like trypsin, pepsin, papain. **[SLO: B-11-F-08]** Demonstrate that the concentration of enzyme affects the rate of enzyme action	

	[SLO: B-11-F-09] Describe enzymatic inhibition, its types and its significance with examples . **[SLO: B-11-F-10]** Name the molecules which act as inhibitors. **[SLO: B-11-F-11]** Categorize inhibitors into competitive and non-competitive inhibitors. **[SLO: B-11-F-12]** Explain feedback inhibition. **[SLO: B-11-F-13]** Classify enzymes on the basis of the reactions catalyzed (oxido-reductases, transferases, hydrolases, isomerases, and ligases). **[SLO: B-11-F-14]** • Classify enzymes on	

	the basis of the substrates they use (lipases, diastase, amylase, proteases etc)	
Benchmark 2: Students will be able to explain the processes of cellular respiration and photosynthesis and the energy conversions.	**Benchmark3:. Explain in detail how photosynthesis and Respiration occurs and understand the processes involved.**	

[SLO: B-09-F-06] Discuss the role of ATP as energy currency. **[SLO: B-09-F-07]** Describe photosynthesis in plants. **[SLO: B-09-F-08]** Explain aerobic respiration and anaerobic respiration		**[SLO: B-11-F-15]** Explain the role of light, carbon dioxide and water in photosynthesis **[SLO: B-11-F-16]** Identify the two general kinds of photosynthetic pigments (carotenoids and chlorophylls) **[SLO: B-11-F-17]** Describe the roles of photosynthetic pigments in the absorption and conversion of light energy **[SLO: B-11-F-18]** Differentiate between the absorption spectra of chlorophyll 'a' and 'b' **[SLO: B-11-F-19]**	

		[SLO: B-11-F-19] Describe the arrangement of photosynthetic pigments in the form of photosystem-I and II. **[SLO: B-11-F-20]** Describe the events of non-cyclic photophosphorylation and cyclic photophosphorylation. **[SLO: B-11-F-21]** Explain the Calvin cycle (the regeneration of RuBP should be understood in outline only.) **[SLO: B-11-F-22]** Explain the process of anaerobic respiration in terms of glycolysis and conversion of pyruvate into lactic acid or ethanol. **[SLO: B-11-F-23]** Illustrate the links reaction as conversion of pyruvate to acetyl-CoA.	

		[SLO: B-11-F-24] Outline the steps of Krebs cycle. [SLO: B-11-F-25] Trace the passage of electrons through the electron transport chain. [SLO: B-11-F-26] Describe chemiosmosis and Relate it with electron transport chain. [SLO: B-11-F-27] Explain the substrate-level phosphorylation during which exergonic reactions are coupled with the synthesis of ATP. [SLO: B-11-F-28] Justify the importance of G3P in photosynthesis [SLO: B-11-F-29] Outline the formation of acetyl CoA from fats	

		[SLO: B-11-F-30] Compare and contrast respiration of fats and glucose . **[SLO: B-11-F-31]** Define photorespiration **[SLO: B-11-F-32]** Outline the events occurring through photorespiration. . **[SLO: B-11-F-33]** Rationalize how the disadvantageous process of photorespiration evolved. **[SLO: B-11-F-34]** Explain the effect of temperature on the oxidative activity of RuBP carboxylase. **[SLO: B-11-F-35]** Outline the process of C 4 photosynthesis as an adaptation evolved in some plants to deal with the problem of photorespiration.	

Domain G: Nervous System

Standard: Students should be able to:

Describe the structure and function of the nervous system, including the central and peripheral nervous systems.
Explain the role of neurons in transmitting and processing information.
Describe the process of neurotransmission and how it affects the functioning of the nervous system.
Explain how the nervous system regulates and coordinates body functions, including the role of reflex arcs..
Describe the structure and function of the human endocrine system, including the role of hormones in regulating body functions.
Explain the process of hormone secretion, including the role of the hypothalamus and pituitary gland.
Describe the effects of hormones on various target tissues, including the growth and development of cells and tissues.
Explain the role of hormones in regulating metabolism and energy balance, including the regulation of glucose and insulin levels

Benchmark 1: Students will be able to describe the organization of the nervous system into the central and peripheral nervous system, and explain the role of the brain, spinal cord, and nerves in transmitting signals and coordinating responses.		**Benchmark 1: Explain the functions of the nervous system, including the structure and function of neurons and nerve impulses and synapses**	
	[SLO: B-10-G-01] Describe the nervous system and its role. **[SLO: B-10-G-02]** 2. Discuss the central nervous system and peripheral nervous system **[SLO: B-10-G-03]** Outline the types of neurons with diagrams. **[SLO: B-10-G-04]**		**[SLO: B-12-G-01]** Recognize receptors as transducers sensitive to various stimuli. **[SLO: B-12-G-02]** Trace the path of a message transmitted to the CNS(central nervous system) for processing. **[SLO: B-12-G-03]** Identify the three neurons (sensory, intermediate, motor) involved in nervous transmission.

	Define a stimulus with examples. **[SLO: B-10-G-05]** State that nerve impulses are electrical signals that travel across neuron **[SLO: B-10-G-06]** Define and sketch synapses. **[SLO: B-10-G-07]** Introduce neurotransmitters . **[SLO: B-10-G-08]** Explain through sketching a diagram the involvement of the nervous system when a person accidentally touches something painfully hot and withdraws their hands as a reflex.. [**SLO: B-10-G-09]** 12. Explain the Endocrine system **[SLO:B-10-G-10]** Identify the major endocrine glands and hormones with their functions.		**[SLO: B-12-G-04]** Identify muscles and glands as the effectors. **[SLO: B-12-G-05]** Annotate the detailed structure of a sensory neuron, associative and a motor neuron **[SLO: B-12-G-06]** Relate the structure of neurons with functions. **[SLO: B-12-G-07]** Differentiate between myelinated and non-myelinated neurons. **[SLO: B-12-G-08]** Explain the function of the three types of neurons with the help of a reflex arc. **[SLO: B-12-G-09]** Define nerve impulse. [**SLO: B-12-G-10]** • Describe the generation and transmission of nerve impulse.

			[**SLO: B-12-G-11**] • Name the factors responsible for the resting membrane potential of neuron. **[SLO: B-12-G-12]** • Evaluate from a graph the phenomena of polarization, depolarization and hyperpolarization of membrane. [**SLO: B-12-G-13]** • Compare the velocities of nerve impulse in the axon membrane and in the synaptic cleft. **[SLO: B-12-G-14]** • Describe the role of local circuits in saltatory conduction of nerve impulse. **[SLO: B-12-G-15]** Outline the structure of synapse. **[SLO: B-12-G-16]** Explain synaptic

			transmission of nerve impulse. **[SLO: B-12-G-17]** Classify neurotransmitters as inhibitory and excitatory and list some common examples. [**SLO: B-12-G-18]** Identify the main components of the nervous system. [**SLO: B-12-G-19]** Explain briefly the major parts functions of major divisions of the brain and its functions of brain. **[SLO: B-12-G-20]** • Describe the architecture of human brain **[SLO: B-12-G-21]** Describe cranial and spinal nerves in man. **[SLO: B-12-G-22]** Explain the structure,

			types and functions of the autonomic of autonomic nervous system. **BENCHMARK 2: Describe the roles of hormones and the endocrine system in maintaining homeostasis in the human body.** **[SLO: B-12-G-23]** State the role of hormones as chemical messengers. **[SLO: B-12-G-24]** Describe the chemical nature of hormones and correlate it with important hormones. **[SLO: B-12-G-25]** Locate the endocrine glands in human body name the hormones they release and their functions ; (pituitary, thyroid, parathyroid, pancreas, adrenal, gonads.) **[SLO: B-12-G-26]** Relate the problems associated with the

			imbalance of these hormones. **[SLO: B-12-G-27]** Explain the neurosecretory role of hypothalamus. **[SLO: B-12-G-28]** Outline the concept of Feedback mechanism of hormones and .Describe positive feedback with reference to Oxytocin and negative feedback with reference to Insulin and Glucagon BENCHMARK3: **Benchmark 3: Explain how different sensory receptors work and the effect of drugs on these receptors and the nervous system.** [**SLO: B-12-G-29]** Explain the structure and functioning of the receptors for smell, taste and touch / pain. [**SLO: B-12-G-30]** Define narcotic drugs as agents that interact with

			the normal nervous activity. **[SLO: B-12-G-31]** Compare the use and abuse of drugs with respect to heroine, *Cannabis*, nicotine, alcohol and inhalants like nail polish remover and glue. **[SLO: B-12-G-32]** Explain the terms; drug addiction and drug tolerance with reference to caffeine and nicotine and their adverse effects. **[SLO: B-12-G-33]** Associate the effects of drug addiction and tolerance with the functioning of the nervous system. [**SLO: B-12-G-34]** Describe the way how pain medicines can reduce or numb pain in the human body. [SLO: B-12-G-35] Discuss that certain pain

			medications are addictive. [SLO: B-12-G-36] Classify nervous disorders into vascular, infectious, structural, functional and degenerative disorders **[SLO: B-12-G-37]** Describe the causes, symptoms and treatment of one type of each category of disorders outlined above (e.g., stroke as vascular, meningitis as infectious, brain tumor as structural, headache as functional, and Alzheimer disease as degenerative disorder). **[SLO: B-12-G-38]** Explain the principles of the important diagnostic tests for nervous disorders i.e. EEG, CT scan and MRI
Domain H: Reproduction and Inheritance			
Standard: Students should be able to:			

