National School Curriculum

INSTRUCTIONAL GUIDE FOR BIOLOGY

CLASSES XI & XII

Department of Curriculum and Professional Development
Ministry of Education, Royal Government of Bhutan

“Your parents, relatives, and friends would be very proud of what you have achieved. At your age, to have completed your studies is your personal accomplishment. Your knowledge and capabilities are a great asset for the nation. I congratulate you for your achievements.

Finally, your capabilities and predisposition towards hard work will invariably shape the future of Bhutan. You must work with integrity, you must keep learning, keep working hard, and you must have the audacity to dream big.”

- His Majesty Jigme Khesar Namgyel Wangchuck

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Foreword

The overriding aspirations of Bhutanese science education is grounded on the philosophical foundations of Gross National Happiness (GNH). In its curricular forefront, Bhutanese science education is informed, in part, by the underlying assumptions of the 21st century educational paradigms. Historically, the Bhutanese science curriculum witnessed several episodes of changes, including the refinement of, and changes to, theories, ideas, and beliefs over time. Therefore, the current Bhutanese science curriculum (NSC) is shaped by several rounds of initiatives undertaken over the past several decades.

In the recent few years, state of affairs around the world witnessed the advent of 21st century real-world issues and challenges. Consequently, as never seen before, the priority to overhaul the art of education itself was echoed at the heart of many education systems around the world. Typically, but not necessarily, there was a unified call to move away from traditional standard-based education systems towards competency-based education systems. The 21st century competency-based education model is, thus, virtually at the centre of many today's education systems. In the face of such global changes, Bhutanese education system cannot afford to sit back and wait for the right time and space. The DCPD at the centre is, therefore, in full pursuit of transforming the art of science teaching from traditional didactic approaches to contemporary approaches of learning.

At the heart of the classes IX to XII biology curriculum is the notion that learners maintain robust understanding when the culture of science practises is enacted either wholly or partially. Such a notion believes that engaging in science practises not only help learners acquire sophisticated understanding but also hone scientific temper and scientific habits of mind. The classes IX to XII biology curriculum, thus, desires to chart a milestone shift from the act of "transmitting science" towards the culture of "doing science". By far, the classes IX to XII biology curriculum also dwells on the philosophical assumptions of the integrated approach of STEM education. As never done before, the classes IX to XII biology curriculum now entails situating both content and instructional practises, oftentimes, in complex phenomena, authentic contexts, or real-world situations. The classroom practises, in contrast to past common practises, are now expected to be either performance tasks or competency-based propelled by scientific inquiry and engineering design process.

I am confident that this instructional guide serves as a springboard in the effective delivery of the classes IX to XII biology curriculum intentions. Overall, I believe that this guide would serve a strong foundation of science education in equipping learners with the ability to think critically, analyse information, and solve complex problems —the skills needed to pursue opportunities within and beyond STEM fields.

Tashi Namgyal
Director

Contents

Introduction

Science education in Bhutan started with a curriculum borrowed from a neighbouring country. In 1986, however, the Royal Government of Bhutan (RGoB) replaced the foriegn borrowed curriculum by implementing a localised science curriculum founded on the principles of New Approach to Primary Education (NAPE). Since then, the Bhutanese science curriculum witnessed several episodes of changes, including the refinement of, and changes to, theories, ideas, and beliefs over time. Therefore, the current Bhutanese science curriculum (NSC), including biology is shaped by several rounds of initiatives undertaken over the past several decades.

With the dawn of the 21st century, nations around the world experienced a wide array of unique real-world problems in social, economical, and environmental contexts. In light of such pressing issues, education systems around the world embraced the 21st century educational framework as the new conceptual windows of education. At the centre, this growing call was no exception for Bhutanese education system. The erstwhile Royal Education Council (REC), therefore, initiated science curriculum reform towards the fall of 2020. The science curriculum revision was motivated in part by the growing consensus of competency-based or STEM education.

The goals of science education in Bhutan revolves around the premise of educating youths with a multitude of scientific abilities. At the national level, the classes IX to XII biology curriculum aspires to produce individuals with scientific abilities capable of understanding and evaluating information; have a voice in science funding decisions; evaluating policy matters; and weighing scientific evidence provided in legal proceedings. Further, it purports to produce skilled and motivated future scientists, doctors, biology domain related engineers, and STEM-based workforce or professionals.

At the individual level, the classes IX to XII biology curriculum, however, increasingly seeks to help learners engage in the ethos of scientific practises and scientific habits of mind. It expects that learners become critically aware of the nature of science; possess strong proficiency in designing solutions and conducting scientific inquiry; and possess sharp abilities to participate in the culture of scientific practises and STEM related discourses. It also aspires to provide strong foundations of academic rigour and biological literacy that lends ultimate proficiency to make sense of the phenomena, scientific discoveries, and scientific inventions.

Informed by the new vision of science education, the culture of "doing science" lies at the heart of classes IX to XII biology curriculum. The classes IX to XII biology curriculum, thus, desires to transform science teaching from the culture of "transmission of science" towards "investigating science" or "doing science" in itself. This is certainly, however, not possible if the curriculum itself believes in providing a large number of isolated facts of equal priority. Therefore, in contrast to earlier curriculum, the present classes IX to XII biology curriculum is now principally centred on disciplinary core ideas to avoid shallow coverage of multiple disconnected facts. The reduction of

the sheer sum of details to be mastered is intended to give time for students to engage in scientific investigations and argumentation and to achieve depth of understanding of the core ideas presented. On the same footing, the curriculum also aspires to teach both science contents and practises as one science standard. This is seemingly as opposed to the divorce between science contents and science practises that used to be the common features of the past curriculum.

By far, the classes IX to XII biology curriculum is also motivated, in part, by a growing consensus to augment the spirit of STEM education. It entails transitioning science teaching from a silo-based approach to 21st century integrated or interdisciplinary nature of STEM. As never before, it attempts to raise the standards of engineering and technological design at par with science standards. As its name implies, the engineering, in a very broad sense is, purported to upscale any engagement in a systematic practise of design to achieve solutions to particular human-made problems. Therefore, instructional practises are expected to be delivered in conjunction with other STEM disciplines to make sense of the phenomena and design solutions to address human-made issues. On the whole, like other science disciplines, the classes IX to XII biology curriculum calls for following paradigm shifts:

1. teaching many isolated facts towards teaching disciplinary core ideas.
2. teaching disciplinary core ideas (science contents) and science processes (science practises) together as one science standard.
3. raising the standards of engineering design process/design challenge at par with the science standards.
4. infusing technological design where appropriate to augment science standards and engineering design.

Purpose of the Instructional Guide

As classes IX to XII biology curriculum put-forth a new vision, the urgency of having this guide appeared more than necessary. This instructional guide (IG) was, thus, developed with the purpose of assisting both teachers and learners in situating robust and heralding classroom practises. The IG in its entirety contains suggestive learning experiences drawn mostly from the classes IX to XII biology curriculum framework. These suggestive learning experiences, at the core, are lesson-like formats developed for each learning objective. They are tied closely with a topic, competencies, and a strand or a theme.

Specifically, each lesson-like learning experience contains suggestive approaches of delivering curriculum intentions. Each of them contains some generic roles of both teachers and learners. Depending on the nature of the learning objective, each learning experience is driven either by the art of scientific inquiry or the engineering design process. Certain learning experiences, though not often, are centred on some specific inquiry-derived or design-thinking based pedagogical approaches. At the centre, almost all the learning experiences are nested on the pedagogical frameworks of blended learning approaches, such as flip class, virtual enriched, etc. Therefore, almost all the learning experiences contain prolific or sporadic use of digital contents and digital platforms wherever appropriate. Besides, each learning experience is closely followed by suggestive follow-up questions; and suggestive assessment techniques and tools purported to assess learners' learning progression or performance tasks.

Categorically, with such learning experiences in place, it is expected that learners are provided uninterrupted education irrespective of situations or circumstances. With blended learning at the heart of each learning experience, it is expected that teaching is carried out in times of prolonged closure of schools (due to emergencies), holidays, and when subject teachers are on leave or away for official duties.

Class XI

1. Molecules to Organisms: Structures and Processes

Organisms contain structures and processes organised from micro-entities, such as small biomolecules to macro-entities, such as organs and organ systems. This organisation, though not much visible in small organisms, is quite noticeable in higher organisms, including plants and animals. How are structures and processes organised in organisms? Every organism, whether small or big, contains cells as the smallest units. Cells, depending on their structures and biological roles, influence almost all structures, processes, and behaviour of the organism. Cells, in themselves, are made up of biomolecules, such as carbohydrates, fats, proteins, and nucleic acids. In large organisms, cells combine to form structures and functions of tissues, which in turn form organs, organ systems, and organisms in themselves. It is, therefore, important to understand how interacting systems and subsystems coordinate to form behaviour, function, and emotion of the organisms.

Competencies

By the end of class XI, a learner should be able to:

a. apply the understanding from biomolecules to explain that all organisms contain biomolecules, such as carbohydrates, fats, proteins and nucleic acid which forms the basis for cellular processes.
b. provide a scientific explanation that all living organisms are a biological system of interacting subsystems that coordinate the processes, functions, or emotions of an organism.

1.1 Biomolecules: What makes up living organisms?

1.1.1. Scope: Carbohydrates are primary sources of energy. Monosaccharides (e.g., glucose, fructose, galactose) are the smallest units that combine to form different types of carbohydrates. Polysaccharides (e.g., starch, cellulose, and glycogen) are formed by the combination of monosaccharides through the formation of glycosidic bonds.

1.1.2. Scope: Lipids are naturally occurring esters that are formed by glycerol and fatty acids. They have widespread functions in organisms (e.g. source of energy, insulation, etc.)

1.1.3. Scope: Proteins are formed by the combination of amino acids, through the formation of polypeptide chains. Polypeptide chains form larger protein molecules. The folding of polypeptide chains is supported by the interacting forces of protein residues. The working of proteins is determined by their 3D structural conformations.

1.1.4. Scope: Scientists and engineers are working to develop and produce biomolecule-based materials that can satisfy our high demands for quality and performance while at the same time

posing no burden to the environment because they are made of renewable resources and are fully biodegradable.

1.1.5. Scope: Nucleic acids are formed by the arrangement of nucleotides in the form of a long chain. A nucleotide is composed of a pentose sugar, nitrogenous base, and phosphate group. DNA and RNA are two different nucleic acids.

1.1.6. DNA contains information that directs the production of proteins. A DNA molecule contains two strands (polynucleotide chains) arranged to form a double helix. The sequence of nitrogenous bases determines the sequence of amino acids in a polypeptide chain.

1.1.7. RNA contains a single strand of nucleotides. There are three different types of RNA (i.e., rRNA, mRNA, and tRNA). Each RNA performs specific roles during protein synthesis.

Objective(s):

LO-1. Construct a scientific explanation that biomolecules are formed by the combination of monomers (*limited to carbohydrates-monosaccharides, disaccharides, starch, and cellulose; fats-simple lipids; and proteins-simple proteins*).

Learning Experiences:

The teacher may begin the lesson by informing the learners that living organisms are composed of some common elements. These are carbon, hydrogen, oxygen, and nitrogen. These elements combine to form different compounds of carbohydrates, fats, proteins, and nucleic acids. For instance, the teacher may share on how the large chunk of a tree is composed of a carbohydrate called cellulose. The learner may be informed that without these biomolecules, life on the earth is certainly impossible. The teacher may pose the question: How are carbohydrates (*disaccharides, starch, and cellulose),* fats (*simple lipids*), and proteins (*simple proteins*) formed? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains and evaluate information on how biomolecules, such as carbohydrates (*disaccharides, starch, and cellulose),* fats (*simple lipids*), and proteins (*simple proteins*) are formed from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://cutt.ly/9zwkYgx).
- Based on the information gathered, the learner constructs scientific explanations on how biomolecules, such as carbohydrates (*disaccharides, starch, and cellulose),* fats (*simple lipids*), and proteins (*simple proteins*) are formed.
- The learner communicates scientific information on how biomolecules, such as carbohydrates (*disaccharides, starch, and cellulose),* fats (*simple lipids*), and proteins (*simple proteins*) are formed.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. What are monomers? Give three examples.
2. How are carbohydrates, fats, and proteins formed? Explain.
3. Why are biomolecules necessary for life to exist?
4. Proteins are referred to as the building blocks of life. Relate the statement to the structural roles of proteins?

Assessment:

Use rubrics to assess the learner's information management skill and ability to comprehend that carbohydrates, lipids, and proteins are composed of several units of monomer. Provide necessary feedback and intervention to the learners.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
- https://cutt.ly/9zwkYgx

Objective(s):

LO-2. Design a 3D model of a protein that demonstrates how interacting forces trigger the formation of stable 3D conformation of a protein.

Learning Experiences:

The teacher may inform the learner that proteins play a major role in our life. The teacher may inform the learner that almost all of our body structures and processes are carried out by proteins. For instance, enzymes and hormones that carry out various biological roles in our body, are made up of proteins. On this note, teachers may inform the learner that proteins must attain 3D structural conformations to carry out their biological functions. The teacher may ask the question: How does a protein attain its 3D structural conformation? The teacher may ask the learner to obtain information on how interacting forces helps the protein to attain 3D configuration from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://cutt.ly/Uzwk2Ll) one day before the lesson. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner gathers information on how proteins attain 3D structural confirmation from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://cutt.ly/Uzwk2Ll).
- Based on the information obtained, the learner constructs a model (conceptual, theoretical, physical, or simulation) that explains how interacting forces help in the formation of the 3D conformations of proteins.
- The learner critiques each other's 3D model of the protein.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Chemical bonds are the fundamentals for the stability of proteins. Relate the statement to the nature of bonds in proteins.
2. Derive a relation between the structure and function of proteins.
3. How does a protein attain its 3D conformation structure? Explain.

Assessment:

Use rubrics to assess the learner's ability to design models of protein and the ability to use and critique the model of protein to explain how interacting forces help in the stability of primary, secondary, tertiary, and quaternary protein structures. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
- https://cutt.ly/Uzwk2Ll

Objective(s):

LO-3. Design a solution to address the environmental issues, using the concept of biomolecules.

Learning Experiences:

The teacher may introduce the lesson by informing the learner that the use of non-degradable materials has lots of environmental issues. The teacher may pose the question: How do you think the use of biomolecules can minimise the environmental issues? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on how the concept of biomolecules can be used in addressing environmental issues from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., (https://cutt.ly/1IEJBVo).
- Based on the information obtained, the learner designs a solution to address the environmental issues using the concept of biomolecules.
- The learner tests the designed solution.
- The learner communicates and critiques each other's solution developed to address environmental issues using the concept of biomolecules.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. How does bioremediation benefit the environment?
2. Using biomolecules, is it possible to remove toxic chemicals that cause biomagnification? Explain your answer.
3. What are some of the common methods to treat wastewater before releasing them into water bodies?
4. Water tanks are usually treated with chlorine to prevent bacterial growth. Chlorine has some impacts on human health and also corrodes metal pipes. Is it possible to replace chlorine with biomolecules to prevent bacterial growth? Explain.

Assessment:

Use rubrics to assess the learner's information management skill, ability to design a solution, and their abilities to critique and defend on solutions presented to address the environmental issue. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSF- 2022).
- https://bit.ly/3tHibA1
- https://bit.ly/3FJWO3s

Objective(s):

LO-4. Construct a scientific explanation on how the structure of the DNA molecule is adapted to store information to make proteins.

Learning Experiences:

The teacher may begin the lesson by informing the learner that DNA is one of the icon molecules of modern genetics. Its discovery shook off many myths and beliefs held by classical genetics. The teacher may inform the learner that the double helix molecular model of DNA was proposed by Watson and Crick in 1953. Ever since, the idea of the double helix molecular model of DNA unlocked many potentials leading towards some marvels of modern biology, such as genetic engineering, gene cloning, DNA fingerprinting, human genome project, gene therapies, etc. The teacher may inform the learner that DNA contains information to make proteins. This information to make proteins are stored in the 3D structure of the DNA molecule itself. The teacher may pose a question: How is the structure of DNA adapted to store information to make proteins? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the 3D structure of a DNA molecule from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://bit.ly/32gJuWx).
- The learner constructs a scientific explanation on the 3D structure of the DNA molecule (double helix molecular structure-polynucleotide chains, nucleotides, sequence of nitrogenous bases, hydrogen bonds, etc.). The learner may relate the 3D structure of the DNA molecule with its biological role in coding proteins.
- The learner critiques each other's ideas that relate how the structure of the DNA molecule is adapted to store information to make proteins.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. How is the structure of DNA formed?
2. Are two DNA strands identical? Comment.
3. Why do the two strands of DNA run antiparallel to each other?
4. How does the structure of DNA contribute to its stability?
5. The biological role of the DNA molecule is dependent on its 3D structure. Explain giving reasons.

Assessment:

Use rubrics to assess the learner's information management skill, ability to comprehend how DNA is adapted to carry out its biological role in coding proteins, and ability to critique and defend each other's claim. Provide necessary feedback and interventions to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)
- https://bit.ly/32gJuWx
- https://bit.ly/3nHp2FR

Objective(s):

LO-5. Construct scientific explanation on how the structure of RNA is adapted to carry out its biological role in protein synthesis (*limited to transcription and translation*).

Learning experiences:

The teacher may begin the lesson by explaining that ribonucleic acid (RNA) is a molecule that is similar to DNA but is single-stranded. It has a backbone that is made up of alternating sugar (ribose) and phosphate groups. One of four bases; adenine (A), uracil (U), cytosine (C), or guanine (G) is attached to the sugar group. The teacher may pose a question: How do the structure of RNA (rRNA, tRNA, and mRNA) is adapted to carry out its biological role in protein synthesis? The teacher may deliver the lesson based on the following order of science and engineering practises:

- The learner obtains information from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://go.nature.com/3IkRbum) that contains information on how the structures of RNAs are responsible for carrying out protein synthesis.
- The learner constructs scientific information explaining how the structure of RNA is responsible for carrying out protein synthesis.
- The learner communicates and critiques each other's work.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. How are RNAs different from DNA? Explain.
2. How are the three types of RNA important for gene expression?
3. How is mRNA structurally designed to support protein synthesis?
4. Why are RNA structures stable in single-stranded forms?

Assessment:

Use rubrics to assess the learner's information management skill, ability to explain how the structure of RNA is responsible for carrying out protein synthesis and the ability to communicate and critique. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
- https://go.nature.com/3IkRbum

Challenge Your Learners

Teacher may ask the following questions to challenge the thoughts of the learner:

1. Microorganisms are employed for bioremediation practises like clearing oil spills, land pollution, and many more. What are some of the ecological risks associated with the practise?
2. DNA holds the information for our differences. Argue on the statement giving scientific reasons.
3. How has the presence of biomolecules influenced the existence of life?
4. Evaluate the roles of DNA and RNA in protein synthesis.
5. The working of proteins is associated with their structures. Explain with scientific reasons.
6. Though proteins are made up of the same amino acids, they still exhibit differences amongst different organisms. Explain giving reasons.

1.2. The Power of Enzymes.

1.2.1. Scope: Enzymes influence biochemical reactions occurring inside and outside of the cells, without themselves undergoing changes. These enzymes are produced by living cells.

1.2.2. Scope: An enzyme brings reactant molecules together and increases the rate of the intermediate complex by lowering the activation energy. The process of formation of intermediate complexes and the products are explained by some models (e.g. Lock and Key and induced-fit hypothesis).

1.2.3. Scope: Enzyme activity is affected by certain factors (e.g., temperature, pH, substrate concentration, etc.)

1.2.4. Enzymes have a wide range of applications, starting from the production of simple homemade and industrial products to being used as tools for technologies involving the manipulation of genes. Enzymes are used to deal with various real-world issues (e.g., oil spillage, bioremediation, etc.).

Objective(s):

LO-1. Argue with scientific reasons on the credibility of lock and key, and induced fit hypothesis in explaining the mechanism of enzyme action. .

Learning Experiences:

The teacher may begin the lesson by informing the learner that all biological processes that occur within living organisms are regulated by enzymes. The teacher, for instance, may inform the learner that the chemical digestion of meals that we consume happens in various parts of the alimentary channels, such as the buccal cavity, stomach, and intestines. The teacher may ask the students to think about how enzymes break down large food particles into small, simple, and soluble molecules. The teacher may inform that the working of an enzyme is explained by the lock and key hypothesis and induced fit hypothesis. The teacher may pose the questions: How is the working of enzymes explained by lock and key, and induced fit hypothesis? What is the credibility of these hypotheses in explaining the working of an enzyme? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on lock and key hypothesis and induced fit hypothesis that explain the mechanism of enzyme action from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://cutt.ly/SIuq40l).
- The learner evaluates the information on lock and key hypothesis and induced fit hypotheses that explain the mechanism of enzyme action.
- The learner supports or refutes the idea of the lock and key hypothesis and the induced fit hypothesis that explain the mechanism of enzyme action.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. How does an enzyme influence the rate of a chemical reaction?
2. Why are enzymes important for a biological system?
3. Explain the working of enzymes based on lock and key and induced fit hypothesis.
4. Which between the lock and key, and induced-fit hypothesis, is more credible in explaining the working of enzymes?
5. What is the credibility of lock and key, and induced-fit hypothesis in explaining the working of enzymes? Comment.

Assessment:

Use rubrics to assess the learner's information management skill and reasoning skills in defending their stand in support or refute the idea that lock and key hypothesis are reliable models in explaining the mechanism of enzyme action. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/SIuq40l

Objective(s):

LO-2. Investigate to study the effects of pH, temperature, and substrate concentration on enzyme action.

Learning Experiences:

The teacher may begin the lesson by informing the learner the working of an enzyme is affected by several factors. The teacher may inform the learner that there are many factors, such as temperature, pH, substrate concentration, etc., that influence the activity of an enzyme. The teacher may ask the student to reflect on why the shelf life of vegetables and fruits increases when placed inside the refrigerator. The teacher may pose the question: How is the enzyme action affected by temperature, pH, and substrate concentration? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the enzyme action affected by temperature, pH, and substrate concentration from the relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://cutt.ly/yILqIYF)
- The learner carries out an experiment to study the effect of temperature, pH, substrate concentration on the enzyme action.
- The learner analyses data gathered from experiments and interprets the data (tabulation, statistics, graphing, etc.) on the influences of temperature, pH, substrate concentration on the enzyme action.
- The learner draws the conclusion from the findings to the class.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. How do factors such as temperature, pH, and substrate concentration influence the working of enzymes?
2. The enzymes of the stomach do not function well in the intestine. Explain giving reasons.
3. How would the rate of an enzyme-catalyzed reaction differ if the external factors are constant?
4. What kind of changes does an enzyme undergo during its denaturation?
5. Why does the shelf life of vegetables increase when placed inside the refrigerator? Explain giving suitable reasons.

Assessment:

Use rubrics to assess the learner's information management skill, ability to design and carry out experiments, ability to analyse and interpret data, ability to draw the conclusion on the effect of factors (e.g., temperature, pH, substrate concentration, etc.) on the enzyme action, and ability to critique and defend each other's claim. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/2Iurq1d
- https://cutt.ly/yILqIYF

Objective(s):

LO-3. Design a solution to remove stains (*e.g., betel nut, urine, graffiti, paints, etc*.) using the concepts of enzymes.

Learning Experiences:

The teacher may begin the lesson by informing the learner that enzymes are used for various purposes, such as medical treatment, industrial uses, alcoholic beverages, removal of stains, etc. The teacher may inform the learner that enzymes can possibly be used to remove stains. In this context, the teacher may inform the learner that betel nut (*Doma)* stains have become one of the social ills in Bhutan. The learner may be informed about the possibility of removing betel nut (*doma)* stains, graffiti, paints, etc., using enzymes. The teacher may pose the question: How can we remove stains using enzymes? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the properties of enzymes, nature of stains, and application of enzymes in removing stains from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://bit.ly/35CIgGy).
- The learner designs a solution to remove stains (e.g., betel nut, urine, graffiti, paints, etc.) using the concepts of enzymes.
- The learner presents the designed solution to remove stains (e.g., betel nut, urine, graffiti, paints, etc.) using the concepts of enzymes.
- The learner critiques each other's work, and refine the designed solution to remove stains (e.g., betel nut, urine, graffiti, paints, etc.) using the concepts of enzymes.

Assessment:

Use rubrics to assess the learner's information management skill, ability to comprehend conceptual understanding in designing and developing a solution to remove stains (e.g., betel nut, urine, graffiti, paints, etc.) using the concepts of enzymes, and critiquing skills. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

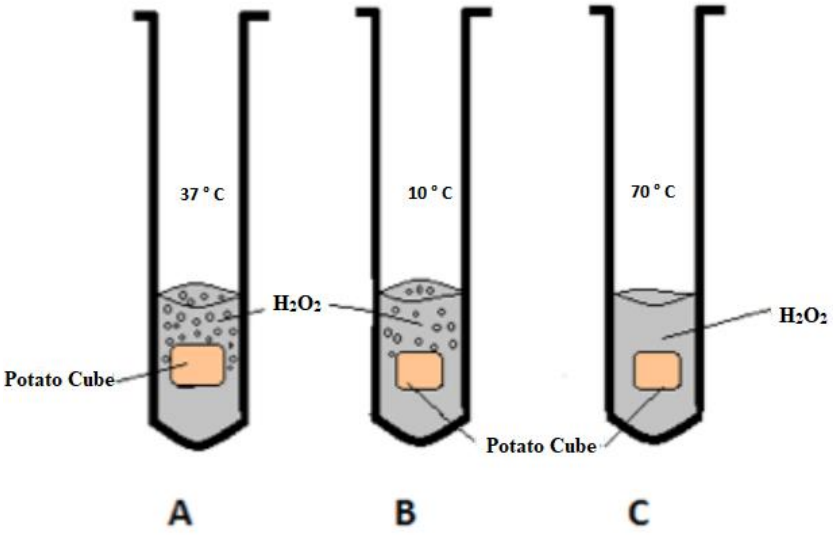
Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
- https://bit.ly/35CIgGy

Challenge Your Learners

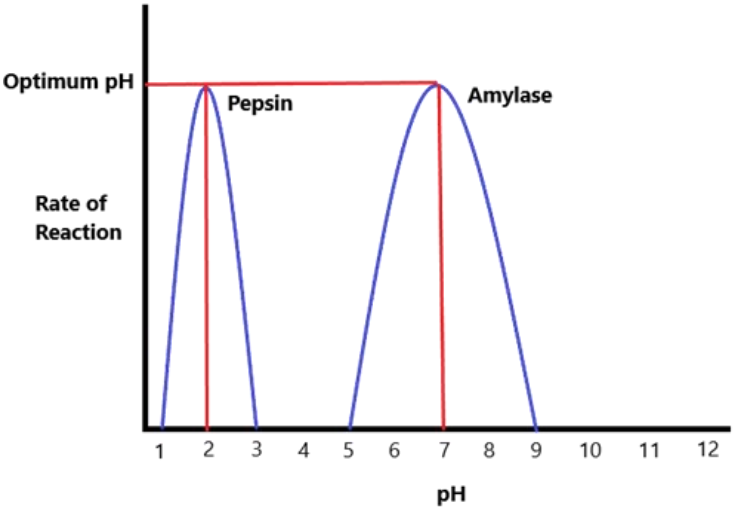
Teacher may ask the following questions to challenge the thoughts of learner:

1. *Salivary amylase* is dysfunctional in the stomach. Comment.
2. Given below is part of an experiment to determine enzyme action. Study the diagram given below and answer the questions that follow:



a. Develop a hypothesis for the experiment.
b. Identify the independent and dependent variables.
c. Develop a research question based on the above experiment.
d. How will the results differ amongst the three test tubes? Give reasons.

3. Use the concept from the diagram below to show the significance of having a variety of enzymes for digestion?



4. Yangki took 2 mL of saliva each in test tubes A and B. She added 5 ml of 2% starch solution in test tube A and added 2 mL of distilled water in test tube B and allowed both the test tubes to stand for an hour. After that, she added 2 drops of iodine solution to both the tubes and observed the changes.
   a. At what pH is salivary amylase active?
   b. Why does the solution in test tube 2 remain blue?

c. Why does test tube 1 become colorless?
d. What do you conclude from the experiment?

1.3. Organs for Breathing

1.3.1. Scope: The respiratory system comprises of respiratory tract and organs, that are designed to support the movement and exchange of gases.

1.3.2. Scope: The movement of air while breathing is facilitated by the combined activities of the intercostal (ribcage) and phrenic (diaphragm) muscles. The internal structures of the lungs are well-developed to facilitate the exchange of gases between the alveolar air and the blood. The exchange of gases in the lungs and tissues occurs in a similar manner, depending on the relative concentrations and pressures of respiratory gases.

1.3.3. Scope: Respiratory disorders range from mild (e.g., common cold, influenza, pharyngitis, etc.) to life-threatening (e.g., pneumonia, lung cancer, asthma, tuberculosis, etc.) Respiratory disorders are caused by microbial infections, smoking, pollution, genetic factors, etc. As altitude increases, the number of oxygen molecules per breath is reduced. In order to properly oxygenate the body, the breathing rate has to increase. Since the amount of oxygen required for bodily activity is the same, the body must adjust to having less oxygen. Continuing to higher altitudes without proper acclimatisation can lead to potentially serious, even life-threatening illnesses (e.g., high-altitude pulmonary edema).

Objectives:

LO-1. Develop a model that explains the working of the human respiratory system.

Learning Experiences:

The teacher may instruct the learner to obtain information on the mechanism of the exchange of respiratory gases from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://bit.ly/3ITiOuN), a day before the class. The teacher may begin the class by saying that respiration is an essential process for the exchange of respiratory gases and involves various respiratory organs. These respiratory organs are responsible for providing energy by breaking the glucose. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- Based on the information obtained, the learner develops a model (conceptual, theoretical, physical, or simulation) to explain the mechanism of the exchange of respiratory gases.
- The learner constructs an explanation on the mechanism of the exchange of respiratory gases.
- The learner presents and critiques each other's designed model to explain the exchange of respiratory gases.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. How are the nasal passages designed to condition the air before entering the lungs?
2. Illustrate the role of muscles in the movement of air while breathing?
3. Generally nasal breathing is considered better than oral breathing. Explain with scientific reasons.
4. How are lungs designed to support respiration?

Assessment:

Use rubrics to assess the learner's information management skills, ability to construct scientific explanations on the mechanism of the exchange of respiratory gases using the model developed, and ability to critique. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)
- https://bit.ly/3ITiOuN

Objective(s):

LO-2. Investigate the trend of the common respiratory disorders in your locality.

Learning Experiences:

The teacher may begin the lesson by informing the learner that various types of lung diseases can cause chronic respiratory conditions (e.g., pneumonia, asthma, bronchitis, etc.). Although genetic and environmental factors may lead to lung diseases, smoking is the top preventable cause of many respiratory conditions. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on common respiratory disorders in the locality by visiting a nearby health centre or maybe through an interview. The learner may also obtain information from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://bit.ly/3u8b7g9)
- The learner collects data to investigate the trends in common respiratory diseases in the locality.

- The learner analyzes (tabulation, statistics, or graphing) the data obtained to investigate the trends in common respiratory diseases in the locality.
- The learner presents the results on trends of common respiratory diseases to the class.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. What are some of the common respiratory issues in your locality? Identify the causes.
2. How can we relate respiratory disease to the environment a person lives in?
3. Why is smoking not a good practise when it comes to affecting the working of the respiratory system?
4. Sangay is coughing with sputum, shortness of breath, chest discomfort and visits the doctor. On consultation, he said he has been working as a road site engineer for 15 years.
    a. What is the possible cause of his discomfort?
    b. What do you think is the condition?
    c. How would you advise Sangay?

Assessment:

Use rubrics to assess the learner's information management skill, ability to analyse the data on trends of the common respiratory diseases, and presentation skills. Provide necessary feedback and intervention to the learner. For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
- https://bit.ly/3u8b7g9

Objective(s):

LO-3. Design a solution that can help a person acclimatise in high altitude conditions and reduce the risk from altitude sickness.

Learning experiences:

The teacher may begin the lesson by posing a question: How do you think you would come up with a solution that can help a person acclimate to high altitude and reduce the risk of altitude sickness? The teacher may deliver the lesson based on the following order of science and engineering practises:

- The learner obtains information on the causes of altitude sickness from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://wb.md/3KRfPF3).
- The learner designs a solution to help a person acclimate to high altitudes and reduce the risk of altitude sickness.
- The learner makes a solution to help a person acclimate to high altitudes and reduce the risk of altitude sickness.
- The learner presents and critiques each other's designed solutions through the class presentations.

Assessment:

Use rubrics to assess the learner's information management skill, ability to comprehend information in developing a solution, ability to design and make a solution to help a person acclimate to high altitude, and ability to critique. Provide necessary feedback and intervention.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
- https://wb.md/3KRfPF3

Challenge Your Learners

Teacher may ask the following questions to challenge the thoughts of learner:

1. A person suffers punctures in his chest cavity with a broken rib cage during a car accident. However, he was lucky enough as his lungs were not damaged in the accident. How would this affect the functioning of the respiratory system?
2. A lot of megacities around the world report deaths related to air pollution in the millions. What measures do you think would help reduce such issues?
3. Gomtu, Nganglam and other industrial areas in Bhutan have reportedly higher degrees of air pollution specifically depending on the nature of the finished product. How would this affect the respiratory health of the people living in those places?
4. Why is nasal breathing considered healthier than oral breathing?
5. How does the breathing mechanism in amphibians differ from that of mammals?

