



National Council for Science
& Technology Communication
(DST), Govt. of India, New Delhi



जन जन के लिये विज्ञान

Science Centre (Gwl.)
Madhya Pradesh

PRAKRUTI MEDIA SHALA

(An Activity Manual)



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जन जन के लिये विज्ञान

Science Centre (Gwl) Madhya Pradesh

Science Centre (Gwl) M.P. is a voluntary organisation devoted to science popularisation and people's science Movement, started work in 1987, but was formally established in 1988. In a short span, the centre organised a science popularisation movement in the most backward areas of Madhya Pradesh, and provided it a meaningful direction. The Science Centre has a well-knit composition consisting of thousands of children, teacher activists, scientists and villagers. The Centre has established children's science councils for school children with a view to taking science to the people, including development of scientific thinking among children, promoting scientific activities, helping people to free themselves from the blind-faiths and traditions and arousing self-confidence. The achievement of this organisation in the past have been significant. The various programmes undertaken reached lakhs of people directly through the medium of science rallies, science songs, science plays, science quizzes, seminars and surveys etc. The Science Centre has also organised a large number of training programmes for activists of other sister organisations in the country and helped hitherto small or infant organisations in neighboring states to come up and grow.

To help Children and teacher in developing a scientific temperament and more frequent use of the Method of Science a **Children Science Congress & Teachers Science Congress** have been started. The basic idea is to demonstrate on a large scale that it is possible to turn the learning of science into an enjoyable and creative pursuit (i.e. joy of learning), that even within the frame work of the existing system of educational itself, it is possible to encourage children to learn science by doing it, by making use of their own hand and head and by treating their environs as a big open and endless laboratory. Other activities of Science Centre include Environment Education Programme, Bal Vigyan Parishad, Science Communication and explaining Miracles, Science Writing Training Workshop for Newspapers/ Radio, Science Popularization, through Folk Arts and Origami, Vigyan Yatra, Seminars and Symposium, Nature Camps, Drinking Water Survey, Clean-up School activity, Peoples Science Festival, Eco Smart School, Chambal Ghati Bachao Andolan and Health Activities.

Science Centre's activities are well appreciated by various State Govt. and NGOs nationally. It was recognised by NCSTC(DST), Govt. of India by awarding its top award of science popularization for the period extending from 1987-91 and its top award for Science Popularization among children to its secretary Late Shri Arun Bhargava in year 2001.

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(DST), Govt. of India, New Delhi



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**Science Centre (Gwl.)
Madhya Pradesh**

PRAKRUTI MEDIA SHALA

(An Activity Manual)

Development and Dissemination by

SCIENCE CENTRE (GWL) M.P.

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मध्यप्रदेश शासन



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संदेश

मुझे साइंस सेंटर ग्वालियर को बधाई देते हुए बेहद खुशी हो रही है कि उन्होंने पर्यावरण के प्रमुख घटकों, वातावरण और खगोलविज्ञान को समाहित करते हुए एक साइंस किट 'ईको यूरेका किट' का निर्माण किया है।



प्रकृति स्वयं में एक प्रयोगशाला है उसे किसी कमरे में या प्रयोगशाला में बैठकर नहीं समझा जा सकता है। जब कोई भी प्रकृति प्रेमी किसी प्रयोग को करने के उद्देश्य से प्रकृति के बीच में जाये तो उसे इस बात का अफसोस न हो कि उसके पास इस प्रयोग को करने के लिए आवश्यक उपकरण नहीं है। वह इस किट के माध्यम से प्रयोग कर सकता है।

यह जानकर प्रसन्नता हुई है कि साइंस सेंटर ग्वालियर द्वारा 'ईको यूरेका किट' के प्रयोगों को पूरे भारत तथा वैश्विक स्तर पर फैलाने के उद्देश्य से एक वेबसाइट 'प्रकृति मीडिया शाला' का निर्माण किया जा रहा है। साथ ही वेबसाइट की निर्देशिका का निर्माण भी किया जा रहा है। इस निर्देशिका से प्रतिभागी अपने प्रयोगों को आसानी से समझ सकेंगे।

शुभकामनाओं सहित,

(विश्वास कैलाश सारंग)

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National Council for Science and Technology Communication (DST) GOI, New Delhi

NCSTC is an apex organization of the Department of Science and Technology of Government of India that endeavours to :

- Communicate Science and Technology
- Stimulate Scientific and Technological temper
- Coordinate and orchestrate such efforts

Goals:

- To create excitement concerning advances in Science & Technology
- To enable informed decision-making at the grass roots level
- To encourage intelligent debate on developmental issues
- Research in thrust areas of science and technology communication
- Development of scripts, films, video and radio programmes, books, slide sets, etc., on selected areas of science and technology
- Training (short term) for school teachers and activists of science & technology based voluntary organisations in science communication
- Development of science journalists through University Courses in Science and Technology Communication
- Awards and recognition for outstanding science communicators
- Coordination with state councils and networks of S&T based organisations
- Developing capacity through science communication
- Field programmes for demonstrating innovative ideas of science popularisation, outreach and extension activities including Children's Science Congress, Science Day celebrations, Promotion of voluntary blood donation programmes, environmental awareness and positive action, etc., and Promoting International Cooperation for mutual benefit.

National Council for Science & Technology Communication,
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MESSAGE



Introducing young minds to the scientific method through hands-on, activity-based learning is essential for nurturing their understanding of the world around them. Such experiential learning fosters the construction of knowledge and enhances awareness of various aspects of the physical, chemical, and biological environment. While the importance of sustainable living is widely acknowledged, the question of how to instill a deep understanding of sustainability in the younger generation remains a pressing concern.