Describe the processes of reproduction in organisms, including asexual and sexual reproduction. **Explain the role of meiosis in producing genetically diverse offspring.** **Describe the structure and function of gametes and the role of fertilization in sexual reproduction.** **Explain the patterns of inheritance, including dominant and recessive traits, and how they are influenced by genes and chromosomes.** **Describe how genetic variation and mutations can lead to evolutionary change.** **Describe the central dogma of molecular biology, which outlines the flow of genetic information from DNA to RNA to protein.** **Explain the basic structure and function of genes, including the role of codons and introns.** **Distinguish between different types of inheritance patterns, including dominant and recessive traits, and sex-linked traits.**			
Benchmark 1: Students will be able to explain the differences between asexual and sexual reproduction, and describe the steps involved in the process of fertilization, development, and birth.		**Benchmark 1: Students will be able to explain the laws of inheritance, including the principles of dominant and recessive genes, segregation, and independent assortment, and demonstrate an understanding of how traits are passed from one generation to the next.**	
	[SLO: B-10-H-01] Describe the role of hormones in both male and female sexual development. **[SLO: B-10-H-02]** Describe the process of gametogenesis and fertilization. **[SLO: B-10-H-03]** Describe asexual reproduction and sexual reproduction mechanisms with examples (plants and animals) **[SLO: B-10-H-04]** Describe sex determination in	**[SLO:B-11- H-01]** Describe the structures of the male reproductive system and identify their functions **[SLO:B-11-H-02]** Define male reproductive hormones and explain their functions **[SLO: B-11-H-03]** Explain the structures of female	

	humans. **[SLO: B-10-H-05]** Sketch the structure of chromosomes.. **[SLO: B-10-H-06]** Define genotype and phenotype, allele homozygous, heterozygous, dominant, recessive **[SLO: B-10-H-07]** Illustrate Mendelian inheritance laws through monohybrid and dihybrid cross.	reproductive system and describe their functions **[SLO: B-11-H-04]** Describe the menstrual cycle and the hormones involved. **[SLO: B-11-H-05]** Define gene (as a sequence of nucleotides as part of DNA, which codes for the formation of a polypeptide.) **[SLO: B-11-H-06]** Explain the law of segregation and independent assortment, using a suitable example related to the pea plants. **[SLO: B-11-H-07]** Relate the Law of independent assortment to random orientation of chromosomes	

		during Meiosis **[SLO: B-11-H-08]** Express limitations of independent assortment and its usefulness. **[SLO: B-11-H-09]** Show that independent assortment leads to variation in the gametes. **[SLO: B-11-H-10]** • Evaluate that inheritance of genes and their mixing during fertilization is based on mathematical probabilities. **[SLO: B-11-H-11]** Describe the exceptions to the Mendel's laws of inheritance. **[SLO: B-11-H-12]** • Explain incomplete dominance and	

		exemplify it through the inheritance of flower color in 4 O' clock plant. **[SLO: B-11-H-13]** • Differentiate between incomplete dominance and codominance. [SLO: B-11-H-14] • Define alleles and multiple alleles [SLO: B-11-H-15] State the alleles responsible for the trait of ABO blood groups. [SLO: B-11-H-16] • Explain the case where two alleles have equal dominance through the genetics of human blood group AB. [SLO: B-11-H-17] • Name the various human blood group	

		systems. [SLO: B-11-H-18] • Investigate the reasons for O-ve individual as the Universal donor and AB +ve as the Universal recipient. [SLO: B-11-H-19] • Describe the occurrence of some other blood group systems. [SLO: B-11-H-20] • Associate the positive and negative blood groups with the presence and absence of Rh factor. [SLO: B-11-H-21] • Justify why Rh incompatibility could be a danger to the developing fetus and mother. [SLO: B-11-H-22] • Explain	

		Erythroblastosis fetalis in the light of antigen-antibody reaction. [SLO: B-11-H-23] • Suggest measures to counter the problem of Erythroblastosis fetalis before it occurs. [SLO: B-11-H-24] • Define and relate the terms; polygenic and epistasis. [SLO: B-11-H-25] • Describe polygenic inheritance using suitable examples from plants (grain color in wheat) and animals (skin color in man). [SLO: B-11-H-26] • List at least five polygenic traits discovered in humans.	

		[SLO: B-11-H-27] • Give one example of epistasis from mammals (coat color inheritance in Labrador retrievers) and one from plants (pigment phenotype in foxgloves) and justify modified Mendelian ratios. [SLO: B-11-H-28] • Describe the terms gene linkage and crossing over. [SLO: B-11-H-29] • Explain that gene linkage counters independent assortment and crossing-over modifies the progeny. [SLO: B-11-H-30] • Suggest that linkage can be observed / evaluated	

		only if the number of progeny is quite large. [SLO: B-11-H-31] • Explain the XX-XY mechanism of sex determination in mammals. . [SLO: B-11-H-32] • Identify male and female individuals from the karyotype of man. [SLO: B-11-H-33] • Solve the genetics problems related to XX-XY, sex determination. [SLO: B-11-H-34] • Describe the concept of sex-linkage. [SLO: B-11-H-35] • Explain the inheritance of sex-linked traits (eye	

		color) in Drosophila. [SLO: B-11-H-36] • Describe the sex-linked inheritance of male characters due to Y-chromosome and the effect of Hollandric genes. [SLO: B-11-H-37] • Describe the X-linked disorders with reference to the patterns of inheritance. [SLO: B-11-H-38] • Name some of the sex-linked disorders of man (Red green color blindness, Hemophilia) . [SLO: B-11-H-39] • Explain the techniques employed for embryonic screening e.g., Amniocentesis and	

		Chorionic Villus Sampling [SLO: B-11-H-40] • Annotate the detailed structure of a chromosome. BENCHMARK2: Students will be to understand mechanism of DNA replication and its discovery. [SLO: B-11-H-41] Narrate the experimental work of Griffith and Hershey-Chase, which proved that DNA is the hereditary material. [SLO: B-11-H-42] • Describe the three models proposed about the	

		mechanism of DNA replication. [SLO: B-11-H-43] • Narrate the work of Meselson and Stahl to justify the semi-conservative replication as the correct method of replication. [SLO: B-11-H-44] • Describe the events of the process of DNA replication. [SLO: B-11-H-45] • Describe DNA stability and variability as two characters of the replicating DNA molecule. Benchmark 3: Students will be able to understand the process of translation and transcription as part of the protein	

		synthesis process. [SLO: B-11-H-46] • Describe the characteristics of genetic code (universal, triplet, non-overlapping, degenerate, has no punctuation). [SLO: B-11-H-47] • Differentiate between the terms genetic code and codon. [SLO: B-11-H-48] • Explain the mechanism of transcription. [SLO: B-11-H-49] • Explain why the length of transcribed mRNA molecule (in Eukaryotes) shortens as it enters the cytoplasm for translation. [SLO: B-11-H-50] • Describe the	

		mechanism of protein synthesis. [SLO: B-11-H-51] • State the difference between protein synthesis in prokaryotes and eukaryotes. [SLO: B-11-H-52] • Suggest possible ways in which the synthesized protein can be used within or outside a cell that synthesized it. [SLO: B-11-H-53] • State the importance of the regulation of gene expression. [SLO: B-11-H-54] • Describe the negative control of gene expression by repressor proteins. [SLO: B-11-H-55] • Describe the positive control of	

		gene expression by activator proteins. [SLO: B-11-H-56] • Define mutation and identify various sources of mutation. [SLO: B-11-H-57] • Differentiate between natural and induced mutations and mutagens. [SLO: B-11-H-58] • Justify most mutations are harmful. [SLO: B-11-H-59] • Rationalize that mutations might be a contributing factor towards evolution. [SLO: B-11-H-60] • Describe the symptoms, causes and possible available treatments of some of the chromosomal	

		mutations. (Down's, Klinefelter's and Turner's syndrome) [SLO: B-11-H-61] • Describe the symptoms, causes and possible available treatments of some of the gene mutations	
N/A			
		.	

Domain I: Disease and Immunity

Standard: Students should be able to:
Describe the causes of diseases, including infectious and non-infectious diseases.
Explain the role of pathogens, including viruses, bacteria, fungi, and parasites, in causing disease.
Describe the body's immune response to pathogens, including the role of white blood cells, antibodies, and the complement system.
Explain how vaccines work and the importance of herd immunity.
Describe how genetic factors can affect susceptibility to disease and describe examples of inherited diseases.
Explain the mechanisms of immune tolerance and autoimmunity and their impact on human health.
Describe the role of vaccines in preventing disease and the mechanism of action of various vaccine types, including live attenuated, inactivated, and subunit vaccines.