1.4. Transport System in the Human Body

1.4.1. Scope: The circulatory system in organisms comprises organs and fluids (e.g., hemolymph, blood) that circulate in the body collecting and distributing substances. Circulation in lower organisms (e.g. bacteria) occurs by a simple process such as diffusion while the more evolved organisms (e.g., mammals) have heart and blood vessels.

1.4.2. Scope: The architecture of the circulatory system is similar amongst fishes, amphibians, reptiles, and mammals, comprising the heart, blood vessels, and blood. The human heart is designed to pump blood to every part of the body. It is a hollow organ having four chambers (i.e., ventricles and atria) and valves that regulate the flow of blood in a single direction. In certain conditions, one or more valves fail to open or close properly, disrupting the unidirectional flow of blood. Arteries and veins are designed to transport blood to the body and to the heart.

1.4.3. Scope: The sequence of events that take place during a heartbeat is known as the cardiac cycle. The electric impulse is generated in the Sinu-atrial node (SA node) and travels through the conducting system of the heart.

1.4.4. Scope: An electrocardiogram (ECG) is a simple test to check the heart's rhythm based on the electrical activity. The electrocardiograph detects the electrical activities of the heart during the cardiac cycle and produces its graphical representation.

1.4.5. Scope: RBCs have surface antigens that are classified by the ABO system as antigen A and antigen B. The presence or absence of these antigens has led to the grouping of blood into four different types (A, B, AB, and O). Rh antigens occur in some individuals and the presence or absence of Rh antigen is indicated in the blood group by +ve/ -ve symbols. These antigens determine the biochemical compatibility amongst individuals.

Objective(s):

LO-1. Develop a model that explains the structures and functions of the human heart.

Learning Experiences:

The teacher may inform the learner that the human heart contains several structures with specific roles. The teacher may inform the learner to obtain information on parts and functions of the human heart from relevant materials (e.g., books, online pieces, articles, etc) or web links (e.g.,https://cutt.ly/kzyPH5D) one day before the class. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on structures and functions of the human heart from relevant materials (e.g., books, online pieces, articles, etc) or web links (e.g.,https://cutt.ly/kzyPH5D).
- Based on the information gathered, the learner develops a model (e.g., conceptual, theoretical, physical, or simulation) that explains the structures and the functions of the human heart.
- The learner communicates about the structures and functions of the human heart using the model.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Describe the structures and functions of the human heart.
2. Due to developmental abnormality, the wall of the left ventricle of an infant's heart is as thin as that of the right ventricles. How would such a condition affect circulation?
3. How would improper closure of the heart valve impact the blood supply to the body?
4. What would happen to blood circulation if the semilunar valves are damaged or removed. Explain.

Assessment:

Use rubrics to assess the learner's information management skill, ability to use the developed model in explaining the working of the human heart based on the model developed. Provide necessary feedback and intervention to the learner. For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
- https://cutt.ly/kzyPH5D

Objective(s):

LO-2. Analyse the electrocardiogram (ECG) to relate to the working of the human heart.

Learning Experiences:

The teacher may inform the learner that working of the heart conditions can be examined through electrocardiogram (ECG). The teacher may show an example of electrocardiogram (ECG) to the learner. The teacher may inform the learner that the cardiac cycle is a sequence of alternating contraction and relaxation of heart chambers to pump blood throughout the body. The events of the cardiac cycle can be drawn in the form of a graph called an electrocardiogram

(ECG). The electrocardiogram (ECG) is a simple test that can be used to check your heart's rhythm and electrical activity. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on how the working of the heart is related based on electrocardiogram (ECG (from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://cutt.ly/jzyD1hI).
- The teacher may provide an ECG to the learner and ask the learner to relate with the working conditions of the heart.
- The learner analyses the working of the heart based on the electrical signals represented by the ECG.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. What are negative and positive waves in an ECG?
2. What will happen to the P wave if the atrial wall is thickened?
3. Due to an accident, the ventricles fail to repolarise. What will its possible effect be on ECG?
4. Explain how a sinoatrial (SA) node maintains the normal heartbeat?
5. How can we relate the ECG to abnormalities in the working of the human heart?

Assessment:

Use rubrics to assess the learner's information management skill, ability to interpret the working of ECG to that of the human heart, and communication skills. Provide necessary feedback and intervention to the learner. For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
- https://cutt.ly/jzyD1hI

Objective(s):

LO-3. Design a prototype to replace the faulty heart valve.

Learning Experiences:

The teacher may begin the lesson by informing the learner that dysfunction of a human heart valve can be one of the causes of human heart disorders. Can we replace the faulty valve? How can we

design a prototype valve to replace the faulty heart valve? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the dysfunction of the heart caused by faulty valves from relevant sources (e.g., books, online pieces, articles, etc.) or web links (e.g., https://bit.ly/3KVTvtD).
- Based on the information obtained on faulty hearts, the learner designs a solution (preferably a prototype) to replace the faulty heart valve.
- The learner tests the prototype designed to replace the faulty valve.
- The learner presents the working of the prototype designed to the class and critiques each other's prototype.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. How does the heart valve function?
2. Why does my valve need to be replaced? Can it be repaired instead?
3. What will be the possible consequences if a person is suffering from valve stenosis?
4. Differentiate between valve incompetence and valve stenosis.

Assessment:

Use rubrics to assess the learner's information management skill, ability to design the prototype of a heart valve and ability to critique. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
- https://bit.ly/3KVTvtD

Objective(s):

LO-4. Communicate scientific information about the ABO and Rh blood typing in the field of medicine.

Learning Experiences:

The teacher may begin the lesson by informing the learner that there are several human blood grouping systems. The teacher may talk about ABO and Rh blood grouping systems as some of the common blood grouping systems. The learner may be informed that A, B, AB, and O are four blood groups in the ABO grouping system, while in Rh positive or Rh negative are the two blood groups in Rh blood grouping system. The teacher may inform that it is important to match the blood groups during blood transfusion. The teacher may pose a question: What is blood group A, B, AB, and O in ABO blood typing? What are Rh positive and Rh negative blood groups in the Rh grouping system?. What are the possible implications if blood groups are not matched during blood transfusion? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the ABO (blood group A, B, AB, and O) and Rh blood (Rh positive and Rh negative) blood groups from relevant sources (books, articles, handouts, journal articles, etc.) or web link (e.g., https://bit.ly/32JBKfX).
- Based on the information obtained, the learner scientific explanation on the ABO (blood group A, B, AB, and O) and Rh blood (Rh positive and Rh negative) blood groups based on the presence of antigens and antibodies.
- The learner communicates scientific information on the ABO (blood group A, B, AB, and O) and Rh (Rh positive and Rh negative) blood typing based on the presence of antigens and antibodies.
- The learner explains health related complications related as a result of unmatched blood groups (ABO and Rh system).

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. What are surface antigens?
2. Explain ABO and Rh blood grouping.
3. What are the possible health related complications if blood groups are not matched during blood transfusion?
4. Some Rh blood groups of couples have serious implications to the growing embryo. Explain giving scientific reasons.
5. Lemo lost a huge amount of blood during delivery. Her husband was willing to donate his blood to her but doctors advised him to look for blood group A^+. What could be possible reasons for doctors refusing to use his blood.

Assessment:

Use rubrics to assess the learner's information management skill and ability to communicate scientific information on the ABO and Rh blood typing. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
- https://bit.ly/32JBKfX

Challenge Your Learners

Teacher may ask the following questions to challenge the thoughts of learner:

1. Why do ventricles have thicker walls than that of atria?
2. A group of class XI students conducted an experiment to determine how the circulatory system works in coordination with the respiratory system of a rat.
    a. Develop a hypothesis for the experiment.
    b. Identify dependent and independent variables.
    c. What would be the likely inferences from the experiment?
    d. Based on the experiment, name the major components of the respiratory system and circulatory system which work closely together for the functioning of the body?
3. Many countries in the world train their athletes at higher altitudes to increase their number of red blood cells per cm^3 of blood. Communicate scientific information on why having more red blood cells per cm^3 of blood is an advantage for the athlete?
4. Mr. Tashi is a biology teacher. He proposed the following hypothesis about the heart rate of a smoker and non-smokers during exercises: " there will be significant difference between the heart rate of smokers and non-smokers during the exercise". Design an investigation to test the hypothesis.

1.5. Homeostasis: The Biological Ropewalk

1.5.1. Scope: A balanced internal body environment is important for the normal functioning of the body. Our body adjusts to the changing environment (internal and external), through biological feedback mechanisms (positive and negative). In biological feedback mechanisms, the effectors either oppose or enhance the change.

1.5.2. Scope: Organisms undergo some physiological and behavioural changes to maintain body conditions (e.g., pH, osmotic concentration, body temperature, glucose level, etc.) at a balanced level. Homeotherms, through thermoregulatory mechanisms, maintain a constant body temperature in response to the changes in the external temperature.

1.5.3. Scope: Pancreas through hormone-mediated mechanisms influence certain body processes (e.g., glycogenesis, respiration, etc.,) to maintain a required level of glucose in the blood.

Objective(s):

LO-1. Construct scientific explanation on how humans maintain balance in the body's internal environment *(limited to glucose, thermoregulation, and osmoregulation).*

Learning experiences:

The teacher may introduce the lesson by informing the learner that the internal and external environment of the body changes constantly. Hence, the body needs continuous adjustment to stay at or near the set-point which is achieved by homeostasis. The teacher may pose a question: How do our body maintain blood glucose level, body temperature, and water/ion at constant range? The teacher may deliver the lesson based on the following order of science and engineering practises:

- The learner obtains information on the regulation of blood glucose, body temperature, and other homeostatic mechanisms from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://bit.ly/3KPfkLD).
- Based on the information obtained, the learner constructs an explanation giving scientific reasons to show how homeostasis is maintained by our body through the functioning of various organs to keep blood glucose level, body temperature, and water/ ion at constant range?
- The learner communicates and critiques the information presented.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. What is homeostasis?
2. How is the concentration of sugar maintained in our body? Explain.
3. Explain how our body maintains body fluid concentration.
4. How is maintaining a balance in the body temperature and pH level in mammals important for their survival?
5. How does feedback mechanism relate to the adaptive ability of an organism?

Assessment:

Use rubrics to assess the learner's information management skill, ability to construct scientific explanations on how homeostasis is maintained by our body and ability to critique. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
- https://bit.ly/3KPfkLD

Objective(s):

LO-2. Develop a solution (*nutrient solution, supplements, sports drinks, etc.,*) to help athletes regain normal state of the body's internal environment during or after workout.

Learning experiences:

The teacher may ask the learner to obtain information on commercial sports drinks, the effect of sports drinks and sports drinks as alternative drinks from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://bit.ly/3Hfp5Aw), a day before the lesson. The teacher may deliver the lesson based on the following order of science and engineering practises:

- Based on the scientific information obtained, the learner develops a solution (nutrient solution, supplements, sports drinks, etc.) to help athletes regain homeostasis during or after working out.
- The learner tests the developed solution.
- The learner presents and critiques each other's solutions developed based on scientific reasons.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Footballers prefer to eat bananas over sandwiches. Justify your answer.
2. If you were a chemist in the Agro-industry and you were assigned to make nutritional drinks for Bhutanese athletes. What nutrients would you consider having in your drinks?

Assessment:

Use rubrics to assess the learner's information management skill, ability to translate conceptual knowledge into developing the solution (nutrient solution, supplements, sports drinks, etc.) and ability to critique. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
- https://bit.ly/3Hfp5Aw

Challenge Your Learners

Teacher may ask the following questions to challenge the thoughts of the learner:

1. The liver is the effector in the regulation of blood glucose. Justify.
2. Why is it necessary for some hormones (e.g., insulin and glucagon) to work in an antagonistic manner?
3. Chimi while running a full marathon experienced heavy sweating, thirst and excretes concentrated urine. Explain how Chimmi's body functions to maintain homeostatic balance.
4. Choki was teased by his classmates for shivering in class. His biology teacher tells the class that it is normal to shiver during cold days. How does shivering help to maintain body temperature?
5. Explain the role of the pancreatic hormones in the regulation of glucose concentration.
6. A person diagnosed with kidney failure is usually characterised by swelling in his/her legs or the entire body. How would you relate the swelling to homeostatic phenomena?

1.6. Chemical Coordination

1.6.1. Scope: Growth, development, and reproduction in organisms are controlled by hormones. Hormones in plants (e.g., auxin, cytokinin, gibberellic acid, ethylene, and abscisic acid) are known as phytohormones and they influence various physiological and cellular activities in plants.

1.6.2. Scope: In animals (e.g., humans) hormones regulate various body functions, such as growth and development, metabolism, electrolyte balances, and reproduction. Hormones are secreted by endocrine glands (limited to the pituitary gland, thyroid gland, adrenal glands, and gonads) and carried by the blood to the target cell to regulate physiological processes.

1.6.3 The development of secondary sexual characters (e.g., breast development, production of ovum or sperm, growth of body hair, etc.) are influenced by reproductive hormones. Hormones influence the emotional state of a person during different stages of development.

1.6.4. Scope: Synthetic hormones are used commercially to stimulate metabolic processes associated with an increased rate and efficiency of body growth. In plants, synthetic hormones (Indole 3-acetic acid, 1-naphthaleneacetic acid) are used to control plants' growth and development.

Objective(s):

LO-1. Investigate the roles of hormones on growth, development, and reproduction in plants *(limited to auxin, cytokinin, gibberellic acid, ethylene, and abscisic acid).*

Learning Experiences:

The teacher may deliver the lesson by informing the learner that plant hormones (also known as phytohormones) are signal molecules produced within plants in extremely low concentrations. Some of the examples of phytohormones are auxin, cytokinin, gibberellic acid, ethylene and abscisic acid. The teacher may inform the learner that these hormones regulate the growth and development of plants, such as growth in height, flowering, fruiting, etc. The teacher, for instance, may inform the learner that the lateral growth of the plant is regulated by cytokinins. The teacher may pose the question: How are these hormones responsible for regulating the growth and development of a plant? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on how phytohormones, such as auxin, cytokinin, gibberellic acid, ethylene, and abscisic acid regulate the growth and development of a plant from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://cutt.ly/oIMhVCM or http://dx.doi.org/10.1007/978-1-4020-5005-3_7)
- The learner carries out an experiment to investigate the roles of phytohormones on growth and development of a plant.
- The learner analyses and interprets the data collected from the experiment.
- The learner shares the findings from the experiment on how auxin, cytokinin, gibberellic acid, ethylene and abscisic acid regulate the growth and development of a plant.
- The learner critiques each other's work.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Explain the role of auxins, cytokinins, ethylene, and abscisic acid in plant growth and reproduction. .

2. Why do the pinching tips of the house plants make them bushier?
3. Why has ethylene become commercially important to farmers? Explain.
4. Gibberellins are able to overcome dwarfism in plants. Comment.
5. It is scientifically considered that the interaction amongst the plant growth regulators leads to all the changes during the life cycle of plants. Explain the nature of interaction that leads to flowering in plants.

Assessment:

Use rubrics to assess the learner's information management skill, ability to investigate the role of phytohormones in regulating plant growth and development, communication skills, and ability to answer questions. Provide necessary feedback and intervention to the learner.

For recording and reporting, science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
- https://cutt.ly/oIMhVCM DOI: 10.1007/978-1-4020-5005-37)

Objective(s):

LO-2. Communicate scientific information on the application of synthetic hormones in enhancing agricultural productivity.

Learning experiences:

The teacher may begin the lesson by informing the learner that hormones are required for normal growth, development, and reproduction in plants. The teacher may inform the learner that their absence would cause improper growth of plants or plant parts. The learner may be informed that one can also apply synthetic plant hormones to speed up or increase the productivity of the plant. The teacher may pose questions: What are the synthetic plant hormones applied to improve agriculture productivity? How the application of phytohormones could improve agricultural productivity? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on applications of hormones in the improvement of agriculture productivity from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://doi.org/10.1080/09168451.2018.1462693).
- The learner communicates scientific information on the applications of hormones in the improvement of agriculture productivity.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Name three synthetic plant hormones applied in agriculture.
2. Do the usage of synthetic hormones for the modification of plant growth have any environmental implications?
3. How would using hormones to manipulate plant growth disturb the evolution pattern of plants?
4. A farmer grows cucumbers in his field. He wants to increase the number of female flowers in them. Which plant hormone would you suggest him apply to increase the number of female flowers?
5. 'The knowledge of plant hormones is a boon for horticulturists.' Justify to support the statement with scientific reasons.

Assessment:

Use rubrics to assess the learner's information management skills, communication skills and ability to answer questions on how the applications of hormones could improve agriculture productivity. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)
- https://doi.org/10.1080/09168451.2018.1462693

Objective(s):

LO-3. Develop a model that represents the role of hormones secreted by major endocrine glands in humans *(limited to pituitary gland, thyroid gland, adrenal glands, and gonads)*

LO-4. Construct scientific explanation that change in organisms (*e.g., human*) over time, including reproductive capacities and functions; and emotions are regulated by hormones.

Learning Experiences:

The teacher may deliver the lesson by informing the learner that the endocrine system plays a major role in the growth and development of our body. The teacher may inform the learner that

the endocrine system consists of endocrine glands, such as the pituitary gland, thyroid gland, adrenal glands, and gonads. These glands secrete hormones that influence our physiology, emotions, reproductive capacities and functions. The teacher may pose the questions. What are the biological roles of hormones secreted by major endocrine glands? The teacher may deliver the lesson based on the following order of science and engineering practises:

- The learner obtains information on the role of hormones (physiological, emotions, and reproductive capacities and functions) secreted by major endocrine glands (*pituitary gland, thyroid gland, adrenal glands, and gonads* from materials) from relevant sources (e.g., books, online pieces, articles, etc.) or web links (e.g., https://cutt.ly/3IMg1W3)
- The learner develops a model that represents the role of hormones (physiological, emotions, and reproductive capacities and functions) secreted by major endocrine glands (*pituitary gland, thyroid gland, adrenal glands, and gonads)* in humans.
- The learner constructs an explanation on the roles of hormones physiological, emotions, and reproductive capacities and functions) secreted by major endocrine glands (*pituitary gland, thyroid gland, adrenal glands, and gonads)* in humans.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Name major endocrine glands and their corresponding hormones.
2. Hormones regulate our emotions. Comment.
3. Why are hormones required in smaller quantities?
4. The physiological changes of our body, such as the onset of menses, growth of hair, production of sperm and eggs, are normal processes. Comment.
5. How would the lack or deficiency of hormones affect the body?
6. Male children, on reaching puberty, produce testosterone.
    a. Identify the part of the body responsible for the production of testosterone.
    b. List three functions of testosterone.

Assessment:

Use rubrics to assess the learner's information management skill, ability to develop a model that represents the role of hormones, ability to construct explanations on how hormones are responsible for regulating the hormonal changes in an organism, communication skill, and ability to answer questions. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
- https://cutt.ly/3IMg1W3

Objective(s):

LO-5. Communicate scientific information on the implications of using steroids on biological , psychological, social, and reproductive capacities of humans.

Learning experiences:

The teacher may begin the lesson by informing the learner that consumption of steroids are common in many parts of the world. The learner may be informed of some of the biological or short term benefits of steroids. For instance, the teacher may cite how steroid hormones, such as i-pills, have some relief and biological benefits. In contrast to this, the teacher may inform the learner that hormones and drugs produced artificially (e.g., steroids) have biological, psychological, and social impacts. The teacher may pose the question: What are the biological, psychological, and social impacts of using steroids? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains the information about the biological, psychological, and social impacts of using steroids (e.g., hormone-based pills) from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://cutt.ly/IPrUdrO).
- The learner constructs scientific explanations on the biological, psychological, and social impacts of using steroids (e.g., hormone-based pills).
- The learner shares and argues the biological, psychological, and social impacts of using steroids (e.g., hormone-based pills).

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. What are some of the areas where steroids are applied?
2. Is the use of steroids in animals or humans an ethically correct practise? Why or why not?
3. The consumption of steroids has psychological and social impacts. Explain giving scientific reasons.
4. Which between hormonal therapy and using medicine would be a better alternative for the treatment of diseases? Why?

Assessment:

Use rubrics to assess the learner's information management skill and ability to communicate the claims on the roles of hormones (steroids or extracts) in altering one's body appearances, treating health issues, including infertility; and as a contraceptive method. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)
- https://wb.md/3GirVmN,
- https://bit.ly/34lMTUx,

Challenge Your Learners

Teacher may ask the following questions to challenge the thoughts of learner:

1. Sangay experienced rapid and irregular heartbeats, increased appetite and sweating, unexplained weight loss, and swelling at the base of her neck. On examining her blood doctor advised her to start anti-thyroid medication.
    a. Identify the hormone responsible for her condition.
    b. What may be the possible cause of her condition?
2. Fruits like watermelon and pomegranate, despite having many health benefits, are not among favourites of many due to the presence of a large number of seeds. How would you as a biology student help in creating watermelon and pomegranate without seeds?
3. Pituitary gland is known as the master gland. Justify.
4. Why is abscisic acid known as a stress hormone?
5. Unripened bananas get ripened when a ripened fruit cover is placed in between them. Comment.
6. The consumption of steroids and extracts have both benefits and adverse impacts. Justify giving scientific reasons.
7. The physiological changes of our body, such as onset of menses, growth of hair, production of sperm and eggs, are hormone-mediated changes. Give reasons.

1.7. Nervous Coordination

1.7.1. Scope: The central nervous system plays an integral role in the control and coordination of bodily processes. The brain and spinal cord are designed to perform specific functions to enable an organism to adapt according to the changes in the external or internal environment.

1.7.2. Scope: The peripheral nervous system (PNS) acts as a physical link to relay information between the central nervous system, the receptors, and other organs.

1.7.3. Scope: The autonomic nervous system (ANS) contains sympathetic and parasympathetic systems that regulate body processes under different circumstances. The sympathetic system helps the body function during emergencies (fight or flight responses) while the parasympathetic system regulates body processes under normal conditions.

Objective(s):

LO-1. Communicate scientific information on the structures and functions of the central nervous system (brain and spinal cord) in humans.

Learning experiences:

The teacher may instruct the learner that the brain and spinal cord form the capital-like network called central nervous system (CNS) that coordinates the functions of the body. The teacher, for instance, may say that all stimuli received from five sense organs are coordinated, analysed, and modulated by the brain. The stimuli from the lower parts of the body are received either by the spinal cord which generates fast and instant responses or by the brain that generates the rational type of response. The teacher may inform the learner that the brain and spinal cord contain several parts that carry out special functions. The teacher may pose the question: What are the structures and functions of the brain and spinal cord? The teacher may deliver the lesson based on the following order of science and engineering practises:

- The learner obtains information on the structures and functions of the central nervous system of a human from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://bit.ly/32IQwUb). The learner may focus on different parts of the brain and spinal cord with their corresponding functions.
- Based on the information obtained, the learner communicates scientific information on the structures and functions of the human central nervous system (brain and spinal cord).
- The learner answers the questions posed.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. List different parts of the human brain and its functions.
2. How can you differentiate between the brain and spinal cord?
3. How does the central nervous system help an organism to adapt to the changes in the environment?

4. The response generated by the spinal cord is always fast and involuntary. Explain giving reasons.
5. Withdrawal of our hands from touching hot pan is an adaptive behaviour. Argue on the statement giving reasons.
6. Does having grey matter on the outer part (cortex) of the cerebrum have some sort of functional advantage for the brain?

Assessment:

Use rubrics to assess the learner's information management skill, ability to communicate and ability to answer questions on structures and functions of the central nervous system of a human.

Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)
- https://bit.ly/32IQwUb

Objective(s):

LO-2. Design a model that explains the coordination between the central nervous system visual, auditory, or tactile senses in an organism.

Learning experiences:

The teacher may begin the lesson by asking a question: How does a central nervous system coordinate with visual, auditory, or tactile senses to bring coordination in an organism? On this note, the teacher may inform the learner that vision, sound, smell, or senses detected by our body are the results of coordination between the central nervous system (brain) and sense organs. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on how the central nervous system coordinates with visual, auditory, or tactile senses to bring coordination, such as vision, smell, sense of touch from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://bit.ly/34oQly1).
- Based on the information, the learner develops a model (e.g., conceptual, theoretical, physical, or simulation) that explains how the central nervous system coordinates with

visual, auditory, or tactile senses to bring coordination, such as vision, smell, sense of touch.

- The learner explains how the central nervous system coordinates with visual, auditory, or tactile senses to bring coordination, such as vision, smell, sense of touch using the model.
- The learner critiques each other's model and provide feedback.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Explain the nervous pathway that an impulse travels during the formation of a visual image?
2. How is sound detected by our nervous system? Explain.
3. Will a sense of touch be detected by our brain? If so, how?

Assessment:

Use rubrics to assess the learner's information management skill; and the ability to relate the developed model that explains how the central nervous system coordinates with visual, auditory, or tactile senses to bring coordination, such as vision, smell, sense of touch; and the ability to critique. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)
- https://bit.ly/34oQly1

Challenge Your Learners

Teacher may ask the following questions to challenge the thoughts of learner:

1. Explain the role of the spinal cord in various situations, such as touching hot pots, hot water, fire, and touching a stinging nettle.
2. The information that comes from the brain is always late than the response that comes from the spinal cord. Give reasons.
3. Establish coordination amongst CNS and PNS in doing any body functions.
4. How are nerve cells adapted to carry out its functions?
5. Nerve cells carry messages only in the form of electrical impulses. Comment on the statement.

6. The injury to the spinal cord usually leads to paralysis to the lower part of the body. Relate the statement to the functioning of neurons.

1.8. Body's Defence System

1.8.1. Scope: Organisms have systems (immune system) and processes to protect them from pathogenic organisms and related conditions. The immune system in humans comprises the three lines of defence (i.e., first, second and third lines of defences). The first line consists of physical barriers to block the entry of pathogens. The second line of defence consists of cells and proteins of the immune system that are non-specific and work on a variety of pathogens. The third line of defence is the most effective and works to eliminate pathogens in a specific manner. The third involves the formation of antibodies which enables the organisms to have long term protection against a particular pathogen.

1.8.2. Scope: Immunity is achieved against many pathogens through vaccination. Vaccines are weakened pathogens or their body parts, which when introduced into the body of an organism, trigger an immune response. Immunisation is a process whereby a person develops immunity against a particular disease, possibly by administering a vaccine.
1.8.3. Communicable diseases are usually caused by microorganisms (e.g., viruses, bacteria, etc) and can be transmitted from one person to another through direct or indirect contacts. The risks of transmission of communicable diseases can be reduced through vaccination and following hygienic protocols.

Objective(s):

LO-1. Construct scientific explanation on how three lines of defence in humans respond to the entry of pathogens.

Learning Experiences:

The teacher may instruct the learner to obtain information on the structures and functions of the central nervous system from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://bit.ly/3IMUuuo) one day before the lesson. The teacher may deliver the lesson based on the following order of science and engineering practises:

- The learner explores the sources provided to obtain information on the three lines of defence and defensive responses in humans.
- The learner constructs scientific explanation to specify the roles of three lines of defence in carrying out defensive responses against the pathogen.

- The learner communicates how three lines of defensive response are made by the host body to the incoming pathogen to the class.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. What are the three lines of defence?
2. Why is it important to have the three different lines of defence?
3. How is specific immunity important for an organism?
4. A part of our body is usually cleansed with alcohol carrying out som medical procedure like injection, surgery, etc. Why is cleaning with alcohol necessary?
5. A person usually gets infected with tuberculosis possibly once in a lifetime however, the same person gets influenza almost every year. Justify giving scientific reasons.

Assessment:

Use rubrics to assess the learner's information management skill, ability to communicate the roles of three lines of defence in carrying out defensive responses against the pathogen and ability to answer questions. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)
- https://bit.ly/3IMUuuo

Objective(s):

LO-2. Construct scientific explanation on how vaccines help to develop immunity against infections.

Learning experiences:

The teacher may begin the lesson by informing the learner that when the normal functioning of our body system gets disturbed, people become sick and this can happen when a microorganism enters our body, and vaccines prevent the spread of diseases. The teacher may pose a question: How do vaccines help to develop immunity against infections? The teacher may deliver the lesson based on the following order of science and engineering practises:

- The learner obtains information from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://bit.ly/3rdA5Zr) that contain information on how vaccines help to develop immunity against infections.
- The learner applies what they have learned in the working of covid vaccines (e.g., Pfizer, Moderna, Covishield) against Coronavirus.
- The learner communicates and critiques a scientific explanation on how vaccines help to develop immunity against infections.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. What are vaccines?
2. How does vaccination help in attaining immunity?
3. Are there any risks associated with vaccines?

Assessment:

Use rubrics to assess the learner's information management skill, ability to communicate how vaccines help to develop immunity against infections and ability to critique. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
  - https://bit.ly/3rdA5Zr

Objective(s):

LO-3. Communicate scientific information on transmission and prevention of common communicable diseases *(limited to HIV, Hepatitis B virus, Helicobacter pylori , and coronavirus).*

Learning experiences:

The teacher may begin the lesson by informing the learner that diseases related to some microorganisms (e.g., *HIV, Hepatitis B virus, Helicobacter pylori , and coronavirus)* are spreading at an alarming rate both in Bhutan and world-wide. The teacher may inform the learner on the status of Bhutanese people living with HIV/AIDS or the recent outbreak of diseases caused by *Helicobacter pylori* in some parts of eastern Bhutan. The teacher may pose the question: How can we stay safe from microbial infections caused by HIV, Hepatitis B virus, Helicobacter pylori , and coronavirus?. The teacher may carry out the instructional practises based on the following science and engineering practises:

- The learner obtains information on the causes, symptoms, and transmission of microbial infections caused by HIV, Hepatitis B virus, *Helicobacter pylori* , and coronavirus from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://cutt.ly/SIeX6f1).
- The learner communicates scientific information on the measures to stay safe from microbial infections, such as HIV, Hepatitis B virus, *Helicobacter pylori* , and coronavirus and critiques each other's works.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. How is HIV/AIDS transmitted?
2. Mention methods to keep oneself safe from the infection of HIV.
3. Explain how *Helicobecter pylori* causes gastric ulcers?
4. With the outbreak of COVID-19 diseases in the world, doctors and scientists have come up with several health protocols to keep ourselves safe from infections. Outline some of the preventive measures of COVID-19.

Assessment:

Use rubrics to assess the learner's information management skill, communication skill and ability to answer the questions posed.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
- https://bit.ly/34lf3iw

Challenge Your Learners

Teacher may ask the following questions to challenge the thoughts of learner:

1. How do the human body defend entry of pathogens?
2. How do vaccines develop immunity of the body?
3. After a vaccination a patient develops fever and nausea. Explain the statement based on scientific judgement.
4. What are some preventive measures to stop the spread of communicable diseases?
5. Differentiate between specific and nonspecific immunity with an example each.

1.9. Transport System in Plants

1.9.1. Scope: Water potential is a measure of the concentration of free water molecules to diffuse to another area. With the increase in solute concentration in a solution, the value of water potential decreases.

1.9.2. Scope: Transpiration creates a suction pressure (transpiration pull) that aids in the upwards movement of sap in plants. The cohesive force between the water molecules maintains the continuous column of water from the root to the leaves.

1.9.3. Scope: Inflow of water into the cell creates hydrostatic pressure. When external pressure applied to a solution exceeds osmotic pressure, reverse osmosis is created. Reverse osmosis is used for the treatment of contaminated water.

Objective(s):

LO-1. Investigate to study the effect of solute concentration on water potential.

Learning Experiences:

The teacher may provide the learner with different concentrations of sucrose solutions and potato tubers. The teacher may ask the question: How does solute concentration affect water potential? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner develops a hypothesis supporting or refuting the problem statement and identifies the variables on the effect of solute concentration on water potential.
- The learner carries out the experiment to investigate the effect of solute concentration on water potential. The learner analyses and interprets the data in the form of a graph/ table and constructs an explanation to relate solute concentration to water potential.
- The learner presents the findings and critiques each other's findings.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. How does water potential change with the increase in solute concentration?
2. Why is water potential often taken as the measure of the ability of a solution to absorb water?
3. Compare water potential between 5 grams salt solution and 8 grams salt solution for equal amounts of water in both solutions.

Assessment:

Use rubrics to assess the learner's ability to investigate, analyse, interpret, and critique the effect of solute concentration on water potential. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).

Objective(s):

LO-2. Design a model that explains absorption and movement of water in plants applying the concepts of transpiration.

Learning experiences:

The teacher may begin the lesson by providing the learner with the information that absorption of water by root is related to the difference in the concentration of the cell sap and the soil water. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the absorption and movement of water by plants applying the concept of transpiration from relevant sources (books, articles, journal articles, etc.) or web link (e.g., https://bit.ly/3HgwiAk).
- Based on the data obtained, the learner develops a model(e.g., conceptual, theoretical, physical, or simulation) that illustrates absorption and movement of water by plants applying the concept of transpiration.

- The learner explains the absorption and movement of water by plants applying the concept of transpiration.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Transpiration is often referred to as a 'necessary evil'. How does that term hold true in relation to the physiological effects of transpiration?
2. How is transpiration related to the upward movement of water and minerals in plants?
3. The areas having forest coverage are found to have proper rainfall patterns. How does the concept relate to transpiration?