Life on Earth depends on five fundamental elements — Water, Air, Land, Living Organisms, and Space (including the atmosphere and celestial bodies). Observing, analyzing, and comprehending issues related to these elements is key to understanding the necessity of their sustainable use and conservation.

The National Council for Science & Technology Communication (NCSTC) is committed to promoting a "learning by doing" approach among children. By encouraging curiosity and scientific inquiry, we aim to develop a generation equipped with a scientific temperament and the capability to contribute meaningfully to nation-building.

I am delighted to learn that the Science Centre has launched the *Prakruti Media Shala*, a virtual platform designed to help children, teachers, youth, and the general public explore and understand nature and its components. This initiative builds upon the *Eco Eureka Kit*, developed with the support of the Department of Science & Technology, Government of India. As a virtual extension of the kit, *Prakruti Media Shala* provides an engaging, experiment-based learning experience that helps various target groups gain deeper insights into environmental phenomena and ecological processes.

It is particularly encouraging to know that *Prakruti Media Shala* is open to individuals and institutions alike. Users from diverse backgrounds can register as partners, participate in scientific activities, and share their experiences through various media formats such as text, videos, photographs, audio clips, and more.

I extend my heartfelt appreciation to the Science Centre, Gwalior, Madhya Pradesh, and its dedicated team for conceptualizing and developing *Prakruti Media Shala*. This innovative platform offers a valuable opportunity for both school-going and out-of-school children, youth, and practitioners to engage, interact, and learn collaboratively in a virtual environment.

Dr. Rashmi Sharma

Head

National Council for Science &
Technology Communication (NCSTC),
Department of Science & Technology,
Government of India

From President's Desk



Since its inception in 1987, the Science Centre (Gwalior), Madhya Pradesh, has been at the forefront of the People's Science Movement, actively working to popularize science across communities. One of the Centre's landmark initiatives was the launch of a child-centric scientific research program, which eventually evolved into the flagship initiative of the National Council for Science and Technology Communication (NCSTC), Department of Science and Technology, Government of India — the **National Children's Science Congress (NCSC)**. Today, the Centre proudly serves as the state-level coordinating agency for both the **National Children's Science Congress** and the **National Teachers' Science Congress**.

Under the banner of the People's Science Movement, the Science Centre has conceptualized and conducted a wide range of impactful programs and activities. These include environmental education campaigns, nature camps, surveys assessing local natural resources, science rallies (Vigyan Yatra), quizzes, workshops, street plays, media-based science communication, folk-art integration, health awareness initiatives, and constitution of **Children's Science Councils (Baal Vigyan Parishads)** in schools. These efforts are designed to engage children, youth, parents, the broader society in meaningful scientific dialogue.

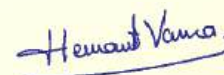
To support and enhance learning outcomes, the Science Centre has also developed and distributed educational modules and activity kits that promote both curricular and co-curricular development. These resources are created with a focus on equity—addressing gender, economic, social, and geographical disparities—while ensuring engaging, quality education.

One of the Centre's recent innovations is the **Eco-Eureka Kit**, an experiential learning tool designed for diverse age groups and communities. This kit encourages users to explore environmental parameters—including air, water, soil, atmosphere, space, and biodiversity—through hands-on experiments. The activities are structured to foster critical thinking and creativity, and most tools can be assembled using locally available materials.

To complement the physical kit, the Centre has developed a virtual counterpart — **Prakruti Media Shala**. This digital platform brings the Eco-Eureka experience online, offering children, educators, youth, and the general public an interactive space to explore environmental science. Leveraging science media, gamification, and DIY methodologies, Prakruti Media Shala enables participants to share and learn collaboratively, deepening their understanding of nature through shared exploration.

Both the Eco-Eureka Kit & Prakruti Media Shala represent the Centre's commitment to a **people-centric approach** to science education, aligning with its broader mission of participatory science communication.

I would like to express my sincere gratitude to the **National Council for Science and Technology Communication (NCSTC), DST, Government of India**, for their trust in our vision and for supporting the development of the Prakruti Media Shala platform. I also extend heartfelt congratulations to **Mrs. Sandhya Varma**, Secretary, for her unwavering dedication, and acknowledge with appreciation the valuable contributions of all experts, professionals, volunteers, technical staff, and team members of the Science Centre who made this initiative possible.



Hemant Varma

President

Science Centre (Gwl) M.P., Bhopal

From Secretary's Desk

It is a well-established fact that activity-based learning plays a vital role in nurturing inquisitiveness, curiosity, observation, and innovation among children. Beyond building knowledge through play, this approach enhances children's social development by promoting collaboration, discussion, communication, logical reasoning, and mutual cooperation. It emphasizes learning through hands-on experiences rather than rote memorization, allowing children to construct their own understanding of concepts. During assessments, instead of recalling memorized text, children can confidently draw on their experiential learning in a stress-free environment.



Interest fuels attentiveness, and when children are allowed to learn at their own pace, it leads to deeper, more meaningful learning. Recognizing this, the International Bureau of Education, the UNESCO Centre of Excellence in curriculum development, has endorsed the 'Child-Centric Approach' — placing children at the heart of the learning process, actively participating in their education through self-chosen activities.