Benchmark 1: Students will be able to explain the mechanisms of the immune system, including the role of white blood cells, antibodies, and vaccines, and describe how they protect the body against invading pathogens and promote recovery from infection.	**Benchmark 1: Students should be able to explain the functioning and interplay of the various components of the immune system and human body in identifying and combating pathogens.**

	[SLO: B-10-I-01] Define disease, illness and infection and pathogen. [SLO: B-10-I-02] List the 4 different types of pathogens (Viruses, Bacteria, Plasmodium, Fungi). and list their common diseases [SLO: B-10-I-03] Discuss antibiotics [SLO: B-10-I-04] Discuss the development of resistance in bacteria. [SLO: B-10-I-05] Define immunity and List the roles of the immune system. [SLO: B-10-I-06] Describe the components of the immune system (Lymphatic system (lymph nodes), Types of immune cells and their roles, Innate immunity, adaptive immunity and the three lines of defense) [SLO: B-10-I-07] Describe the process of blood clotting.		[SLO: B-12-I-01] • List the structural features of human skin that make it an impenetrable barrier against invasion by microbes. (1st line of defense) [SLO: B-12-I-02] Explain how oil and sweat glands within the epidermis inhibit the growth and also kill microorganisms. (1st line of defense [SLO: B-12-I-03] Recognize the role of the acids of the digestive tract as killing bacteria present in food. [SLO: B-12-I-04] State the role of the ciliated epithelium of the nasal cavity and the mucous of the bronchi and bronchioles in trapping airborne microorganisms. [SLO: B-12-I-05] Describe the role of

	[SLO: B-10-I-08] State that the function of adaptive immunity [SLO: B-10-I-09] Discuss that vaccines help boost immunity with examples.		macrophages and neutrophils in killing bacteria. [SLO: B-12-I-06] Explain how Natural Killer (NK) cells kill cells infected by microbes and cancer cells. [SLO: B-12-I-07] State the way proteins of the complement system kill bacteria and that interferons inhibit viruses from infecting cells. [SLO: B-12-I-08] State the events of the inflammatory response as a generalized, nonspecific defense. [SLO: B-12-I-09] Outline the release of pyrogens by microbes and their effect on the hypothalamus to boost the body's temperature. [SLO: B-12-I-10] List the ways that fever affects microbes.

			[SLO: B-12-I-11] Define the specific immune system as providing specific defense and acting as the most powerful means of resisting infection. [SLO: B-12-I-12] Identify monocytes, T-cells, and B-cells as components of the immune system. [SLO: B-12-I-13] State inborn and acquired immunity as the two basic types of immunity. [SLO: B-12-I-14] Differentiate between active and passive immunity as the two types of acquired immunity. [SLO: B-12-I-15] Describe the role of T-cells in cell-mediated immunity. [SLO: B-12-I-16] Describe the role of B-cells in antibody-mediated

			immunity. [SLO: B-12-I-17] Discuss the role of T-cells and B-cells in transplant rejections. [SLO: B-12-I-18] Evaluate the discovery of monoclonal antibodies and justify how this accomplishment revolutionized many aspects of biological research.
Benchmark 2: Understand how numerous illnesses like Diabetes, Cancer, COVID-19, Alzheimer's, and other prevalent diseases harm the body and the measures that are taken to treat them.		**Benchmark 2: Describe the types of vaccines, their mechanisms of action and the types of acquired immunity.**	
	[SLO: B-10-I-10] Describe the discovery of penicillin. [SLO: B-10-I-11] Define Diabetes and its subtypes explain the effects on the human body . [SLO: B-10-I-12] Discuss cancer and its effects on the human body. .		[SLO: B-12-I-19] Identify the process of vaccination as a means to develop active acquired immunity. [SLO: B-12-I-20] Draw the structural

	[SLO: B-10-I-13] Narrate Covid 19 and list the harmful effects on the human body. [SLO: B-10-I-14] Discuss that HIV compromises the Immune system and over times leads to development Acquired Immune Deficiency Syndrome (AIDS) [SLO: B-10-I-15] Explain plant diseases commonly present in Pakistan, in terms of their effect on plant health and yield and their treatment. (Rust, smut, red rot of sugarcane)		model of an antibody molecule. [SLO: B-12-I-21] Explain the role of memory cells in long-term immunity. [SLO: B-12-I-22] Define allergies and correlate the symptoms of allergies with the release of histamines. [SLO: B-12-I-23] Describe the autoimmune diseases with examples.
N/A		**Benchmark 3: NA**	

Domain J: Biotechnology

Standard: Students should be able to:

Describe the application of biotechnology in various fields, including medicine, agriculture, and industry.
Explain the principles of genetic engineering and recombinant DNA technology, including gene cloning, PCR, and sequencing.
Describe the process of gene cloning and how it is used in biotechnology.
Describe the use of biotechnology in producing therapeutic proteins, including vaccines, monoclonal antibodies, and growth hormones.
Explain the principles of synthetic biology, including metabolic engineering, gene circuit design, and biosensors.

Benchmark 1: Explain the basic principles of biotechnology, and applications in agriculure, medicine, gene editing, marine biology, environment and industry.	**Benchmark 1: Describe the role of biotechnology in addressing global issues, including organ transplant, healthcare and environment.**

	[SLO: B-10-J-01] Introduce biotechnology. [SLO: B-10-J-02] Explain with examples that food biotechnology has advanced agriculture especially inside Pakistan. [SLO: B-10-J-03] Explain with examples that medical biotechnology has advanced healthcare in diabetes and cancer. [SLO: B-10-J-04] State the potential advantages that genetic editing provides with examples in the context of medicine and agriculture. [SLO: B-10-J-05] Describe with examples the benefits of marine biotechnology. [SLO: B-10-J-06] Describe that bioremediation can help us in taking better care of our environment with an example.		**[SLO:B-12-J-01]** Introduce genetic engineering **[SLO: B-12-J-02]** Explain polymerase chain reaction (PCR) [SLO: B-12-J-03] Outline the Function of Restriction Enzymes [SLO: B-12-J-04] Describe plasmid as vector prokaryotes and Explain how recombinant plasmids can be formed [SLO: B-12-J-05] Define Genetically modified organism [SLO: B-12-J-06] Explain the formation of human insulin protein in bacteria

	[SLO: B-10-J-07] Explain the concept and applications of industrial biotechnology with examples.		[SLO: B-12-J-07] Describe how vertical food farms (soil free) work. [SLO: B-12-J-08] Compare and contrast the advantages of vertical food farms with general agricultural practices prevalent in Pakistan.

Domain K: Biostatistics and Data Handling

Standard: Students should be able to:

Define biostatistics and explain its role in biology.
Explain the process of collecting, organizing, and analyzing data in biology.
Describe various statistical methods used in biology, including descriptive statistics, inferential statistics, and hypothesis testing.
Explain the importance of proper data management, including data accuracy and data security.
Describe how data can be represented graphically, including bar graphs, histograms, and scatterplots.

Benchmark 1: Collect, analyze, and interpret data using appropriate statistical methods, including graphical representation and analysis.		**Benchmark 1: Analyze data and apply statistical techniques to make sense of it better, use different plotting techniques to graph the data, and carry out different statistical tests relevant for the nature of data.**	
	[SLO: B-10-K-01] Define biostatistics and its uses. [SLO: B-10-K-02] Define and calculate mean, median and mode, [SLO: B-10-K-03] Sketch a bar chart for a given set of biological data.		[SLO: B-12-K-01] Define biostatistics and its use. [SLO: B-12-K-02] Define mean, median, mode, standard deviation, range, percentile. [SLO: B-12-K-03] Calculate mean, median, mode, standard deviation,

			range, percentile from a given set of data. [SLO: B-12-K-04] Sketch a bar chart for a given set of data. [SLO: B-12-K-05] Sketch error bars based off of range or standard deviation for a given set of data on a bar chart. [SLO: B-12-K-06] Evaluate the appropriate type of figure or chart for a given set of data and/or experiment (bar chart, pie chart, x-y axis data figure etc). [SLO: B-12-K-07] Make the appropriate chart with proper title, labeled axes, legend,

			axes units. [SLO: B-12-K-08] Design an appropriate experiment with a control group and dependent, independent and control variables.
Domain L: Structural Biology and Computational Biology			
Standard: Students should be able to: Describe the study of the three-dimensional structures of biological molecules, including proteins, DNA, and RNA. Explain the techniques used in structural biology, including X-ray crystallography, nuclear magnetic resonance spectroscopy, and cryo-electron microscopy. Describe the role of structural biology in understanding biological function and disease. Define computational biology and explain its role in biology. Describe the application of computational methods in various areas of biology, including genetics, genomics, systems biology, and evolution.			
Benchmark 1: Students will be able to explain the molecular basis of biological structure and function and different techniques used to estimate these structures.		**N/A**	
			[SLO: B-12-L-01] Define structural biology. [SLO: B-12-L-02]

			Explain that structure determination of biomolecules are important [SLO: B-12-L-03] Describe how X-ray crystallography works. [SLO: B-12-L-04] Outline the online databases where biomolecule structures are available.
Benchmark 2: Students should develop an understanding of computational applications, and its applications in understanding structural biology, evolution, genomics, proteomics, and biological structures in addition to its role in agriculture and industry.		**N/A**	
			[SLO: B-12-L-05] Describe computational Biology. [SLO: B-12-L-06] Define Sequence Homology [SLO: B-12-L-07] Define Structural Homology