Assessment:

Use rubrics to assess the learner's information management skill, and the ability to relate the developed model in illustrating the absorption and movement of water by plants applying the concept of transpiration. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)
- https://bit.ly/3HgwiAk

Objective(s):

LO-3. Design a solution to purify water (*e.g., saline water*) through the application of the concepts of reverse osmosis.

Learning experiences:

The teacher may inform the learners that the seawater or brackish water can be purified by applying the principle of reverse osmosis. The teacher may ask the question: How is reverse osmosis used in treating seawater or brackish water? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on purifying water through the application of the concept of osmosis from relevant sources (books, articles, journal articles, etc.) or web links (e.g., https://bit.ly/3rc8k3n).

- Based on the data obtained, the learner designs a solution to purify water(e.g., saline water) through the application of the concept of reverse osmosis.
- The learner tests the designed solution in purifying water based on the concept of reverse osmosis.
- The learner presents the designed solution to purify water(e.g., saline water) based on the application of the concept of reverse osmosis.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. How is osmosis related to the concentration of a solution?
2. What conditions would be required for reverse osmosis to occur?
3. Does reverse osmosis occur under natural conditions?

Assessment:

Use rubrics to assess the learner's information management skill, and the ability to relate the developed solution to purify water(e.g., saline water) through the application of the concept of reverse osmosis.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)
- https://bit.ly/3rc8k3n

Challenge Your Learner

Teacher may ask the following questions to challenge the thoughts of learner:

1. Define water potential in your own words.
2. Explain the relationship between solute concentration and water potential.
3. What will happen if excessive fertilizers are added to soil?
4. Why do well watered plants transpire more rapidly during sunny and windy days than in cool and calm mornings?
5. Despite the availability of plenty of water, certain plants wilts during the day and recovers in the evening. Comment.

2. Ecosystems: Interactions, Energy and Dynamics

Ecosystems consist of complex interacting systems that include both living and nonliving things. Ecosystems contain several hierarchical structures, where groups of the same organisms form populations and communities. Individual organisms or populations live, grow, or reproduce within ecosystems. How does this happen? This happens with organisms' inherent ability to utilise resources through interdependent relationships with other organisms and the physical environment. These interactions restrain growth; enhance or limit the size of populations; or maintain the balance between resources and those who consume them. The individual organisms and ecosystems remain sustained by continuous flow of energy, originating primarily from the sun, and the recycling of matter and nutrients within systems. The ecosystems, though dynamic, often experience shifts in biotic and abiotic characteristics of the environment; population composition and abundance; and changes in the physical environment over time. These shifts in the ecosystem affects stability and resilience of the entire ecosystem.

Competencies

By the end of class XI, a learner should be able to:

a. use the understanding from interactions, energy and dynamics to explain that the ecosystem is composed of interacting physical and biological components.
b. use the understanding from the effects of pollution on the environment to design solutions to minimize anthropogenic impact on the environment and to maintain sustainable use of resources.

2.1. Organism in their Environment

2.1.1. Scope: An ecosystem consists of biotic and abiotic components that interact with each other. The biotic components (e.g., plants, animals, microorganisms, etc.) interact amongst each other and also with abiotic factors (e.g., water, soil, air, sunlight, temperature, minerals, etc.) to maintain balance in an ecosystem.

2.1.2. The diversity of organisms of an ecosystem depends on its ability to provide support for their needs. The interdependence amongst organisms through various food interactions contributes to the stability of an ecosystem. Energy and biomass transfer occurs from one trophic level to the next. The number of organisms that occupy lower trophic levels exceeds the higher levels.

2.1.3. Anthropogenic activities are increasing threats to the environment that often result in the loss of biodiversity. Biodiversity loss has several direct and indirect implications on the health of the ecosystem and also human society. Conservation of biodiversity is important to maintain the

essential ecological processes, in order to have a sustained life-supporting system and also balance in the environment.

Objective(s):

LO-1. Construct a model that explains interactions amongst biotic and abiotic components of local ecosystems.

Learning experience:

The teacher may begin the lesson by posing a question: How do biotic components interact with abiotic components in an ecosystem? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner chooses one of the local ecosystems to collect data.
- Based on the data obtained from the local ecosystem, the learner constructs a model (e.g., conceptual, theoretical, physical, or simulation) that explains how one organism interacts with another along with non-living matters in an ecosystem.
- The learner communicates and critiques each other's model.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. 'An ecosystem is a complex establishment formed as a result of intricate interactions.' Comment on the statement.
2. Weight the relative importance of the biotic and abiotic components of an ecosystem?
3. How does human interference in the ecological interactions hamper its stability?

Assessment:

Use rubrics to assess the learner's information management skill, ability to find the relationship between biotic and abiotic components in an ecosystem, communication skill, and critiquing skill.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)

Objective(s):

LO-2. Construct scientific explanation on why the population of organisms at higher trophic levels (*e.g., tiger, leopard etc.*) are lesser than the number of herbivores.

Learning experiences:

The teacher may begin the lesson by posing a question: Why organisms at the higher trophic level (e.g., tiger, leopard etc.) are less than the number of herbivores? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on why organisms at the higher trophic level (e.g., tiger, leopard etc.) are less than the number of herbivores from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://cutt.ly/LIWgeUA).
- The learner constructs a scientific explanation on why the population of organisms at higher trophic level (e.g., tiger, leopard etc.) is lesser than the number of herbivores.
- The learner concludes by giving scientific reasons on why the population of organisms at higher trophic level (e.g., tiger, leopard etc.) is lesser than the number of herbivores.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. What are trophic levels?
2. Why does the number of organisms decrease as we go up the trophic level?
3. Why is energy flow important for an ecosystem?

Assessment:

Use rubrics to assess the learner's information management skill, ability to give reason on why the population of organisms at higher trophic level (e.g., tiger, leopard etc.) is lesser than the number of herbivores and communication skill. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/LIWgeUA

Objective(s):

LO-3. Communicate scientific information on environmental, social, and economic implications of biodiversity loss.

Learning experiences:

The teacher may begin the lesson by informing the learner that biodiversity provides a functioning ecosystem to all the organisms. We value biodiversity for utilitarian as well as intrinsic values however due to various anthropogenic activities taking place, humans have been one of the major threats to biodiversity. The teacher may pose a question: What are some of the environmental, social and economic consequences caused due to biodiversity loss The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on environmental, social and economic consequences of biodiversity loss (e.g., books, online pieces, articles, etc.) or web links (e.g., https://cutt.ly/pIEcvWK).
- The learner engages to discuss various environmental, social and economic consequences of biodiversity loss.
- The learner explains various environmental, social, and economic consequences of biodiversity loss.
- The learner communicates scientific information on environmental, social, and economic consequences of biodiversity loss.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. How does the loss of biodiversity affect a community?
2. Why is it important to conserve biodiversity?
3. What are some of the common factors leading to the loss of biodiversity?

Assessment:

Use rubrics to assess the learner's information management skill, ability to explain how the loss of biodiversity poses serious consequences, and ability to communicate the points. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/pIEcvWK

Objective(s):

LO-4. Design a solution to reduce the impacts of human activities on the environment and biodiversity.

Learning experiences:

The teacher may begin the lesson by informing the learner that biodiversity is under great threat due to natural and manmade activities. For instance, oceanic oil spills have become a major environmental problem. Oil spills can harm sea creatures, ruin a day at the beach, and make seafood unsafe to eat. It takes sound science to clean up the oil, measure the impacts of pollution, and help the ocean recover. The teacher may pose a question: How can we come up with a solution in reducing such problems? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the impacts of human activities on the environment or biodiversity such as oil spill in ocean from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://cutt.ly/5OtneOe)
- The learner identifies the problem.
- The learner ideates and designs a solution to overcome or reduce the oil spill problem.
- The learner tests the designed solution.
- The learner critiques each other's designed solution based on scientific reasons.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. How does excessive use of fertilisers affect the environment?
2. To design a solution for the impacts of human activities on the environment, what aspects of the impacts must be evaluated?
3. Is the manipulation of microorganisms for use in activities (e.g., cleaning oil spillage) an ethically correct approach?

Assessment:

Use rubrics to assess the learner's information management skill, ability to design solutions to reduce impacts on the environment and biodiversity, ability to critique and ability to communicate. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)

- (https://cutt.ly/5OtneOe)

Challenge Your Learner

Teacher may ask the following questions to challenge the thoughts of learner:

1. Explain the interaction amongst biotic and abiotic factors of the ecosystem.
2. Flow of energy through various trophic levels in an ecosystem is unidirectional and non-cyclic. Explain the statement.
3. Human welfare is hidden in coexistence with biodiversity. Comment.
4. What would happen to the ecosystem if all carnivores were removed?
5. How does over exploitation of beneficial species affect biodiversity? Explain with help of one example.
6. Human activities greatly interfere with the ecosystem. Comment.

2.2. Environmental Pollution

2.2.1. Scope: Pollution is an increasing global concern. The increased human activities due to developmental progress have led to large-scale pollution. For instance, air pollution, land pollution, water pollution, etc. are some of the pressing issues that threaten the health of the environment.

2.2.2. Scope: Pollutants are the agents (e.g., elements, molecules, particles, etc.) that cause pollution. Pollutants are introduced into the environment in many ways, both by natural processes and human activities. Primary pollutants are emitted directly into the environment, while secondary pollutants are formed from primary pollutants and external factors.

Objective(s):

LO-1. Communicate scientific information on how pollutants affect the environment.

Learning experiences:

The teacher may begin the lesson by informing the learner that environmental pollution is not a new phenomenon, yet it remains the world's greatest problem facing humanity, and the leading environmental causes of morbidity and mortality. Man's activities through urbanisation, industrialization, mining, and exploration are at the forefront of global environmental pollution. The teacher may pose a question: How do pollutants affect the environment? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on how various pollutants affect the environment from relevant materials (e.g, books, online pieces, articles, etc.) or web links (e.g., https://cutt.ly/xOtTDFy).
- The learner identifies the cause and effect of various pollutants on the environment and communicates the information with the whole class.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. What are some common pollutants in your locality?
2. Pollutants are also released by some natural sources. What are some of them?
3. How do these pollutants affect your locality?

Assessment:

Use rubrics to assess the learner's ability to identify the problem, ability to analyse and interpret data in explaining how the pollutants affect the environment. Provide necessary feedback and intervention to the learners.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/xOtTDFy

Objective(s):

LO-2. Investigate how human activities in your locality contribute to pollution.

Learning experiences:

The teacher may instruct the learner to obtain information on how human activities lead to pollution from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://cutt.ly/vIUsoMk). The teacher may also pose a question: What are some of the human activities that lead to pollution in your locality? What could be the reason for such pollution? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner predicts some of the causes of air, water, land and soil pollution in their locality.

- The learner observes the consequences that have resulted from different pollution.
- The learner explains how human activities in the locality might have contributed to various pollution.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. How are human activities around you associated with various forms of pollution that exist in your locality?
2. Identify some efforts that are in place in your locality to reduce pollution.
3. A lot of places prohibit the washing of cars near streams and rivers. What are some long term benefits of such action?

Assessment:

Use rubrics to assess the learner's information management skill, ability to predict, observe and explain on how human activities might have led to various pollution. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
- https://cutt.ly/vIUsoMk

Objective(s):

LO-3. Design a solution to treat effluents and sewerage before being discharged into water bodies.

Learning Experiences:

The teacher may have the learner tour the locality to gather information on any bad drainage system or sewerage system, a day before the class. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner analyses the situation and identifies the problem.
- The learner designs a solution to treat (removal of impurities or foul smell) drain water, waste, or sewage water that is discharged into freshwater streams.

- The learner shares the solution and critiques each other's solutions based on the feedback provided.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Why is discharging untreated wastewater or sewage into the water bodies, not a wise move?
2. What are some challenges associated with the treatment of effluents and sewerage in your locality?
3. What are some common harmful components of effluents and sewage which are a threat to the environment?

Assessment:

Use rubrics to assess the learner's ability to identify the problem, ability to design a solution to treat drain water, waste, or sewage water, critiquing and presentation skills. Provide necessary feedback and intervention to the learners.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).

Challenge Your Learners

Teacher may ask the following questions to challenge the thoughts of learner:

1. What are some common pollutants in your locality which impede the health of the ecosystem?
2. How does the simple act of throwing garbage affect the environment?
3. Water pollution is the contamination of water bodies (e.g. lakes, rivers, oceans, aquifers, and groundwater), very often by human activities. How can you control water pollution?
4. How does the use of fertilisers and pesticides affect the environment?

2.3. Invasive Species: The Threat to Biodiversity

2.3.1. Scope: Invasive species pose major threats to biodiversity. The invasive species (e.g, Ageratina adenophora, Mikania micrantha, Cuscuta campestris, invasive carp, etc.) have prolific growing habits out-competing native species and could lead to ecological disturbance.

2.3.2. Scope: Invasive species hamper crop yield as they compete with the crops for nutrients and space. Some invasive species (e.g., Parthenium sp.) are known to be hazardous to human health.

2.3.3. Scope: The contamination by exotic genes to a population is a serious concern. The breeding between closely related species results in the production of hybrids that usually dominate the ecosystem. Implementation of strategies to minimise the risk and consequences of genetic pollution is important for the sustainability of native species.

Objective(s):

LO-1 Construct scientific explanation on how the introduction of exotic species leads to ecological and economic implications.

Learning Experiences:

The teacher may inform the learner that Bhutan is grappling with issues caused by certain extotic species, such as *Eupatorium* spp., *Lantana camara*, etc. The teacher may inform the learners that invasion by exotic species has several implications, including ecological and economical implications. The teacher may provide relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g.,https://cutt.ly/xU6nOsQ) on the impacts of exotic species a day before the lesson. The teacher may pose a question: How does introduction of exotic species lead to ecological and economic implications?

- The learner obtains information on the ecological and economical impacts of exotic species (*Eupatorium* spp., *Lantana camara*, etc.) from relevant sources (e.g., books, online pieces, articles, etc.) or web links (e.g., https://cutt.ly/xU6nOsQ).
- The learner constructs a scientific explanation on the ecological and economic implications of exotic species (*Eupatorium* spp., *Lantana camara*, etc.).
- The learner argues on the statement "introduction of exotic species often impacts the native species" with scientific reasons.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. 'Every organism living in an ecosystem plays an important role that contributes to the stability of the ecosystem.' How does the introduction of exotic species impact the roles as stated by the statement?
2. 'Introduction of exotic species are often considered as threats to the native species.' Comment on the statement.

3. What are some of the common invasive species in Bhutan, which are considered to have potential of greater environmental concern?

Assessment:

Use rubrics to assess the learner's information management skill, ability to interpret and explain how the invasive species render impacts upon local communities or native species, and ability to answer questions. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
- https://cutt.ly/xIEWk5h
- https://cutt.ly/TIUdofo

Objective(s):

LO-2. Design a solution to mitigate the spread of invasive species in the locality.

Learning Experiences:

The teacher may introduce the lesson by informing the learner that invasive species can harm the environment, the economy, or even human health. As an example, the teacher may cite how *Ageratina adenophora*, *Mikania micrantha,* etc., have become common in Bhutan and other parts of the world. The teacher may also pose a question: How can you think of mitigating the spread of invasive species (e.g., *Ageratina adenophora*, *Mikania micrantha,* etc.) in your locality? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on how to mitigate the spread of invasive species in your locality from relevant materials (e.g, books, online pieces, articles, etc.) or web links (e.g., https://cutt.ly/8ITrAdd).
- The learner designs a solution to mitigate the spread of invasive species based on the information gathered.
- The learner presents each other's designed solution and critique ideas.
- The learner refine and make changes to the designed solution based on comments and feedback. The learner may test the designed solution.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. What are some measures in place in Bhutan to control the introduction of exotic species?
2. Is it wise to wipe out the population of exotic species from Bhutan? Comment.
3. Is it wise to introduce exotic species? If not, why?

Assessment:

Use rubrics to assess learners' information management skills and relate the developed solution to mitigate the spread of invasive species and evaluate skills.

Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/8ITrAdd

Challenge Your Learners

Teacher may ask the following questions to challenge the thoughts of learner:

1. What is meant by invasive species?
2. How are invasive species a threat to biodiversity?
3. What are some common invasive species in Bhutan?
4. Select one local invasive species and explain its impact in the ecosystem.
5. How can you control the spread of invasive species in the ecosystem?

3. Heredity: Inheritance and Variation of Traits

Did you ever wonder why offspring from same parents are alike but not identical? This is influenced largely by characteristics or traits that are passed from one generation to the next via genes. Genes encode the information for making specific proteins, which are responsible for the specific traits of an individual. Each gene can have several variants, called alleles, which code for different variants of the trait in question. Genes reside in a cell's chromosomes, each of which contains many genes. Every cell of any individual organism contains an identical set of chromosomes. In species that reproduce sexually, each cell contains two variants of each chromosome, one inherited from each parent. Thus, sexual reproduction gives rise to a new combination of chromosome pairs with variations between parent and offspring. Very rarely, mutations also cause variations, which may be harmful, neutral, or occasionally advantageous for an individual. Environmental, as well as genetic variation and the relative dominance of each of the genes in a pair, play an important role in how traits develop within an individual. Complex relationships between genes and interactions of genes with the environment determine how an organism will develop and function.

Competencies

By the end of class XI, a learner should be able to:

a. apply the understanding of body cell division and sex cell division to explain that growth, repair, reproduction and development of organisms are the result of mitosis and meiosis; and anybody cell contains the same genetic composition while the sex cell contains different genetic information.
b. use the understanding of patterns of inheritance to explain that each individual offspring receives half of the genes from each parent and either of the genes received from parents, express and mask the expression of the other gene.
c. apply the understanding of the concept of inheritance and variation to explain why individuals of the same species vary in how they look, function, and behave based on the context of genetic inheritance, environmental factors and DNA technologies.

3.1. DNA Replication

3.1.1. Scope: Prior to cell division (i.e., during interphase), a DNA molecule undergoes replication producing two identical DNA molecules. This helps in maintaining the same genetic composition in all the somatic cells of an organism. DNA replication is a semiconservative process regulated by a group of enzymes and has a high degree of accuracy.

Objective(s):

LO-1. Design a model that provides a scientific explanation on the events of DNA replication.

Learning Experiences:

The teacher may begin the lesson by setting the context saying that DNA, or deoxyribonucleic acid, is the hereditary material in almost all other organisms, including humans. It is essential for the continuity of life as it contains information needed to make functional molecules called proteins. The double-stranded DNA molecule is copied to produce two identical DNA molecules by the process called DNA replication. The teacher may pose a question: How does a DNA molecule replicate? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on how the DNA replication process takes place from the relevant materials (e.g., books, online pieces, articles, etc.). or the web links (e.g., https://bit.ly/3G8xx3f).
- Based on the scientific information obtained, the learner designs a model (e.g., conceptual, theoretical, physical, or simulation) that explains how the DNA replication process takes place.
- The learner communicates and critiques each other's model.

Questions:

The teacher may ask the following questions to assess the understanding of the learner:

1. How does the structure of DNA provide for the process of replication?
2. Why is DNA replication important?
3. Why is the formation of Okazaki fragments during DNA replication necessary?

Assessment:

Use rubrics to assess the learner's information management skill, comprehensiveness of the model, ability to use the developed model in explaining how the DNA molecule gets replicated, communication skill, and critiquing skill.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)
- https://bit.ly/3G8xx3f

Challenge Your Learners

Teacher may ask the following questions to challenge the thoughts of learner:

1. Discuss how a semi-conservative mechanism minimises errors in DNA replication.
2. How is the semiconservative nature of DNA replication important for genetic stability?
3. How similar or different are the mechanisms of DNA replication between prokaryotes and eukaryotes?

3.2. Growth, Development, and Reproduction

3.2.1. Scope: Growth, development, and reproduction in organisms occur as a result of cell division. Cell division involves several stages marked by a series of changes in chromosomal and centriolar behaviours. Cell division helps in maintaining stability in genetic information.

3.2.2 Scope: During mitosis, a cell(mother) divides to produce two identical daughter cells. The daughter cells have the same genetic composition as each other and also with the mother cell. Mitosis leads to growth and repairment in organisms.

3.2.3 Scope: During meiosis, a cell(mother) divides to produce four daughter cells. There is a reduction in the number of chromosomes to half as compared to the mother. The genetic composition of each daughter cell is different. Meiosis occurs in some animals (e.g. humans) to produce gametes (sperm and egg) that help in sexual reproduction.

3.2.4. During meiosis, crossing over occurs between non-sister chromatids of the homologous chromosomes whereby genes are exchanged resulting in new combinations (recombinations) of genes.

Objective(s):

LO-1. Develop a model that explains the production of body cells (somatic cells) by mitotic division and sex cells (*gametes*) by meiotic division.

Learning Experiences:

The teacher may begin the lesson by informing the learner that body cells divide repeatedly to produce new daughter cells. The teacher may inform that without such a division of the body cells, the processes such as growth, differentiation, repair, and replacement would not not be possible. The teacher may ask the learner if he or she has noticed how the wounded parts of our body are healed after some time. The teacher may inform this division of body cells as mitotic division. The learner may be informed that during mitotic division, our skin cells divide again and again to produce many new skin cells. Then the teacher may pose questions: How do you think this occurs? Would the new skin cells and the original skin cell contain the same or different genetic

information? Why? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information to explore how a skin cell divides to produce many new skin cells through mitotic division from the relevant materials (e.g., books, online pieces, articles, etc.). or the web links (e.g., https://bit.ly/3gc7BZW).
- The learner develops a model (conceptual, theoretical, physical or simulation) to show the behaviour of chromosomes, centrioles and nuclear membrane. The learner may use digital software or any other programming language.
- The learner constructs an explanation on how skin cells are produced through mitotic division using the developed model.
- The learner identifies where, in the body apart from skin cells, this type of cell division takes place. Will the cells from different parts of the body have the same genetic information? Whether or not such cell division also occurs in plants.
- The learner presents and evaluates each other's work on how skin cells are produced through mitotic division.

Questions:

The teacher may ask the following questions to assess the understanding of the learner:

1. Where in the body does mitosis take place?
2. Explain the behaviour of chromosomes and centrioles during metaphase and anaphase.
3. The nature of genetic information remains the same in mitotic division. Why?
4. Mention the significance of mitotic division.

Assessment:

Use rubrics to assess the information management skill, comprehensiveness of model, ability to relate the information obtained on how body cells are produced through mitotic division, and ability to evaluate each other's work. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer to science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)
- https://bit.ly/3gc7BZW

LO-1. Develop a model that explains the production of body/somatic cells by mitotic division and sex cells (*gametes*) by meiotic division.

Learning Experiences:

The teacher may inform the learner that like mitosis, some body cells, such as sperms and eggs also undergo a similar type of cell division. Teacher may inform the leaner that without the division of the sex cells, it would be impossible to mantain the continuity of life, induce variation in the population, or maintain same number of chromosomes generation after generation. The learner may be informed of this division as meiosis or meiotic division. The teacher may inform the learner that the sex cells (sperm in testes and egg in the ovary)zaqgtf divide again and again to produce many new sex cells through meiotic division. The teacher may pose questions: How do you think this occurs? Would the new sex cells and the original sex cell contain the same or different genetic information? Why? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the processes of meiotic division from relevant sources (e.g., books, online pieces, articles, etc.) or web links (e.g.,https://cutt.ly/7IeP1hl).
- The learner develops a model (conceptual, theoretical, physical or simulation) to show how sex cells (sperms and eggs) are produced through meiotic division.
- The learner constructs an explanation on how sex cells (sperms and eggs) are produced through meiotic division using the developed model.
- The learner identifies where, in the plant, this type of cell division takes place.
- The learner presents and evaluates each other's model.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Where in the body does meiotic division take place in animals.
2. Would meiotic division take place in a plant? If yes, name the site.
3. What happens to the nature of genetic information during meiotic division? Why?
4. Would daughter cells in meiotic division have the same genetic composition? Why?
5. Mention the significance of meiotic cell division.

Assessment:

Use rubrics to assess a learner's information management skill, ability to develop a model that explains the production of sex cells through meiotic division, ability to explain the process of meiosis, and ability to evaluate or critique each others' work. Provide necessary feedback and intervention if needed.

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)

- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/7IeP1hl

Objective(s):

LO-2. Construct scientific explanations on why cells from different body parts of an organism contain the same genetic composition.

Learning Experiences:

The teacher may begin the lesson by informing the learner that the body cells have the same genetic composition. The teacher may inform that a cell from the nose would have the same genetic composition of a cell from the liver. The teacher may pose a question: Why do you think that the body cells have the same genetic composition?. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on why body cells have the same genetic composition from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://cutt.ly/FIYAo7A).
- The learner constructs the information on why body cells have the same genetic composition.
- The learner shares and argues to support or refute the idea on why body cells have the same genetic composition.
- The learner answers the questions posed.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. If you could take one of your skin cells and one of your nerve cells, would the genetic information in them be the same or different? Support your answer with reason(s).
2. If you could take one of Pema's skin cells and one of Pema's sperm cells, would the genetic information in them be the same or different? Support your answer with reason(s).
3. If you could take one of your skin cells and one of Pema's skin cells, would the genetic information in them be the same or different? Support your answer with reason(s).

Assessment:

Use rubrics to assess the learner's information management skill, ability to defend the claim on why body cells have the same genetic composition, and ability to answer the questions. Provide necessary feedback and intervention to the learner.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/FIYAo7A

Objective(s):

LO -3. Construct scientific explanations on why individuals, including siblings, differ from one another.

Learning Experiences:

The teacher may begin the lesson by asking the question: Did you ever think why siblings differ one to another? The teacher may inform the learner that siblings from the same parents may look alike to a certain degree but would never look the same or identical. On this note, the teacher may inform about identical twins as an exception. The teacher may ask the question: Why do siblings differ one to another? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on why individual offspring differ from one to another from the relevant materials (e.g., books, online pieces, articles, etc.) or the web links (e.g., https://bit.ly/3Gi44nk).
- The learner constructs an explanation on why individuals, including siblings, differ from one another.
- The learner shares why individuals, including siblings, differ from one another.

Questions

The teacher may ask the following questions to assess the understanding of learner:

1. Why do individual offspring differ from each other? Explain.
2. Variation between individual offsprings is related to meiotic division. Comment.
3. If you could take two of Pema's sperm cells, would the genetic information in them be the same or different? Support your answer with reason(s).

Assessment:

Use rubrics to assess the information management skill, ability to construct an explanation on why siblings differ from each other, and ability to answer questions. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)
- https://bit.ly/3Gi44nk

Challenge Your Learners

Teacher may ask the following questions to challenge the thoughts of learner:

1. If you take one cell from your toe and one cell from your arm, will they have the same or different genetic information? Support your answer with reason(s).
2. Explain why the daughter cells produced during mitosis contain the same genetic composition.
3. Would Dawa's two sperm cells contain the same genetic material? Comment.
4. Nima and Dawa are dizygotic twins, would they have the same or different genetic information? Give scientific reason(s).
5. Why does one look similar to both parents but not the same to either?

3.3 Inheritance of Characters

3.3.1. Scope: Gene is the unit of heredity. The transmission of genes to offspring is the basis of the inheritance of phenotypic traits (e.g., height, eye colour, hair colour, skin colour, hair quality, etc.). In sexually reproducing organisms, offspring receives half of the chromosomes from each of their parents. The chromosomes pair up to form homologous pairs. The alternative form of genes present in each chromosome of a homologous chromosome is known as alleles. Each allele expresses protein and the dominant allele masks the effect of the recessive allele.

3.3.2. Scope: The mechanism of inheritance of traits is explained by Mendel's laws of inheritance. The Punnett square is a table in which all of the possible outcomes for a genetic cross between two individuals with known genotypes are given.

3.3.3. Scope: There are certain conditions (blending inheritance, codominance) in which inheritance of characters is not in the way as explained by Mendel's laws of inheritance. These conditions lead to the appearance of unique traits which were not visible in parents and their inheritance show deviation from Mendel's law of inheritance.

3.3.4. Scope: Sex chromosomes contain a huge number of genes directly linked to physical traits. Abnormalities in these genes are found to cause certain diseases that pass down the family line.

Objective(s):

LO-1. Develop a model that explains the mechanism of inheritance of characters in humans, based on the concept of expression of alleles.

Learning Experiences:

The teacher may begin the lesson by informing the learner that body characters, such as height, tongue rolling, colour of eyes, the shape of ear lobes, etc., are inherited from parents to offspring. Teachers may inform that the offspring, oftentimes, do not exhibit the characteristics of a father or mother or both. For instance, a tongue roller father may not have sons or daughters with the same ability to roll their tongue. The teacher may pose a question: How does this happen? How do we inherit characters (eg., height, tongue rolling, colour of eyes, shape of earlobes, etc.) from our parents? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the mechanism of inheritance of characters in humans from relevant sources (e.g., books, online pieces, articles, etc.) or the web links (e.g., https://bit.ly/3AHeCeI).
- Based on the information obtained, the learner develops a model that expresses how characters (e.g., height, eye colour, the shape of ear lobes, etc.) are inherited based on the concept of expression of alleles. The learner may use Punnett square and probability statements.
- The learner explains how the inheritance of characters (e.g., height, eye colour, the shape of ear lobes, etc.) are based on the expression of alleles using a model.
- The learner critiques and provides feedback on each other's work.

Questions:

The teacher may ask the following questions to assess the understanding of learner:

1. Explain how characters, such as height, tongue rolling, earlobe, and eye colour are inherited.
2. Why is it such that a son would be a non-tongue roller even if parents are tongue roller?
3. It is visible that we possess certain features similar to father and some to mother? Explain with reasons.
4. A homozygous freckled man marries a non-freckled woman. If freckles are dominant, will their children have freckles? Explain your answer.
5. Can a child have blood group O, if his/her parents have blood group 'A' and 'B'. Explain?
6. Red-green colorblindness is a common inherited trait in humans. About 1 in 10 men have some form of colour blindness, however, very few women are colour blind. Why?

Assessment:

Use rubrics to assess the information management skill, comprehensiveness of the model, the ability to relate the information obtained on how the inheritance of characters (e.g., height, eye colour, the shape of ear lobes, etc.) based on the expression of alleles, presentation skill, and ability to evaluate each others' works. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)
- https://bit.ly/3AHeCeI

Objective(s):

LO-2. Develop a model that explains the patterns of inheritance of traits *(*e.g., *height, sex-linked diseases,* etc.) based on Mendel's laws of inheritance using Punnet squares and probability statements.

Learning Experiences:

The teacher may begin the lesson by informing the learner that body characteristics, such as height, tongue rolling, colour blindness, haemophilia, etc., are inherited from parents to offspring. The teacher may inform that the inheritance of these characters can be explained by Mendel's laws of inheritance using Punnett square and probability statements. Teachers may inform that the offspring, oftentimes, do not exhibit the characteristics of a father or mother or both. For instance, a tongue roller father may not have sons or daughters with the same ability to roll their tongue. A colour blind woman may not have colour blind sons and daughters. The teacher may pose a question: How do these happen? How do we inherit characters (e.g., height, tongue rolling, colour blind, etc.,) from our parents? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the inheritance of body characters, such as height, tongue rolling, colour blindness, haemophilia, etc., from the relevant materials (e.g., books, online pieces, articles, etc.). or the web links (e.g., https://bit.ly/3AHeCeI).
- Based on the information obtained, the learner develops a model (e.g., conceptual, theoretical, physical, or simulation) to represent the patterns of inheritance of certain traits (e.g., height, sex-linked diseases, etc). The learner may represent a model using Punnett squares and probability statements.

- The learner constructs an explanation on how certain traits are inherited from parents to offspring based on the model using Punnett squares and probability statements.
- The learner critiques each other's models.

Questions:

The teacher may ask the following questions to assess the understanding of learners:

1. How is haemophilia inherited from parents to offspring? Explain.
2. Construct a Punnett square to predict the correct phenotypic and genotypic ratio of the offspring in a cross between a dwarf pea plant (homozygous recessive) and a tall pea plant (heterozygous).
3. A couple planning a family hopes to eventually have three children. What is the probability that the couple will have three daughters? Justify your claim with reasoning.
4. The most common form of haemophilia affects 1 out of every 5,000 male births worldwide, but the condition is much rarer in females. Why is this the case?

Assessment:

Use rubrics to assess the information management skill, the comprehensiveness of the model, and their ability to construct an explanation on the patterns of inheritance of certain traits based on Mendel's laws of inheritance using Punnett square and probability statements. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer to the science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
- https://bit.ly/3AHeCeI
- https://bit.ly/3KYB87k

Objective(s):

LO-3. Argument with scientific reasons that blending inheritance and codominance deviate from Mendel's laws of inheritance.

Learning Experiences:

The teacher may begin the lesson by showing some examples of blending inheritance and codominance seen in animals and plants (pictorial). The teacher may inform the learner that not every character is inherited based on Mendel's laws of inheritance. To set the context, the teacher may talk about the cross between red and white flowers that give pink flowers. The learner may be informed that the deviations from Mendelism are seen in blending inheritance and codominance. The teacher may pose the question: How are blending inheritance and codominance deviation from Mendel's laws of inheritance?. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the blending inheritance and codominance from the relevant materials (e.g., books, online pieces, articles, etc.) or the web links (e.g., https://bit.ly/3AHeCeI).
- The learner constructs scientific explanations on how blending inheritance and codominance deviates from Mendelism with scientific reasons.
- The learner engages in an argument with scientific reasons.