In line with this philosophy, the **Science Centre (Gwalior), Madhya Pradesh**, was founded in 1987 with a strong commitment to child-centric education. Its mission has focused on promoting science through the design and implementation of activity-based learning programs. Acknowledging the limitations of conventional education — particularly in tribal and rural areas where children often lacked access to quality schooling — the Centre initiated the **People's Science Movement** in 1988. This flagship initiative aimed to foster scientific awareness in underserved communities and create supportive environments for meaningful science learning.

Through this movement, the Science Centre introduced a wide range of engaging activities, including environmental education, nature camps, local resource surveys, science rallies, quizzes, plays, workshops, training sessions, and awareness campaigns. Efforts also included establishing **Children's Science Councils (Baal Vigyan Parishad)** in schools, promoting grassroots involvement in science education.

One of the Centre's landmark contributions has been the creation of the **Children's Science Congress (CSC)** in 1987. The idea was to make science an enjoyable, creative, and locally relevant pursuit for children, even within the formal education system. By planning studies on local issues, designing experiments, collecting and analyzing data, children could engage with science in an authentic, hands-on manner. The success of CSC led to its adoption in 1993 by the **National Council for Science and Technology Communication (NCSTC), Department of Science & Technology**, Government of India, as the **National Children's Science Congress (NCSC)**. The Science Centre continues to serve as the coordinating agency for both the NCSC and the **National Teachers' Science Congress (NTSC)** in Madhya Pradesh.

To further embed the child-centric approach in formal education, the Centre has also designed and distributed innovative activity modules and kits. These tools aim to enhance both curricular and co-curricular learning opportunities with a focus on equity across gender, socio-economic status, and geography. A wide network of training programs has helped scale the People's Science Movement nationwide.

In the past two decades, environmental studies have become a central theme in the Centre's science programs. Increasing environmental degradation due to human activities has made it imperative to study natural systems more closely. Nature offers indicators — such as water and air quality, biodiversity characteristics, and ecological interactions — that reflect its health and integrity. Understanding these indicators is essential for assessing environmental change and promoting sustainability.

Recognizing a gap in scientific tools suitable for children to study nature, the Science Centre has developed the **Eco Eureka Kit**. This kit provides simple, low-cost instruments and resources for exploring environmental components — **Water, Soil, Biodiversity, Earth & Atmosphere, and Astronomy** — in a hands-on, playful manner. It encourages experiential learning, making science accessible beyond the classroom.

The accompanying **Eco Eureka Kit Manual** outlines 34 structured activities across the five themes. Each activity includes step-by-step instructions, diagrams, materials lists, data collection methods, key learnings, and open-ended questions. Children are also encouraged to devise their own experiments and tools using the kit's components. Designed to be inclusive, the kit is suitable for children of varying ages, educators, parents, and science enthusiasts. The packaging itself promotes sustainability, made from recycled paper and cloth by **SADEV Creations**, the Centre's recycling unit.

To extend the reach and impact of the Eco Eureka Kit, the Centre has launched a digital platform — **Prakruti Media Shala**. This virtual edition allows a broader audience to access and interact with the Eco Eureka content using science media, gamification, and DIY learning strategies.

Target Audience:

- Children
- Teachers
- Youth
- General Public
- Civil Society

Objectives of Prakruti Media Shala:

- Promote interdisciplinary understanding of environmental concepts.
- Foster ecological awareness and action-oriented learning.
- Encourage curiosity and hands-on exploration of natural phenomena.
- Support communication and collaboration among learners and educators.
- Enhance appreciation and respect for nature and biodiversity.
- Strengthen the human-nature relationship.
- Develop scientific temper through interactive and aesthetic engagement.

Key Features:

- Scripting and production of instructional videos for Eco Eureka Kit activities.
- Regional workshops to train teachers and practitioners.
- Development of educational games and playful learning resources.
- Additional materials including reports, facts, and references.
- Creation of a dedicated website for Prakruti Media Shala, enriched by user contributions (videos, photos, reports, news, etc.).

Benefits:

- Promotes ecological understanding through virtual, experiment-based learning.
- Encourages practical identification of environmental changes.
- Offers an interactive, accessible platform for experiential science learning.
- Facilitates collaborative innovation and sharing of ideas across communities.
- Empowers individuals and groups to become active participants in environmental solutions.

The Prakruti Media Shala affirms that we are all part of the solution to environmental challenges — individually and collectively. It is with great pleasure that I express my gratitude to all the advisors, subject experts, and contributors who provided valuable insights during brainstorming sessions, helping to design the thematic content of the Eco Eureka Kit. I extend my heartfelt thanks to the dedicated team of the Science Centre, our designers, filmmakers, trainers, and collaborators — all of whom played crucial roles in the successful development of the Eco Eureka Kit and its virtual extension.

Special thanks to **Vinay Graphics** for the design and production of the Prakruti Media Shala activity manual.

This initiative was made possible with the **catalytic support of the National Council for Science and Technology Communication, Department of Science & Technology, Government of India.**

Sandhya Varma
State Secretary
Science Centre (Gwl) M.P., Bhopal

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Theme - Water

Water is the intrinsic part of the global ecosystem. It incorporates in the global water cycle and is the source of life. In healthy form and adequate availability it supports the life forms and if mismanaged or polluted it can be the cause of disasters. The quality of water directly affects our life. Good water quality sustains healthy ecosystems and hence leads to improved human well-being. However, poor water quality also negatively affects the environment and human well-being. The quality of water is increasingly threatened by anthropogenic pollution; many of the water pollutants constitute high risk to human health.