Domain N: Ecology			
Standard: Students will be able to: **Describe the role of living organisms in their environment, including the relationships between and among biotic and abiotic factors.** **Describe the structure and function of ecosystems, including biomes, communities, populations, and individuals.** **Analyze the effects of human activities on the environment and the impact on biodiversity.** **Evaluate the methods used to monitor and manage environmental resources, such as habitat restoration and conservation.** **Describe the processes that drive the cycling of matter and energy in ecosystems, including photosynthesis, cellular respiration, and decomposition.**			
N/A		**Benchmark 1: Students will be able to describe and explain the basic principles of ecology, tropic levels and energy transfer between them.**	
		[SLO: B-11-N-01] Define species, population, community and ecosystem. [SLO: B-11-N-02] Distinguish between the various modes of nutrition different species possess. [SLO: B-11-N-03] Identify plants as producers for	

		converting light energy to chemical energy [SLO: B-11-N-04] Define trophic levels. [SLO: B-11-N-05] Discuss the loss of energy between trophic levels.	
N/A		**Benchmark 2: Students will be able to analyze and interpret ecological data, including species interactions, food webs, energy flow, and nutrient cycling. Additionally, students will be able to evaluate and discuss the impacts of human activities (e.g., pollution, habitat destruction, introduction of non-native species) on ecosystems and biodiversity.**	
		[SLO: B-11-N-06] Explain the greenhouse effect with examples of gases that exhibit this behavior . [SLO: B-11-N-07] Describe the	

		harmful effects of greenhouse gases on the environment. [SLO: B-11-N-08] Explain with regards to ocean acidification coral reefs are used as a barometer for the health of an aquatic ecosystem. [SLO: B-11-N-09] Define biogeochemical cycles and locate the primary reservoirs of the chemicals in these cycles. [SLO: B-11-N-10] Describe the water cycle in detail. [SLO: B-11-N-11] Define the terms aquifers and	

		water table. [SLO: B-11-N-12] Discuss nitrogen cycle in detail. [SLO: B-11-N-13] Describe productivity in terms of gross primary productivity and net primary productivity. [SLO: B-11-N-14] Interpret the pyramids of number, biomass and energy. [SLO: B-11-N-15] Define ecological succession as the process through which ecosystems change from simple to complex.	

		[SLO: B-11-N-16] Describe primary and secondary succession. [SLO: B-11-N-17] Differentiate between xerarch and hydrarch succession. [SLO: B-11-N-18] Explain the xerarch succession on a bare rock starting from the small pockets of lichens to the vegetations of flowering plants. [SLO: B-11-N-19] Describe characteristics of a population, such as growth, density, distribution, carrying capacity, minimum/viable	

		size. [SLO: B-11-N-20] Explain the effect of growth of human population on the ecosystem and [SLO: B-11-N-21] Describe the 4 important ecosystems of Pakistan	

Domain O: Prokaryotes, Protists and Fungi

Standard: Students will be able to:

Explain the differences in structure and function between prokaryotic and eukaryotic cells.
Classify and describe the diversity of organisms within the domains of Bacteria and Archaea.
Describe the unique characteristics and functions of protists, including those that are unicellular, colonial, or multicellular.
Explain the importance of fungi in the ecosystem, including their role in decomposition, nutrient cycling, and symbiotic relationships with other organisms.
Compare and contrast the different modes of nutrition and lifestyle of prokaryotes, protists, and fungi.

N/A		**Benchmark 1: Students will be able to distinguish and compare the structures and functions of prokaryotes, protists, and fungi.**	
		[SLO: B-11-O-01] Outline the taxonomic	

		position of prokaryotes in terms of domains archaea and bacteria and in terms of kingdom monera. [SLO: B-11-O-02] Explain the phylogenetic position of prokaryotes. [SLO: B-11-O-03] Justify the occurrence of bacteria in the widest range of habitats. [SLO: B-11-O-04] Draw an annotated diagram of a generalized bacterial cell. [SLO: B-11-O-05] Justify cyanobacteria are considered as the	

		most prominent of the photosynthetic bacteria [SLO: B-11-O-06] Describe detailed structure and chemical composition of bacterial cell wall and other coverings. [SLO: B-11-O-07] Compare cell wall differences in Gram-positive and Gram-negative bacteria. [SLO: B-11-O-08] Illustrate with diagrams the great diversity of shapes and sizes found in bacteria.	
N/A		**Benchmark 2: Evaluate the molecular and genetic structures of Bacteria and their life cycles.**	
		[SLO: B-11-O-09] Justify the endospore	

		formation in bacteria as a mechanism of survival to withstand unfavorable conditions. [SLO: B-11-O-10] Explain motility in bacteria. [SLO: B-11-O-11] Describe with diagram structure of bacterial flagellum. [SLO: B-11-O-12] Describe genomic organization of bacteria with respect to circular DNA and plasmids.. [SLO: B-11-O-13] Classify bacteria on the basis of methods of obtaining energy and carbon.	

		[SLO: B-11-O-14] Differentiate between the photosynthesis mechanisms in cyanobacteria and other photosynthetic bacteria. [SLO: B-11-O-15] List the phases in the growth of bacteria. [SLO: B-11-O-16] Describe different methods of reproduction in bacteria.	
N/A		**Benchmark 3: Explain the ecological significance of these organisms, including their role in nutrient cycling, decomposition, and mutualistic relationships.**	
		[SLO: B-11-O-19]	

		• Describe bacteria as recyclers of nature.Outline the ecological and economic importance of bacteria. [SLO: B-11-O-20] Explain the use of bacteria in research and technology. [SLO: B-11-O-21] Describe important bacterial diseases in man e.g. cholera, typhoid, tuberculosis, and pneumonia; emphasizing their symptoms, causative bacteria, treatments, and preventative measures. [SLO: B-11-O-22]	

		Describe important bacterial diseases in plants in terms of spots, blights, soft rots, wilts, and galls; emphasizing their symptoms, causative bacteria, and preventative measures. [SLO: B-11-O-23] Define the term normal flora. [SLO: B-11-O-24] Describe the benefits of the bacterial flora of humans. [SLO: B-11-O-25] List the chemical and physical methods used to control harmful bacteria. [SLO: B-11-O-26]	

		Explain protists as a diverse group of eukaryotes that has polyphyletic origin and defined only by exclusion from other groups. [SLO: B-11-O-27] Describe the salient features with examples of protozoa, algae, myxomycota and oomycota as the major groups of protists. [SLO: B-11-O-28] • Justify how protists are important for humans. [SLO: B-11-O-31] • Classify fungi into zygomycota, ascomycota, deutromycota and basidiomycota	

		and give the diagnostic features of each group. [SLO: B-11-O-32] • Explain yeast as unicellular fungi that are used for baking and brewing and are also becoming very important for genetic research. [SLO: B-11-O-33] • Name a few fungi from which antibiotics are obtained. [SLO: B-11-O-34] • Explain the mutualism established in mycorrhizae and lichen associations. [SLO: B-11-O-35] • Give examples of edible fungi.	

		[SLO: B-11-O-36] • Describe the ecological impact of fungi causing decomposition and recycling of materials. [SLO: B-11-O-37] • Discuss the pathogenic role of fungi.	
Domain P: Acellular life			
Standard: Students will be able to: **Describe the characteristics and diversity of acellular life, including viruses and viroids.** **Explain the replication and infection cycles of viruses.** **Compare and contrast the structure and function of virus particles.** **Analyze the impacts of viruses on human health and the environment.** **Evaluate the current methods for controlling and preventing viral infections.**			
N/A		**Benchmark 2: Students should be able to analyze the role of acellular life forms in maintaining the balance of ecosystems, causing diseases, and in biotechnology applications.**	
		[SLO: B-11-P-01] Justify the status of viruses among living and non-living things.	

		[SLO: B-11-P-02] Trace the history of viruses since their discovery. [SLO: B-11-P-03] Classify viruses on the bases of their hosts and structure. [SLO: B-11-P-04] Describe the structure of a model bacteriophage, and HIV and. [SLO: B-11-P-05] Justify that a virus must have a host cell to parasitize in order to complete its life cycle. [SLO: B-11-P-06] Explain a virus survives inside a host cell, protected from	

		the immune system. [SLO: B-11-P-07] Determine the method a virus employs to survive/ pass over unfavorable conditions when it does not have a host to complete the life cycle. [SLO: B-11-P-08] Describe the Lytic and Lysogenic life cycles of a virus.	
N/A		**Benchmark 2: Students should be able to analyze the role of acellular life forms in maintaining the balance of ecosystems, causing diseases and the treatment of these diseases.**	
		[SLO: B-11-P-09] Outline the usage of bacteriophage in genetic engineering. [SLO: B-11-P-10] Explain the life cycle of HIV.	

		[SLO: B-11-P-11] Justify the name of the virus i.e., “Human Immunodeficiency Virus” by establishing T-helper cells as the basis of immune system. [SLO: B-11-P-12] Reason out the specificity of HIV on its host cells. [SLO: B-11-P-13] List the symptoms of AIDS. [SLO: B-11-P-14] Explain opportunistic diseases that may attack an AIDS victim. [SLO: B-11-P-15] Describe the	

		treatments available for AIDS. [SLO: B-11-P-16] List some common control measures against the transmission of HIV. [SLO: B-11-P-17] Describe the causative agent, symptoms, treatment and prevention of the following viral diseases:hepatitis C, herpes, polio and leaf curl virus disease of cotton. [SLO: B-11-P-18] List the sources of transmission for each of the above-mentioned diseases. [SLO: B-11-P-19] Describe the	

		structure of prions and viroids. [SLO: B-11-P-20] • List the diseases caused by prions and viroids. [SLO: B-11-P-21] • Interpret how viral infections cause global economic loss. [SLO: B-11-P-22] • Describe the limitations of the vaccine for the common cold / flu virus	

Domain Q: Plants

Standard: Students will be able to:

Describe the basic structure and anatomy of plant cells and organs, including stems, roots, leaves, and flowers.
Explain the process of photosynthesis, including the role of chlorophyll and other pigments.
Discuss the significance of seeds and the different methods of seed dispersal.
Describe the basic processes of plant growth and development, including germination, shoot and root development, and the role of hormones.
Outline the adaptations that allow plants to survive in different environments, including ways to conserve water, regulate temperature, and defend against herbivores.