Questions:

The teacher may ask the following questions to assess the understanding of the learner:

1. What is incomplete dominance?
2. What are some possible factors that result in blending inheritance?
3. How is codominance different from Mendel's idea of inheritance?
4. If you cross a white flower with black flower, what would be the colour of a flower in the first filial generation? Explain with reasons.

Assessment:

Use rubrics to assess the information management skill, their ability to construct an explanation on the patterns of inheritance of certain traits based on Mendel's laws of inheritance using Punnett square and probability statements, and their ability to refute and defend their claims. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).

- https://bit.ly/3AHeCeI

Challenge Your Learners

Teacher may ask the following questions to challenge the thoughts of learner:

1. The trait for widow's peak can be considered a monoallelic dominant trait in humans. If a man with a widow's peak and a woman with a straight hairline have a child together, what is the probability that the child will inherit the widow's peak if you know that the father's mother had a straight hairline?
2. If you cross a white flower with black flower, what would be the colour of a flower in the first filial generation? Explain with reasons
3. How do phenomena such as incomplete dominance, codominance, recessive lethals, multiple alleles, and sex linkage explain deviations from Mendel's model of inheritance?
4. Down's syndrome is a condition caused by chromosomal disorder. Why is it that the chances of having a child with Down's syndrome increases with the ageing of a mother?

3.4. Gene Cloning and Genetic Engineering

3.4.1. Scope: It is now possible to make clones or exact genetic copies of organisms. Cloning involves the multiplication of organisms to produce offspring with the same genetic makeup. Naturally, it occurs through asexual reproduction while the artificial process involves multiplying genes and also organisms. As animals are multiplied with the same genetic composition by cloning, plants are multiplied by tissue culture techniques.

3.4.2. Scope: The application of animal cloning (limited to the use of embryonic cells to clone animals) has gained widespread scepticism from moral, ethical, religious, cultural, and societal values, in association with the use or destruction of embryonic cells for stem cells research.

3.4.3. Scope: Genetic engineering is a technique carried out to manipulate the genetic makeup of the organism through the application of Recombinant DNA technology.
Enzymes are employed as major tools for the manipulation of genes. GMOs are produced for their widespread applications in agriculture, medicine, and controlling environmental pollution.

3.4.4. Scope: The application of GMOs has a lot of societal, bioethical, and moral issues.

Objective(s):

LO-1. Develop a model that provides scientific explanations on cloning by somatic cell nuclear transfer and embryo splitting techniques.

LO-2. Argue with scientific reasons on why cloning is against bio-ethical, moral, religious, and social values.

Learning Experiences:

The teacher may introduce the lesson with short background information on cloning. The teacher may inform the learner that cloning is one of recent marvels or wonders of biotechnology. On this note, the teacher may inform the learner on the first cloned mammal, the Dolly. To gain the learner's attention further or to spark the curiosity, the teacher may also set the context by saying it's possible to clone every individual using just an empty cell from a hair, tear, nail, etc. The teacher may then pose a question: How is cloning carried out based on somatic cell nuclear transfer technique and embryo splitting technique ? Is it ethically right to clone organisms? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on cloning techniques (somatic cell nuclear transfer technique and embryo splitting technique) and their moral and ethical considerations from relevant sources (books, articles, handouts, journal articles, etc.) or the web links (e.g., https://cutt.ly/EzvXzxq, https://cutt.ly/GzvXbBA).
- Based on the information, the learner develops a model (e.g., conceptual, theoretical, physical, or simulation) that explains how cloning is carried out based on the somatic cell nuclear transfer technique and embryo splitting techniques.
- The learner develops a claim with scientific reasons on moral, ethical, religious, cultural, and social issues of cloning.
- The learner argues based on their claims to refute or support why cloning, especially related to the use of embryonic cells to clone animals, is carried out and is against moral, ethical, religious, cultural, and social values.

Questions:

The teacher may ask the following questions to assess the understanding of the learner:

1. Outline the procedures of cloning carried out based on the somatic cell nuclear transfer technique and embryo splitting technique.
2. Can we bring back extinct animals, like dinosaurs and woolly mammoths based on cloning? Comment.
3. Some of the critically endangered animals or plants can be saved through cloning. Comment.
4. What are some potential applications of cloning to improve living conditions?
5. “Cloning deprives the clone of the right to be a genetically unique individual. It impairs the uniqueness of the individual, and is intrinsically immoral”. Justify with scientific reasons?
6. Is cloning biologically, ethically, socially, and morally right? Comment.

7. What would be the scenario in society if cloning is allowed in humans? Comment.

Assessment:

Use rubrics to assess the learner's information management skill, ability to relate the developed model in explaining somatic cell nuclear transfer and embryo splitting technique, ability to provide the reason why cloning, especially related to the use of embryonic cells to clone animals, is against moral, ethical, religious, cultural and social values, and arguing skill. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
- https://cutt.ly/EzvXzxq
- https://cutt.ly/GzvXbBA

Objective(s):

LO-3. Develop a model that provides scientific explanations on the process of genetic engineering.

LO-4. Construct arguments with scientific reasons on how genetic engineering and production of GMOs are against biological, societal, ethical, and moral values.

Learning Experiences:

The teacher may inform the learner that genetic engineering is one of the wonders of science and technology. With genetic engineering, it is possible to manipulate one's genetic makeup and incorporate foriengn DNA or genes. The teacher may cite some examples of GMOs common in Bhutan and worldwide to gain the learner's attention or to spark curiosity in the learner. The teacher may also inform that like cloning, genetic engineering is also associated with controversies, such as biological, ethical, social, and religious concerns. The teacher may ask the questions: How is genetic engineering carried out? What are biological, social, ethical issues of genetic engineering? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on how genetic engineering is carried out from relevant materials (e.g., books, online pieces, articles, etc.) or the web links (e.g., https://cutt.ly/fIUeNQf).
- The learner also gathers information on how genetic engineering is associated with certain controversies, suc as moral, ethical, and social issues from the relevant materials (e.g., books, online pieces, articles, etc.) or the web links (e.g., https://cutt.ly/fIUeNQf).
- Based on the information obtained, the learner develops a model to show how the genetic engineering is being carried out.
- The learner displays the model that explains the processes involved in genetic engineering.
- The learner constructs arguments on how the production of GMOs and other aspects are surrounded by controversies, such as societal, bioethics and moral issues.

Questions:

The teacher may ask the following questions to assess the understanding of learner:

1. Explain genetic engineering?
2. How is genetic engineering carried out? Explain.
3. What are some of the benefits of genetic engineering?
4. What are some of the arising risks posed by application of GMO besides ethical concerns?
5. While creating genetically modified organisms, genetic barriers are not respected. How can this be dangerous in the long run?
6. Are GMOs allowed to be imported in Bhutan? Comment.

Assessment:

Use rubrics to assess the learner's information management skill, ability to relate the developed model in explaining how the genetic makeup of an organism is manipulated to produce a genetically modified organism, ability to defend or refute their claims on how the production of GMOs and other aspects are mired with societal, bioethics and moral issues. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer to science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).

- https://cutt.ly/fIUeNQf

Challenge Your Learners

Teacher may ask the following questions to challenge the thoughts of learner:

1. Explain with reasons how genetically modified plants can reduce usage of chemical pesticides and enhance nutritional value of the food crops.
2. How is genetically modified organisms (GMO) different from hybrids?
3. Cloning can be used to quickly replicate crops that have advantageous genes, such as greater disease resistances or greater fruit production. However, cloning also produces crops that have little genetic variation. Discuss the advantages and disadvantages of using clones as human food sources in an era where the Earth is undergoing a period of climate change. How well will cloned populations of crops be able to adapt to climate change?
4. Can we bring back extinct animals, like dinosaurs and woolly mammoths based on cloning? Comment.
5. Some of the critically endangered animals or plants can be saved through cloning. Comment.
6. Cloning and genetic engineering are biologically, ethically, socially and religiously not right. Comment.
7. Are GMOs allowed to be imported in Bhutan? Comment.
8. What would be the scenario in society if cloning is allowed in humans? Comment.

3.5. Variation of Traits

3.5.1. Scope: Differences that exist within an individual or amongst individuals of the same species. For instance, leaves borne from the same plant at the same time may not be the same. A person's right hand may not be alike with that of a left hand. Moreover, a person's thumb digit may not be identical to the thumb digit of another person. These differences are called variations. Variations are caused either by genetic differences (genotypic variation) or by the effect of environmental factors on the expression of the genetic potentials (phenotypic variation).

3.5.2. Scope: Variations are caused by various environmental factors (e.g., nutrient, light, water, etc.) or genetic factors (e.g., random mating, random fertilisation, recombination of genes, mutation, etc.)

Objective(s):

LO-1. Construct scientific explanations on why variation occurs within an organism or amongst the organisms of the same species.

Learning Experiences:

The teacher may inform the learner that structures within an organism may vary from one structure to another. The teacher, for instance, may show how the index finger of a left hand varies from the index finger of a right hand in terms of handling ability, texture, etc. The teacher may also inform that such variations also exist within the leaves of a plant. The learner may also be informed that structures, such as the thumb digit, index finger, earlobe, etc., differ from one person to another. The teacher may ask the questions: Why do leaves vary within the plant? Why do leaves of two plants of the same species vary from one to another? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner gathers information on why structures within an organism or amongst the organism vary from one to another from relevant materials (e.g., books, online pieces, articles, etc.) or weblinks (e.g., https://cutt.ly/GIe58W6).
- The learner investigates structural differences amongst the leaves born on the same plant or amongst the leaves of the two or more plants of the same species.
- The learner justifies why leaves of a single plant or amongst the leaves of two or more plants of the same species differ one to another.
- The learner constructs scientific explanations on why variations occur amongst the leaves of a single plant or amongst the leaves of the two or more plants of the same species.

Questions:

The teacher may ask the following questions to assess the understanding of learner:

1. What are the causes of variation?
2. Classify the following variations as either caused entirely by genetic effects or caused by a combination of genetic and environmental effects.
   (obesity, eye colour, tallness, ability to sing, maleness, masculinity, blood group, natural hair colour; sickle-cell anaemia, agility)
3. Explain why siblings from the same family show differences in their eye colour, nature of ear lobe, skin colour, height and weight?
4. People living in the arctic are shorter and wider compared to tall and slender people in tropical regions. How would you explain these variations of traits?

Assessment:

Use rubrics to assess the learner's information management skill, ability to explain why variation exists amongst individuals, and communication skill. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/GIe58W6

Challenge Your Learners

Teacher may ask the following questions to challenge the thoughts of learner:

1. What is variation?
2. Is it possible to find variation within an organism? If yes, give two examples.
3. Why do structures within an organism differ one to another?
4. Classify the following variations as either caused entirely by genetic effects or caused by a combination of genetic and environmental effects.
   (obesity, eye colour, tallness, ability to sing, maleness, masculinity, blood group, natural hair colour; sickle-cell anaemia, agility).

4. Biological Evolution: Unity and Diversity

Biological evolution is the unifying concept of biology. It provides a basis for both the unity and the diversity of life that exists on the Earth. Biological evolution is supported by credible scientific evidence, ranging from fossils to DNA and protein sequence analyses. But what is evolution? Evolution is an ongoing process that occurs when forces, such as natural selection, act on the population that contains genetic variation. The evolutionary forces change the composition of both genes and their corresponding traits in a population gradually over several generations. Through genetic variations, traits that provide an individual with an advantage to best meet the selection pressure and reproduce are more likely to be passed on to the next generation. Over several generations, such a process can lead to the emergence of new species. At the centre, evolution explains both the similarities of genetic material across all species and the multitude of species existing in diverse conditions on Earth. The concept of evolution is, thus, central and critical to understand all the aspects of biology.

Competencies

By the end of class XI, a learner should be able to:

a. use the knowledge from the phylogenetic relationship of five kingdoms to explain that all the organisms have originated from common ancestors.
b. apply the concepts and understanding of classification systems to categorise organisms found in the localities into relative groups and families to demonstrate common line of ancestry.

4.1. Origin of Life

4.1.1. Scope: Organisms are believed to have originated as a result of some simple and complex chemical reactions. Scientific explanations and evidence direct the origin and evolution of life in three major phases (i.e., chemogeny, biogeny, and cognogeny) as explained by Lederberg. Organisms are believed to have changed the environment and have themselves undergone gradual changes to adapt to new conditions.

4.1.2. Scope: The development of oxygenic photosynthetic mechanisms led to major changes in the atmosphere. The change in the atmosphere further led to the evolution and diversification of life forms on earth.

Objective(s)

LO - 1. Construct scientific explanations the processes of the biochemical origin of life.

Learning Experiences:

The teacher may begin the lesson by stating that life on the Earth began 3.7 billion years ago through spontaneous biochemical processes. The teacher may pose a question: How might have life originated on earth? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner gathers information on steps involved in the origin of life on earth through series of biochemical events from relevant materials (e.g., books, online pieces, articles, etc.) or weblinks (e.g., https://bit.ly/3AMKGh3).
- The learner constructs scientific explanations on how life originated on earth through biochemical processes.
- The learner communicates to each other how life originated on earth through biochemical processes.

Questions:

The teacher may ask the following questions to assess the understanding of learner:

1. Explain the biochemical evolution of life.
2. What would have happened, had there been an oxidising atmosphere on the primitive earth?
3. How credible is biochemical evolution of life? Argue with reasons.

Assessment:

Use rubrics to assess the learner's information management skill, ability to construct an explanation on the steps involved in the process of origin of life and communication skills. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022)
- https://bit.ly/3AMKGh3)

Objective(s):

LO-2. Construct an argument giving scientific reasons, to support or refute the idea, that life originated on water bodies as a result of bio-chemical reactions.

Learning Experiences:

The teacher may begin the lesson by recapitulating how life originated on earth through biochemical processes. The teacher may pose the questions: Is it true that life originated on water bodies? Why or why not?. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains scientific information on why life originated on water bodies from relevant materials (e.g., books, online pieces, articles, etc.) or weblinks (e.g., https://bit.ly/3fCT3lW).
- The learner constructs scientific explanations on why life originated on water bodies.
- The learner defends his/her claim that "life originated on water bodies" with scientific reasons.

Questions:

The teacher may ask the following questions to assess the understanding of learner:

1. Why did life originate on water bodies?
2. Why was life not formed on land?
3. "Life first originated on water bodies". Defend or refute this claim with reasons.

Assessment:

Use rubrics to assess the learner's information management skill, ability to explain why life originated on water bodies and ability to defend the claim. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
- https://bit.ly/3AIpMQq
- https://bit.ly/3fCT3lW

Objective(s)

LO-3. Construct arguments giving scientific reasons, to support or refute the idea, that evolution of oxygenic photosynthetic mechanisms had major impacts on the development of the present-day atmosphere.

Learning Experiences:

The teacher may begin the lesson by recapitulating on how the evolution of oxygenic organisms transformed the primitive atmosphere and surrounding environment into modern day atmosphere. The teacher may pose the question: Is evolution of oxygenic photosynthetic mechanisms the main cause for the formation of the present day atmosphere? Why or why not? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner gathers scientific information on how the evolution of oxygenic photosynthetic mechanism transformed the primitive atmosphere and surrounding environment into modern day atmosphere from relevant materials (e.g., books, online pieces, articles, etc.) or weblinks (e.g., https://bit.ly/3GGRJdx).
- The learner constructs the scientific explanation to support or refute the idea that the "evolution of oxygenic photosynthetic mechanisms transformed the primitive atmosphere and surrounding environment into the modern day atmosphere".
- The learner supports or refutes the idea that the "evolution of oxygenic photosynthetic mechanisms transformed the primitive atmosphere and surrounding environment into the modern day atmosphere".

Questions:

The teacher may ask the following questions to assess the understanding of learner:

1. What are the first photosynthetic organisms?
2. Construct an argument to show that the emergence of photosynthetic organisms was crucial in life reaching the surface of the sea and later dry land?
3. Explain the significance of the oxygen revolution in development of the present-day atmosphere?
4. Is it true that the "evolution of oxygenic photosynthetic mechanisms transformed the primitive atmosphere and surrounding environment into the modern day atmosphere". Comment.

Assessment:

Use rubrics to assess the learner's information management skill, and ability to argue why the evolution of oxygenic photosynthetic mechanisms is considered as the main cause for oxygen revolution. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
- https://bit.ly/3GGRJdx

Challenge Your Learners

Teacher may ask the following questions to challenge the thoughts of learner:

1. How would life on present day earth be different if there were no evolution of photosynthetic organisms?
2. How credible is biochemical evolution of life? Explain.
3. Is it true that the "evolution of oxygenic photosynthetic mechanisms transformed the primitive atmosphere and surrounding environment into the modern day atmosphere". Comment.
4. "Life first originated on water bodies". Defend or refute this claim with reasons.
5. Anything that grows on the present day earth begins or needs water. How would it relate with the origin of life?
6. Can we represent conditions of the primitive earth and replicate the origin of life? Comment.
7. New forms of life keep on forming on the earth. Comment.

4.2. Diversity of Life

4.2.1. Scope: Living organisms are classified under the five kingdoms (i.e., Monera, Protista, Fungi, Plantae and Animalia). Organisms are classified on the basis of morphological character which shows evolutionary relationships between organisms. The system of classification based on phylogeny organises species or other groups in ways that reflect our understanding of how organisms evolved from a common ancestor. Moving from the point of origin, the groups become more specific, until one branch ends as a single species. These evolutionary relationships are, oftentimes, represented by a phylogenetic tree or cladograms.

Objective(s):

LO-1. Design a model that classifies organisms from the locality into five kingdoms based on scientific reasons.

Learning Experiences:

The teacher may begin the lesson by informing the learner that animals and plants are classified into various categories based on the taxonomical triangle or taxonomic hierarchy. The teacher may then provide a brief background on the emergence of different methods of classification of organisms. The teacher may continue to deliver the lesson based on the following order of scientific and engineering practises:

- The learner gathers scientific explanations on the methods of classifying living organisms from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://bit.ly/3KrsyOs).
- Based on the information gathered, the learner constructs a model that explains the classification of living organisms.
- The learner chooses an area and observes a few organisms present in their locality.
- The learner classifies the living organism observed in the chosen area.

Questions:

The teacher may ask the following questions to assess the understanding of learner:

1. Why do living organisms need to be classified?
2. Illustrate the taxonomic hierarchy of at least five plants and animals found in your locality?
3. If you come across a plant or animal which you feel is a new species. How would you go about its identification, classification and nomenclature?

Assessment:

Use rubrics to assess the learner's information management skill, and ability to design a model and ability to use and critique the model of classification of an organism with scientific reasons. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
- https://bit.ly/3KrsyOs
- https://bit.ly/3IgYYt1

Objective(s):

LO-2. Design a model (phylogenetic tree or cladogram) that explains the evolutionary relationship of a group of organisms from the locality.

Learning Experiences:

The teacher may begin the lesson by informing the learner that all life on Earth evolved from a common ancestor. The teacher, for instance, may inform the learner that bacteria-like organisms or archaea bacteria are believed to have evolved into diversified forms of life that exist on the earth. The learner may be informed about human's phylogenetic relationships shared with primates. The teacher may continue to deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains scientific information on the evolutionary relationship shared between different groups of organisms either in the form of phylogenetic tree or cladograms from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://bit.ly/3qInqOb).
- The learner choses or identifies a group of organisms from the locality to derive their evolutionary relationships. The learner may choose to draw a model (e.g., conceptual, theoretical, physical, or simulation) to draw the evolutionary relationships amongst different groups of organisms identified. The learner may choose to draw the evolutionary relationships using phylogenetic trees or cladograms.
- The learner constructs scientific explanations on the evolutionary relationship of a group of organisms identified from their locality. The learner may use the phylogenetic trees or cladograms to support the explanations.

Questions:

The teacher may ask the following questions to assess the understanding of learner:

1. How is phylogenetic tree different from cladograms
2. Differentiate between homologous and analogous organs?
3. Explain the evolutionary relationships of humans with that of primates.
4. Explain how molecular systems widen the evolutionary relationships amongst different groups of organisms?

Assessment:

Use rubrics to assess the learner's information management skill, communication skill, ability to use and critique the model developed in explaining evolutionary relationships amongst different groups of organisms. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 11, REC (2015)
- Science Curriculum Framework (NSC- 2022).
- https://bit.ly/3nANYyI
- https://bit.ly/3qInqOb

Challenge Your Learners

Teacher may ask the following questions to challenge the thoughts of learner:

1. What are the scientific benefits of classification of organisms?
2. What are phylogenetic trees and cladograms?
3. Why is it important for scientists to distinguish between homologous and analogous characteristics before building phylogenetic trees?
4. Biological classification is a dynamic and ever evolving phenomenon which keeps changing with our understanding of life forms. Justify the statement.
5. Choose a group of organisms from your locality and make their phylogenetic tree.

Class XII

1. Molecules to Organisms: Structures and Processes

Organisms contain structures and processes organised from micro-entities, such as small biomolecules, to macro-entities, such as organs and organ systems. This organisation, though not much visible in small organisms, is quite noticeable in higher organisms, including plants and animals. How are structures and processes organised in organisms? Every organism, whether small or big, contains cells as the smallest units. Cells, depending on their structures and biological roles, influence almost all structures, processes, and behaviour of the organism. Cells, in themselves, are made up of biomolecules, such as carbohydrates, fats, proteins, and nucleic acids. In large organisms, cells combine to form structures and functions of tissues, which in turn form organs, organ systems, and organism in itself. It is, therefore, important to understand how interacting systems and subsystems coordinate to form behaviour, function, and emotion of the organisms.

Competencies

By the end of class XII, a learner should be able to:

a. use the understanding from the cell with scientific evidence to explain that all organisms, either simple or complex, or prokaryotic or eukaryotic; are made up of cells that contain similar structures that carry out similar functions.
b. construct an explanation with scientific evidence that the body of an organism, including humans, contains interacting systems and subsystems that coordinate the functioning of an organism.

1.1. Prokaryotic and Eukaryotic Cells

1.1.1. Scope: Organisms are made up of cells. Cells are categorised as prokaryotic and eukaryotic cells based on the difference in structure and functions. Prokaryotes contain nucleoid and lack well-developed organelles. Eukaryotes have a nucleus and well-developed organelles that are designed to carry out specific functions. Some similar structures are present in both prokaryotes and eukaryotes.

1.1.2. Scope: Prokaryotes comprise the Kingdom Monera. Eukaryotes are both unicellular and multicellular organisms and constitute the protista, fungi, plant, and animal kingdoms. As per the endosymbiont hypothesis, eukaryotes are presumed to have evolved from prokaryotes as a result of some symbiotic associations.

Objective(s):

LO-1. Construct scientific explanation on how eukaryotes are more complex than prokaryotes.

Learning experiences:

The teacher may begin the lesson by informing the learner that the cells can be classified into two classes: prokaryotic and eukaryotic cells. Both types of cells show variation in their structure and functions. Prokaryotic cells have less developed structures while the structures in eukaryotes are well developed to carry out specific functions. The teacher may ask the question: How are eukaryotes more complex than prokaryotes?. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on prokaryotic and eukaryotic cells, and their structures (focused on components that are same or different), from relevant materials (e.g., books, online piece, articles, etc.) or web link (e.g., https://cutt.ly/ZzkbDUj).
- The learner develops a model (conceptual, theoretical, physical or simulations) that explains how eukaryotes are more complex than prokaryotes.
- The learner constructs scientific explanations on how eukaryotes are more complex than prokaryotes using the model.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Eukaryotic cells are more complex than prokaryotic cells. Argue giving reasons to support the statement.
2. Does the efficacy of a cell always depend on its complexity? Justify.
3. Investigate to draw a comparison between a skin and a bacterial cell.

Assessment:

Use rubrics to assess the learner's information management skills, ability to comprehend the information, ability to construct and communicate explanations with scientific reasoning to show the variation in complexity between eukaryotes and prokaryotes. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022).
- https://cutt.ly/ZzkbDUj

Objective(s):

LO-2 Design a model that explains the nature of changes that occurred during the evolution of eukaryotes from prokaryotes.

Learning experiences:

The teacher may deliver the lesson by informing the learner that the prokaryotic cells are the simplest forms of living organisms. Eukaryotic cells have a cellular structure more complex than the prokaryotic cell and hence are more evolved than prokaryotes. The teacher may pose a question: How has eukaryotes evolved from prokaryotes? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on prokaryotes, eukaryotes, unicellularity and multicellularity, the kingdom Monera, kingdoms of eukaryotes, and evolution of eukaryotes from prokaryotes from relevant materials (e.g., books, online pieces, articles, etc.) or a web link (e.g., https://cutt.ly/Izkm0hd).
- The learner designs and develops a model (conceptual, theoretical, physical or simulations) that explains the changes in the structure during the evolution of eukaryotes from prokaryotes. The learner may use relevant software or any programming language to develop the model.
- The learner constructs an explanation on the nature of changes that occurred during the evolution of eukaryotes from prokaryotes, using the model.
- The learner communicates and critiques each other's model.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. According to the endosymbiont theory, some organelles in eukaryotic cells are believed to have formed through a symbiotic relationship between prokaryotic cells. Describe TWO observations that support the endosymbiont theory.
2. Evaluate the credibility of the endosymbiont hypothesis in explaining the mechanism of evolution of eukaryotes from prokaryotes.

Assessment:

Use rubrics to assess the learner's information management skill, ability to design a model (conceptual, theoretical, physical, simulation) that explains the changes in the structure during the evolution of eukaryotes from prokaryotes based on conceptual understanding, ability to construct and communicate explanation on the nature of changes that occurred during the evolution of eukaryotes from prokaryotes, based on the model designed. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer \ science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/Izkm0hd

Challenge Your Learner

Teacher may ask the following questions to challenge the thoughts of learner:

1. Weigh the efficacy of using prokaryotes over eukaryotes for certain industrial purposes and energy production.
2. Construct an explanation to include the role of environmental factors during the evolution of eukaryotes from prokaryotes.
3. Formulate a hypothesis on how the multicellular organism might have evolved from a eukaryotic cell.

1.2. Support and Movement Systems

1.2.1. Scope: Movement in organisms occurs at cytoplasmic, cellular, organ, and organism level. The support and movement system of humans is composed of bones, muscles, and cartilage. The system provides support, stability, and various internal and external movements.

1.2.2. Scope: The skeletal system consists of bones and cartilages, connected by other tissues to form a framework of the body. Like any other connective tissue, the skeletal tissues (bones and cartilages) are formed of cells, matrix, and fibres. The nature of bones and cartilages is determined by the types of cells, matrix, and fibres that they are made of.

1.2.3. Scope: Muscle fibres are adapted to undergo contraction and electrical excitation. These muscle fibres are bundled to form larger muscles. Muscle fibres contain contractile proteins (actin and myosin) arranged to form thin filaments (actin and myosin myofilaments). The actin and myosin myofilaments are arranged to form myofibrils. The sliding of myofilaments in myofibrils leads to the contraction and relaxation of muscles.

Objective(s):

LO-1. Construct scientific explanation on how various components are arranged to form bones and cartilages.

Learning experiences:

The teacher may begin the lesson by informing the learner that the support and movement in humans is brought about by the skeletal and muscular systems respectively. Muscular systems consist of muscle tissue formed of a specialised cell and skeletal system consisting of bones and cartilages. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains scientific information on components of bones and cartilages and how different components are arranged to form bones and cartilages from the relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://cutt.ly/tzkWrnH)
- The learner constructs an explanation on how the cells, matrix, and fibres are arranged in bones and cartilages.
- The learner communicates their explanations on how various components are arranged to form bones and cartilages to the class.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Explain how each component of cartilage and bones are arranged to form a support system in humans.
2. What is the significance of cartilage in the support system in humans?
3. Though bones are harder, their capacity to heal is better than cartilages. Provide scientific reasons to support the statement.

Assessment:

Use rubrics to assess the learner's information management skill, and ability to construct and communicate explanations on how different components are arranged to form skeletal tissues (bones and cartilages). Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/tzkWrnH

Objective(s):

LO-2. Design a model that relates the arrangement of proteins in a muscle fibre to muscle contraction.

Learning experiences:

The teacher may begin the lesson by informing the learner that locomotion in organisms occurs when muscles contract. The muscles are formed of muscle cells or muscle fibres. The sarcoplasm of muscle cells contains contractile protein, actin, and myosin. These contractile proteins give muscle its property of extensibility and contractility. The teacher may pose a question: How are contractile and regulatory proteins arranged in a muscle fibre? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains scientific information on the structure and arrangement of contractile proteins in a muscle fibre and theories of muscle contraction from relevant sources (e.g., books, online pieces, articles, etc.) or web links (e.g., https://cutt.ly/czkT1Wz)
- The learner designs and develops a model (conceptual, theoretical, physical or simulation) that relates the arrangement of proteins in a muscle fibre to muscle contraction. The learner may use relevant software or any other programming languages to develop a model.
- The learner constructs an explanation to relate the arrangement of proteins in a muscle fibre to muscle contraction using the developed model.
- The learner presents and critiques each other's model.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Proteins are important structural components that also determine the function of a particular organ. Relate the significance of proteins to the functioning of skeletal muscles.
2. Construct a flowchart that describes the sequence of events that leads to the contraction of the muscles.

Assessment:

Use rubrics to assess the learner's information management skill, the ability to use conceptual understanding in designing and developing a model (conceptual, theoretical, physical, simulation) to relate the arrangement of proteins to form myofibrils and ability to construct and communicate an explanation to relate the arrangement of proteins in a muscle fibre to muscle contraction using the developed model. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)

- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/czkT1Wz

Objective(s):
LO-3. Develop a model that explains the roles of muscles in the movement of bones.

Learning experiences:
The teacher may begin the lesson by informing the learner about the significance of the movements in an organism. The teacher may pose a question: What are the roles of muscle in the movement of bones? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the roles of muscles in the movement of bones from the relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://cutt.ly/EzkKxFr)
- The learner designs and develops a model (conceptual, theoretical, physical or simulation) that explains the roles of muscles in the movement of bones. The learner may use locally available materials or software or any other programming languages for developing a model.
- The learner constructs a scientific explanation on the roles of muscles in the movement of bones using the model.
- The learner communicates and critiques each other's model.

Questions:
The teacher may ask the following questions to check the understanding of the learner:

1. How does the contraction of muscles lead to the movement of body parts?
2. A certain chemical X prevents the release of acetylcholine at neuromuscular junctions. Explain how this might affect the movement/locomotion in organisms.

Assessment:
Use rubrics to assess the learner's information management skill, ability to translate conceptual understanding in designing and developing a model (conceptual, theoretical, physical, simulation) that explain the roles of muscles in the movement of bones, ability to construct and communicates explanation using model, communication skill and critiquing skill. Provide necessary feedback and intervention to the learner.
For recording and reporting, refer science curriculum framework.

Suggested Resources:
- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)

- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/EzkKxFr

Objective(s):
LO-4. Design a solution to help people with skeletal limb abnormalities live a normal life**.**

Learning experiences:
The teacher may carry out the lesson by informing the learner that some people are physically challenged with deformed limbs, but with technical innovation, these physically challenged people now have a chance to live a comfortable life. The teacher may pose a question: How would you create a functional prosthetic limb that can be used by people with dysfunctional limbs? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the prosthesis, development of artificial limbs and creation of functional prosthetic limbs before attending the class from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g.,https://cutt.ly/QzkLbUM)
- The learner designs and develops a solution (artificial limb) to help people with skeletal limb abnormalities live a normal life, using locally available materials, based on the working principle of muscles, bones, and cartilage.
- The learner tests the developed solution (artificial/prosthetic limb).
- The learner presents and critiques each other's solution in the class.

Questions:
The teacher may ask the following questions to check the understanding of the learner:

1. How safe is the use of prosthetic parts for enhancing the working of internal body parts?
2. Explore some local practises that involve the use of prosthetics designed and produced locally.

Assessment:
Use rubrics to assess the learner's information management skill, ability to translate conceptual understanding in designing and developing a solution (artificial limbs), communication skill and ability to critique on the designed solution. Provide necessary feedback and intervention to the learner.
For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)

- https://cutt.ly/QzkLbUM

Challenge Your Learner

Teacher may ask the following questions to challenge the thoughts of learner:

1. Explain the role of bone cells in bone remodelling.
2. Tendons being made chiefly of collagen fibres, are less flexible as compared to ligaments. How does this property of tendons help in the movement of bones?
3. Plaster of Paris (POP) is used medically to immobilise the fractured limbs. Why is it necessary to immobilise the fractured limbs?
4. Does the use of prosthetic limbs have some associated ethical implications?

1.3. What is on the Plate?

1.3.1. Scope: The human digestive system comprises the alimentary canal and digestive glands. The alimentary canal is structurally adapted to perform various functions during the digestive process. The secretions of chemicals from different digestive glands aid in chemical digestion.

1.3.2. Scope: Digestion occurs by the physical and chemical breakdown of food. During physical digestion, the larger food chunks are broken down into smaller particles due to chewing and movements. Chemical digestion involves enzymatic hydrolysis of food molecules to soluble forms in different parts of the alimentary canal.

1.3.3. Scope: The digested food particles are absorbed into the bloodstream through blood capillaries and lacteals. Blood transports the absorbed food to the liver for detoxification and is ultimately assimilated in the cells.

1.3.4 The growth, development, and health of an organism depend on its food. The human lifestyle is undergoing a rapid change due to which people depend more on processed food (fast foods) that barely meets the dietary requirements. Healthy dietary practises contribute to good immunity and help in preventing diseases (e.g., malnourishment, heart diseases, stroke depressed immune functions, etc.).