It is far cheaper to protect water resources than to spend on measures for its clean up after pollution. Protection and maintenance of the quality of aquatic environments ensures the sustainability of their ecosystem services like potable water, nutrient flows, biodiversity, fisheries, recreation etc. The water theme of Eco Eureka Kit also supports the achievement of Sustainable Development Goal 6 : water and sanitation for all by 2030.

Common characteristics of water that greatly affect human beings and ecosystem health and require our attention have been focused under this theme. These are

- **pH of Water,**
- **Hardness of Water,**
- **Residual Chlorine in Water,**
- **Transparency of Water,**
- **Bacterial Contamination (E. coli) in Water**

Sub-Theme: pH of Water

pH is generally understood in terms of acidity or basicity (to which people sometimes get confused with sour or salty) but it is a chemical characteristic which is affected by contents dissolved in the water and is determined by the concentration of hydrogen ions in it. pH is exhibited as a value ranging between zero to 14. Water pH is an important operational water quality parameter. It fluctuates with differing environmental factors including gases, chemicals and solids. The pH (acidity or basicity) of water effects its composition. The safe pH range for drinking water spans between 6.5 to 8.5. The WHO guidelines for drinking water quality do not propose health-based guideline value for it. The Central Pollution Control Board (CPCB) of India has prescribed Designated Best Use Water Quality Criteria according to which the pH for drinking water without conventional treatment but after disinfection has been prescribed between 6.5 and 8.5, whereas after conventional treatment and disinfection it can be between 6 to 9. For propagation of wildlife and fisheries the water pH may range between 6.5 to 8.5.

There are different methods for estimation of the pH like test by pH strip or titrimetric method or through electronic sensors etc.

Activity: Determination of pH of water sample by 'pH paper test'

About this experiment -

pH is the measure of the acidic or basic nature of a solution. Its value ranges between zero to 14. To know the acidic or basic nature of a solution a litmus paper (which is a filter paper that is treated with natural-soluble dye obtained from lichens) is used whereas to ascertain the range or value of acidity or basicity standard pH paper strip (which is a paper treated with mixture of indicators) is used. The pH paper strip is much useful as it can be used to test more accurate value or range of the pH.

Basic Concept of pH:

- **pH of Neutral Solution** – If the pH of a solution is 7, it will be a neutral solution. Such solution shall not react with litmus or any other liquid indicator.
- **pH of Acidic Solution:** All acidic solutions have pH less than 7. Therefore, whenever the pH of a solution is less than 7 it will be acidic in nature and it will turn the blue litmus to red, and will cause liquid indicators, methyl orange turn to pink and phenolphthalein to colourless.

- **pH of alkaline solution:** All alkaline solutions have a pH greater than 7. Therefore, whenever the pH of a solution is greater than 7 it will be alkaline in nature and will turn the red litmus to blue, and will cause methyl orange turn to yellow and phenolphthalein turn to pink.

Material required-

pH paper strip, any clean small vessel of glass or metal in which some water sample can be taken.

Method -

1. Take the water sample whose pH is to be determined in the vessel,
2. Take a strip from the pH paper strip booklet,
3. Dip the pH paper strip into the sample water and take it out immediately and let it dry for few seconds for any change of colour,
4. Observe the change in colour of pH paper and match it with the colour scale printed on the pH paper strip booklet.
5. The pH of sampled water will be corresponding to the pH value printed on pH booklet with which the changed colours of the tested pH strip matches.

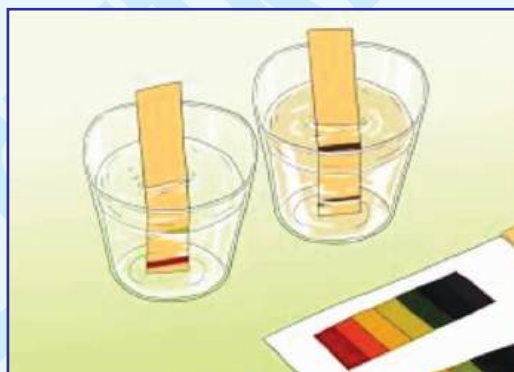


Figure: Dipping of pH Strip in Sample Water



Figure: Change in Colour of pH Strip

Data collection and analysis -

Use reference range and write the determined pH value in the appropriate cell of pH range, in a table whose suggested format is given below

Sample Code	Source of Water	pH < 7.0 Acidic	pH = 7.0 Neutral	pH > 7.0 Alkaline	Determined Nature
01	Well	-	7	-	Neutral
02	Tubewell	-	-	8	Alkaline

Results -

Systematically write the pH value observed for different samples of water.

Key points learned -

- Concept of pH related acidity, basicity and neutrality.
- Classification of solutions based on acidic, basic and neutral nature.
- You can test the acidic, basic or neutral nature of any solution by pH test.
- pH of a solution is one of the factors that determine its reaction with other materials

Open ended questions -

- Is it possible for you to make pH test paper strip? Explore how.
- Why water samples from different sources show variations in acidity or basicity?
- Mix the lime juice, soda and other substances in water and find out the pH value. Is any change is observed? If yes, why? By comparative analysis find out the reason of different pH observed in these solutions.
- What is acid rain? How it occurs? Is there any alkaline rain too?