N/A		Benchmark 1: Students should be able to describe the unique characteristics and adaptations of different types of plants, their life cycles and life processes including respiration, photosynthesis, nutrient intake and movement of water and sugar.	
[SLO: B-09-Q-01] Define mineral nutrition in plants. [SLO: B-09-Q-02] Categorize minerals nutrients of plants into macronutrients and micronutrients. [SLO: B-09-Q-03] State that nitrogen is important in protein synthesis and magnesium for chlorophyll formation. [SLO: B-09-Q-04] Conceptualize transport and its needs. [SLO: B-09-Q-05] Explain the internal structure of root and root hair. [SLO: B-09-Q-06] Describe how roots take up water and mineral salts by active and passive absorption. [SLO: B-09-Q-07] Describe transpiration and relate this process with cell surface and stomatal opening and closing.		[SLO: B-11-Q-01] List the macro and micronutrients of plants highlighting the role of each nutrient. [SLO: B-11-Q-02] State the examples of carnivorous plant. [SLO: B-11-Q-03] • Explain the role of stomata and palisade tissue in the exchange of gasses in plants. [SLO: B-11-Q-04] • Relate transpiration with gas exchange in plants. [SLO: B-11-Q-05]	

[SLO: B-09-Q-08] Describe temperature, wind and humidity as the factors affecting the rate of transpiration. [SLO: B-09-Q-09] Describe the mechanism of transport of water and salt in plants. [SLO: B-09-Q-10] Explain the mechanism of food translocation by the theory of Pressure Flow Mechanism. [SLO: B-09-Q-11] Describe the process of gaseous exchange in plants [SLO: B-09-Q-12] Define homeostasis and describe its importance. [SLO: B-09-Q-13] • Describe the mechanisms adaptations in plants for the excretion. [SLO: B-09-Q-14] • Explain osmotic adjustments in plants. [SLO: B-09-Q-15] Describe different types of asexual reproduction		• Assess the structure of xylem vessel elements, sieve tube elements, companion cells, tracheids and relate their structures with functions. [SLO: B-11-Q-06] Discuss the movement of water between plant cells, and between the cells and their environment in terms of water potential. [SLO: B-11-Q-07] Describe the movement of water through roots in terms of symplast, apoplast and vacuolar pathways.	

i.e. binary fission, budding, spore formation and vegetative propagation. [SLO: B-09-Q-16] Distinguish between vegetative propagation and artificial propagation. [SLO: B-09-Q-17] Explain vegetative propagation in plants (through stem, suckers and leaves). [SLO: B-09-Q-18] • Describe the two methods of artificial vegetative propagation (stem cuttings and grafting). [SLO: B-09-Q-19] • Rationalize how parthenogenesis is a type of asexual reproduction. [SLO: B-09-Q-20] • Define cloning. [SLO: B-09-Q-21] explain sexual reproduction in Plants		[SLO: B-11-Q-08] Explain the movement of water in xylem through TACT mechanism. [SLO:B-11-Q-09] Describe the mechanisms involved in the opening and closing of stomata. [SLO: B-11-Q-10] • Explain the movement of sugars within plants.	
N/A		**Benchmark 2: Explain osmotic adjustment in plants and be acquanited with growth and movement in plants in response to environmental factors.**	
		[SLO: B-11-Q-11] • Define osmotic	

		adjustment. [SLO: B-11-Q-12] • State movement of water into or out of the cell in isotonic, hypotonic, and hypertonic conditions. [SLO: B-11-Q-13] Explain the osmotic adjustments in hydrophytic (marine and freshwater), xerophytic and mesophytic plants and plants in saline soil. [SLO: B-11-Q-14] • List the adaptations in plants to cope with low and high temperatures [SLO: B-11-Q-15] Describe Explain	

		the turgor pressure and its significance in providing support to herbaceous plants. [SLO: B-11-Q-16] • Describe the structure of supporting tissues in plants. [SLO: B-11-Q-17] • Define growth and explain primary and secondary growth in plants. [SLO: B-11-Q-18] • Justify the formation of annual rings [SLO: B-11-Q-19] Explain influence of apical meristem on the growth of lateral shoots.	

		[SLO: B-11-Q-20] • outline the role of important plant growth regulators. [SLO: B-11-Q-21] • Explain the types of movement in plants in response to light, force of gravity, touch and chemicals. [SLO: B-11-Q-22] • Define photoperiodism. [SLO: B-11-Q-23] • Classify with examples plants on the basis of photoperiodism and Describe the mechanism of photoperiodism with reference to the mode of action of phytochrome.	

		[SLO: B-11-Q-24] • Explain the role of low temperature treatment on flower production especially to biennials and perennials.	
Domain R: Human Physiology			
Standard: Students should be able to: **Describe the structure and function of the various systems of the human body, including the skeletal, muscular, respiratory, circulatory, digestive, urinary, and nervous systems.** **Explain the role of hormones in regulating body functions and describe the endocrine system.** **Describe the processes of cellular respiration and energy production and their relationship to human health.** **Explain how the human body maintains homeostasis and the role of feedback mechanisms.** **Describe how the different systems of the body interact to maintain health and respond to disease and injury.**			
N/A		**Benchmark 1: Identify and explain the functions of the major organs of the respiratory system in the human body.**	
	[SLO:B-10-R-01] Describe the needs of ingestion, digestion, absorption, assimilation and egestion. [SLO: B-10-R-02]		[SLO: B-12-R-01] • Define the respiratory surface and list its properties [SLO: B-12-R-02] • Describe the main structural features and

	Identify and describe the structures of the main regions of the alimentary canal and the associated organs. [SLO: B-10-R-03] Describe swallowing and peristalsis. [SLO:B-10-R-04] Sort out the action of enzymes in specific regions of alimentary canal, with respect to their substrates and products. [SLO: B-10-R-05] State the role of the liver. [SLO:B-10-R-06] Describe the structure of a villus, including the roles of capillaries and lacteals. [SLO: B-10-R-07] State the signs and symptoms, causes, treatments and preventions of the disorders of gut i.e. diarrhea, constipation, and ulcer. [SLO: B-10-R-08] Describe how the blood is circulated inside the human body.		functions of the components of human respiratory system. [SLO: B-12-R-03] • Explain the ventilation mechanism in humans. [SLO: B-12-R-04] • Discuss the transport of oxygen and carbon dioxide through blood. [SLO: B-12-R-05] • Outline the role of respiratory pigments. [SLO: B-12-R-06] • State the causes, symptoms and treatment of upper Respiratory Tract Infections (sinusitis, otitis media)and lower Respiratory Tract Infections (pneumonia, pulmonary tuberculosis).

	[SLO: B-10-R-09] Explain how blood is used to transport materials throughout the human body. [SLO: B-10-R-10] Identify the different types of organs connected to the blood system and their roles. [SLO: B-10-R-11] Identify the different components that make up the blood [SLO: B-10-R-12] Name the cell types found in blood and their roles. [SLO: B-10-R-13] Explain the structure of the heart with a diagram. **[SLO: B-10-R-14]** Explain common heart diseases. (Coronary Heart Disease, Myocardial Infarction, Angina) [SLO: B-10-R-15] Explain the harmful effects		[SLO: B-12-R-07] • Describe the disorders of lungs (emphysema and COPD) [SLO: B-12-R-08] • List the effects of smoking on respiratory system

	of smoking related to heart diseases [SLO: B-10-R-16] Identify the different organs of urinary system. [SLO: B-10-R-17] • Relate the structure of the kidney with its function. [SLO:B-10-R-18] • State that nephron is the excretory unit of kidney. [SLO: B-10-R-19] • Locate the different parts of nephrons and relate them with their function. [SLO: B-10-R-20] • State that main role of the kidney is urine formation. [SLO: B-10-R-21] • Describe that urine formation involves three processes i.e. filtration, reabsorption and secretion.		

	[SLO: B-10-R-22] • Explain that the kidney plays an important role in osmoregulation. Identify the causes and treatment of kidney stones. [SLO: B-10-R-23] • Outline the causes of kidney failure and treatments. [SLO: B-10-R-24] Describe the roles of the parts of the air passageway and lungs. [SLO: B-10-R-25] • Describe the mechanism of breathing in terms of movements ribs and diaphragm. [SLO: B-10-R-26] • Differentiate between the composition of inspired and expired air. [SLO: B-10-R-27] Discuss briefly diseases related to respiratory system like bronchitis, emphysema, pneumonia, asthma, and lung cancer [SLO: B-10-R-28] Describe infectious and non		

	infectious diseases and their types with examples [SLO: B-10-R-29] Define zoonotic diseases and give their types. [SLO: B-10-R-30] Describe vector borne diseases with examples [SLO: B-10-R-31] Enlist allergies with some common types.		
N/A		**Benchmark 2: Identify and explain the functions of the major organs of the Urinary system in the human body.**	
			[SLO: B-12-R-09] • List various nitrogenous compounds excreted

			during the process of excretion. [SLO: B-12-R-10] • Explain the nature of excretory products in relation to habitat. [SLO: B-12-R-11] •outline different organs of the urinary system. [SLO: B-12-R-12] • Describe the structure of kidney [SLO: B-12-R-13] Relate the structure of the kidney with its function. [SLO: B-12-R-14] • Explain the detailed structure of a nephron. [SLO: B-12-R-15] • Explain the processes of glomerular filtration, selective re-absorption and tubular secretion

			as the events in kidney functioning. [SLO: B-12-R-16] •Explain regulatory mechanism involved in concentration of urine [SLO: B-12-R-17] • Justify the functioning of kidneys as both excretion and osmoregulation. [SLO: B-12-R-18] • Compare the function of two major capillary beds in kidneys i.e. glomerular capillaries and peritubular capillaries. [SLO: B-12-R-19] • List urinary tract infections and the bacteria responsible. [SLO: B-12-R-20] • Explain the causes and treatments of kidney stones.