Objective(s):

LO-1. Develop a model that explains the chemical breakdown of food materials in the alimentary canal by enzymes (*limited to carbohydrates, fats, and protiens).*

Learning experiences:

The teacher may begin the lesson by informing the learner that the food that enters the alimentary canal gets broken down into its simple forms with the help of digestive organs and the enzymes of

digestive glands. The teacher may pose questions: How are different components of food chemically broken down in the alimentary canal? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the human digestive system, alimentary canal, digestive gland, physical and chemical digestion of various components of food in the alimentary canal from relevant materials (e.g., books, online pieces, articles, etc.) or web link (e.g., https://cutt.ly/xzkZE2d).
- The learner designs and develops a model (conceptual, theoretical, physical, or simulation) that represents the chemical breakdown of various food materials in the alimentary canal. The learner may use relevant software or any programming languages to develop a model.
- The learner shares and critiques each other's model that represents the chemical breakdown of various food materials in the alimentary canal.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. How would the absence of enzymes impact digestion?
2. Design an experiment to demonstrate the effect of amylase on starch.
3. Do digestive juices help in maintaining the internal environment of the alimentary canal? Give reasons for your answer.
4. Drinking water right after eating is thought to dilute enzymes and hinder digestion. Comment your views on the statement giving reasons.

Assessment:

Use rubrics to assess the learner's information management skill, ability to translate conceptual understanding in designing and developing a model to represent the chemical breakdown of various food materials in the alimentary canal and ability to critique each other's model. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer to the Science Curriculum Framework (NSC- 2022).

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/xzkZE2d

Objective(s):

LO-2. Construct scientific explanation on how the end products of digestion are absorbed and assimilated in the cells.

Learning experiences

The teacher may begin the lesson by informing the learners that the end products of digestion of various components of food are absorbed and transported by the blood and lacteals. These end products of digestion of various components of food are then assimilated into the cells. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on absorption and assimilation of end products of digestion of various components of food from relevant materials (e.g., books, online pieces, articles, etc.) or web link (e.g., https://rb.gy/mozmou) before attending the class.
- Based on the information gathered, the learner constructs and communicates scientific explanations on how the end products of digestions are absorbed and assimilated in the cells, in the class.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. How are end products of digestion of various components of food absorbed in the small intestine?
2. What happens to the various components of food that are absorbed into the blood or lacteals?
3. Why is it important to take a diet that is rich in protein?

Assessment:

Use rubrics to assess the learner's information management skill, comprehension skill, and ability to construct and communicate the explanation on how the end products of digestions are absorbed and assimilated in the cells. Provide necessary feedback and intervention to the learner.
For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://rb.gy/mozmou

Objective(s):

LO-3. Design a solution to treat conditions related to digestion applying the concepts of botano-chemicals.

Learning experiences

The teacher may begin the lesson by informing the learner that unhealthy eating practises, stress, and our lifestyles may lead to mild to serious digestion problems. Digestion problems, such as constipation, diarrhoea, heartburn, and bloating are very common conditions related to digestion and are treatable at home. The simplest form of treating conditions associated with digestion is by using plants. The teacher may pose a question: How are plants used in treating conditions associated with digestion? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learners obtain information on one or more conditions related to digestion and plants used in treating conditions related to digestion from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://rb.gy/gqsfze , https://rb.gy/l5kreb).
- The learner designs and develops solutions to treat conditions related to digestion, applying the concept of botanochemicals.
- The learner communicates and critiques the designed solutions to treat conditions related to digestion to the class.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Highlight some of the local practises where plants are used in healing or treating conditions related to digestion.
2. Identify some plants and their products that are used in traditional practises for treating digestive problems.
3. Which between home remedy (using plants) or pharmaceutical medicine (drugs), is a more effective way of treating conditions related to digestion? Give reasons.

Assessment:

Use rubrics to assess the learner's information management skill, ability to design and develop solutions to treat conditions related to digestion applying the concept of botanochemicals. Assess learners' ability to construct, communicate and critique the designed solutions. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer to the Science Curriculum Framework (NSC- 2022).

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)

- Science Curriculum Framework (NSC- 2022)
- https://rb.gy/gqsfze
- https://rb.gy/l5kreb

Objective(s):

LO-4. Design a diet plan that provides scientific explanations on the daily nutritional requirements of a person for a healthy lifestyle.

Learning experiences

The teacher may begin the lesson by informing the learner that eating too much or less of certain food groups can cause many health-related issues including heart disease, high blood pressure, type 2 diabetes, tooth decay and may even cause cancer. For a healthy body, the right nutrient in an appropriate amount must be provided to the body. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on daily nutritional requirements of the body and balanced diet from relevant materials (e.g., books, online pieces, articles, etc.) or from the web links (e.g., https://cutt.ly/YzkNQkL).
- Based on the information gathered, the learner designs and develops a diet plan to meet the daily nutritional requirements of a person for a healthy lifestyle.The learner may use relevant software or any programming languages to design and develop the diet plan.
- The learner communicates and critiques each other's diet plan.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. What are the daily nutritional requirements for an average normal person?
2. Why is taking a balanced diet important?
3. What are the possible consequences of unhealthy dietary habits?
4. Investigate the dietary habits of Bhutanese to determine if the nutritional requirements for a healthy lifestyle are met.

Assessment:

Use rubrics to assess the learner's information management skill, comprehension skill, ability to translate conceptual understanding in designing a diet plan and ability to communicate and critique each other's design. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/YzkNQkL

Challenge Your Learner

Teacher may ask the following questions to challenge the thoughts of learner:

1. Insulin is also synthetically produced to treat diabetes mellitus and is usually administered in the form of injection rather than in tablets. Are there some physiological benefits associated with the practise?
2. "A healthy diet is less about choosing the right foods and more about choosing the right ingredients." Do you agree with the statement? Justify giving reasons.
3. How would the absence of physical digestion affect human nutrition?
4. Explain how different parts of the alimentary canal are structurally adapted to carry out various functions of digestion.
5. Design an experiment to test the presence of different nutrients (carbohydrate, protein, and fats) in food.

1.4. Respiration: The Source of Energy

1.4.1. Scope: Food (glucose) is broken down by a series of enzyme-controlled biochemical reactions during respiration, to release energy. Respiration occurs in two major phases, i.e., glycolysis and Krebs cycle. Aerobic respiration requires oxygen for the complete breakdown of biomolecules (glucose) and release energy. Glucose is broken down to form pyruvic acid in the cytoplasm (glycolysis). Pyruvate is converted to Acetyl CoA which is oxidised during Krebs cycle through a series of chemical reactions in the mitochondria. Incomplete breakdown of food materials occurs during anaerobic respiration (lactic acid and alcoholic fermentation).

1.4.2. Scope: Microbes are economically and environmentally important due to their ability to break down organic materials by anaerobic respiration. Using them for the treatment of sewage and other wastes have contributed towards minimising environmental pollution. Due to their abilities to carry out anaerobic respiration, microbes are also applied in a range of food processing industries to synthetically add flavour to processed food.

Objective(s):

LO-1. Develop a model that represents the events leading to the breakdown of food during respiration *(limited to basic concepts of glycolysis, Krebs cycle, and electron transport chain).*

Learning experiences:

The teacher may introduce the lesson by informing the learner that cells require energy for metabolic processes. The energy is obtained from the oxidative breaking down of food. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the steps involved in breaking down glucose to release energy (glycolysis, pyruvate oxidation, Kreb's cycle, electron transport chain, oxidative phosphorylation) from the relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://rb.gy/b396pd).
- The learner designs and develops a model (conceptual, theoretical, physical, or simulation) that represents the events leading to the breakdown of food during respiration.The learner may use software or any other programming language for developing the model.
- The learner shares and critiques each other's model representing the events leading to the breakdown of food during respiration, to the class.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. During cellular respiration, the metabolites are oxidised and the resulting energy transfer process supports the synthesis of ATP. How do the following activities during respiration influence ATP synthesis?
    a. Breakdown of glucose during glycolysis
    b. Oxidation of pyruvate
    c. Movement of electrons along the electron transport chain
2. ATP is produced in two different ways during respiration:
    - Some ATP are produced in glycolysis and Krebs cycle.
    - ATP is also produced through reduced NAD and reduced FAD in oxidative phosphorylation.

    Outline the differences in the two ways of ATP production in respiration.
3. What is the significance of releasing energy in a stepwise manner during cellular respiration?

Assessment:

Use rubrics to assess the learner's information management skill, comprehension skill, ability to use conceptual understanding in designing and developing a model (conceptual, theoretical, physical, simulation) that represents the events leading to the breakdown of food by respiration, and ability critique.Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://rb.gy/b396pd

Objective(s):

LO-2. Design a solution to treat wastewater/sewage/kitchenwaste/municipal waste using the idea of anaerobic respiration.

Learning experiences:

The teacher may introduce the lesson by informing the learner that wastewater/ sewage/domestic waste/municipal waste/vehicle wash wastewater can affect the environment if not treated properly before discharging.The teacher may pose a question:How would you come up with the solution to treat these wastes? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner studies a case on water and soil pollution caused by untreated wastewater/ sewage/domestic waste/municipal waste provided by the teacher before attending the class. The teacher may provide the web link (e.g., https://rb.gy/sjuej7) a case on water and soil pollution caused by untreated wastewater/ sewage/domestic waste/municipal waste/vehicle wash wastewater.
- In the class, based on the case study studied, the learner designs a solution to treat wastewater/sewage/kitchen waste/municipal waste/vehicle wash wastewater, using the concept of anaerobic respiration.
- The learner tests the developed solution in treating wastewater/sewage/kitchen waste/municipal waste/vehicle wash wastewater.
- The learner critiques each other's designed solution.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Assess the effectiveness of using microorganisms to treat wastewater over chemical treatment. Justify your answer with scientific reasons.
2. Are there any risks associated with the use of microorganisms to treat wastewater?

Assessment:

Use rubrics to assess the learner's information management skill, comprehension skill, ability to analyse the situation given in the case study, ability to design a solution to treat

wastewater/sewage/kitchen waste/municipal waste/vehicle wash wastewater based on the concept of anaerobic digestion, ability to critique and communication skill. Provide necessary feedback and intervention to the learner.
For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://rb.gy/sjuej7

Objective(s):

LO-3. Design a solution to enhance the flavour of food based on the concept of cellular respiration.

Learning experiences:

The teacher may introduce the lesson by informing the learner that economically important bacteria are used in food processing industries to enhance the flavour of food due to their ability to carry out cellular respiration. The teacher may pose a question: How would you come up with the solution to enhance the flavour of food? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the use of microbes in food processing industries in enhancing the flavour of food, from the relevant materials (e.g., books, online pieces, articles, etc.) and web links (e.g., https://rb.gy/duaab4).
- Based on the information gathered, the learner designs a solution to enhance the flavour of food based on the concept of cellular respiration.
- The learner tests the developed solution in enhancing the flavour of food.
- The learner communicates and critiques each other's designed solution.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Explore some local practises whereby the idea of anaerobic respiration is used in food processing.
2. Does aerobic respiration help in the preservation of food? Explain giving reasons.

Assessment:
Use rubrics to assess the learner's information management skill, comprehension skill, ability to design a solution to enhance the flavour of food based on the concept of cellular respiration, ability to communicate and critique the designed solutions. Provide necessary feedback and intervention to the learner.
For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://rb.gy/duaab4

Challenge Your Learner
Teacher may ask the following questions to challenge the thoughts of learner:

1. The pyruvate dehydrogenase complex (PDC) located in the mitochondrial matrix catalyses the conversion of pyruvate to acetyl CoA (a substrate for the Krebs cycle). Make a claim about how PDC deficiency might affect the amount of NADH produced by glycolysis and the amount of NADH produced by the Krebs cycle in a cell. Provide reasons to support your answer.
2. How do the electron transport chain and chemiosmosis (oxidative phosphorylation) affect the acidity/pH of the intermembrane space and mitochondrial matrix?
3. Give reasons why the anaerobic respiration pathway in animal cells can be reversed, but the anaerobic respiration pathway in yeast cells cannot be reversed.
4. Countries across the globe face the problem of water pollution which has resulted in the shortage of drinking water. Devise a method to purify polluted water applying the concept of respiration.

1.5. Perception and Interaction

1.5.1. Scope: Organisms interact and respond to the changes that occur in their environment in order to survive. Central Nervous System (CNS) coordinates the responses shown by an organism. Receptors sense the changes in the surrounding (stimuli) and generate electrical impulses (sensory) which are transmitted to the CNS. CNS modulates and generates a new impulse (motor) which determines the nature of the response that an organism exhibits.

1.5.2. Scope: Neurons have electrolytes (Na+, K+, etc.) on the inner and outer sides of their membranes. The distribution of electrolytes determines the potential difference of the membrane. On being stimulated, the pattern of distribution keeps changing, allowing transmission of the impulse. During rest, the membrane is in a polarised state having more positive charge outside

the membrane and less inside. During the generation of transmission of impulse, the potential difference is reversed (action potential) and the membrane is depolarised. The transmission of impulses is a result of the movement of electrolytes in and out of the nerve fibres. The electrical state of a neuron keeps changing during impulse conduction

1.5.3. Scope: Artificial Intelligence (AI) is a field of computer science, associated with enabling machines to work in a similar manner as the human nervous system. These systems are designed to perform tasks that require human intelligence. Through this, robots/ machines are employed to work in situations that are not usually possible for humans. The working principle of AI-based systems is similar to that of the human nervous system.

Objective(s):

LO-1 Construct scientific explanation on how organisms respond to the changes in their surroundings.

Learning experiences:

The teacher may introduce the lesson by creating a scenario in class, whereby the teacher provides a stimulus to the learners and the learners respond to a stimulus. The teacher may ask the learner to make conclusions on how they responded to the stimulus. The teacher may inform the learner that all organisms respond to change in the environment. The teacher may pose a question: How does an organism respond to the changes in the environment? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on how organisms respond to change in the environment from the relevant materials (e.g., books, online pieces, articles, etc.) or web link (e.g., https://rb.gy/ayw4eo).
- The learner constructs a scientific explanation on how organisms respond to the changes in their surroundings.
- The learner communicates the scientific explanation on how organisms respond to the changes in their surroundings to the class.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. How does an organism respond to the change in the environment?
2. Processing of information occurs through a complex neural pathway and requires a certain time to show a response after a stimulus has been sensed. The information is transmitted and processed either through the reflex arc or the typical stimulus-response pathways, depending on the nature of the stimulus. Explain the differences between the processing of information through the reflex arc and typical stimulus-response pathways.

3. Explain how the neurosensory cells are adapted to perceive sensations of various nature.

Assessment:
Use rubrics to assess the learner's information management skill, ability to construct and communicate a scientific explanation on how organisms respond to the changes in their surroundings. Provide necessary feedback and intervention to the learner.
For recording and reporting, refer science curriculum framework.

Suggested Resources:
- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/xzluswM

Objective(s):
LO-2. Develop a model using scientific evidence that represents the chemical events leading to the transmission of information (impulse) across a nerve fibre.

Learning experiences:
The teacher may inform the learner that the transmission of nerve impulses occurs because of a difference in electrical charge across the neurolemma. The teacher may pose questions: How does this difference in electrical charge occur? How are the differences in electrical charges transmitted across a neuron? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on chemical events that take place during the transmission of information (impulse) across the nerve fibre from relevant materials (e.g., books, online pieces, articles, etc.) or web link (e.g., https://cutt.ly/PzliEY4)
- The learner designs and develops a model (conceptual, theoretical, physical, or simulation) that represents the chemical events leading to the transmission of information (impulse) across a nerve fibre. The learner may use relevant software or any other programming language to design a model.
- The learner communicates and critiques each other's models.

Questions:
The teacher may ask the following questions to check the understanding of the learner:
1. Electrolytes are the fundamental elements required for the transmission and processing of information in animals. Evaluate the statement giving suitable reasons.
2. Response to a stimulus (e.g., change in environment) involves complex interactions amongst receptors, neurons, brain or spinal cord, and the effectors. Explain the events

involving the change in the distribution of electrolytes during the transmission and processing of information.

3. Transmission of information from the receptor to the effectors involves more than one neuron. Illustrate with a diagram how an action potential is transmitted from the end of one neuron to the dendrite of the next neuron.

Assessment:

Use rubrics to assess the learner's information management skill, comprehension skill, ability to translate conceptual knowledge into developing a model that represents the chemical events leading to the transmission of information (impulse) across a nerve fibre. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/PzliEY4

Objective(s):

LO-3. Communicate the scientific information on artificial intelligence(AI) and robotics, and their influences in our daily lives.

Learning experiences:

The teacher may introduce the lesson by informing that artificial intelligence and robotics are going to permeate in every aspect of human life in the future. The teacher may pose a question: What are some of the ways in which artificial intelligence(AI) and robotics influence our daily lives? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on artificial intelligence, robotics, and their influences in our daily lives from relevant materials (e.g., books, online pieces, articles, etc.) or web link (e.g., https://rb.gy/2aoiqe).
- The learner constructs and communicates explanations on artificial intelligence(AI) and robotics, and their influences on our daily lives to the class.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Artificial Intelligence (AI) systems and robotics are becoming an integral part of human life. Comment on the statement citing some instances whereby artificial intelligence and robotics have influenced our lives.
2. What is machine learning?
3. Derive a comparison between the working of the human nervous system and an Artificial intelligence system.

Assessment

Use rubrics to assess the learner's information management skill, ability to construct and communicate scientific explanations on artificial intelligence(AI) and robotics, and their influences in our daily lives.. Provide necessary feedback and intervention to the learner.
For recording and reporting, refer science curriculum framework.

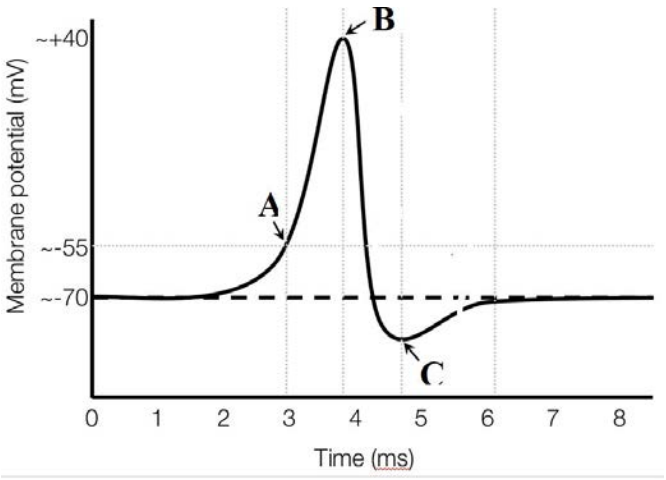
Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://rb.gy/2aoiqe

Challenge Your Learner

Teacher may ask the following questions to challenge the thoughts of learner:

1. The graph shows an action potential across an axon membrane following the application of a stimulus.



   a. What will happen at the site following the highest point of the action potential (B)?
   b. What causes the membrane potential to drop below its resting potential at point C?
2. Why is ATP required in maintaining the resting membrane potential of a neuron?

3. Sensors are used widely in the field of medicine, industries, automobiles and are becoming an integral part of almost every advanced technology. How is the working of sensors similar to that of sense organs?
4. Artificial intelligence and robotics are going to permeate in every aspect of human life and the dependency of humans on AI and robotics will be the biggest threat to mankind. Argue on the statement giving reasons.

1.6 Excretion: The Removal of Waste

1.6.1. Scope: Excretion involves cellular processes in removing substances that are not required in the body, and maintaining the required concentration of substances in the body fluids. The nature of nitrogenous waste excreted varies amongst different types of species and also depends on the environment that an organism lives in.

1.6.2. Scope: All vertebrates have kidneys formed of nephrons, that specialise in removing metabolic waste and retaining useful substances. Human kidneys are highly developed and adapted to excrete urea (the main metabolic waste) dissolved in the urine. Urine formation (uropoiesis) occurs by ultrafiltration, tubular secretion, and tubular reabsorption. Substances are retained during uropoiesis by movement across the membrane of nephrons. The exchange of substances occurs depending on the concentration of solutes and in turn regulates the osmotic concentration of urine, blood, and body fluids.

1.6.3.Scope: Inefficiency or dysfunction of the excretory organs results in the accumulation of harmful substances in the body causing problems (e.g., anaemia, decreased immune response, etc.). Hemodialysis is used to maintain the osmotic concentration of body fluid during kidney failure.

Objective(s):

LO-1 Construct scientific explanation on how the working of the excretory system helps organisms to attain a balanced internal environment.

Learning experiences:

The teacher may inform the learner that our body produces different types of waste, such as excess salt and water, nitrogenous waste, carbon dioxide, etc. Various organs remove these wastes from our bodies to maintain homeostasis. The teacher may pose a question: How does the excretory system work in an organism to help attain a balanced internal environment? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on components of the excretory system and how excretory system works in organisms to help attain a balanced internal environment, from relevant materials (e.g., books, online pieces, journal articles, etc.) or web link (e.g., https://rb.gy/4wxwrf).
- The learner constructs and communicates scientific explanations on how the working of the excretory system in an organism helps in attaining a balanced internal environment to the class.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. How does an excretory system help maintain a balanced internal environment in an organism?
2. Why are principal metabolic waste in animals of nitrogenous nature?
3. Derive a relationship between the nature of metabolic waste and the environment that an organism lives in.

Assessment:

Use rubrics to assess the learner's information management skill, comprehension skill, ability to construct and communicate explanations on how the working of the excretory system in an organism helps in attaining a balanced internal environment. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://rb.gy/4wxwrf

Objective(s):

LO- 2 Develop a model that explains how different parts of a nephron in humans are structurally adapted to remove nitrogenous waste.

Learning experiences:

The teacher may begin the lesson by informing the learner that the organisms have specialised structures to remove excess body fluids and nitrogenous waste from the body. Each kidney is composed of millions of these specialised structures (nephrons). The teacher may pose a question: How are different parts of nephron structurally adapted in removing nitrogenous waste from the

body? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the structure of nephron and how different parts of a nephron in humans are structurally adapted in removing nitrogenous waste from relevant materials (e.g., books, online pieces, journal articles, etc.) or web link (e.g., https://rb.gy/quwna1)
- Based on the information gathered, the learner designs and develops a model (conceptual, theoretical, physical, or simulation) that explains how different parts of a nephron in humans are structurally adapted to remove nitrogenous waste. The learner may use relevant software or any programming language to design a model.
- The learner shares and critiques each other's designed model that explains how different parts of a nephron in humans are structurally adapted to remove nitrogenous waste to the class.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. How do the differently adapted structures of nephron help in regulating the osmotic concentration of the body fluids?
2. What happens to various components of the blood (given in the table below) during the process of urine formation?

Composition of blood	Parts of nephron	Description
a. Urea b. Ions c. Glucose d. Water e. Red blood cells	I. Glomerulus	
	II. Proximal convoluted tubules	
	III. Descending limb of loop of Henle	
	IV. Ascending limb of loop of Henle	
	V. Distal convoluted tubules	
	VI. Collecting ducts	

3. How are the physiological conditions of the body related to the volume of urine?

Assessment:
Use rubrics to assess the learner's information management skill, comprehension skill, ability to translate conceptual understanding into developing a model that explains how different parts of a nephron in humans are structurally adapted to remove nitrogenous waste and ability to critique each other's model. Provide necessary feedback and intervention to the learner.
For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://rb.gy/quwna1

Objective(s):
LO-3. Design a solution to help a person with kidney dysfunctionalities attain an osmotic balance of the body fluids.

Learning experiences:
The teacher may begin the lesson by informing the learner that the kidneys play a vital role in removing nitrogenous waste and helps in maintaining salt and water balance in the body. Any damage to the kidneys will severely affect the normal functioning of the body, especially the body homeostasis (osmoregulation). The teacher may pose a question: How would you come up with a solution to maintain the osmotic balance of the body during kidney dysfunction? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on kidney dysfunctionalities, membrane transport, dialysis, the principle of working of dialysis, and artificial membranes from relevant materials (e.g., books, online pieces, articles, etc.) or web link (e.g., https://rb.gy/7oobnw).
- Based on the information gathered, the learner designs and develops a solution to help a person with kidney dysfunctionalities attain an osmotic balance of the body fluids. The learner may use relevant software or any programming language to develop the model.
- The learner tests the designed solution to help a person with kidney dysfunctionalities attain an osmotic balance of the body fluids.
- The learner analyses (e.g., graphing, tabulation, or statistics) and interprets the data obtained from testing of the developed solution.
- The learner evaluates and presents the designed solution to the class.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Kidney failure has serious consequences for the individual. Highlight the effect of kidney failure on human health.
2. In the case of chronic kidney dysfunctionalities, one way to replace kidney function is through haemodialysis. Explain the need for dialysis in a person with kidney dysfunctionalities.
3. Assess the effectiveness of peritoneal dialysis and haemodialysis for a person with kidney failure.

Assessment:

Use rubrics to assess the learner's information management skill, comprehension skill, ability to evaluate the pros and cons of a designed solution, and ability to translate conceptual understanding into developing a solution to help a person with kidney dysfunctionalities attain an osmotic balance of the body fluids. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer to science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://rb.gy/7oobnw

Challenge Your Learner

Teacher may ask the following questions to challenge the thoughts of learner:

1. "A person moving from a cold to a hot place experiences a change in the nature and volume of his urine." Support or refute the statement giving scientific reasons.
2. Detection of a higher level of protein in the urine is usually considered a symptom of kidney damage. Describe the circumstances that lead to the increase in the protein concentration of urine.
3. Extract of dandelions are known for their diuretic effect and in some parts of the world are used as a measure to deal with high blood pressure. What effect will taking dandelion extracts or other similar substances have on the physiological processes of the body?
4. 'Organs other than the ones that belong to the excretory system also play an important role in excretion.' How does the statement connect to your idea of excretion?
5. Camels live in dry and hot conditions and excretes a very small volume of urine. The loops of Henle in the kidneys of these mammals are longer than those found in mammals of a similar size that do not live in desert conditions. How is the structure of nephrons in camels adapted to support their urination nature?

6. A major concern for fisheries is change in the pH of pond water due to the increase in NH_4OH, and sometimes it is found to have lethal effect on the fishes. Suggest some reasons and a suitable solution for the problem above.

1.7. What is inside a Plant?

1.7.1. Scope: In plants, cells are arranged to form tissues that are integrated to form different organs. The apical part of the plant contains meristematic tissue, that divides indefinitely forming new tissues. The meristematic tissues give rise to permanent tissues that form different parts of the plant and are specialised to take up different functions.

1.7.2. Scope: Plant tissues are organised to form epidermal, ground, and vascular tissue systems.
These tissue systems are adapted to take up different functions in the roots, stems, and leaves. Plants exhibit both physiological and morphological adaptations to survive in various types of environments.

Objective(s):
LO-1. Construct a scientific explanation that plant tissues form tissue systems designed to carry out specific functions.

Learning experiences:
The teacher may begin the lesson by informing the learner that the plant contains different tissues. The apical part of the plant contains a group of cells that have the tendency to divide indefinitely (meristematic tissue). These cells later mature to become specialised/ permanent structures and perform a permanent function. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on different types of tissues found in plants from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://cutt.ly/6zllyUs).
- The learner constructs and communicates an explanation that plant tissues form tissue systems designed to carry out specific functions, to the class.

Questions:
The teacher may ask the following questions to check the understanding of the learner:

1. How does the ability of meristematic tissue to differentiate contribute to the growth and development of plants?

2. How is the distribution of meristematic tissues related to varying growth patterns during different phases of plant growth?

Assessment:
Use rubrics to assess the learner's information management skill, communication skill and ability to construct the explanation that plant tissues form tissue systems designed to carry out specific functions. Provide necessary feedback and intervention to the learner.
For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/6zllyUs

Objective(s):

LO-2. Investigate to draw a comparison on the structure and functions amongst the epidermal, vascular and ground tissue systems with scientific reasons.

Learning experiences:
The teacher may begin the lesson by informing the learner that the leaf, stem and root of the plant are organised into epidermal, vascular and ground tissue systems. These tissue systems have specific structures and functions in the plant body. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the structure and function of the epidermal, vascular and ground tissue systems from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g.https://cutt.ly/KzlxbvI).
- The learner plans and carries out experiments (section cutting) to compare the structure and function of the epidermal, vascular and ground tissue systems for scientific reasons.
- The learner collects data from the experiment.
- The learner analyses the data. The data analysis can be in the form of cellular diagrams of the structure and function of the epidermal, vascular and ground tissue systems for scientific reasons.
- The learner draws a comparison on the structure and function of the epidermal, vascular and ground tissue systems for scientific reasons.

Questions:
The teacher may ask the following questions to check the understanding of the learner:

1. How is the modification of the external structure of plants related to their distribution in different environmental conditions?
2. Why do the structures vary amongst the epidermal, vascular and ground tissue systems?
3. How does the organisation of tissues to form tissue systems benefit a plant?

Assessment:
Use rubrics to assess the learner's information management skill, comprehension skill, scientific skill (planning, observing, analysing, interpreting), and ability to construct and communicate an explanation on a comparison in the structure and function of the epidermal, vascular and ground tissue systems. Provide necessary feedback and intervention to the learner.
For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/KzlxbvI

Objective(s):
LO-3. Investigate to illustrate the variation amongst monocot and dicot plants in terms of their anatomies giving scientific evidence.

Learning experiences:
The teacher may begin the lesson by asking the learner: How are the anatomies of the leaves, stems and roots of dicot and monocot plants different? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner plans and carries out experiments (section cutting) to show the anatomical differences in leaves, stems, and roots.
- The learner collects data from the experiment.
- The learner analyses the data. The data analysis can be in the form of cellular diagrams of the transverse section of leaves, stems, and roots.
- The learner constructs and communicates explanations on the variation seen between monocot and dicot plants in terms of their anatomies, based on the data analysis (cellular diagram).

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Relate the difference in the anatomies between the monocot and dicot plants to their survivability in a variety of environments.
2. How do the differences in the anatomy of leaves amongst monocot and dicot plants relate to their differences in physiological processes?

Assessment:

Use rubrics to assess the learner's information management skill, scientific skill (planning, observing, analysing, interpreting), and ability to construct and communicate an explanation on the variation seen amongst monocot and dicot plants in terms of their anatomies. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer to science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://rb.gy/nvhobz

Objective(s):

LO-4. Construct arguments to support or refute the idea that adaptive features of plants are directly related to the environment where they grow.

Learning experiences:

The teacher may begin the lesson by informing the learner that the organism shows structural, physical and behavioural adaptation to the environment they live/grow in. The teacher may pose a question: How are the plants growing in particular environmental conditions adapted to their environment? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on adaptive features of plants to the environment where they grow from relevant materials (e.g., books, online pieces, journal articles, etc.) or web links (e.g., Plants Adaptations in Different Habitats (isebindia.com))
- Based on the information gathered, the learner argues with scientific reasons to claim or refute that adaptive features of plants are directly related to the environment where they grow.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. How do environmental conditions affect the development of adaptive features in plants?
2. Do plants exhibit temporary adaptations like in animals? How?
3. How are adaptations in plants regulated?

Assessment:

Use rubrics to assess the learner's information management skill, ability to defend their claim based on evidence. Provide feedback and intervention to the learner.
For recording and reporting, refer to science curriculum framework.

Suggested Resources:

- REC repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)

Challenge Your Learner

Teacher may ask the following questions to challenge the thoughts of learner:

1. Draw a comparison between the cells of the meristematic tissue in plants and the stem cells of animals.
2. Tissue culture is a growing field of plant propagation that has widespread applications across education and agriculture. How is it possible to multiply plants using tissues?
3. Monocot plants are usually used as roofing materials and making brooms. How does the anatomical features of monocot plants support the mentioned utilities?
4. Southern foothills in Bhutan are warmer, receive heavy rainfall and experience more windstorms. It is also observed that broad-leaved plants and monocot plants grow more in such places. Relate the pattern of distribution to the anatomy of the plants.

1.8. Photosynthesis: Food for Life

1.8.1. Scope: Some organisms (e.g., plants, algae, bacteria, etc.) are capable of absorbing sunlight and using the energy in synthesizing organic compounds (e.g., glucose), which is used as the source of metabolic energy for cellular activities. Plants use light energy from the visible spectrum (PAR) for photosynthesis. Plant pigments absorb energy from different wavelengths of visible light and in a synergistic manner, attain the energy level required for the light reaction to take place. Photosystems make the light reaction very efficient.

1.8.2. Scope: Photosynthesis is a physicochemical process that involves light and dark phases. The light phase takes place in the thylakoids and involves the transduction of light energy into chemical energy and ultimately storing it into energy carriers (i.e., NADPH and ATP). The dark

phase takes place in the stroma and involves the usage of energy from the energy carriers for the fixation of CO2 by the Calvin Cycle(C3 cycle). Glucose is produced as the main product while oxygen is released as a by-product.

1.8.3. Scope: The rate of photosynthesis keeps changing, depending on a variety of internal and external factors. The external factors are the environmental factors (e.g., light, temperature, CO2 concentration) while the internal factors are leaf structure and protoplasmic factors.

1.8.4. Scope: Photosynthesis has a wide range of potential applications. The evolution of oxygen is presumed to have a major impact leading to the formation of the present-day atmosphere(oxygen revolution). Due to photosynthetic abilities, plants have potential applications in controlling the rising CO2 concentration in the atmosphere and extra-terrestrial applications such as creating suitable environments for the survival of organisms.

Objective(s):
LO-1 Construct scientific explanation on how plant pigments absorb energy from lights of different wavelengths and cause the light reaction.