Sub-Theme: Hardness of Water

Water hardness is a measure of mineral ions present in it. Primarily the dissolved of Magnesium and Calcium cause hardness in it which is expressed in milligrams/Liter. Hardness of water can be of two types temporary and permanent hardness. Temporary hard water contains carbonates or bicarbonates of Calcium and Magnesium whereas permanent hard water contains chlorides and sulfates of Calcium and Magnesium. The degree of hardness is determined as soft for 0 to 60 mg/ltr. lons, slightly hard for 61 to 120 mg/ltr, hard for 121 to 180 mg/ltr and very hard for more than 180 mg/ltr dissolved carbonates or bicarbonates of calcium or magnesium in it. Temporary hardness can be removed by boiling whereas permanent hard water is treated differently to make it useful. Hard water can be the cause of formation of kidney stones in your body or may be the cause of reduced life of water heating equipments. But the effects of hard water on living and non-living systems are not always negative. The permissible hardness of water is also beneficial to supplement the mineral requirement of humans and other living beings.

There are different methods of estimation and determination of Hardness of water, simplest is comparing the lather produced with the soap or time taken in cooking of vegetables in open vessel, and other methods like titration and using electronic sensor etc.

Activity : Determination of hardness of water by ‘testing the lather produced with soap’

About this experiment -

Hardness of water is an important characteristic that is good if within permissible limits and not good if it is more than permissible. In our daily life we experience the hardness of water but mostly unable to relate the experience with the characteristics and its effect. There are simple means by which one can observe and understand as well as can test to know whether water from a source is ‘hard’ or not. We can determine the degree of hardness of any water sample by testing the foam/lather produced by it with soap and comparison with lather produced by known water sample which is not hard.

Material required -

Soap or detergent powder, distilled water, mug or small bucket, 2 screw cap small vials (50 ml vials are sufficient for the test) / alternatively you can take any small bottles made of glass or transparent material, of same quantity which are washed well and dried).

Method -

1. Take soap and rub and mix it in distilled water. This will be used as soap water for producing lather.
 2. Take a screw cap bottle and fill it up to $\frac{1}{4}$ volume with soap water and further fill another $\frac{1}{4}$ volume with distilled water. Lather produced in it will be used (as controlled) to compare with the lather produced in another bottle with tested water sample.
 3. Take second bottle and fill it to $\frac{1}{4}$ volume with soap water and fill further same volume with sample water whose hardness is to be tested.
 4. Shake both bottles equally for one minute.
 5. Watch the amount of foam/lather produced in both bottles.
 6. Compare the lather produced in second bottle (having sampled water) with that produced in first bottle (with distilled water).
 7. If the amount produced in both bottles is same, it would reflect that sampled water is soft.
 8. If the foam produced is lesser then the corresponding water shall be considered having hardness.
 9. If no foam/lather is produced at all then the corresponding water shall be considered as very hard (i.e. the amount of hardness would be more than 180 mg/liter).
 10. Take more samples of water from different sources and compare the lather produced with the controlled sample and document the observations systematically.
- # Instead of soap you can take small quantity of detergent water for producing lather and follow the same procedure.



Figure: Test of lather production in water



Figure: Comparison of lather production

Data collection and Analysis -

The observations of hardness test for different water samples may be documented comparatively in a tabular form. An example of the table format and sample entries is given here –

Source of Water	Comparison of Foam/Lather Produced in Sampled Water			Determined Nature of Water
	Soft Water (Hardness less than 60 mg/ltr)	Hard Water (Hardness between 121-180 mg/ltr)	Extremely Hard (Hardness more than 180 mg/ltr)	
Tap Water (1)	Same amount of foam in both bottles	-	-	Soft Water
Tube well Water	-	-	Very Less Foam	Extremely Hard Water
Tap Water (2)	-	Less Foam	-	Hard Water

Results -

Write the comparative degree of hardness of different water samples through observations of foam produced. A database of hardness of water samples from different sources is prepared.

Key points learned -

- Concept of hardness of water.
- Water from different sources may have different degree of hardness.
- Water hardness can be understood by observation, and the degree of hardness can be ascertained by simple tests.
- There are two broad categories of hardness in water – permanent and temporary, that are caused due to presence of different compounds. Permanent hardness is caused due to sulfates and phosphates of calcium and magnesium whereas temporary hardness is caused due to presence of their carbonates and bicarbonates.

Open ended questions -

- How can hardness of water be removed? Can you remove the hardness of water and test again the amount of foam produced from it?
- Can we prepare hard water by mixing some substances? Try with adding salt or soda in soft water in different amounts and test the change in hardness through observation of lather produced.
- In the control bottle, instead of distilled water try with RO water / rain water / battery water / condensed water to produce foam.

Sub-Theme: Residual Chlorine in Water

Chlorine in water can be present in two forms namely available chlorine which is naturally present in the water and residual chlorine which is extra and tends to be added externally. Externally additive chlorine comes in several forms like granules, tablets, powder, liquid and gas. It dissolves easily in water. When chlorine is added to water, it will attack organic matter and attempt to destroy it. If enough chlorine is added, some will remain in the water after all possible organisms have been destroyed and what is left is called residual chlorine. It does not remove chemical contaminants from the water.

Although chlorine does not destroy all micro-organisms but it is effective against a wide variety of disease causing microorganisms. It kills most of the microbial agents at the treatment point and its residual can further protect the water through long delivery pipeline to give the chemical time to perform its disinfecting action before it reaches the consumer. The presence of Residual Chlorine in drinking water indicates that most of the microbial organisms have been killed and the water will remain protected from decontamination during storage until the residual chlorine dissipates itself or is dissipated by heating of water. For domestic use the amount of residual chlorine at the point where the consumer collects water should be between 0.2 to 0.5 milligram per litre.

There are different methods of estimation of residual chlorine. The simplest and quickest method is detecting its concentration in water by adding Ortho-toluidine indicator and comparing the colour change in water using a color comparator.