			[SLO: B-12-R-21] • Outline the causes of kidney failure. [SLO: B-12-R-22] • Explain in detail the mechanism and problems related to dialysis. [SLO: B-12-R-23] • Describe the principles and the problems associated with kidney transplant.
N/A		**Benchmark 3: Identify and explain the functions of the major organs of the digestive system in the human body.**	
			[SLO: B-12-R-24] • Describe the mechanical and chemical digestion in the oral cavity. [SLO: B-12-R-25] • Explain swallowing and peristalsis. [SLO: B-12-R-26] • Illustrate with a diagram the structure of the stomach and

			relate each component with the mechanical and chemical digestion in the stomach. [SLO: B-12-R-27] • Identify the role of the nervous system and gastrin hormone on the secretion of gastric juice. [SLO: B-12-R-28] • Describe the major actions carried out on food in the three regions of the small intestine. [SLO: B-12-R-29] • Trace the absorption of digested products from the small intestine lumen to the blood capillaries and lacteals of the villi. [SLO: B-12-R-30] • Describe the component parts of large intestine with

			their respective roles. [SLO: B-12-R-31] • Correlate the involuntary reflex for egestion in infants and the voluntary control in adults. [SLO: B-12-R-32] • Explain the storage and metabolic role of the liver. [SLO: B-12-R-33] • Describe composition of bile and relate the constituents with respective roles. [SLO: B-12-R-34] • Outline the structure of pancreas and explain its function as an exocrine gland. [SLO: B-12-R-35] • Relate the secretion of bile and pancreatic juice with the secretin hormone.

N/A		Benchmark 4: Identify and explain the functions of the major organs of the circulatory system in the human body.	
			[SLO: B-12-R-36] • State the location of heart in the body and define the role of pericardium. [SLO: B-12-R-37] • Describe the structure of the walls of heart and rationalize the thickness of the walls of each chamber. [SLO: B-12-R-38] • Trace the flow of blood through the heart as regulated by the valves. [SLO: B-12-R-39] • State the phases of heartbeat. [SLO: B-12-R-40] • Explain the role of SA node, AV node and Purkinje fibers in controlling the

			heartbeat. [SLO: B-12-R-41] • List the principles and uses of Electrocardiogram. [SLO: B-12-R-42] • Describe the detailed structure of arteries, veins and capillaries. [SLO: B-12-R-43] • Describe the role of arterioles in vasoconstriction and vasodilation. [SLO: B-12-R-44] • Describe the role of precapillary sphincters in regulating the flow of blood through capillaries. [SLO: B-12-R-45] • Trace the path of the blood through the pulmonary and systemic circulation (coronary, hepatic-portal and renal

			circulation). [SLO: B-12-R-46] • Compare the rate of blood flow through arteries, arterioles, capillaries, venules and veins. [SLO: B-12-R-47] • Define blood pressure and explain its periods of systolic and diastolic pressure. [SLO: B-12-R-48] • State the role of baroreceptors and volume receptors in regulating the blood pressure. [SLO: B-12-R-49] • Define the term thrombus and differentiate between thrombus and embolus. [SLO: B-12-R-50] • Identify the factors causing

			atherosclerosis and arteriosclerosis. [SLO: B-12-R-51] • Categorize Angina pectoris, heart attack, and heart failure as the stages of cardiovascular disease development. [SLO: B-12-R-52] • State the congenital heart problem related to the malfunctioning of cardiac valves. [SLO: B-12-R-53] • Describe the principles of angiography. [SLO: B-12-R-54] • Outline the main principles of coronary bypass, angioplasty and open-heart surgery. [SLO: B-12-R-55] • Define hypertension and describe the

			factors that regulate blood pressure and can lead to hypertension and hypotension. [SLO: B-12-R-56] • List the changes in lifestyles that can protect man from hypertension and cardiac problems. [SLO: B-12-R-57] • Describe the formation, composition and function of intercellular fluid. [SLO: B-12-R-58] • Compare the composition of intercellular fluid with that of lymph. [SLO: B-12-R-59] • State the structure and role of lymph capillaries, lymph vessels and lymph trunks.

			[SLO: B-12-R-60] • Describe the functions of lymph nodes and state the role of spleen as containing lymphoid tissue.`
N/A		**Benchmark 5: Identify and explain the functions of the major organs of the skeletal system in the human body.**	
			[SLO: B-12-R-61] • Describe the structure of bone and compare it with that of cartilage. [SLO: B-12-R-62] • Explain the functions of osteoblasts, osteoclasts and osteocytes. [SLO: B-12-R-63] • Identify the main divisions of the human skeleton. and List the bones of the appendicular and axial skeleton of man.

			[SLO: B-12-R-64] • Describe three types of joints i.e. fibrous joints, cartilaginous joints and synovial joints and give example of each. [SLO: B-12-R-65] • Describe the disorders of human skeleton (disc-slip, spondylosis, sciatica, arthritis, osteoporosis) and their causes. [SLO: B-12-R-66] • State different types of fractures (simple, compound and complicated) and describe the repair process of simple fractures. [SLO: B-12-R-67] • Describe the injuries in joints (dislocation and sprain) and their first aid treatment.

			[SLO: B-12-R-68] • Compare smooth muscles, cardiac muscles and skeletal muscles. [SLO: B-12-R-69] • Annotate the ultrastructure of the skeletal muscle. [SLO: B-12-R-70] • Explain the sliding filaments model of muscle contraction. [SLO: B-12-R-71] • Describe the action of antagonistic muscles in the movement of knee joint. [SLO: B-12-R-72] • Explain muscle fatigue, cramps and tetany. [SLO: B-12-R-73] • Differentiate between tetanus and muscle tetany.

N/A		**Benchmark 6: Identify and explain the functions of the major organs involved in thermoregulation in the human body.**	
			[SLO: B-12-R-74] • Define thermoregulation and explain its needs. [SLO: B-12-R-75] • Classify animals on the basis of the source of body heat i.e. ectotherms and endotherms. [SLO: B-12-R-76] • Classify the animals on the basis of the ability to thermoregulate i.e. poikilotherms and homeotherms. [SLO: B-12-R-77] • Describe the regulatory strategies in man for thermoregulation.
N/A		**Benchmark 7: Explain how the different organ systems interact to maintain homeostasis in the human body.**	

			[SLO: B-12-R-78] • Describe three elements i.e. receptors, control center and effectors which operate homeostatic mechanisms. [SLO: B-12-R-79] • Relate the homeostatic mechanisms with the negative and positive feedback systems. [SLO: B-12-R-80] • Differentiate between osmoconformers and osmoregulators. [SLO: B-12-R-81] • Define osmoregulation. [SLO: B-12-R-82] • Explain the problems faced by osmoregulators. [SLO: B-12-R-83] • Explain the different

			methods of osmoregulation found in freshwater, marine water and terrestrial
Domain T: Pharmacological Drugs			
Standard: Students should be able to: **Describe the mechanism of action of various drug classes, including pain relievers, antidepressants, and antibiotics.** **Explain the factors that determine drug efficacy and toxicity, including dose, route of administration, and pharmacokinetics.** **Describe the side effects and potential drug interactions of various drugs.** **Explain the principles of drug design and development, including target selection, lead optimization, and clinical trials.** **Describe the role of pharmacology in the treatment of diseases, including the use of drugs to prevent, diagnose, and treat a range of medical conditions.**			
N/A		**Benchmark 1: Explain the role of pharmacological drugs in treating diseases like HIV and Hepatitis C and understand their mechanisms of action, side effects, and drug interactions.**	
			[SLO: B-12-T-01] • Explain the drug discovery and development process. [SLO: B-12-T-02] Define 4 classes of antibiotics (penecillins, Tetracyclins, Fluriquinolones and Sulfonamides) and describe their mode of

			action [SLO: B-12-T-04] • Define antivirals and antiretrovirals [SLO: B-12-T-05] • Describe advantages of monoclonal antibodies enjoy compared to other drug classes.

Domain U: Climate Change

Standard: Students should be able to:

Describe the role of greenhouse gases in the Earth's atmosphere and their impact on climate change.
Explain the evidence for and against the existence of climate change, including data from temperature records, ice cores, and other sources.
Describe the potential impacts of climate change on various ecosystems and species, including changes in distribution, migration patterns, and extinction risk.
Explain the role of human activities, such as deforestation and fossil fuel burning, in contributing to climate change.
Describe the mitigation and adaptation strategies used to reduce the impacts of climate change on biodiversity and ecosystems.