Learning experiences:
The teacher may inform the learner that the plants have a variety of pigments that absorb light of different wavelengths and synergistically attain the energy required for photosynthesis. The pigments collectively form photosystems, which contain a reaction centre, primary photosynthetic pigment and light-harvesting complex (accessory pigments). The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the visible spectrum (PAR), wavelengths of light, photosynthetic pigments, absorption spectrum, photosystem, steps of light reaction, photosystems, cyclic and non-cyclic photophosphorylations from relevant materials (e.g., books, online pieces, journal articles, etc.) or web link (e.g., https://cutt.ly/DzcZN0a) before attending the class.
- Based on the gathered information, the learner constructs an explanation on how plant pigments absorb energy from lights of different wavelengths and collectively cause the light reaction.
- The learner communicates to the class on how plant pigments absorb energy from lights of different wavelengths and collectively cause the light reaction..

Questions:
The teacher may ask the following questions to check the understanding of the learner:

1. Using the concept of resonance, explain how various pigments work in a coordinated manner to attain the required energy for the light reaction to occur.
2. Explain how electrons act as vehicles for energy transfer during photosynthesis.
3. Explain the significance of transduction (during photosynthesis) in making metabolic energy available for the heterotrophs.

Assessment:

Use rubrics to assess the learner's information management skill, ability to comprehend and translate conceptual knowledge, ability to develop a model and communicate to the class on the absorption of light energy of different wavelengths and collectively that produces energy in light reaction.

For recording and reporting, refer to the Science Curriculum Framework (NSC- 2022).

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/DzcZN0a

Objective(s):

LO-2. Design a model that explains the mechanisms involved during light and dark phases of photosynthesis *(limit dark reaction to carboxylation, reduction and regeneration).*

Learning experiences:

The teacher may begin the lesson by informing the learner that photosynthesis involves two phases; light-dependent and light independent phase. The products of light dependent phase (NADPH and ATP) are used in fixing carbon dioxide during the light independent phase. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the light reaction (Z-scheme) and C_3 cycle (Carboxylation, reduction and RuBP regeneration) from the relevant materials (books, online pieces, articles, etc.) or weblinks (e.g., https://cutt.ly/IzcXd5r) before attending the class.
- Based on the information gathered, the learner designs and develops a model (conceptual, theoretical, physical, or simulation) that explains the mechanisms involved during light and dark phases of photosynthesis.
- The learner may use relevant software or any programming language to design the model.

- The learner explains the model to the class and critiques each other's model.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Comment on the significance of light and dark reactions during photosynthesis.
2. How do light and dark reactions work together?
3. Photosynthesis can combat global warming. Comment.
4. Quality of the rice depends on the nature of light reaction and dark reaction. Comment.
5. How does photosynthesis maintain the global food supply chain? Comment.
6. How does photosynthesis vary amongst plants and protists?

Assessment:

Use rubrics to assess the learner's information management skill, ability to comprehend and communicate and relate between light dependent and light independent reaction. Provide necessary feedback and intervention to the learner. For recording and reporting, refer to the Science Curriculum Framework (NSC- 2022).

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/IzcXd5r

Objective(s):

LO-3. Investigate the impacts of light intensity, carbon dioxide and temperature on the rate of photosynthesis.

Learning experiences:

The teacher may inform the learner that while the plants prepare their own food by photosynthesis, the rate of photosynthesis may be different for different plants and controlled by different external and internal factors. The teacher may pose a question: How do different factors affect the rate of photosynthesis? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner develops an educated guess (hypothesis) on any one of the factors that affect the rate of photosynthesis. The learner may identify variables (independent, dependent and control variables) for the different factors

- The learner plans, designs and conducts an experiment to investigate the effect of chosen factors on the rate of photosynthesis.
- The learner analyses and interprets (graphing, tabulation, textual) the data from the experiment to draw a relation between the chosen factor and the rate of photosynthesis.
- The learner draws the conclusion from the investigation.
- The learner communicates their findings to the class.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Does photosynthesis occur at the same rate throughout the day?
2. How does the construction of greenhouses at high altitudes help in crop production?

Assessment:

Use rubrics to assess the learner's ability to develop a hypothesis, ability to identify variables, design and carry out an experiment to investigate the impact of a chosen factor on the rate of photosynthesis and ability to draw conclusions from the findings. Provide necessary feedback and intervention to the learner. For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)

Objectives:

LO-4 Design an investigation to understand what type of plant would be the most effective to take to Mars in order to produce enough oxygen for aerobes to survive.

Learning experiences:

The teacher may inform the learner that the National Aeronautics and Space Administration (NASA) carries out deep space exploration on Mars with the possibility of finding life forms or the method to sustain life on it. However, the atmosphere of Mars has little oxygen that may not support various forms of life. The teacher may pose the question: How can we use plants to create the greatest amount of oxygen in the atmosphere of Mars to sustain life? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on climatic conditions of Mars in terms of atmosphere, temperature and land condition from the relevant materials (e.g.books, online pieces, articles, etc.)

- The learner researches one plant from each biome that could survive in the condition of Mars. The learner also compiles information on the sunlight and water requirements of plants.
- The learner designs a container with the climatic condition of Mars that would house a small plant, but would still allow data to be collected to investigate the type of plant that would best adapt and evolve maximum oxygen. Students then critique each other's design and then choose a design that would be best for the entire class.
- The learner constructs a climatic condition of Mars and plants their choice of plant. The learner collects data on oxygen evolution once a day for a week.
- The learner makes a recommendation to NASA on which plant would be the best to take it to Mars to provide oxygen based on the amount of oxygen produced during the experiment. The redesign could take place by testing other plants or retesting the top 2 oxygen producers.
- The learner communicates the result of the experiment to the class.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Using the idea of climatic conditions of Mars, predict the type of plants that could have existed when the earth's atmosphere was primitive.
2. Compare the climatic conditions between Mars and Earth which can prove to be effective for the growth of plants.
3. What type of plant will be suitable to survive on Mars?

Assessment:

Use rubrics to assess the learner's information management skill, scientific skill (data analysis, investigation, drawing a conclusion), ability to critique each other's design. Provide necessary feedback and intervention to the learner. For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)

Objective(s):

LO-5 Construct an argument with scientific reasons to support or refute the claim that plants can be employed to mitigate global warming.

Learning experiences:

The teacher may carry out the lesson by informing the learner that global warming has become one of the most pressing issues globally. However, plants can be one of the ways of mitigating this issue. The teacher may pose the questions: Do you agree? How can we employ plants to mitigate global warming? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner claims whether plants can be one of the ways of mitigating global warming.
- The learner gathers information on global warming, air pollution, greenhouse gases, the role of plants in controlling air pollution, the potential use of plants to mitigate global warming from relevant materials (books, online pieces, articles, etc.) or web links (e.g., https://rb.gy/devlcu) to study whether plants can be one of the ways of mitigating global warming.
- Based on the information gathered, the learner argues with scientific reasons to claim or refute whether plants can be one of the ways of mitigating global warming.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Maintaining 70% forest coverage helped Bhutan to become one of the two carbon negative countries. Relate the statement to show the potential of plants in mitigating the emission of carbon dioxide in the atmosphere.
2. What type of plant will be effective for slowing the process of global warming? Why?

Assessment:

Use rubrics to assess learners information management skills, ability to gather information and claim evidence from various sources on global warming, air pollution, greenhouse gases, the role of plants in controlling air pollution, the potential of using plants to mitigate global warming and ability to reason how plants can be used as one of the ways to mitigate global warming. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://rb.gy/devlcu

Challenge Your Learner

Teacher may ask the following questions to challenge the thoughts of learner:

1. “Nature has put itself the problem of how to catch in flight, light streaming to the earth and to store the most elusive of all powers in rigid form. To achieve this aim, it has covered the crust of earth with organisms which in their life processes absorb the light of the sun and use this power to produce a continuously accumulating chemical difference. Plants take in one form of power, light; and produce another power, chemical difference.”
    a. Relate the abstract to energy transformation and storage that occurs during photosynthesis.
    b. How is the concept of energy transformation relevant to the human energy system?
2. Why is photosynthesis an important process for life on earth to exist?
3. “Photophosphorylation is necessary to drive the process of driving the dark reaction.” Support or refute the statement giving suitable reasons.
4. The idea of using plants to mitigate global warming/climate change is a rising topic. Why are plants considered a suitable option?

2. Ecosystems: Interactions, Energy and Dynamics

Ecosystems consist of complex interacting systems that include both living and nonliving things. Ecosystems contain several hierarchical structures, where groups of the same organisms form populations and communities. Individual organisms or populations live, grow, or reproduce within ecosystems. How does this happen? This happens with organisms' inherent ability to utilise resources through interdependent relationships with other organisms and the physical environment. These interactions restrain growth; enhance or limit the size of populations; or maintain the balance between resources and those who consume them. The individual organisms and ecosystems remain sustained by continuous flow of energy, originating primarily from the sun, and the recycling of matter and nutrients within systems. The ecosystems, though dynamic, often experience shifts in biotic and abiotic characteristics of the environment; population composition and abundance; and changes in the physical environment over time. These shifts in the ecosystem affects stability and resilience of the entire ecosystem.

Competencies

By the end of class XII, a learner should be able to:

a. apply an understanding that sustainable use of natural resources is essential and change in biodiversity can influence human's resources, such as food, energy and medicine, as well as ecosystem services that humans rely on.
b. using the understanding from biodiversity, appreciate that biodiversity has economical, ecosystem services, ethical and aesthetic values.

2.1. Our Environment

2.1.1. Scope: Earth is inhabited by various life forms. The distribution of different species varies in every ecosystem depending on a variety of factors(e.g. ability to adapt, climatic conditions, food availability, etc.). The diversity of species in an area is studied by determining their richness and evenness. The richness and evenness of organisms in a community can be quantified through numerous methods and can determine the health of an ecosystem.

2.1.2. Scope: Humans share an intricate relationship with their environment. The environment and biodiversity have deeply associated social, economic, cultural, and spiritual importance with the human community. Bhutan's cultural practises exhibit a lot of connections to the environment.

2.1.3. Scope: Plants and their derivatives (e.g., plant parts, botanochemicals, etc.) are widely used for traditional healing practises and producing indigenous medicines. The traditional knowledge on the usability of plants has led to the development of recent applications in modern medicine.

Objective(s):

LO-1. Develop a model (mathematical representation) to quantify biodiversity based on species richness and species evenness of a community.

Learning experiences:

The teacher may inform the learner that biodiversity is measured to quantify the diversity of an area. The diversity of an area is calculated in terms of the number of species and the relative abundance of individual species. Species richness and evenness of biodiversity, thus, explains the health of an ecosystem. The teacher may pose the question: How can we measure the species richness and evenness of an area using a mathematical representation? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on diversity, species richness, species evenness, and methods to measure and quantify the diversity of an area from materials (e.g, books, online pieces, articles, etc.).
- The learner constructs and communicates explanations using mathematical representation to quantify the biodiversity of a community.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Which between species richness and evenness is a better parameter to understand the biodiversity of an ecosystem?
2. How can we relate species evenness and richness to the health of an ecosystem?
3. Why is the measurement of the biodiversity of an area important?
4. Devise a mathematical relation to express the correlation between species richness and biodiversity.
5. Species richness is one of the indicators of healthy biodiversity. Using Simpson's diversity index, devise a method to measure the species richness of flowers found in our school. You can create fictitious data.

Assessment:

Use rubrics to assess learners' information management skills, ability to comprehend, plan and investigate to measure species evenness and species richness in an area. Assess the learner's ability to construct and communicate explanations on the diversity of the area using scientific reasoning. Provide necessary feedback and intervention to the learner. For recording and reporting, refer science curriculum framework.

Suggested Resources:

- REC repository

- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)

Objective(s):

LO-2. Communicate scientific information on how the biodiversity in the locality is connected with social, economic, cultural and spiritual values.

Learning experiences:

The teacher may inform the learner that humans share an intricate relation with the environment. The biodiversity of an area is associated with social, economic, cultural, and spiritual importance to the community. The teacher may pose the question: How is the biodiversity of an area associated with social, economic, cultural, and spiritual importance to your community? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the social, economic, cultural, and spiritual association of their community to the biodiversity around from relevant materials (e.g, books, online pieces, articles, etc.).
- The learner evaluates the information obtained on the social, economic, cultural, and spiritual association of their community to the biodiversity around them.
- The learner communicates information on the social, economic, cultural and spiritual association of their community to the biodiversity around, to the class.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. What are ecosystem services?
2. People throughout Bhutan have a practise of hosting flags and making offerings along the mountains and higher passes. How do such practises act as a link between culture and the environment?
3. Bhutan is a part of one of the biodiversity hotspots of the world and known throughout the world for its biodiversity. What could be the reasons for Bhutan's rich biodiversity?
4. Highlight some of the cultural practises that depict the roles of our beliefs in the conservation of natural resources.

Assessment

Use rubrics to assess learners' information management skills, ability to comprehend and evaluate the information obtained, ability to communicate information on social, economic, cultural, and spiritual aspects of biodiversity using scientific reasoning. Provide necessary feedback and intervention to the learner. For recording and reporting, refer science curriculum framework.

Suggested Resources:

- REC repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)

Objective(s):

LO- 3. Investigate to identify the plants *(along with their botanochemicals)* that are used for healing practises in your locality.

Learning experiences:

The teacher may inform the learner that plants have been an integral part of people and their culture. Plants have been used in many ways to benefit humans. There are many organic compounds obtained from plants. Some of the plants with active botanochemicals are used in healing practises. The teacher may pose a question: How are plants with active botanochemicals used in healing? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the uses of plants (along with their botanochemicals) in their community from relevant materials (e.g, books, online pieces, journal articles, etc.).
- The learner evaluates and constructs an explanation on how the plants have been employed in healing practises in their locality.
- The learner communicates their explanation on how the plants have been employed in healing practises in their locality.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Name some plants used for healing purposes in your locality.
2. What properties of some plants make them an effective choice for healing?

Assessment:

Use rubrics to assess learners' information management skills, ability to evaluate, construct and communicate explanations on how the plants have been employed in healing practises in their locality. Provide necessary feedback and intervention to the learner. For recording and reporting, refer science curriculum framework.

Suggested Resources:

- REC repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)

Challenge Your Learner

Teacher may ask the following questions to challenge the thoughts of learner:

1. Bhutan has a National Institute of Traditional Medicine established for the development of traditional medicinal practises and encourages the use of locally available plant resources for healing purposes. How has this benefited the people?
2. Cultural practises, though known for their advantages towards conservation of nature, also have some neglected disadvantages. Critique the statement by giving reasons.
3. How has the dependency of humans on ecosystem services led to undesirable changes in nature?
4. Evaluate the contribution of cultural services to the conservation of biodiversity in the Bhutanese context.
5. The scheme focuses on the protection and enhancement of the Yakpugang community forest, which forms a catchment area and serves as the main source of water for Mongar Township. The PES scheme is based on a contractual agreement signed between the Yakpugang community forest management group (as service providers) and the municipal authority of Mongar town (as service recipients). The agreement lists six specific activities pertaining to grazing control, protection of community forest against illegal extraction, maintenance of buffer area (with no clearance of vegetation) along the streams and above the source, and removal of forest debris from the streams.
    a. How does the scheme benefit the Yakpugang community and Mongar town?
    b. How does a scheme like this help the community and the environment?
    c. Strategise a similar scheme to be applied for conditions related to environmental pollution.

2.2. Threats on Biodiversity.

2.2.1. Scope: The nature of interactions amongst organisms, has a direct connection to the health of the environment in an area. Natural and anthropogenic disturbances bring changes in the environmental conditions, as a result, numerous vulnerable species (e.g., White-bellied heron, Chinese caterpillar, red-panda, etc.) are facing increased threats to their survival. Human efforts for the improvement of plant and animal species has resulted in some visible consequences(e.g., gene pollution) and is an increasing global concern.

2.2.2. Scope: Anthropogenic activities (e.g., construction, agriculture, hunting, etc.) cause disturbances to the environment on a greater scale resulting in a decline in the population of a

lot of species. Numerous species (e.g., White-bellied herons, Red panda, etc.) have reached a staggering low population and are on a continual threat of extinction. The illegal wildlife trade has led to the escalation of illegal activities such as poaching and trafficking and is becoming a growing concern for conservation.

2.2.3. Scope: Clearing of forests and manipulation of landscapes for industrial growth, human settlement, and agricultural expansion has led to habitat fragmentation and increased incidences of human encounters with wildlife. Human-wildlife conflict is increasing global concern over the years and has resulted in the loss of a lot of important species.

Objective(s):

LO- 1. Construct arguments supported by scientific reasons to support or refute the claim that socio-economic development impacts the natural environment.

Learning experiences:

The teacher may begin the lesson by informing the learner that industrial growth, construction, mining, agriculture activities, etc., are some of the socio-economic developments that impact the natural environment. The teacher may pose a question: How does socio-economic development impact the natural environment? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the various forms of socio-economic developments, corresponding impacts of socio-economic development, and ways to control the impacts caused by economic development on the natural environment from the relevant materials (e.g., books, online pieces, articles, etc.).
- The learner constructs an explanation to support or refute the claim that socio-economic development impacts the natural environment.
- The learner engages in an argument to support or refute the claim that socio-economic development impacts the natural environment.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Why is socio-economic development often associated with environmental degradation?
2. The health of the natural environment is in the hands/will of humans. Do you agree? Justify your answer.
3. Identify some socio-economic activities in your locality that either directly or indirectly impact the environment.
4. What are some of the impacts of socio-economic development on the environment?

Assessment:

Use rubrics to assess the learner's information management skill, ability to construct an explanation based on the conceptual understanding of impacts of socio-economic development on the natural environments, ability to defend their claim with scientific reason. Provide necessary feedback and intervention to the learner. For recording and reporting, refer science curriculum framework.

Suggested Resources:

- REC repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)

Objective(s):

LO- 2. Design a solution to control the environmental impact caused due to economic development.

Learning experiences:

The teacher may begin the lesson by posing a question: How can the environmental impact caused due to economic development be minimised? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on developmental activities and the environmental impacts due to economic development from the relevant materials (e.g., books, online pieces, articles, etc.).
- The learner designs solution(s) to control the environmental impact caused due to economic development. The learner may use relevant software or programming languages to design the solution(s).
- The learner communicates and critiques each other's designed solution.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. "The darker side of economic development is seen in pollution and its consequences. Some experts believe, the impacts of economic development on the natural environment can be controlled." Comment on the statement.
2. How can we minimise the impact of economic development on the environment?
3. What are some of the strategies that are implemented at various levels in Bhutan to reduce the impacts of socio-economic development?

Assessment:

Use rubrics to assess the learner's information management skill and ability to design solutions based on the conceptual understanding of the economic development and environmental impacts and ability to defend their claim with scientific reason. Provide necessary feedback and intervention to the learner. For recording and reporting, refer to the Science Curriculum Framework.(NSC- 2022).

Suggested Resources:

- REC repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)

Objective(s):

LO- 3 Design a solution to protect species(*white-bellied heron, Chinese caterpillar, etc*.) that are under threat.

Learning experiences:

The teacher may begin the lesson by setting a context that due to natural and anthropogenic activities, a number of species, such as White-bellied heron, Chinese caterpillar, etc., are critically threatened. The teacher may also pose a question: How can we help to protect critically threatened species like White-bellied heron and Chinese caterpillar? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on species that are critically threatened (e.g., white-bellied heron, Chinese caterpillar, etc.) and ways to protect threatened species from the relevant materials (e.g., books, online pieces, articles, etc.).
- The learner designs solutions to protect species (e.g. White-bellied heron, Chinese caterpillar, etc.) that are critically threatened. The learner uses relevant software or programming languages to design the solution(s).
- The learner shares and critiques each other's design in the class.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Make a list of threatened species in Bhutan.
2. How would the decrease in the population of the threatened species be important?
3. How do those threatened species impact our environment if their population decreases?

4. White-bellied heron is known to be a critically endangered species with its number decreasing year by year. If you are one of the staff working in RSPN and given the project to protect the species, what would be some of the strategies that you would initiate to protect them?

Assessment:
Use rubrics to assess the learner's information management skill and ability to design solutions based on the information obtained, ability to defend and critique their designed solution. Provide necessary feedback and intervention to the learner.
For recording and reporting, refer science curriculum framework.

Suggested Resources:
- REC repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)

Objective(s):
LO- 4 Design a solution to address human-wildlife conflict.

Learning experiences:
The teacher may begin the lesson by informing the learners that human-wildlife conflict is an increasing concern in the rural part of our country. Bhutanese farmers witnessed many issues related to the invasion of farms by wild animals, such as elephants, bears, monkeys, etc., over the years. The teacher may pose a question: How can we minimise human-wildlife conflicts? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on one or more chosen human-wildlife conflicts from the relevant material (e.g., books, online pieces, articles, etc.). The information may be in the form of the nature of the conflicts, causes, and impacts in terms of biological and economical threats.
- The learner designs solutions that would help to address human-wildlife conflicts.
- The learner communicates the designed solution and critiques each other's design.

Questions:
The teacher may ask the following questions to check the understanding of the learner:
1. What is human-wildlife conflict?
2. The expansion of human settlement and activities is resulting in an increasing encounter of humans with wild life. What could be some of the consequences of such encounters?

3. What are some of the common incidents related to human-wildlife conflicts usually reported in Bhutan? How can we reduce such incidences?
4. How successful has Bhutan been in dealing with the human-wildlife conflicts?

Assessment:

Use rubrics to assess the learner's information management skill and ability to design solutions based on the information obtained, ability to defend and critique each other's designed solution with scientific reasons. Provide necessary feedback and intervention to the learner.
For recording and reporting, refer science curriculum framework.

Suggested Resources:

- REC repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)

Challenge Your Learner

Teacher may ask the following questions to challenge the thoughts of learner:

1. "Human-wildlife conflict is an increasing concern for the conservation of certain species that are undergoing a rapid decline in population." How does the use of technology help in curbing the issue?
2. How does GNH contribute towards reducing the implications of socio-economic development on the environment?
3. 'Overharvesting is seen as a potential cause for the extinction of species.' Examine the impact of overharvesting on the sustenance of Ophiocordyceps.
4. Use of technology can help reduce the detrimental effects of development on the environment. Support the statement giving reasons.
5. Why is the conservation of species important?
6. Socio-economic development involves activities like construction, agriculture, growth of industries, etc., which have direct impact on the environment and often is found to be associated with the decreased ability of the environment to provide ecosystem services. How does this affect the sustenance of livelihood?

2.3. Sustainable Management of Natural Resources

2.3.1. Scope: Unsustainable consumption and production patterns have resulted in huge economic and social costs that endanger life on the planet. Sustainable Management of Natural resources meets the needs of the natural resources for the present and future through

conservation. Sustainable development requires actions on delivering legitimate strategies for economic and social progress, and at the same time strengthening environmental protection.

2.3.2. Scope: Sustainable Management of natural resources involves conservation of forest, wildlife, habitats at community and national levels. Strategies developed at community, national and international levels are used to promote conservation. Management of biodiversity and natural resources is hindered by a lower literacy rate, poverty, illegal marketing, lack of human resources, and other challenges.

2.3.3. Scope: Conservation of the Environment is a pivotal part of Bhutan's Developmental Philosophy. Bhutan's economic development policy is guided by the philosophy of Gross National Happiness (GNH). The country's pursuit of development remains within the limit of environmental sustainability.

Objectives(s):
LO-1. Construct scientific explanation on how sustainable development contributes towards conservation of the environment.

Learning experiences:
The teacher may begin the lesson by informing the learner that the unsustainable consumption and production patterns have resulted in huge economic and social costs that endanger life on the planet. Sustainable development requires actions on delivering legitimate strategies for economic and social progress, and at the same time strengthening environmental protection. The teacher may pose a question: How does sustainable development help in the conservation of the environment? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the role of sustainable development, policies and practises applied in sustainable development contribute towards conservation of the environment.
- The learner constructs an explanation on the role of sustainable development, both policies and practises, contributes towards conservation of the environment. The learner may use the information gathered related to the pillar of GNH; and policies and regulations drafted by RSPN and NEC in supporting the explanation.
- The learner communicates the information on how sustainable development contributes towards the conservation of the environment.

Questions:
The teacher may ask the following questions to check the understanding of the learner:

1. What is sustainable development?
2. What are some of the practises related to the sustainable management of natural resources?
3. How does sustainable development contribute towards the conservation of the environment?
4. Community forestry, through the involvement of people at the local community level, has been a successful approach towards the sustainable management of natural resources.
    a. Express your views on the statement giving suitable reasons.
    b. Suggest two ways for the sustainable management of natural resources.

Assessment:

Use rubrics to assess the learner's information management skill; ability to comprehend and communicate how sustainable development, both policies and practises, aid in the conservation of the environment. Provide necessary feedback and intervention to the learner. For recording and reporting, refer to the Science Curriculum Framework (NSC- 2022).

Suggested Resources:

- REC repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)

Objectives(s):

LO-2. Investigate the challenges of the management of natural resources faced in the locality.
LO-3. Design a solution to conserve natural resources at the community level.

Learning experiences:

The teacher may begin the lesson by setting the context that Bhutan, like any other country, is experiencing unprecedented challenges in the areas of natural resources. The teacher may ask the learner to investigate some challenges in the management of natural resources in their locality. The teacher may ask the learner to choose one or more environmental issues faced by Bhutanese and design a solution to manage and conserve natural resources at the community level. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner investigates and collects data related to the challenges faced in the management of natural resources in their locality.
- The learner analyses (e.g., graphing, tabulation, statistic, etc.) the data collected from the investigation of the challenges in the management of natural resources using graphs, tables, statistics, or text.

- The learner defines and delimits the challenges in managing natural resources.
- The learner designs solutions to conserve natural resources at the community level.
- The learner communicates the solutions designed to the class. The learner critiques each other's solution.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. What are some of the practises at the community level for the management of natural resources in your locality?
2. Using resources in an efficient method can sustain natural resources. What are some of the challenges for managing natural resources in Bhutan?
3. Develop some ways to manage and conserve natural resources in the locality to maximise its services.
4. Involvement of community for the management of natural resources is found to be one of the most effective strategies for conservation of natural resources. Argue on the statement giving suitable reasons.

Assessment:

Use rubrics to assess the learner's ability to investigate, analyse and interpret the data and communication skills in the challenges faced in the management of natural resources in their localities. Assess learners ability to design solutions to manage and conserve natural resources at the community level and ability to critique the solutions. Provide necessary feedback and intervention to the learner. For recording and reporting, refer science curriculum framework.

Suggested Resources:

- REC repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)

Objectives(s):

LO-4. Analyse the significance of Gross National Happiness in the sustainable management of natural resources.

Learning experiences:

The teacher may begin the lesson by informing the learners that the conservation of the environment is a pivotal part of Bhutan's Developmental Philosophy. Bhutan's economic development policy is guided by the philosophy of Gross National Happiness (GNH). The country's pursuit of development remains within the limit of environmental sustainability. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on sustainable development, sustainable management of resources, Bhutan's Development Philosophy (GNH).
- The learner analysis (e.g., graphing, tabulation, statistics, etc.) the information obtained on the significance of GNH in the sustainable management of natural resources.
- The learner constructs an explanation of the significance of GNH in the sustainable management of natural resources.
- The learner communicates the information on the significance of GNH in the sustainable management of natural resources.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. How does GNH explain the importance of the environment?
2. Explain the role of GNH in the sustainable management of natural resources.

Assessment:

Use rubrics to assess the learner's information management skill, analyse and interpret the data. Assess learners ability to construct and communicate explanations on the role of GNH in the sustainable management of natural resources. Provide necessary feedback and intervention to the learner. For recording and reporting, refer science curriculum framework.

Suggested Resources:

- REC repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)

Challenge Your Learner

Teacher may ask the following questions to challenge the thoughts of learner:

1. How does governance contribute to sustainable management of natural resources?
2. The inability to provide food security contributes to the increase in activities such as overharvesting, poaching, hunting, etc. and if not controlled through proper measures, these could cause irreparable damage to the natural ecosystem. Devise a plan to use the idea of sustainable development in protecting the environment.
3. Since 1972, Bhutan has oriented its national policies and developmental plans towards achieving Gross National Happiness. How does considering happiness as a top priority contribute to sustainable development?

3. Heredity: Inheritance and Variation of Traits

Did you ever wonder why offspring from same parents are alike but not identical? This is influenced largely by characteristics or traits that are passed from one generation to the next via genes. Genes encode the information for making specific proteins, which are responsible for the specific traits of an individual. Each gene can have several variants, called alleles, which code for different variants of the trait in question. Genes reside in a cell's chromosomes, each of which contains many genes. Every cell of any individual organism contains an identical set of chromosomes. In species that reproduce sexually, each cell contains two variants of each chromosome, one inherited from each parent. Thus, sexual reproduction gives rise to a new combination of chromosome pairs with variations between parent and offspring. Very rarely, mutations also cause variations, which may be harmful, neutral, or occasionally advantageous for an individual. Environmental, as well as genetic variation and the relative dominance of each of the genes in a pair, play an important role in how traits develop within an individual. Complex relationships between genes and interactions of genes with the environment determine how an organism will develop and function.

Competencies

By the end of class XII, a learner should be able to:

a. apply the understanding from DNA and genetic code to explain that information to build an organism is stored in the four-letter language of DNA (genetic code) that differs from one individual to another.
b. use the understanding from gene technologies and their ethical, moral, and societal issues to make decisions in biological, social, economical, and political context.

3.1. DNA: The Blueprint of Life

3.1.1. Scope: DNA contains information to make proteins that determine our structures and life processes. The information to make proteins are stored in the form of genetic codes. The genetic codes are formed by four-letter languages of DNA (adenine, guanine, thymine and cytosine).Then nature of genetic information or genetic codes specify the sequence of amino acids in a polypeptide chain. The amino acid sequence, thus, determines the 3D conformation (structure) and function of the proteins.

3.1.2. Scope. Proteins take a central role in linking the DNA (genes or genetic information) to traits expressed in the organisms. The nature of proteins, including their structure and function, depends on the nature of the genetic information stored in DNA or genes. The nature of protein, in turn, influences the structure and function of cells and tissues, and therefore determines the traits of an organism. This occurs at various stages, including molecular, cellular and subcellular levels catalysed by enzymes. For instance, the colour of our hair or the nature of our earlobes are influenced by the nature of proteins specified by our genetic code.

Objective(s):

LO-1. Construct scientific explanation how the structure of the DNA molecule is adapted to carry out its biological role in coding proteins.

Learning Experiences:

The teacher may begin the lesson by informing the learner that DNA is one of the icon molecules of modern genetics. Its discovery shook off many myths and dierhard beliefs held by classical genetics. The teacher may inform the learner that the double helix molecular model of DNA was proposed by Watson and Crick in 1953. Ever since, the idea of the double helix molecular model of DNA unlocked many potentials leading towards some marvels of modern biology, such as genetic engineering, gene cloning, DNA fingerprinting, human genome project, gene therapies, etc. The teacher may inform the learner that DNA contains information to make proteins. This information to make proteins are stored in the 3D structure of the DNA molecule itself. The teacher may pose a question: How is the structure of DNA adapted to store information to make proteins? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the 3D structure of a DNA molecule from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://bit.ly/32gJuWx).
- The learner constructs a scientific explanation on the 3D structure of the DNA molecule (double helix molecular structure-polynucleotide chains, nucleotides, sequence of nitrogenous bases, hydrogen bonds, etc.). The learner may relate the 3D structure of the DNA molecule with its biological role in coding proteins.
- The learner critiques each other's ideas that relate how the structure of the DNA molecule is adapted to store information to make proteins.

Questions:

The teacher may ask the following questions to check the understanding of the learner:

1. Explain the double helical structure of the DNA molecule.
2. Are two DNA strands identical? Comment.
3. Do two DNA strands run parallel to each other? Comment.
4. What is the significance of complementary base pairing? Explain.
5. The biological role of the DNA molecule is dependent on its 3D structure. Comment.
6. The structure of the DNA molecule is everything that makes each one of us unique. Outline how the structure of the DNA makes us how we look.

Assessment:
Use rubrics to assess the learner's information management skill, ability to comprehend how DNA is adapted to carry out its biological role in coding proteins and ability to critique and defend each other's claim. Provide necessary feedback and interventions to the learner.
For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2015)
- Science Curriculum Framework (NSC- 2022)
- https://bit.ly/32gJuWx
- https://bit.ly/3nHp2FR

LO-2. Construct scientific explanations on how the genetic information stored in DNA code for proteins that determine traits of the organisms.

Learning Experiences:
The teacher may begin the lesson by informing the learner that every type of structures or life processes performed by living organisms are all driven by proteins specified by DNA. The teacher, for instance, may inform the learner that our life processes and structures, such as colour of an eye and hair, type of hair (curly and straight), the shape of nose, rate of body's metabolism, etc., are influenced by proteins specified by our DNA molecules. The teacher may inform the learner that proteins as biomolecules link DNA with traits of the organisms. The teacher may ask the question: How do proteins link DNA with traits? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on DNA structure, polynucleotide chains with nitrogenous base sequence (genetic code or genetic information), proteins specified by genetic code or genetic information encoded in DNA, and traits determined by proteins from the relevant materials (e.g., books, online pieces, articles, etc.) or weblinks (e.g., https://cutt.ly/SIeqxdn)
- Based on the information obtained, the learner develops a model that explains how genetic information stored in DNA specifies proteins that determine traits through cellular and subcellular mechanisms.
- The learner provides scientific explanation on how genetic information stored in DNA specifies proteins that determine traits through cellular and subcellular mechanisms using the model.