Activity : Determination of residual chlorine in water by 'Ortho-toluidine Indicator Test'

About this experiment -

Chlorine is used as a disinfectant in drinking water supply, to kill the microbes and other pathogens. For domestic use the amount of residual chlorine at the point where the consumer collects water should be between 0.2 to 0.5 milligram per litre. This activity is to help common masses and learners to test the range of residual chlorine present in a water sample.

The quickest and simplest test for residual chlorine is the **Ortho-toluidine Indicator Test**. In this test when Ortho-toluidine indicator reacts with chlorine that is present in water, it produces a dye of distinct yellow colour and the darkness / intensity of that colour is

proportional to the amount of chlorine present in water. With the help of a standard colour comparator chart and given reference range of chlorine we can compare the colour change in corresponding water sample and know the concentration of chlorine present in it.

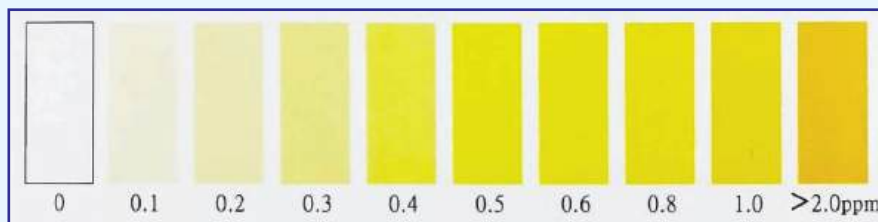


Figure: Standard Colour Comparator Chart for Residual Chlorine

Material required -

- Test tube or a small measuring glass vessel,
- Dropper,
- Ortho-toluidine indicator,
- Standard Residual Chlorine color comparator chart.

Method -

1. Take 10 ml water sample in the test tube and add 1-5 drops of Ortho-toluidine test reagent in it (Remember that for each water sample the same amount of water and same amount of Ortho-toluidine indicator has to used).
2. Wait for 30 seconds while any change occurs in the water color
3. The strength of changed color is measured against standard colors on a chart to determine the chlorine concentration. Stronger the colour, higher the concentration of residual chlorine in the water.

Data collection and Analysis -

- Record the details of the sample source and assign a code to it
- Record the concentration of residual chlorine for each sample

A sample of data table and idea of how to enter the data is given here for reference -

Sample Code	Source of Sample	Date and Time of Sampling	Concentration of Residual Chlorine (mg/liter)	Remarks
A	House tap	Date & time	0.3	Safe Water
B	Water Supplied in Camper	Date & time	1.0	Unsafe Water

Results –

Record the concentration of residual chlorine in milligram per liter (mg/l.) for each of the sample water and draw inferences like average concentration, minimum, maximum etc. At a grassroots level inference you can make a map of residual chlorine concentration recorded from different sources (test sites) in your area. For that you may also need to record the location of each sampling.

Key points learned -

- Chlorine helps in disinfection of water.
- Residual chlorine is the amount of chlorine that remains in water after a certain time period of treatment of water with chlorine.
- Residual chlorine is good for health when it is within permissible limits.

Open ended questions -

- What would be the result if you test the residual chlorine of a water sample at the site (of its collection) and later at different time intervals after bringing it to the test facility?
- Which of the drinking water would be better for health – one that is chlorinated and other that is not chlorinated? Why?
- What are the local / traditional practices in your area by which the drinking water is treated to make is safe for consumption?

Sub-Theme: Transparency of Water

Transparency of water relates to the depth in water up to which the light will penetrate. Since the sun is the primary source of energy for all biological phenomenon, transmission of sunlight into the water body is extremely important to help the aquatic plants perform photosynthesis, production of Oxygen and food for the consumers. Transparency of water is adversely affected when it has large amount of sediments and / or suspended material. Transparency affects the distribution and depth of aquatic plants and other aquatic organisms, dissolution of Oxygen content and distribution of temperature in water.

The simplest method of measuring the transparency in water is determination of depth of light penetration by using Secchi disc.

Activity: Determination of transparency of water by 'Secchi Disc method'

About this experiment

Light is an important abiotic factor in a water body which helps in photosynthesis in aquatic plants. If the photosynthesis process is obstructed by any means, the production of food at primary level and the subsequent food chains get affected. In a water body the aquatic plants are distributed up to the depth to which the sunlight reaches. In the same manner, the visibility in a water body or **transparency** is possible up to the depth to which the sunlight or light from any other source reaches.

Transparency in any water body can be measured with the help of a simple device called '**Secchi Disc**'. Secchi Disc is a metallic plate having alternate black and white quadrants painted on it. The metallic material is for making it heavy and not to float in water if it is lowered in any water body.

The working principle of the Secchi disc is that it that when it is lowered in the water it is visible up to the depth to which the light would be reaching at that time and it becomes invisible if lowered further deep. It becomes visible again when it is pulled up. The depth is measured by measuring the rope with which it is tied. The average of the depth of disappearance and reappearance is the depth of penetration of light or the transparency of water at that time.