N/A	**Benchmark 1: Explain the causes and impacts of**

		global climate change on different regions, ecosystems and species and how to mitigate the issue.	
			[SLO: B-12-U-01] • Describe how climate change impacts flora and fauna. [SLO: B-12-U-02] • Describe how climate change can impact ocean biology in terms of its temperature and acidity as well as the resulting harmful effects. [SLO: B-12-U-03] • Name species that have gone extinct due to climate change.
Domain V: Selected Topics			
Standard: Students should be able to: **Describe the history and current state of biological warfare and its impact on society.** **Explain the mechanisms by which pathogens are used as weapons, including delivery methods, transmission routes, and virulence factors.** **Describe the types of modern-day biological weapons, including biotoxins, bioregulators, and biovectors.** **Explain the principles of biodefense, including vaccine development, disease surveillance, and countermeasure research.** **Describe the ethical and societal implications of biological weapons and biodefense, including issues related to biosecurity, international regulations, and dual-use research.**			

N/A		**Benchmark 1: Understanding the history of biological warfare and biodefences the development of modern-day biological weapons and other applications in biosynthethics.**	
			[SLO: B-12-V-01] • Explain the role of biological biological warfare occurs with examples. [SLO: B-12-V-02] • Describe how biodefenses could work to protect from biological warfare with examples. [SLO: B-12-V-03] • Examine the hype behind the comics "genomics, transcriptomics, proteomics metabolomics", to what extent is it valid or overblown? [SLO: B-12-V-04] • Explain synthetic biology with examples

Experimentation Skills Progression Grid

Guidance for the Reader

Guidance on Practical Work Expectations: For the sciences, there is no compulsory list of practical experiments that students have to conduct during their studies. Students *are* still expected to do extensive practical work (ideally two lessons in the lab per week), but the purpose of the lab work is to build their critical thinking, experiment designing, data collection and analysis skills. In their board exams, they will *not* be expected to reproduce a memorized practical that they have already studied in their classes. In Grade 10 board exams they are expected to conduct experiments (with apparatus and on broad topics that they have studied) as per the instructions they will be provided, and then analyze the data collected and then critique the experimental methodology followed. A more advanced version of this practical exam is also expected to be conducted in Grade 11 board exams. In Grade 12 they are expected to be able to rigorously design experiments of their own to test provided hypotheses (on broad topics that they have studied).

Grade-Wise Progression of Skills: This progression grid is about building skills. Grades 9-10 have the same skills listed, because the idea is to reinforce them through the practical work they will do associated with the topics they are studying. For example, in Grade 9 students may learn about photosynthesis and conduct practical work to investigate the effects of sunlight exposure on plants. In this experiment they would learn experimental design, data collection and analysis skills. Similarly in Grade 10 they may learn about cells and examine them under a microscope. Here again they would be building experimental design, data collection and analysis skills; just with a different topic. In contrast, Grade 11 and 12 have their skills learning outcomes separately listed. This is because in Grade 11, compared with Grade 10, the empirical research skills expected are more advanced. In Grade 12, there is a much stronger emphasis on learning how to design experiments to investigate given hypotheses, and these skills are hence listed in more detail at this level. Further guidance for educators on how to conduct lab classes keeping in mind this vision is provided in the Curriculum Guidelines.

Organization of the SLOs in the Progression Grid: Inside a grade, teachers are free to teach the content in any order of preference. Textbook publishers are also free to organize the contents of their books in any manner that they consider most effective, as long as all the SLOs in the Progression Grid and Cross-Cutting themes are covered. The SLOs inside a grade do not need to be taught in the order presented in a grade in this PG.

Grades 9-10	Grade 11	Grade 12
Domain X: Experimentation Skills **These cover the skills that are necessary for understanding how to design and practically conduct biology experiments. These skills are not meant to be applied not only in the science lab, but as skills of critical analysis for understanding empirical data as well.**		
Standard: Students should be able to demonstrate knowledge of common experimental terminology and how to select and safely use techniques, apparatus and materials		
Benchmark 1: Understand the terminology and methodology with various experimental techniques.	**N/A**	
[SLO: B-09-10-X-01] Students should to able to simple measurements in SI Units of: volumes of gases or solutions/liquids • – masses • – temperatures • – times • – lengths: : [SLO: B-09-10-X-02] Students should be able to carry out simple experiments of: • diffusion • osmosis • food tests • rates of enzyme-catalysed reactions • pH and the use of hydrogencarbonate indicator, litmus and universal indicator • photosynthesis (rate and limiting factors) • effect of mineral ions on plant growth • transpiration • heart rate and breathing rate		

• respiration • tropic responses • nervous responses • observation and dissection of seeds and flowers • germination • continuous and discontinuous variation • sampling techniques [SLO: B-09-10-X-03] Should be able to use of a microscope to examine biological specimens [SLO: B-09-10-X-04] • calculating the magnification of biological specimens		
Benchmark 2: Students should be able to understand and replicate the required techniques for the given experiments.	**N/A**	
[SLO: B-09-10-X-05] Students should:be able to select and safely use techniques, apparatus and materials • – identify apparatus from diagrams or descriptions • – draw, complete or label diagrams of apparatus and biological specimens • – use, or explain the use of, common techniques, apparatus and materials • – select the most appropriate apparatus or method for the task and justify the choice made • – describe food tests • – describe tests to determine the pH of solutions and substances using a universal indicator		

• – describe and explain techniques • –describe and explain hazards and identify safety precautions to ensure the accuracy of observations and data		
Standard: Students should be able to demonstrate knowledge of how to select and safely use techniques, apparatus and materials		
Benchmark 1: Students should be able to follow provided safety instructions and take general precuations in a lab setting	**N/A**	
[SLO: B-09-10-X-06] **Students should be able to understand for safety measurements and precautions** - **understand the need to wear PPE** - **tie up long hair** - **Wear goggles when dealing with caustic materials**		
Standard: Students should be understand the essence of scientific experimentation and carry out the necessary steps of understanding the terminology, taking general lab precautions, understanding the lab equipment, recording data and providing suggestions on improving the experimental techniques.		
Benchmark 1: Understand the scientific ideas that general science lab terms convey.	**Benchmark 1:** Plan the experiment and clearly convey the reasons for the experimental technique to follow.	
[SLO: B-09-10-X-07] Students are able to Understand and express scientific ideas using the below terms: - True value: the value that would be obtained in an ideal measurement - Measurement error: the difference between a measured value and the true value of a quantity - Accuracy: a measurement result is described as accurate if it is close to the true value - Precision: how close the measured values of a quantity are to each other - Repeatability: a measurement is repeatable if	[SLO: B-11-X-01] Decisions relating to measurements and observations [SLO: B-11-X-02] Within an investigation, students should be able to: • identify the independent variable and dependent variable • decide a suitable range of	Defining the problem [SLO: B-12-X-01] Using the context provided, students should be able to: • state a relevant prediction, either in words or in the form of a sketch graph showing the expected result, and link this to an underlying hypothesis • identify the independent and dependent variables

the same or similar result is obtained when the measurement is repeated under the same conditions, using the same method, within the same experiment - Reproducibility: a measurement is reproducible if the same or similar result is obtained when the measurement is made under either different conditions or by a different method or in a different experiment - Validity of experimental design: an experiment is valid if the experiment tests what it says it will test. The experiment must be a fair test where only the independent variable and dependent variable may change, and controlled variables are kept constant - Range: the maximum and minimum value of the independent or dependent variables - Anomaly: an anomaly is a value in a set of results that appears to be outside the general pattern of the results, i.e. an extreme value that is either very high or very low in comparison to others - Independent variables: independent variables are the variables that are changed in a scientific experiment by the scientist. Changing an independent variable may cause a change in the dependent variable - Dependent variables: dependent variables are the variables that are observed or measured in a scientific experiment. Dependent variables may change based on changes made to the independent variables	values to use for the independent variable at which measurements of the dependent variable are recorded • decide the number of different values of the independent variable (a minimum of five) and the intervals between them • decide how to change the value of the independent variable • decide how the dependent variable should be measured • decide the number of replicates at each value • decide on appropriate controls for the experiment or investigation • decide which variables need to be standardised and how to standardise them. (Variables expected to have a minimal effect, such as variation between test-tubes of the same type, do not need to be standardised.) When using the light microscope and photomicrographs, students should be able to: • set up a light microscope to view and observe specimens	• identify which key variables must be standardised in order to test a hypothesis. (Variables expected to have a minimal effect, such as variation between test-tubes of the same type, do not need to be standardised.) Methods [SLO: B-12-X-02] Using the context provided, students should be able to: • describe how to vary the independent variable • describe how to measure the values of the independent and dependent variables accurately and to an appropriate precision • describe how to standardise each of the other key variables • describe, where appropriate, suitable volumes and concentrations of reagents. Concentrations may be specified in % (w/v), or mol dm–3 • describe how different concentrations would be prepared by serial dilution or proportional dilution • describe appropriate control experiments • describe, in a logical sequence, the steps involved in the procedure, including how to use the apparatus to collect results • describe how the quality of results can be assessed by considering: – the occurrence of anomalous results – the spread of results including the use of standard deviation, standard