Questions:
The teacher may ask the following questions to check the understanding of the learners:

1. How is the genetic information stored in DNA?
2. How is genetic information stored in DNA related to the 3D conformations of proteins?
3. Explain how proteins mediate genetic information of DNA with traits.
4. Our eye colours are directly related to the nature of information stored in our DNA. Comment.
5. Proteins act as links between DNA and physical traits in organisms. Argue on the statement giving scientific reasons.

Assessment:

Use rubrics to assess learner's information management skill, and the ability to construct how proteins mediate genetic information with traits. Provide necessary feedback and interventions. For recording and reporting, refer to the Science Curriculum Framework (NSC-2022).

Suggested Resources:

- REC repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/SIeqxdn

Challenge Your Learner

Teacher may ask the following questions to challenge the thoughts of the learner:

1. How is genetic information stored in DNA?
2. How does a protein mediate DNA and traits of the organism? Explain.
3. The traits or observable features of the organism are determined by genetic information. Comment.
4. The biological role of a DNA molecule is determined by its structure. Comment.
5. The colour of a rose flower is determined by red pigments called carotene. Explain this from the structure of the DNA molecule.

3.2. Breaking the Code

3.2.1. Scope: DNA contains genetic codes or information to make proteins that determine our structures and life processes. The genetic codes are formed by a long chain of four-letter languages of DNA (adenine, guanine, thymine and cytosine) that occur in groups of three nucleobases or nucleotides. These triplet nitrogenous bases are called codons. There are 64 codons in the human genome. The sequence of codons in a mRNA determines the sequence of amino acids in a polypeptide chain.

3.2.2. Scope: DNA codes proteins. This is initiated when the information stored in DNA (genetic code or genetic information) is carried into the cytoplasm by mRNA. A part of the template strand of DNA is transcribed to form RNA. Transcription (a process similar to replication), results in the synthesis of a single strand mRNA. The RNA further undergoes post-transcriptional modification to become functional mRNA. Conversion of the genetic information on a mRNA to protein occurs by translation in the cytoplasm, where ribosomes mediate the combination of amino acids in accordance with the sequence of codons on mRNA.

Objective(s):

LO -1. Develop a model that explains how the sequence of nucleotides codes for amino acids of a polypeptide chain (*limited to the collinearity between codons and amino acids).*

Learning experiences:

The teacher may begin the lesson by informing the learner that the proteins that form our body structures and life processes are synthesised based on the sequence of nucleotides or genetic codes of DNA. The teacher may inform that the sequence of nucleotides or genetic codes are formed by four letter languages of DNA. The four letter languages of DNA occur in groups of three nucleobases (nitrogenous bases) called codons. There are 64 codons in the human genome. The teacher may ask the question: How does a sequence of nucleotide codes for amino acids in a polypeptide chain? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on codon, genetic code, and essential features of genetic code from any relevant material (e.g., books, online pieces, articles, etc.) or web link (e.g., https://rb.gy/8od8lh)
- The learner designs a model (conceptual, theoretical, physical, or simulation) based on the information gathered, that explains how the sequence of nucleotide codes for amino acids.
- The learner communicates and critiques each other's model.

Questions:

The teacher may ask the following questions to check the understanding of the learners:

1. How are the codes encoded in the DNA?
2. What are codons?
3. Determine the mRNA template for the given non-template strand of DNA: 5'-AAGGTCGGGAATATCGTACT-3'.
4. Some codons do not contain complementary anticodons. How are they significant for organisms?

5. The existence of degeneracy of genetic code is claimed to reduce the chances of getting abnormalities in organisms. Argue on the statement giving suitable reasons.

Assessment:

Use rubrics to assess the learner's information management skill, ability to develop a model that explains how sequences of nucleotides code for various amino acids, ability to construct and communicate explanations on how sequences of nucleotides code for various amino acids. Provide necessary feedback and interventions. For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://rb.gy/8od8lh

Objective(s):

LO-2. Develop a model that explains the expression of information encoded in DNA into protein through translation and transcription.

Learning experiences

The teacher may begin the lesson by asking the learner to reflect upon how the genetic code or sequence of nucleotides codes for amino acids. The teacher may inform the learner that our life processes and structures, such as colour of an eye and hair, type of hair (curly and straight), the shape of nose, rate of body's metabolism, etc., are determined by proteins. Similarly, in plants, the genetic information stored in DNA segments are expressed in the form of colour of flowers, shape of the flower, size of the leaves, etc. The teacher may inform the learner that proteins that determine these characters of humans and plants are specified by four-letter languages of DNA (adenine, guanine, cytosine, and thymine) or simply the codons. The teacher may inform the learner that the expression of DNA into protein takes place through various cellular events of transcription and translation. The teacher may pose the question: How is the information encoded in DNA expressed into proteins through transcription and translation? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on transcription and translation from relevant sources (e.g., books, online pieces, articles, etc.) or web link(e.g., https://rb.gy/s5yqmo)
- Based on the information obtained, the learner designs a model (conceptual, theoretical, physical, or simulation) that explains the expression of information encoded in DNA into

protein through cellular events, such as transcription and translation. The learner may use digital software or any programming language to design the model.

- The learner explains how the information encoded in DNA is expressed into protein through cellular events, such as transcription and translation using the model.

Questions:

The teacher may ask the following questions to check the understanding of the learners:

1. Explain the role of *RNA polymerase* in the transcription of mRNA from the DNA.
2. Relate the colour of petals to gene expression in plants.
3. Why is a post-transcriptional modification of RNA necessary?
4. How does the loss or addition of a nucleotide in a DNA impact translation?
5. Why are the three types of RNAs important for protein synthesis? Explain giving suitable reasons.

Assessment:

Use rubrics to assess the learner's information management skill, ability to develop a model that explains the expression of information encoded in DNA into protein through cellular events, such as transcription and translation, and the ability to explain the processes of gene expression.
Provide necessary feedback and interventions. For recording and reporting, refer science curriculum framework.

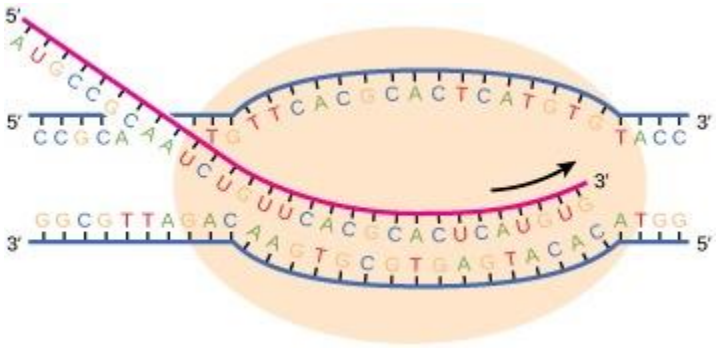
Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://rb.gy/s5yqmo

Challenge Your Learners

The teacher may ask the following questions to challenge the thoughts of students:

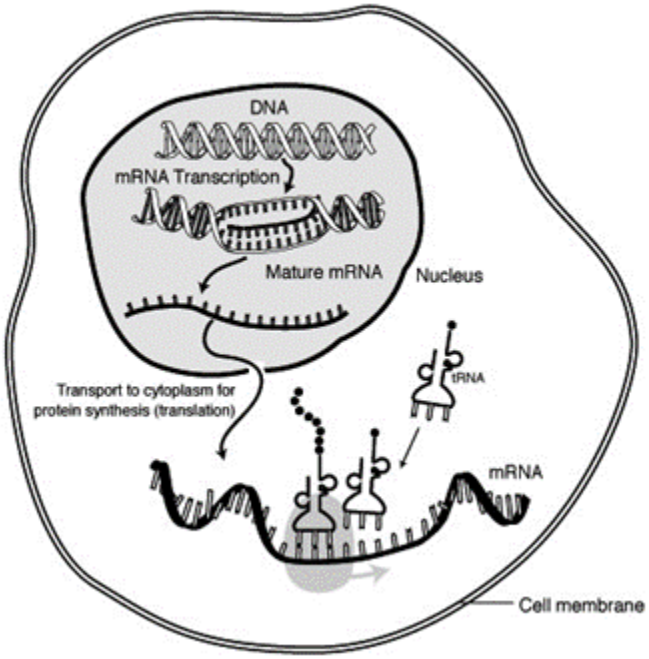
1. Study the figure below and answer the questions that follow:



   a. Why does the formation of RNA occur in the 5' to 3' direction?

b. Why is it necessary for the 3'-5' strand to be the template strand?

2. Why is newly-transcribed mRNA not ready for the synthesis of protein?
3. Why is the success rate of mutation usually high in retroviruses?
4. Study the diagram below and answer the questions that follow.



a. Use your understanding from the diagram to explain why the nucleus controls all the activities in a cell.
b. How are the three different types of RNA important for the process?

3.3. Gene Therapy and Genetic Fingerprinting

3.3.1. Scope: Medical conditions related to genes can potentially be treated by gene therapy. The therapeutic procedures are performed on stem cells and germs cells. There are ethical and moral issues associated with the application of gene therapy.

3.2.3. Scope: CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) technology involves techniques that allow the editing of genes with the use of an enzyme (Cas9). It has a wide range of applications in correcting genetic defects, treating medical conditions, and improving the growth and resilience of crops. Epigenetics is a growing field of science that aims at improving organisms without the necessary manipulation of genes.

3.3.3. Scope: DNA fingerprinting involves sophisticated procedures (e.g., PCR, gel electrophoresis, Southern blotting, etc.) to identify the difference amongst organisms through sequencing and studying the non-coding part of the DNA. It has a wide range of applications in research, medicine, criminology, forensics, and others.

Scope 3.3.3. The Human Genome Project is an ambitious research project to decipher the chemical makeup of the entire human genetic code. The project is aimed at identifying genes involved in causing different types of diseases.

Objective(s):

LO-1. Develop a model that explains the process of gene therapy in the treatment of a genetic disorder.

Learning experiences:

The teacher may begin the lesson by informing the learner that people have long suffered from some of the incurable diseases related to genetic disorders. The teacher, for instance, may inform the learner that the fate of difficulties related to genetic disorders, such as haemophilia, severe combined immunodeficiency, cancers, etc., are finally combining to an end. With gene therapy technology coming into effect, human diseases due to genetic disorders or syndrome, such as haemophilia, severe combined immunodeficiency, cancers, etc., could be treated. The teacher may inform that gene therapy is one of the marvels of gene technology. The teacher may pose a question: How do you think gene therapy is used in treating genetic disorders? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the process of carrying out gene therapy in treating diseases from the relevant sources (books, online pieces, journal articles, etc.) or weblink (e.g., https://cutt.ly/tIepkZX)
- Based on the information obtained, the learner designs a model (conceptual, theoretical, physical, simulation) that explains the process of gene therapy in the treatment of a genetic disorder. The learner may develop augmented reality experiences in a metaverse studio to generate the QR code. Use a metaverse app to scan the QR code to show the process of gene therapy.
- The learner presents the model that explains the process of gene therapy in the treatment of a genetic disorder to the class. The learner critiques each other's model.

Assessment:

Use rubrics to assess the learner's information management skill, ability to develop a model that explains the process of gene therapy in the treatment of a genetic disorder, and ability to explain the process of gene therapy in the treatment of a genetic disorder using the model. Provide necessary feedback and intervention to the learner. For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022).
- https://cutt.ly/tIepkZX

Objective(s):

LO-2. Communicate the scientific information on the potential uses and implications of CRISPR technology.

Learning experiences:

The teacher may inform the learner that the CRISPR technology, the latest tool of the gene-editing system, may revolutionise the field of medicine. The teacher may inform the learner that the CRISPR technology may come with the possible potentials to cure a range of genetic diseases, including cancer, sickle cell anaemia, etc. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on CRISPR technology and its potential use in medicine with the potential to cure different types of genetic diseases including cancer from the relevant sources (books, online pieces, journal articles, etc.) or weblink (e.g., https://cutt.ly/6IevQHH)
- Based on the information obtained, the learner constructs scientific explanations on CRISPR technology and its potential use and implication.
- The learner communicates scientific information on potential use and implication of CRISPR technology in the field of medicine.

Questions:

The teacher may ask the following questions to check the understanding of the learners:

1. What are the different kinds of diseases that are targeted to treat by gene therapy?
2. CRISPR is the latest technology that has potential use in the treatment of different types of diseases.
    a. What is CRISPR technology?
    b. What are the potential uses of this technology in human welfare?
3. How is traditional gene therapy different from CRISPR technology?

Assessment:

Use rubrics to assess the learner's information management skill, ability to construct and communicate explanations on CRISPR technology and its potential use and implication in

medicine. Provide necessary feedback and intervention to the learner. For recording and reporting, refer science curriculum framework.

Suggested resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022).
- https://cutt.ly/6IevQHH

Objective(s):

LO-3. Construct an argument giving scientific reasons to compare the advantages and disadvantages of gene therapy over the use of drugs (i.e., *pharmacotherapy*) for the treatment of diseases.

Learning experiences:

The teacher may inform the learner that the diseases due to genetic disorders are currently treated using drugs, behavioural management, surgery, etc. However, there is hope with gene therapy as alternative ways to treat such diseases including cancer. The teacher may pose a question: Which of the two ways, treatment through the use of drugs or gene therapy is more viable in treating genetic disorders? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner gathers information on the advantages and disadvantages of gene therapy over the use of drugs (i.e., *pharmacotherapy*) for the treatment of genetic disorder, such as haemophilia, severe combined immunodeficiency, cancer, etc., from the relevant materials (e.g. books, online pieces, articles) or weblinks (https://cutt.ly/cIeJPIR)
- Based on the information gathered, the learner claims one of the methods of treating genetic disorder as effective in treating the genetic disorder.
- The learner engages in argument and defends their claims.

Questions:

The teacher may ask the following questions to check the understanding of the learners:

1. How is the use of drugs in the treatment of disease different from gene therapy?
2. What are the risks associated with current gene therapy trials?

Assessment:
Use rubrics to assess the learner's information management skill, ability to defend their claim that either the use of drugs or gene therapy is more viable in treating genetic disorders. Provide necessary feedback and intervention to the learner.
For recording and reporting, refer science curriculum framework.

Suggested resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- (https://cutt.ly/cIeJPIR

Objective(s):
LO- 4. Communicate scientific information on the prospects and social implications of "The Human Genome Project".

Learning experiences:
The teacher may inform the learner that The Human Genome Project (HGP) is one of the ambitious research projects of science and technology. It is so significant and a milestone in nature that it is equivalent to the Apollo mission that landed man on the Moon. The learner may be informed that the HGP is carried out to decipher the chemical makeup of the entire human genome that could identify the genes involved in causing different types of diseases. The teacher may ask the learner to gather information on the prospects and social implication of the project prior to the class. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information about HGP, its prospect, and its social implications from the relevant materials (e.g. books, online pieces, articles) or weblinks (e.g. https://cutt.ly/uIrqAKg) prior to the class.
- Based on the information obtained, the learner constructs an explanation on the HGP, and prospects and implications of HGP.
- The learner communicates information on the HGP, and prospects and implications of HGP.

Questions:
The teacher may ask the following questions to check the understanding of the learners:

1. What do you understand about the Human Genome Project?
2. Give two importance to the Human Genome Project.

3. Explain well being of human society, if the human genome project is materialised as intended?

Assessment:
Use rubrics to assess the learner's information management skill, ability to construct and communicate explanations on the prospect and implications of HGP. Provide necessary feedback and intervention to the learner. For recording and reporting, refer science curriculum framework.

Suggested resources:
- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/uIrqAKg

Objective(s):
LO- 5. Argue with scientific reasons on the bio-ethical issues of gene therapy and its application for the treatment of medical conditions.

Learning experiences:
The teacher may inform the learner that while gene therapy has immense potential to cure a wide range of genetic disorders along with CRISPR technology and HGP, there still are moral and ethical issues in using such therapy to treat the diseases at the human level. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the ethical issues associated with the application of gene therapy in treating the genetic disorder from the relevant materials (e.g. books, online pieces, article, etc.) or weblinks (e.g. https://cutt.ly/Mzb2zGK) before coming to the class.
- Based on the information obtained, the learner engages in arguments on the ethical issue associated with the application of gene therapy for treatment of medical conditions.

Questions:
The teacher may ask the following questions to check the understanding of the learners:
1. Gene therapy is a technique that holds promise to treat a wide range of diseases. However, the technique is not able to materialise despite lots of research and technology.
    a. What are the processes involved in gene therapy?
    b. Why couldn't this technology come into effect despite its potential in treating different types of diseases?

2. What are some of the social and ethical issues surrounding human gene therapy?

Assessment:
Use rubrics to assess the learner's information management skill, ability to engage in constructive arguments, and communication skill. Provide necessary feedback and intervention to the learner. For recording and reporting, refer science curriculum framework.

Suggested resources:
- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/Mzb2zGK

Objective(s):
LO 6. Design a model that explains the process of genetic fingerprinting.
LO-7. Construct a scientific explanation that the application of genetic fingerprinting can contribute towards promoting peace and justice in the society.

Learning experiences:
The teacher may introduce the lesson by informing the learner that many social issues, such as hit and run cases, paternity dispute, vandalism, arson and larson, battery, rape cases, etc., are on the rise. However, with the advancement in a scientific endeavour and technological innovation, it has become possible to identify suspects or individuals. Genetic fingerprinting is one technology used to identify the suspects through biological samples, such as sweat, spit, hair, etc., left by the suspects at the scene. The teacher may also pose the question: How is genetic fingerprinting carried out? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

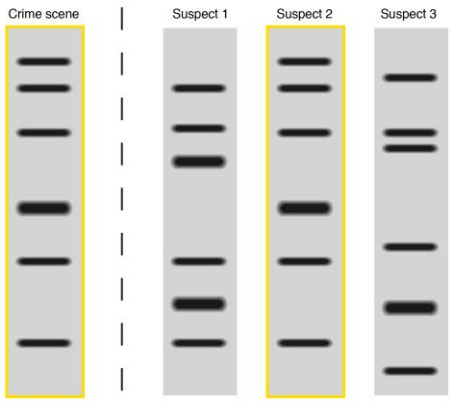
- The learner obtains information on process of genetic finger printing and application of genetic fingerprinting in identification of criminals, kinship analysis, paternity dispute, some factual cases where genetic fingerprinting was used for solving crimes and sex of individuals from relevant sources (e.g., books, online pieces, articles, etc.) or from web link (e.g., https://rb.gy/63m2bn)
- Based on the information obtained, the learner develops a model (conceptual, theoretical, physical, or simulation) that explains the process of genetic fingerprinting. The learner may use relevant software or any programming languages or metaverse studio and metaverse app to develop the model.
- The learner constructs an explanation on the process of genetic fingerprinting using the model.

- The learner constructs and communicates an explanation that the application of genetic fingerprinting can contribute towards promoting peace and justice in the society.

Questions:

The teacher may ask the following questions to check the understanding of the learners:

1. Name the steps involved in the process of DNA fingerprinting.
2. Given below is the DNA fingerprint from the crime scene and the suspect.



   a. Name the technique involved in the above process.
   b. Explain which suspect is most likely to have committed the crime.
3. People feel that DNA can be obtained from the latent fingerprint to identify the suspect. Comment.

Assessment:

Use rubrics to assess the learner's information management skill, ability to design a model that explains the process of genetic fingerprinting and ability to construct explanations using the model, and ability to communicate explanations that application of genetic fingerprinting can contribute towards promoting peace and justice in the society.

For recording and reporting, refer science curriculum framework.

Suggested resources:

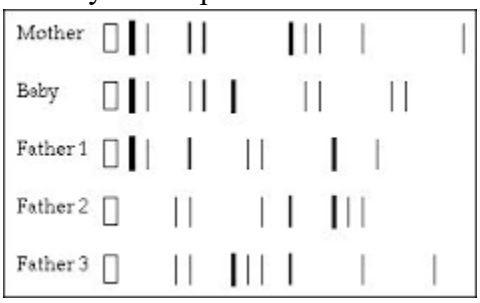
- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://rb.gy/63m2bn

Challenge Your Learner

Teacher may ask the following questions to challenge the thoughts of learner:

1. Gene therapy is biologically, socially, and ethically not right. Comment.

2. What is the Human Genome Project? Explain.
3. What are the benefits of the Human Genome Project?
4. Identify the suspected father from the DNA profile given below



5. Is it necessary to have fingerprints of a person in DNA fingerprinting? Why or why not?
6. While DNA fingerprinting may be able to identify the suspect of the criminal, what type of evidence is needed to link a criminal to a crime?
7. The study of genes and genetic engineering can possibly solve all the real-world problems including the economy and health of people. Comment.

4. Biological Evolution: Unity and Diversity

Biological evolution is the unifying concept of biology. It provides a basis for both the unity and the diversity of life that exists on the Earth. Biological evolution is supported by credible scientific evidence, ranging from fossils to DNA and protein sequence analyses. But what is evolution? Evolution is an ongoing process that occurs when forces, such as natural selection, act on the population that contains genetic variation. The evolutionary forces change the composition of both genes and their corresponding traits in a population gradually over several generations. Through genetic variations, traits that provide an individual with an advantage to best meet the selection pressure and reproduce are more likely to be passed on to the next generation. Over several generations, such a process can lead to the emergence of new species. At the centre, evolution explains both the similarities of genetic material across all species and the multitude of species existing in diverse conditions on Earth. The concept of evolution is, thus, central and critical to understand all the aspects of biology.

Competencies

By the end of class XII, a learner should be able to:

a. using fossil records, similarities in morphological and embryological structures, connecting links, and cytological evidence, explain that all organisms evolved either from common ancestors or divergent ancestral lines.
b. apply the understanding of Lamarckism, Darwinism, mutation theory; modern synthetic theory, and genetic drift theory to explain how modern organisms have evolved from their ancestral forms.
c. using the understanding from evolution, appreciate that all organisms are related to one over another; and have evolved from common ancestors.

4.1. Evidence of Common Ancestry

4.1.1. Scope: Organisms share a lot of similarities in terms of their physical and behavioural characters. The similarities in the organism's morphological structures (homology and analogy) reveal the descendants of organisms from common ancestral forms by evolution. Some organisms are found to contain features of two or more groups of organisms (e.g., duck-billed platypus contains the features of reptiles and mammals).

4.1.2. Scope: The resemblances in the stages of embryonic development and temporary embryonic structures amongst various organisms depict their evolutionary relationships. Embryos of certain organisms provide structural evidence that is not shown by the adults.'

4.1.3. Scope: Fossils and artefacts left by ancestral organisms are sources of information in understanding evolution. These provide a logical basis for understanding the existence of organisms, diversity, extinction, and change of many life forms throughout the history of life on

Earth. Distribution patterns, forms, and ages of fossils are studied to derive the chronological order of evolution (by radioactive carbon dating).

4.1.4. Scope: The nature of fossils (physiology, anatomical structures, or morphological structures) provides substantial information on the nature of change that a region's environment underwent (climate change). Comparing fossils to modern organisms can help to determine the trend of climate change and evolution.

4.1.5. Scope: Organisms exhibit similarities in a lot of cytological features (e.g., biomolecules, cell structure, etc.). Similarities in genetic and biochemical composition indicate the common ancestry amongst organisms. The understanding of molecular biology, cellular processes, information related to genes and proteins are used in studying evolutionary history and developing relationships.

Objective(s):

LO-1. Provide scientific explanation on how morphological structures (*homology and analogy*) indicate the common ancestry of organisms.

Learning experiences:

The teacher may inform the learner that all organisms have evolved from a common ancestor with modifications. The teacher may inform the learner that many organisms share some related structures or processes indicating evolution from a common line of ancestors. The teacher, for instance, may inform the learner that the framework of bird's wings and our forearms are almost similar in nature. The teacher may inform that these shared structures indicate evolution of birds and humans from a common ancestor. The teacher may pose the question: How does the morphological structures indicate the common ancestry of organisms? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on the concept of homologous and analogous organs in plants and animals in relation to convergent and divergent evolution from relevant materials (books, online pieces, articles, etc.) or weblinks (e.g., https://rb.gy/v3d2dc)
- Based on the information obtained, the learner constructs scientific explanations on how morphological structures (homology and analogy) indicate the common ancestry of organisms.

Questions:

The teacher may ask the following questions to check the understanding of the learners:

1. What are homologous structures?

2. Why are human hands and the wings of the bat considered homologous organs?
3. According to the concept of analogy, different organisms when subjected to the same conditions tend to undergo similar changes and, in the long run appear similar. Explain the statement to show the role of the environment in evolution.

Assessment:

Use rubrics to assess learner's information management skills, ability to explain the conceptual understanding of the morphological structure (analogy and homology) of organisms in relation to the convergent and divergent evolution with scientific reason and communication skills. Provide necessary feedback and intervention to the learner.

For recording and reporting, refer science curriculum framework.

Suggested resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)
- https://rb.gy/v3d2dc

Objective(s):

LO-2. Construct a model that represents the evolutionary relationships between different groups of organisms using the concept of missing links and connecting links.

Learning Experiences:

The teacher may begin the lesson by showing a photograph of an archaeopteryx. The teacher may inform the learner about how the fossil of the Archeopteryx was unearthed and what it represents in evolution. The teacher may inform the learner that Archeopteryx is one of the missing links that represents two or more groups of organisms. The teacher may also project some of the living organisms (e.g., duck-billed platypus, lungfishes, euglena, cycas, etc.) that represent two or more groups of organisms. The teacher may inform the learner these living organisms are connecting links that represent two or more groups of organisms. The teacher may pose the question: How are evolutionary relationships of organisms explained by missing links and connecting links ? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner draws the characteristics of an organism (missing link and connecting link) projected by the teacher.
- Based on the characteristics drawn, the learner designs a model (conceptual, theoretical, physical, simulation) that represents the evolutionary relationships between different groups of organisms using the concept of missing links and connecting links.

- The learner presents and critiques each other's model to the class.

Questions:

The teacher may ask the following questions to check the understanding of the learners:

1. What are missing links and connecting links?
2. How do missing links and connecting links demonstrate origin from a common line of ancestry Explain with examples.
3. Duck-billed platypus found in Australia shares some features of reptiles and also mammals. Similarly, there are a lot of other organisms that act as connecting links between different groups of organisms.
    a. How are connecting links important in understanding evolution?
    b. How reliable is the use of connecting links to develop relationships amongst different groups of organisms?
4. Explore for organisms in your locality to construct some evolutionary connections amongst different groups.

Assessment:

Use rubrics to assess learners' information management skills, ability to relate and explain the conceptual understanding of connecting links, and ability to establish evolutionary relationships among different organisms. Provide necessary feedback and intervention.
For recording and reporting, refer science curriculum framework.

Suggested resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)

Assessment:

Use rubrics to assess learner's information management skill, ability to develop a model of a phylogenetic tree (theoretical, conceptual, illustration), the ability to construct explanations using the model to show the evolutionary relationship of various vertebrates, ability to critique and defend on their model of a phylogenetic tree. Provide necessary feedback and intervention to the learner. For recording and reporting, refer science curriculum framework.

Suggested Resources:

- DCPD repository
- Srijan Biology, Bhutan edition, class 12, REC (2016)
- Science Curriculum Framework (NSC- 2022)

Objective(s):

LO-3. Analyse fossil data to understand the pattern of evolution and change in environmental conditions.

Learning Experiences

The teacher may inform the learner that fossils are incredible evidence that forms the basis of evolution. More so, fossils, such as the remains of organisms, including bones, faecal remains, or body structures provide clues to predict the pattern of evolution (in terms diversity, complexity, and extinction) as well as the past environment. The teacher, for instance, may inform the learner that fossils or remains, such as casts, moulds, artefacts, can help to understand life processes and structures of past living organisms, including early human ancestors. The teacher may ask: Can we determine the pattern of evolution and past environment using fossils? How is the pattern of evolution and past environment determined using fossils?.The teacher may provide pictorial fossil records (a fossil or fossils arranged in rock strata from simple to complex); artefacts, such as tools, utensils, cave painting, etc., in the form of pictorial representation. The teacher may ask the learner to deduce the pattern of evolution (in terms diversity, complexity, and extinction) or past living culture and conditions using fossil records and artefacts. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on how the nature of fossils (physiology, morphology, and anatomy) and artefacts are used to deduce pattern of evolution (in terms diversity, complexity, and extinction) and past environment from the relevant materials (e.g., books, online pieces, articles) or web links (e.g.,https://cutt.ly/bzks3aA)
- The learner analyses fossil records (physiology, anatomical structures, or morphological structures) and artefacts to explain patterns of evolution (in terms diversity, complexity, and extinction) and past environmental conditions. The learner may also relate how much an environment of the world has changed over time based on the data presented by fossil records and artefacts.
- The learner communicates scientific information on the patterns of evolution (in terms diversity, complexity, and extinction) and past environmental conditions using fossil records and artefacts.

Questions:

The teacher may ask the following questions to check the understanding of the learners:

1. How does the use of fossils help in understanding the evolutionary pattern of organisms?
2. Can we determine past living conditions of our ancestors based on their artefacts remains. How?
3. How can we use fossil records to understand the change in the patterns of climatic conditions?

4. While the study of fossils in different strata of the rock are convincing evidence of evolution, the fossil may not be the complete record to explain the course of evolution. Comment on the statement giving reasons.
5. How reliable is the use of fossils to study the evolutionary trend of organisms?

Assessment:
Use rubrics to assess the learner's information gathering skill, reliability of their analysis, and ability to communicate comprehensive analysis to the class. Provide necessary feedback and intervention. For recording and reporting, refer science curriculum framework.

Resources:
- DCPD repository
- Srijan Biology Bhutan Edition class 12 (2020), REC
- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/bzks3aA

Objective(s):
LO-5. Make a claim to support which amongst genetic, biochemical, cytological, and fossil evidence is the most credible approach for deriving the evolutionary relationships amongst organisms.

Learning experiences:
The teacher may introduce the lesson by informing the learner that the evolutionary relationship of organisms can be drawn based on genetics, biochemistry, cytology and fossils. The learner may be asked to obtain information on evolutionary relationships of the organism drawn based on genetics, biochemistry, and cytological evidence from the relevant materials (e.g., books, online pieces, articles). The teacher may also pose the question: Which amongst genetic, biochemistry, cytology and fossils is the most credible evidence to explain the evolutionary relationships of the organisms? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on evidence of evolution based on genetics, biochemistry, cytology and fossils and builds relationships between and/or amongst the organisms from the relevant materials (e.g., books, online pieces, articles, etc.).
- Based on the information obtained, the learner claims that one amongst genetic, biochemical, cytological and fossils is the most credible way for deriving relationships between and/or the organisms.
- The learner communicates their claim with scientific reasoning.

Questions:

The teacher may ask the following questions to check the understanding of the learners.

1. Which amongst genetic, biochemical, cytological and fossil evidence is the most reliable to be used in understanding evolution?
2. Does the fossil record tell us the whole story of evolution? Why?
3. Human races (i.e., Negroid, Indian, Caucasian, Mongolian and Malayan) are presumed to have evolved from a common ancestor. Support the statement with scientific evidence.
4. How has the growth of genetics helped in understanding evolution?

Assessment:

Use rubrics to assess the learner's information management skill, ability to construct explanations to build relationships between organisms based on genetic, cytological, fossils and biochemical, ability to communicate and defend the claim that one amongst genetic, biochemical, cytological and fossils is the most credible for deriving the relationship between organisms with scientific reasoning. Provide necessary feedback and intervention to the learner.
For recording and reporting, refer science curriculum framework.

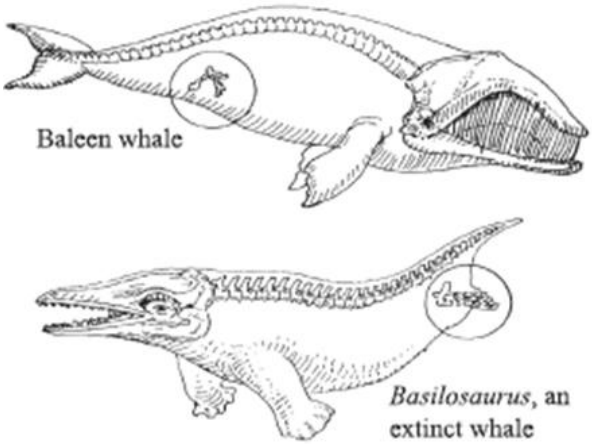
Resources:

- DCPD repository
- Srijan Biology Bhutan Edition class 12 (2020), REC
- Science Curriculum Framework (NSC- 2022)

Challenge Your Learners

The teacher may ask the following questions to challenge the thoughts of students:

1. Amphibians are presumed to have evolved from ancestral fishes by evolution. If evolution indicates the development and replacement of the old forms by the new ones, then why do fish exist today?
2. The concept of 'Ontogeny recapitulates Phylogeny' relies on embryonic development to explain phylogeny. Express your perception on the approach.
3. The figure below shows the presence of bones in the baleen whale and *Basilosaurus,* an extinct whale. Construct an explanation on the course of the evolution of the baleen whale by comparing the structures in these two whales.



4. How do homology and analogy support the concept of the monophyletic origin of life?
5. The table below shows the analysis of DNA sequences of modern primates and their common ancestor.