Figure: Secchi Disc Assembly

Material required -

Secchi Disc, Rope, Measuring tape

Method -

1. Tie the rope at the hook of the Secchi disc and release it slowly into the water,
2. Lower the Secchi disk very slowly into the water until it disappears from the view,
3. Mark the point at the rope (at water surface level or at a static point from where it is lowered) when the disc becomes invisible,
4. Now very slowly pull the rope to lift the Secchi disc and stop when the disc is visible again,
5. Mark the point at the rope again when the disc reappears,
6. Take out the Secchi disc and calculate the transparency (depth of light penetration) of the water body



Figure: Immersion of Secchi Disc in Water Body

Data collection and Analysis –

The observations of depths measured can be tabulated systematically and further calculations can be done. a sample table and data is given here for recording the data and calculation

Site of Experiment	Date & Time	Depth of Disappearance of Secchi Disc (cm) A	Depth of Reappearance of Secchi Disc (cm) B	Average Depth of Transparency (cm) $\frac{(A+B)}{2}$
Water Body - 1	10-06-24 06.00 Hr.	90.8	90.6	90.7
Name or code of site	Date & time	-	-	-

Results -

- For each point the transparency is calculated.
- The transparency recorded at different locations in same water body or different locations in different water bodies also referred as transparency at that point.
- Average transparency of a water body can be found by calculating the average of the transparency measured at all points at that water body.

Key points learned -

- The phenomenon of transparency in a water body is corresponding to the light penetration in the water.
- Transparency in water is an important factor that affects photosynthesis and consequently the food chain, food web as well as distribution of other organisms in water body.
- Transparency is affected by the turbidity or the amount of dissolved or suspended substances in the water body.

Open ended questions -

- What are the factors that affect the transparency of water? Find out for the water body in your locality.
- In a water body find out transparency of water at different locations/zones and find out differences in transparency of different zones (viz. at different locations near shore, at different distances in the water body from the shore. What do you find out? What are the reasons behind that you find out?

- What would be the observations if you measure transparency in a water body at the same place at different times of day and/or in different seasons or at random or periodic intervals?
- What would happen if persons having different eyesight measure the transparency of water at the same point?

Interesting facts -

- The most transparent river in India is Umngot River which is also called Dawki River. It's riverbed is clearly visible even from the far above distance from the water surface. However the transparency does not remains the same and the river is most crystal clear from December to March. Umngot River originates from the East Khasi Hills and travels for about 96 kilometers passing through a small town Dawki and villages Shnongpdeng and Umwah Nongbah, and after making a dividing line between India and Bangladesh it later joins the Kaladan River in Bangladesh.

Sub-Theme: Bacterial Contamination (*E.coli*) In Water

E. coli is type of fecal Coliform bacteria that are commonly found in the large intestine of human beings and other warm-blooded animals. Presence of Coliform bacteria in any form of surface and ground water is strong indication that it is contaminated with sewage or fecal matter of humans and/or animals. The Coliform bacteria are transmitted to humans through contaminated water or food, raw meat, raw or contaminated vegetables etc. After ingestion they can cause severe health hazards like diarrhoea, abdominal cramps, bloody diarrhoea or very acute health hazards like acute renal failure, decline in blood platelets, neurological stroke and coma. Coliform bacteria are destroyed in water and food if heated at temperature of 70° C or above. The unit for expressing presence of Coliform bacteria in water is most probable number (MPN) per 100 ml (MPN/100 ml). The World Health Organization (WHO) standard specifies zero count of *E. coli* in drinking water. The Central Pollution Control Board of India (CPCB) prescribes permissible limit of Coliform bacteria in drinking water be 50 or less MPN/100 ml.

There are different methods of qualitative and quantitative estimation Coliform count in water. The simplest and quickest method for detecting its presence is the vial culture test in which the sampled water is cultured with a pre added growth media in a vial for 24 hours at body temperature (around 36° C). The appearance of turbid pink/red colour and its darkness will give an idea of how severe is the contamination of Coliform in it.

Activity: Testing the presence of fecal Coliform bacteria in water by ‘Vial Culture Test’

About this experiment

The bacterium called *Escherichia coli* (*E. coli*) is naturally found in our digestive system (large intestine) and plays role in keeping it healthy. But if the same bacterium enters our body with water or food, it causes severe health impacts through impairing the functions of the digestive system. Presence of *E. coli* in the water is an indication of water contamination with fecal matter and the contaminated water needs to be treated properly before consumption.

The simplest and quickest method for detecting presence is the Vial Culture Test (also called H₂S Strip Test) in which the sampled water is cultured with a pre added growth media in a vial for 24 hours at room temperature. The vial contains a paper strip which is soaked with the growth media that would help the *E. coli* bacteria to further multiply. The water

sample filled in this vial if has any *E. coli* then the colour of water will change to indicate the presence of *E. coli* in it.

Material required -

H₂S test Vial (containing paper strip laden with growth media)

Method -

1. Collect the water sample in the H₂S vial directly and fill it up to the brim and immediately screw the cap of the vial,
2. Place the vial in dark place at room temperature,
3. Keep the vial for 24 hrs and then examine the change in sampled water,
4. If the sampled water color changes to black, it indicates the presence of *E. coli* in it.

Precaution: Keep your hands clean before and after handling the sample. After the test carefully discard the sample in a drain).

Data collection and analysis -

Record the presence and absence of *E. coli* in the water samples collected in your area. The data can be analysed through mathematical or statistical means to derive inferences. A sample table is given here for example to collect the data -

Name or code of site	Date & Time	Mark for the test result in the appropriate box		Remarks
		Present	Absent	

Results -

Water sample detected with fecal Coliform in the referred area are identified. Apart from the mathematical or statistical inferences you can prepare the *E. coli* distribution map of your area so as to assess the area affected by open defecation / water contamination by fecal matter.