	• follow instructions to find and draw particular tissues in plant and animal specimens and label the drawings appropriately • follow instructions to find and draw particular cells and structures within the cells • make a temporary slide of stained cells or tissues • calculate actual sizes of tissues or cells from measurements of photomicrographs, using magnifications, scale bars or representations of eyepiece graticules and stage micrometers • estimate the number of cells or cell organelles in a given area using a sampling method, such as grids or fields of view.	error and/or 95% confidence intervals (95% CI). • describe how to assess the validity of the results by considering both the accuracy of the measurements and the repeatability of the results • prepare a simple risk assessment of their plans, taking into account the severity of any hazards and the probability that a problem could occur • describe the precautions that would need to be taken to minimise risks where possible.
Benchmark 2: Plan experiments and investigations.	**Benchmark 2:** Collect data and record observations in the form of readings, estimates and accurate drawings.	
[SLO: B-09-10-X-08] **Students are able to** a. identify the independent variable and dependent variable b. describe how and explain why variables should be controlled c. suggest an appropriate number and range of values for the independent variable	[SLO: B-11-X-03] Within an investigation, students should be able to: • follow instructions to collect results • consider the hazards of the procedure, including the use of any solutions and reagents, and assess the risk	

d. suggest the most appropriate apparatus or technique and justify the choice made e. describe experimental procedures f. identify risks and suggest appropriate safety precautions g. describe how to record the results of an experiment h. describe how to process the results of an experiment to form a conclusion or to evaluate a prediction i. make reasoned predictions of expected results	as low, medium or high • take readings to obtain accurate data (quantitative results) or observations (qualitative results). When using the light microscope and photomicrographs, Students should be able to: • draw plan diagrams to show the distribution of tissues in a specimen, with no cells drawn and the correct proportions of layers of tissues • draw the observable features of cells in a specimen showing: – the correct shapes – the thicknesses of cell walls where applicable (drawn with two lines or drawn with three lines where two cells touch) – the relative sizes and proportions – observable cell contents only • measure tissue layers or cells from photomicrographs using a ruler or given scale, including representations of eyepiece graticules • make accurate observations from specimens including	

	counting numbers of cells or cell organelles • record similarities and differences between two specimens using only their observable features.	
Benchmark 3: Make and record observations, measurements and estimates.	**Benchmark 3:** Evaluate and interpret the recorded data and display the calculations and reasoning.	
– take readings from apparatus (analogue and digital) or from diagrams of apparatus – take readings with appropriate precision, reading to the nearest half-scale division where required – correct for zero errors where required – make observations, measurements or estimates that are in agreement with expected results or values – take sufficient observations or measurements – repeat observations or measurements where appropriate – record qualitative observations from tests – record observations and measurements systematically, for example in a suitable table, to an appropriate degree of precision and using appropriate units	**Presentation of data and observations** [SLO: B-11-X-04] Recording data and observations Within an investigation, students should be able to: • record raw results (unprocessed) and calculated results (processed) in an appropriate table with: – descriptive headings, including any required units (no units in body of table) – heading for the independent variable to the left of (or above, if the table is in rows) the dependent variable • record quantitative data to the number of decimal places that is appropriate for the measuring instrument used • record qualitative observations using clear descriptions • record calculated values	Dealing with data [SLO: B-12-X-03] From provided data, students should be able to: • use tables and graphs to show the key points in quantitative data • sketch or draw suitable graphs, displaying the independent variable on the x-axis and the dependent variable on the y-axis including, where required, confidence limit error bars • decide which calculations are necessary in order to draw conclusions • carry out appropriate calculations to simplify or explain data, including means, percentages and rates of change • carry out calculations in order to compare data, including percentage gain or loss • use values of standard deviation or standard error, or graphs with standard error bars, to determine whether differences in mean values are likely to be statistically significant • choose and carry out statistical tests (limited to those described in the Mathematical requirements section

	(processed results) in an appropriate table. When using the light microscope and photomicrographs, Students should be able to: • record the fine details of the specimen, including drawing the detailed shapes of layers or outlines of specimens in plan diagrams and drawing the shape and position of observable cell organelles in cells. [SLO: B-11-X-05] Display of calculation and reasoning [SLO: B-11-X-06] Within an investigation and when using the light microscope and photomicrographs, students should be able to: • display calculations clearly, showing all the steps and reasoning • use the correct number of significant figures for calculated quantities. This should be the same as, or one more than, the smallest number of significant figures in the data used in the calculation.	of the syllabus) appropriate to the type of data collected and justify use of these tests • state a null hypothesis for a statistical test • recognise the different types of variable and the different types of data presented, as shown in the table below. [SLO: B-12-X-04] **Type of variable Type of data** *Qualitative* categoric nominal, i.e. values or observations belonging to it can be sorted according to category, e.g. colour of flowers ordered ordinal, where values can be placed in an order or rank and the interval between them may not be equal, e.g. the order in which test-tubes containing starch and iodine become colourless after adding amylase *Quantitative* continuous, which can have any value within a specific range, e.g. body mass, leaf length

	Layout of data and observations [SLO: B-11-X-07] Within an investigation, Students should be able to: • display data as a graph (continuous data), bar chart (discontinuous or categoric) or histogram (frequency data) • draw a graph, bar chart or histogram clearly and accurately with: – the independent variable on the x-axis and the dependent variable on the y-axis – axes labelled to match the relevant table headings, including units where appropriate – a scale where both axes should use most or all of the grid available and allow the graph to be read easily to within half a square – all graph points plotted accurately using a sharp pencil, as a small cross or a small dot in a circle, with the intersection of the cross or centre of the dot exactly on the required point – the plotted points of a graph connected with a clear, sharp and unbroken line, either as a line of best	

	fit, a smooth curve or with ruled straight lines joining the points – no extrapolation of graph lines unless this can be assumed from the data – all bars on a bar chart or histogram plotted accurately, with clear, unbroken lines that are drawn with a sharp pencil and ruler. [SLO: B-11-X-08] When using the light microscope and photomicrographs, students should be able to: • make drawings, using a sharp pencil to give finely drawn lines that are clear and unbroken • make drawings that use most of the available space and show all the features observed in the specimen, with no shading • organise comparative observations, showing differences and similarities between specimens.	
Benchmark 4: Interpret and evaluate experimental observations and data	**Benchmark 4: Analyze the results of the experiment and provide conclusions.**	
– process data, including for use in further calculations or for graph plotting, using a	**Analysis, conclusions and evaluation** [SLO: B-11-X-09] Interpreting data and	**Conclusions** [SLO: B-12-X-05] Students should be able to:

calculator as appropriate – present data graphically, including the use of best-fit lines where appropriate – analyse and interpret observations and data, including data presented graphically – use interpolation and extrapolation graphically to determine a gradient or intercept – form conclusions justified by reference to observations and data and with appropriate explanation – evaluate the quality of observations and data, identifying any anomalous results and taking appropriate action – comment on and explain whether results are equal within the limits of experimental accuracy (assumed to be ± 10% at this level of study)	observations [SLO: B-11-X-10] Within an investigation, students should be able to: • calculate an answer with the correct number of significant figures using quantitative results or data provided • use a graph to find unknown values • estimate the concentrations of unknown solutions from qualitative results • identify the contents of unknown solutions using biological molecule tests • identify anomalous results and suggest how to deal with anomalies • describe patterns and trends using the data provided in tables and graphs • evaluate the confidence with which conclusions might be made. When using the light microscope and photomicrographs, Students should be able to: • calculate an answer with the correct number of significant figures using quantitative results or data provided	• summarise the main conclusions from the results • identify key points of the raw data and processed data, including graphs and statistical test results • discuss the extent to which a given hypothesis is supported by experimental data and the strengths and weaknesses of the evidence • give detailed scientific explanations of the conclusions • make further predictions and hypotheses based on the conclusions. **Evaluation** [SLO: B-12-X-06] Students should be able to: • identify anomalous values in a table or graph of data and suggest how to deal with anomalies • suggest possible explanations for anomalous readings • assess whether the results have been replicated sufficiently • assess whether the range of values of the independent variable and the intervals between the values were appropriate • assess whether the method of measuring is appropriate for the dependent variable • assess the extent to which selected variables have been effectively controlled • make informed judgements about: – the validity of the investigation – the extent to which the data can be

	• compare observable features of specimens of biological material including similarities and differences between specimens on a microscope slide and specimens in photomicrographs. Drawing conclusions [SLO: B-11-X-11] From results, observations or information provided, students should be able to: • summarise the main conclusions • state and explain whether a hypothesis is supported • make predictions from the patterns and trends in data • suggest explanations for observations, results, patterns, trends and conclusions.	used to test the hypothesis – how much confidence can be put in the conclusions • suggest how an investigation could be improved to increase confidence in the results.
Benchmark 5: Evaluate methods and suggest possible improvements	**Benchmark 5:** Identify sources of error and suggesting improvements	
– evaluate experimental arrangements, methods and techniques, including the control of variables – identify sources of error, including measurement error, random error and systematic error – identify possible causes of uncertainty in data or in a conclusion – suggest possible improvements to the apparatus, experimental arrangements, methods or techniques	[SLO: B-11-X-12] Within an investigation and when using the light microscope and photomicrographs, students should be able to: • identify systematic or random errors in an investigation, understanding that systematic errors may not affect	

	the trend in results whereas a random error may affect the trend • identify the main sources of error in a particular investigation • suggest improvements to a procedure that will increase the accuracy of the observations or measurements, including: – using a more effective method to standardise relevant variables – using a more accurate method of measuring the dependent variable – using smaller intervals for the values of the independent variable – collecting replicate measurements so that a mean can be calculated • suggest how to extend the investigation to answer a new question, for example by investigating a different independent variable or applying the method to a new context • describe clearly, in words or diagrams, improvements to the procedure or modifications to extend the investigation.	

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