Group Member	Name of Organism	DNA Sequence
1	Human	A-G-G-C-A-T-A-A-A-C-C-A-A-C-C-G-A-T-T-A
2	Chimpanzee	A-G-G-C-C-C-C-T-T-C-C-A-A-C-C-G-A-T-T-A
3	Gorilla	A-G-G-C-C-C-C-T-T-C-C-A-A-C-C-A-G-G-C-C
4	Common Ancestor*	A-G-G-C-C-G-G-C-T-C-C-A-A-C-C-A-G-G-C-C

   a. Comment on the use of DNA sequencing in determining the phylogenetic relationships among organisms based on examples given in the table.
   b. Identify the most evolved species from the list giving one reason.

4.2. Theories that Explain Evolution

4.2.1. Scope:Lamarcksim explains evolution as a result of the inheritance of characters that an organism obtains or builds during its lifetime. (e.g., Modern day giraffes are presumed to have evolved from short-necked ancestors with regular elongation of their necks).

4.2.2. Scope: Darwinism builds up on the idea that the population of an organism that are suited to live in the environment survive and reproduce, while others that are not suited do not survive.

4.2.3. Scope: Mutation theory explains that any change in the genetic material or randomness creates the organisms to bear either useful or harmful characteristics. Those that gain useful characteristics get selected by the environment and survive, while those that are harmful do not.

4.2.4. Scope: Modern synthetic theory of evolution defines evolution as a result of variation, recombination, natural selection, isolation, and migration.

Objective(s):

LO-1. Construc arguments on the reliability of Lamarckism in explaining the mechanisms of evolution.

Learning Experiences

The teacher may inform the learner that of the several theories, Lamarckism is one of the theories that explains the process of evolution of organisms. The teacher may give a short background information on Lamark who proposed the "theory of acquired inheritance" or Lamaksim. The teacher may ask the learner to gather information on Lamarckism. The teacher may provide the web link (e.g., https://rb.gy/7ab6ac) or any other relevant materials (e.g., books, online pieces, articles, etc.) which contains information about Lamarckism. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on Lamarckism that explains the processes of the evolution of organisms.
- Based on the information obtained, the learner constructs scientific explanations on the evolution of organisms based on Lamarckism.
- The learners engages in an argument with scientific reasons on the credibility and the reliability of Lamarckism in explaining the mechanisms of evolution.

Questions:

The teacher may ask the following questions to check the understanding of the learners:

1. How does Lamarckism explain the evolution of the organisms? Explain.
2. Explain the evolution of modern Giraffes based on Lamarckism.
3. How does Lamarck's idea consider the role of the environment during evolution of organisms?
4. While there are many criticism on Lamrack's theory of evolution, some evolitionalist still support his theory. How would you support or refute Lamarck's claim on the inheritance of acquired characters?

Assessment:

Use rubrics to assess the learner's information management skills, scientific reasoning, and communication skills to compare and assess the reliability of Lamarckism in explaining the mechanism of evolution. Provide necessary feedback and intervention to the learner.
For recording and reporting, refer science curriculum framework.

Resources:

- DCPD repository
- Srijan Biology Bhutan Edition class 12 (2020), REC
- Science Curriculum Framework (NSC- 2022)
- https://rb.gy/mfyrvlor

Objectives(s):

LO-2. Construct a scientific explanation on the evolution of organisms based on Darwinism.

Learning experiences:

The teacher may begin the lesson by informing learners that Darwinism is one the popular theories of evolution. Darwinism or "theory of natural selection" was proposed by Charles Darwin based on findings from the observation of nature. The teacher may inform the learner to read on Darwinism from the relevant materials (e.g., books, online pieces, articles, etc.) or from a web link (e.g., https://rb.gy/wrjmxr) one day before the lesson. The teacher may pose the question: How does Darwinism explain the evolution of organisms?. The teacher deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on evolution of organisms based on Darwinism or theory of natural selection from relevant sources (e.g., books, online pieces, articles, etc.) or from a web link (e.g., https://rb.gy/wrjmxr) prior to the class.
- Based on the information obtained, the learner constructs scientific explanations on the evolution of organisms based on Darwinism.
- The learner assesses the credibility or reliability of Darwinism with scientific reasons. The learner also compares Darwinism with Lamarckism in terms of credibility to explain the evolution of organisms.

Questions:

The teacher may ask the following questions to check the understanding of the learners:

1. Explain the evolution of organisms based on Darwinism.
2. How does Darwins's theory of natural selection relate to the distribution of humans in the different parts of the world?

3. Does natural selection act on the genotype or the phenotype of an organism? Why?
4. Does natural selection operate in present-day conditions? Explain.
5. What is your view on the credibility of Darwinism? Comment.

Assessment:
Use rubrics to assess the learner's information management skills and the ability to explain the evolution of organisms based on Darwinism. Provide necessary feedback and intervention to the learner.
For recording and reporting, refer science curriculum framework.

Resources:
- DCPD repository
- Srijan Biology Bhutan Edition class 12 (2020), REC
- Science Curriculum Framework (NSC- 2022)
- https://rb.gy/wrjmxr

Objectives(s):
LO-3. Construct scientific explanation on the evolution of organisms based on mutation theory.

Learning experiences:
The teacher may inform the learner that organisms evolve as a result of changes in genetic information. For instance, coronavirus is one of the mutants of the SARS virus that became pandemic recently. Evolution of organisms, such as the evolution of coronavirus, is explained by mutation theory proposed by Hugo de Vries. The teacher may inform that this theory, unlike Lamarckism and Darwinism, explains from the point of genetic composition. The teacher may ask the questions: How does mutation theory explain the evolution of organisms? How credible is mutation theory in explaining the evolution of organisms? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on mutation theory that explains the evolution of the organisms from relevant material (books, online pieces, articles, etc.) or web links (e.g., https://rb.gy/ffgawn).
- The learner constructs scientific explanations on the evolution of organisms based on mutation theory.
- The learner assesses the credibility of mutation theory in explaining the evolution of organisms.

Questions:
The teacher may ask the following questions to check the understanding of the learners:
1. Explain the evolution of organisms based on mutation theory.

2. How does mutation influence a population?
3. How does the mutation theory relate to the role of mutation in evolution?
4. How valid is it to consider mutation as the raw material for evolution?
5. How credible is mutation theory in explaining the evolution of organisms? Explain.
6. Relate mutation theory with the evolution of coronavirus from SARS virus.

Assessment:

Use rubrics to assess the learner's information management skills and the ability to construct scientific explanations on the evolution of organisms based on mutation theory. Provide necessary feedback and intervention to the learner. For recording and reporting, refer science curriculum framework.

Resources:

- DCPD repository
- Srijan Biology Bhutan Edition class 12 (2020), REC
- Science Curriculum Framework (NSC- 2022)
- https://rb.gy/ffgawn

Objective(s):

LO-4. Argue with scientific reasons which amongst Lamarckism, Darwinism, and mutation theory, is the most credible theory in explaining the mechanisms of evolution.

Learning Experiences:

The teacher may inform the learner that Lamarckism, Darwinism, and mutation theory have different ways to explain the evolutionary mechanisms of the organisms. Each theory has its own merits and shortfalls. The teacher may ask the learner to assess each theory of evolution and choose which amongst them is more reliable and credible in explaining the mechanism of evolution. The learner may be asked to defend his or her claim with scientific reasons. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner assesses the reliability of Lamarckism, Darwinism, and mutation theory in explaining the evolutionary mechanisms of organisms.
- Based on the information obtained, the learner claims and defends with scientific reasoning to support the most credible theory of evolution.

Questions:

The teacher may ask the following questions to check the understanding of the learners:

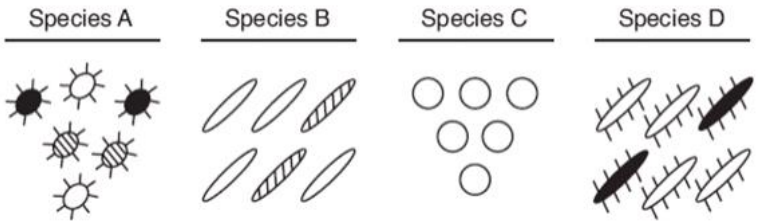
1. Among the following theories of evolution Lamarckism, Darwinism and Mutation, which theory do you feel are more convincing?

2. Modern synthetic theory is said to be a reconciliation of Darwinism and Mutation theory. Explain.

Assessment:
Using rubrics assess learner's comprehension skills and the ability to defend on the choice of the most credible theory of evolution. Provide necessary feedback and intervention to the learner. For recording and reporting, refer science curriculum framework.

Resources:
- DCPD repository
- Srijan Biology Bhutan Edition class 12 (2020), REC
- Science Curriculum Framework (NSC- 2022)
- https://cutt.ly/lzkzrQy)

Challenge Your Learners
The teacher may ask the following questions to challenge the thoughts of students:
1. In Europe, the black pepper moth was supposed to have evolved during the time of industrial revolution. Explain the evolution of such moth based on
    a. Lamarkism
    b. Darwinism.
2. The inability to cure COVID-19 has been linked to the ability of the virus to mutate with a higher success rate. How would the mutation theory explain the survivability of the virus?
3. Explain the evolution of new species of organisms based on Neo-Darwinism.
4. The diagram below shows four different species of bacteria.



Which species will show more adaptability if the environment in which bacteria lives changes? why?

4.3. Evolution from Allele Frequency

4.3.1. Scope: In absence of evolutionary forces, there is no change in gene frequency and genotype frequency and thus no evolution. Natural selection and artificial selection (techniques such as gene cloning, hybridization in agriculture and animal husbandry; and other human

breeding techniques) influence or alter the frequency of allele, genotype and the corresponding traits.

4.4.2. Scope: According to genetic drift theory, change in allele frequency or genotype frequency; and traits in a population occurs by chance due to factors such as natural calamities (sudden change in seasonal temperature, climate change, acidity, and forest fire), and geographical barriers. Moreover, human activities also contribute to evolution.

4.3.3. Scope: According to Hardy-Weinberg's principle, if there is no change in allele frequency, a population is said to be in stable or equilibrium. However, if there is a change in allele frequency, the population is said to be in the state of evolution

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Objective(s):

LO-1. Construct scientific explanation on how natural selection and artificial selection contribute to the evolution of organisms based on change in allele frequency.

Learning Experiences:

The teacher may ask the learner to reflect upon how the evolution of organisms is explained by "theory of natural selection". The teacher may, however, inform the learner that the "theory of natural selection" propounded by Darwin did not touch on genetic aspects. The teacher may inform the learner that natural selection, as a creative force, actually operates on genetic variants and leads to evolution of the organisms. At the same time, the teacher may also inform that human activities, such as artificial selection, selective breeding, gene cloning, or hydration, etc., also contribute to the evolution of organisms. The teacher, for instance, may link how selective breeding has led to the evolution of different varieties of dog breeds. The teacher may pose the question: How does natural selection and artificial selection contribute to evolution through allele frequency? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner obtains information on how natural selection and artificial selection (e.g., selective breeding, gene cloning, hybridisation, manual selection, etc.) contribute to the evolution of organisms through changing gene (allele/genotype) and phenotype (trait) frequency from relevant materials (books, online pieces, articles, etc.) or web link (e.g., https://rb.gy/t8vf7o).
- The learner evaluates and analyse how how natural selection and artificial selection (e.g., selective breeding, gene cloning, hybridisation, manual selection, etc.) contribute to the evolution of organisms through changing gene (allele/genotype) and phenotype (trait) frequency.The learner may use mathematical models, such as Hardy-Weinberg's principle, to assess how natural selection and artificial selection contribute to the

evolution of organisms through changing genotype (allele) frequency and genotype frequency.

- The learner constructs scientific explanations on how natural selection and artificial selection (e.g., selective breeding, gene cloning, hybridisation, manual selection, etc.) contribute to the evolution of organisms through changing gene (allele/genotype) and phenotype (trait) frequency. The learner may use mathematical models, such as Hardy-Weinberg's principle to show how natural selection and artificial selection contribute to the evolution of organisms through changing gene (allele/genotype) frequency and phenotype frequency.

Questions:

The teacher may ask the following questions to check the understanding of the learners:

1. Define the following terms.
    a. Gene frequency
    b. Genotype frequency
2. Alle frequencies of A and alleles in a large population are p and q respectively. What will be the genotype frequencies of their combination in the population?
3. How do natural selection and artificial selection contribute to the evolution of new species? Explain based on allele frequency.
4. If allele frequencies of A are 0.7 and a is 0.3, calculate the genotype frequencies in the gene pool. You may use Punnett square to represent the data.
5. How would artificial selection of crops and ornamental plants affect the genotype frequency in the gene pool of the population?
6. How does the environment affect the allele frequency of a population?

Assessment:

Use rubrics to assess the learner's information management skill, comprehension skill, and the ability to construct explanations on how natural selection and artificial selection contribute to the evolution of organisms through changing gene frequency and genotype frequency. Provide necessary feedback and intervention to the learner. For recording and reporting, refer science curriculum framework.

Resources:

- DCPD repository
- Srijan Biology Bhutan Edition class 12 (2020), REC
- Science Curriculum Framework (NSC- 2022)
- https://rb.gy/t8vf7o

Objective(s):

LO-2. Analyse how the effect of human activities on gene frequencies is related to the endangerment of species.

Learning Experiences:

The teacher may begin the lesson by informing the learner that species are still evolving as well endangered under the influence of evolutionary forces. The teacher may inform the learner that evolutionary forces can be either natural forces (genetic variation, natural selection, genetic drift, isolation, or migration) or human-induced forces (gene technologies, hybridisation, selective breeding, or manual selection). The teacher may pose a question: How do human-induced forces (anthropogenic activities) lead to the endangerment of species through allele frequency? The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner explores information on how human activities, such as gene technologies, hybridisation, selective breeding, and manual selection that lead to endangerment of species through changing gene (allele/genotype) frequency from relevant materials (books, online pieces, articles, etc.) or web link (e.g., https://rb.gy/cjjrkz).
- The learner evaluates and analyse how how human activities (e.g., selective breeding, gene cloning, hybridisation, or manual selection, etc.) contribute to the ead to endangerment of species through changing gene (allele/genotype) frequency.The learner may use mathematical models, such as Hardy-Weinberg's principle, to assess human activities lead to the endangerment of organisms through changing genotype (allele) frequency.
- The learner constructs scientific explanations on how human activities (e.g., selective breeding, gene cloning, hybridisation, or manual selection, etc.) contribute to the endangerment of species through changing gene (allele/genotype) frequency. The learner may use mathematical models, such as Hardy-Weinberg's principle, to support how human activities lead to the endangerment of organisms through changing genotype (allele) frequency.

Questions:

The teacher may ask the following questions to check the understanding of the learners.

1. How does human activities lead to the endangerment of species. Explain based on allele frequency.
2. What are some of the factors that lead to the evolution of species?
3. According to the Hardy-Weinberg principle, the relative frequencies of alleles remain constant generation after generation in a large population if no evolutionary force acts on it. How do environmental factors influence the equilibrium state as explained by the Hardy-Weinberg principle?

4. Though random mating causes variation, the Hardy-Weinberg principle does not list it as a contributing factor for evolution. Explain giving scientific reasons.

Assessment:
Use rubrics to assess the learner's comprehension skill, ability to construct and communicate explanations on how the effect of anthropogenic activities on gene frequencies is related to the endangerment of species, ability to construct arguments with scientific evidence on anthropogenic activities, such as gene technologies, hybridisation and manual selection that lead to evolution through the change in corresponding allele frequency. Provide necessary feedback and intervention. For recording and reporting, refer science curriculum framework.

Resources:
- DCPD repository
- Srijan Biology Bhutan Edition class 12 (2020), REC
- Science Curriculum Framework (NSC- 2022)
- https://rb.gy/cjjrkz

Objective(s):
LO-3. Construct scientific explanation to show the roles of evolutionary factors in the formation of new species (*limited to variation, selection, isolation, migration, and genetic drift theory).*

Learning Experiences:
The teacher may begin the lesson by informing the learner that new species evolve as a result of evolutionary forces, such as genetic variation, genetic drift, isolation, or migration. The teacher may provide the link https://rb.gy/9aia71 or any other relevant materials (books, online pieces, articles, etc.) that describe the role of evolutionary forces that lead to the evolution of new species prior to the class. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner explores information on how evolutionary forces (genetic variation, natural selection, genetic drift, isolation, or migration) lead to the evolution of new species from relevant materials (e.g., books, online pieces, articles, etc.) or web links (e.g., https://rb.gy/9aia71).
- Based on the information explored, the learner constructs scientific explanations on the roles of evolutionary factors in the formation of new species in the class.

Questions:
The teacher may ask the following questions to check the understanding of the learners:
1. What are the different forces of evolution?
2. Explain the role of genetic drift in speciation with an example?

3. How does migration contribute to evolution?

Assessment:
Use rubrics to assess the learner's information management skill, ability to construct and communicate explanations to show the roles of evolutionary factors in the formation of new species. Provide necessary feedback and intervention. For recording and reporting, refer to the Science Curriculum Framework (NSC- 2022).

Resources:

- DCPD repository
- Srijan Biology Bhutan Edition class 12 (2020), REC
- Science Curriculum Framework (NSC- 2022)
- https://rb.gy/9aia71

Objective(s):
LO 4. Construct scientific explanation to derive a relation between Mendel's concept of inheritance and Hardy-Weinberg's principle to develop the role of inheritance in evolution.

Learning Experiences:
The teacher may begin the lesson by informing the learner that the allele and genotype frequencies in a group of offspring, from a given allele frequency of a parent, can be predicted using Mendel's Monohybrid cross. The teacher may deliver the lesson based on the following order of scientific and engineering practises:

- The learner gathers information on Mendel's monohybrid cross and Hardy-Weinberg principle from relevant materials (e.g., books, online pieces, articles, etc.) or web link (e.g., Mendel (biology-pages.info , https://rb.gy/xll7ei)
- Based on the information gathered, the learner analyses (e.g., graphing, tabulation, statistic, etc.) to derive the relation between Mendel's concept of inheritance and Hardy-Weinberg's principle to develop the role of inheritance in evolution.
- The learner derives a relation between Mendel's concept of inheritance and Hardy-Weinberg's principle to acclaim the role of inheritance in evolution.
- The learner provides scientific explanation on the relation between Mendel's concept of inheritance and Hardy-Weinberg's principle to acclaim the role of inheritance in evolution to the class.

Questions:

The teacher may ask the following questions to check the understanding of the learners:

1. A population at Hardy-Weinberg equilibrium has two alleles for fur colour: red and black represented by b and B respectively. Assume black is dominant to red fur colour. Of the animals in the population, 16 percent of the animals have red fur.
    a. What percentage of the alleles in the population code for black fur?
    b. Represent the genotype frequency in F1 and F2 generation, if the parental generation of homozygous red and homozygous black are interbred.
2. How does the inheritance of characters relate to the evolution of the organisms?

Assessment:

Use rubrics to assess the learner's information management skill, ability to construct and communicate explanations to derive a relation between Mendel's concept of inheritance and Hardy-Weinberg's Principle. Provide necessary feedback and intervention. For recording and reporting, refer science curriculum framework.

Resources:

- DCPD repository
- Srijan Biology Bhutan Edition class 12 (2020), REC
- Science Curriculum Framework (NSC- 2022)
- Mendel (biology-pages.info, https://rb.gy/xll7ei

Challenge Your Learners

The teacher may ask the following questions to challenge the thoughts of students:

1. Hardy-Weinberg principle states that gene frequency and genotype frequency remain constant for the population of an organism in an ideal condition.
    a. How do allele frequency and genotype frequency of the population of an organism change over time?
    b. If Hardy-Weinberg's principle does not hold true in the natural population of the organisms, why do scientists use this principle?
2. How does evolution change the relative frequency of alleles in a population?
3. While human activities help to produce new varieties of crops and animals, such anthropogenic activities also threaten the species leading to endangerment and extinction. Explain**.**
4. Design an expression to relate differential reproduction to allele frequency.
5. Humans are one of the active agents that contribute to the evolution of new species. Comment.
6. How would you determine the evolution of a population of squirrels? Explain.

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Appendix A

Science and Engineering Practises

The practises described in this chapter are drawn from those that scientists and engineers actually engage in as part of their work or STEM activities. It is important to recognise that the learner cannot reach the level of competence of professional scientists and engineers, any more than a novice violinist is expected to attain the abilities of a virtuoso. Yet learners' opportunities to immerse themselves in these practises and to explore why they are central to science and engineering are critical to appreciating the skill of the expert and the nature of his or her enterprise.

Science practises are major practises (methods) employed by scientists when they observe and investigate the natural and human-made world and build theories and models. The engineering practises, on the other hand are, major practises (methods) used by engineers when they design and build human-made systems. The classes IX to XII biology curriculum, therefore, emphasises following eight science and engineering practises:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence, and
8. Obtaining, evaluating, and communicating information (NRC, 2012).

Each of the above science and engineering element demands learners and teachers to perform wide arrays of practises. The approach to science practises are considerably similar to engineering practises, however, the role of each element in science briefly contrasts with their counterparts in engineering. Each of the practises can be used iteratively or in combination but not in the orderly fashion as presented. The practises are explained in the following sections as:

DISTINGUISHING PRACTISES IN SCIENCE FROM THOSE IN ENGINEERING

1. Asking Questions and Defining Problems

Science begins with a question about a phenomenon, such as "Why is the sky blue?" or "What causes cancer?" and seeks to develop theories that can provide explanatory answers to such questions. A basic practise of the scientist is formulating empirically answerable questions about phenomena, establishing what is already known, and determining what questions have yet to be satisfactorily answered.

Engineering begins with a problem, need, or desire that suggests an engineering problem that needs to be solved. A societal problem such as reducing the nation's dependence on fossil fuels may engender a variety of engineering problems, such as designing more efficient transportation systems, or alternative power generation devices such as improved solar cells. Engineers ask questions to define the engineering problem, determine criteria for a successful solution, and identify constraints.

2. Developing and Using Models

Science often involves the construction and use of a wide variety of models and simulations to help develop explanations about natural phenomena. Models make it possible to go beyond observables and imagine a world not yet seen. Models enable predictions of the form "if . . . then . . . therefore" to be made in order to test hypothetical explanations.

Engineering makes use of models and simulations to analyze existing systems so as to see where flaws might occur or to test possible solutions to a new problem. Engineers also call on models of various sorts to test proposed systems and to recognize the strengths and limitations of their designs.

3. Planning and Carrying Out Investigations

Scientific investigation may be conducted in the field or the laboratory. A major practise of scientists is planning and carrying out a systematic investigation, which requires the identification of what is to be recorded and, if applicable, what are to be treated as the dependent and independent variables (control of variables). Observations and data collected from such work are used to test existing theories and explanations or to revise and develop new ones.

Engineers use investigation both to gain data essential for specifying design criteria or parameters and to test their designs. Like scientists, engineers must identify relevant variables, decide how they will be measured, and collect data for analysis. Their investigations help them to identify how effective, efficient, and durable their designs may be under a range of conditions.

4. Analyzing and Interpreting Data

Scientific investigations produce data that must be analyzed in order to derive meaning. Because data usually do not speak for themselves, scientists use a range of tools including tabulation, graphical interpretation, visualization, and statistical analysis to identify the significant features and patterns in the data. Sources of error are identified and the degree of certainty calculated. Modern technology makes the collection of large data sets much easier, thus providing many secondary sources for analysis.

Engineers analyze data collected in the tests of their designs and investigations; this allows them to compare different solutions and determine how well each one meets specific design criteria that is, which design best solves the problem within the given constraints. Like scientists, engineers require a range of tools to identify the major patterns and interpret the results.

5. Using Mathematics and Computational Thinking

In science, 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, statistically analyzing data, and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable predictions of the behavior of physical systems, along with the testing of such predictions. Moreover, statistical techniques are invaluable for assessing the significance of patterns or correlations.

In engineering, mathematical and computational representations of established relationships and principles are an integral part of design. For example, structural engineers create mathematically based analyses of designs to calculate whether they can stand up to the expected stresses of use and if they can be completed within acceptable budgets. Moreover, simulations of designs provide an effective test bed for the development of designs and their improvement.

6. Constructing Explanations and Designing Solutions

The goal of **science** is the construction of theories that can provide explanatory accounts of features of the world. A theory becomes accepted when it has been shown to be superior to other explanations in the breadth of phenomena it accounts for and in its explanatory coherence and parsimony. Scientific explanations are explicit applications of theory to a specific situation or phenomenon, perhaps with the intermediary of a theory-based model for the system under study. The goal for students is to construct logically coherent explanations of phenomena that incorporate their current understanding of science, or a model that represents it, and are consistent with the available evidence.

Engineering design, a systematic process for solving engineering problems, 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, technological feasibility, cost, safety, esthetics, and compliance with legal requirements. There is usually no single best solution but rather a range of solutions. Which one is the optimal choice depending on the criteria used for making evaluations.

7. Engaging in Argument from Evidence

In science, reasoning and argument are essential for identifying the strengths and weaknesses of a line of reasoning and for finding the best explanation for a natural phenomenon. Scientists must defend their explanations, formulate evidence based on a solid foundation of data, examine their own understanding in light of the evidence and comments offered by others, and collaborate with peers in searching for the best explanation for the phenomenon being investigated.

In engineering, reasoning and argument are essential for finding the best possible solution to a problem. Engineers collaborate with their peers throughout the design process, with a critical stage being the selection of the most promising solution among a field of competing ideas. Engineers use systematic methods to compare alternatives, formulate evidence based on test data, make arguments from evidence to defend their conclusions, evaluate critically the ideas of others, and revise their designs in order to achieve the best solution to the problem at hand.

8. Obtaining, Evaluating, and Communicating Information

Science cannot advance if scientists are unable to communicate their findings clearly and persuasively or to learn about the findings of others. A major practise of science is thus the communication of ideas and the results of inquiry—orally, in writing, with the use of tables, diagrams, graphs, and equations, and by engaging in extended discussions with scientific peers. Science requires the ability to derive meaning from scientific texts (such as papers, the Internet, symposia, and lectures), to evaluate the scientific validity of the information thus acquired, and to integrate that information.

Engineers cannot produce new or improved technologies if the advantages of their designs are not communicated clearly and persuasively. Engineers need to be able to express their ideas, orally and in writing, with the use of tables, graphs, drawings, or models and by engaging in extended discussions with peers. Moreover, as with scientists, they need to be able to derive meaning from colleagues' texts, evaluate the information, and apply it usefully. In engineering and science alike, new technologies are now routinely available that extend the possibilities for collaboration and communication.

Source: Reprinted [or adapted] from National Research Council (2012).

Appendix B

Technology

Technology is one of the elements of the STEM quartet. It is beyond a limited sense often used schools that equates itself with computational and communication devices. Technology results when scientists and engineers apply their understanding of natural and human world to design ways to satisfy human needs and wants (NRC, 2013). As technology in itself is related to the application of science and enginnering, it holds significant role in strengthening path to understand the role of science and engineering. Therefore, technology may be seamlessly amalgamated with science and engineering practises.

The classes IX to XII biology curriculum considers the amalgamation or leverage of technology with science and engineering practises as:

- ✓ Any human-made systems and processes.
- ✓ Objects - using physical objects, such as gadgets, mobile devices, computers, etc.
- ✓ Body of knowledge-using digital resources, digital learning platforms, search engines, etc.
- ✓ Activities-using software or programming languages in designing and making in terms of gamification, simulations, animations, robotics, or coding;
- ✓ Volition-using technology to promote human and cultural values, socio-economic values, and environmental values.

Appendix C

Specific Science and Engineering Practises

With a growing body of research in science education, numerous specific pedagogies have evolved both in the field of science (scientific methods) and engineering (design process) practises. The specific pedagogical practises of both science and engineering practises are evidence-based and research-proven with adequate theoretical grounding. The specific pedagogies are featured in the following sections as:

A. Specific Science Practises

Specific science practises (scientific inquiry/scientific methods/argument-driven inquiry):

1. Inquiry cycle/science cycle (Question, educated guess, experiment, data analysis, conclusion)
2. Project-based learning
3. Problem-based learning
4. Design-based learning/Biomimcy
5. Nature Inspired Innovation or Natured Inspired Design
6. Case-based learning
7. Game-based learning
8. Story-based learning
9. REI (Research, Evidence, and Inference)
10. RET (Research, Evidence, Task)
11. OMG (observe, measure, and generalise)
12. CER (Claim, Evidence, and Reasoning)
13. Explore-before-Explain (EbE)
14. OEC (Obtain/search, Evaluate, and Communicate)
15. GRE (Gather, Reason, and Explain)
16. IDEAS (Idea, Evidence, and Argument in Science)
17. POE (Predict, Observe, and Explain)
18. PROE (Predict, Reason, Observe and Explain)
19. PEOE (Predict, Explain, Observe, and Explain)
20. POEA (Predict, Explain, Observe, and Apply)
21. TPE (Think, Puzzle, and Explain)
22. Kolbles learning cycle (concrete experience, reflective observation, abstract conceptualization, and active experimentation, etc.)
23. Atkin and Karplus Learning cycle (concept exploration, concept invention, and concept application)

24. Other learning cycles (3E, 4E, 5E, 6E and 7E)
25. 5D inquiry or appreciative inquiry (Define, Discovery, Dream, Design, Deliver)
26. ADDIE model (Analyse, Design, Develop, Implement, and Evaluate)

B. Specific Engineering Practises

Specific engineering practises (engineering design process/ design process/design thinking):

1. DBT (Design, Build, and Test)
2. DDO (Design, Develop, and Optimise the solutions)
3. EDM (Explore, Design, and Make)
4. ADDIE (Analyse, Design, Develop, Implement, and Evaluate)
5. 5D (Definition, Discovery, Dream, Design, Deliver)
6. Comprehensive engineering design process as:
    - Identify the Need & Constraints
    - Research the Problem
    - Imagine: Develop Possible Solutions
    - Create: Build a Prototype
    - Test and Evaluate Prototype
    - Improve: Redesign as Needed
7. Design thinking process:
    - Formulating Problems
    - Seeking Solutions
    - Thriving in Uncertainty
    - Collaborating Constantly
    - Prototyping Ideas
    - Iterating Options
    - Reflecting Frequently

Appendix D

Weighting and Instructional Time for Class XI

Sl No	Core Ideas	Weighting (%)	Instructional Time (min)
1. Molecules to Organism: Structures and Processes			
1.1	Biomolecules: What makes up living organisms?	5	500
1.2	The Power of Enzymes	4	400
1.3	Organs for Breathing	5	300
1.4	Transport System in the Human Body	6	510
1.5	Homeostasis: The Biological Ropewalk	4	480
1.6	Chemical Coordination	5	350
1.7	Nervous Coordination	7	420
1.8	Body's Defense System	4	180
1.9	Transport System in Plants	4	150
2. Ecosystems: Interactions, Energies and Dynamics			
2.1	Organism in their Environment	8	600
2.2	Environmental Pollution	6	570
2.3	Invasive Species: The Threat to Biodiversity	5	540
3. Heredity: Inheritance and Variation of Traits			
3.1	DNA Replication	4	230
3.2	Growth, Development, and Reproduction	7	420
3.3	Inheritance of Characters	6	360
3.4	Gene Cloning and Genetic Engineering	5	300
3.5	Variation of Traits	3	240
4. Biological Evolution: Unity and Diversity			
4.1	Origin of Life	7	400
4.2	Diversity of Life	5	250
Total		**100**	**7, 200**

Appendix E

Weighting and Instructional Time for Class XII

Sl No	Core Ideas	Weighting (%)	Instructional Time (min)
1. Molecules to Organism: Structures and Processes			
1.1	Prokaryotic and Eukaryotic Cells	3	240
1.2	Support and Movement Systems	5	480
1.3	Digestion: What is on the Plate?	6	512
1.4	Food and Engergy	7	515
1.5	Perception and Interaction	5	360
1.6	Excretion: The Removal Waste	6	490
1.7	What is inside a Plant?	7	520
1.8	Food for Life	6	520
2. Ecosystems: Interactions, Energies and Dynamics			
2.1	Our Environment	8	523
2.2	Threats on biodiversity	7	420
2.3	Sustainable Management of Natural Resources	6	360
3. Heredity: Inheritance and Variation of Traits			
3.1	DNA: The Blueprint of Life	5	360
3.2	Breaking the Code	4	200
3.3	Gene Therapy and Genetic Fingerprinting	7	490
4. Biological Evolution: Unity and Diversity			
4.1	Evidence of Common Ancestry	7	490
4.2	Theories that Explain Evolution	5	420
4.3	Evolution from Allele Frequency	6	300
	Total	**100**	**7, 200**

Note:

The disciplinary core idea-wise weighting and the corresponding instructional hours (both class XI and XII) is purported to assist classroom instructional practises and assessment of learner's performance expectations or competencies (performance or authentic assessments). At times, learning in the context of project-based learning, problem-based learning, or engaging in design challenges may entail learning over an extended period of time. In such situation, the specific hours of instructional time cleaved in the table may neither suffice the need nor appear ideal. Therefore, the scale and proportion of instructional time may change as per the need of the hour so long the learning objectives are achieved as intended. At the same time, if the weighting cleaved against each disciplinary core idea is deemed necessary to tinker as per the need, the same can be changed by small margin or so.

Concurrently, the disciplinary core idea-wise weighting is not entirely based on the length of the instructional time. The weighting is computeed considering several parameters, such as length of the instructional hours and the nature of the learning objectives in terms of intricacy, complexity, and relevancy.