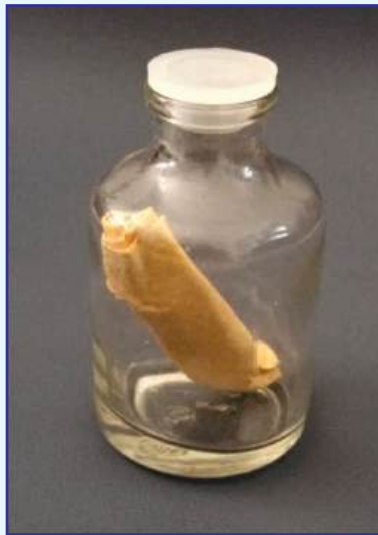


Figure: Coliform Culture Vial (H_2S Vial)



(a) *E. coli* absent



(b) *E. coli* present

Key points learned -

- Fecal bacteria contamination of drinking water,
- Microbes are also found naturally in the human body
- *E. coli* naturally present in the distal part of the gut i.e. large intestine in human beings play helpful role,
- Open defecation is one of the major cause of fecal contamination in surface water bodies

Open ended questions -

- For positive test results, try treatment of the water by alternative means and then again conduct the test of the treated sample to verify whether the *E. coli* contamination has been controlled or not.
- Why it is recommended to wash hands after defecation with soap or ash?
- Why it is recommended that to take water from a vessel one should use a ladle or vessel having long handle?
- What are the materials used to filter water in households? Explore the traditional & modern means of water treatment for safe consumption

Interesting facts -

- The H_2S test medium contains Sodium thiosulfate as a sulfur source and ferrous sulfate or lead acetate as an “indicator. Bacteria of fecal origin like *E. coli* are able to reduce the sulfur to sulphide as H_2S . The produced H_2S reacts with the indicator and forms a black precipitate of ferrous sulfide or lead sulfide.

Theme - Soil

Soil is the repository of the biogeochemical cycles. Healthy soils lay at the foundations of agricultural development, healthy and nutritious food production, and essential ecosystem services. Soil is the fundamental substance that along with water supports survival of our planet. Soil is also the fundamental resource that supports significant proportion of food production on the Earth. Due to anthropogenic climate change and other human activities our soils are being degraded. The [FAO guidelines for soil description](#) can help in correct description of soil.

Common characteristics of soil that are important indicator of its physical, chemical and biological properties and the ecosystem health include the following -

- **Soil Colour**
- **Soil Horizons**
- **Soil Structure**
- **Soil Texture**
- **Soil Consistency**
- **Soil pH**
- **Soil Porosity**

Sub-Theme: Soil Colour

Soil colour is an important indicator of soil health including mineral composition, soil organic matter, soil fertility, soil moisture, drainage etc as well as the past and present oxidation-reduction conditions of the soil. Soil color is also used to distinguish soil horizons. Soil displays a wide range of colors according to presence of minerals and organic content in it. For example, soil having brown/dark brown/black colour indicate the presence of organic matter, darker is the colour more will be the organic matter; yellow/pale brown indicated presence of iron oxides, poor organic matter and nutrients; white colour indicates presence of calcium and silica, red colour indicates presence of iron. All soil colors display darker under wet condition and lighter in dry condition, therefore determination of soil colour should be done under uniform conditions. Early morning and late evening readings are not accurate.

The soil colour is determined by using Munsell colour chart. In his chart different colour chips are systematically arranged by three variables namely Hue, Value and Chroma. Hue indicates the spectral colors like red, yellow, blue, green etc; Value indicates lightness or darkness of the colour on a scale; Chroma indicates the range of strength of colour on a scale. The combination of these three variables is used to describe the colour of a soil.

Activity: Determination of soil types based on their colours.

About this experiment -

Soil colour is an observable indicator of the contents, composition, functions and physic-chemical characteristics of soil. The simplest method of classifying soils is on the basis of their colours. This exercise focuses on understanding soils of an area based on different colors and indirectly inferring the presence of coloring minerals as well.

Material required -

Khurpi/trovel,
Soil Color Chart

(An example of soil colour chart is given here; you can use it to compare the colours of sampled soils. You can also prepare more charts of the known soil colours for further use).

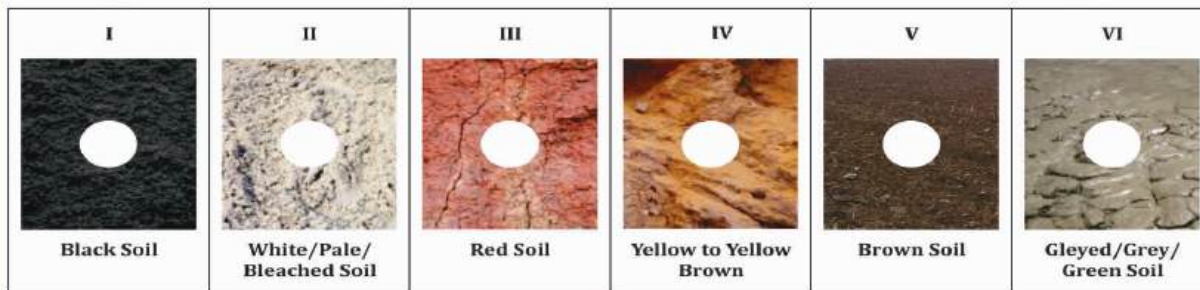


Figure: Soil Color Chart

Method -

1. Collect some amount of soil from different depths (soil horizons) at one place or from different locations,
2. If the sample is dry, moisten it slightly with water,
3. Record the colour of each sample and other information of sampling site

Note: Sometimes, a soil sample may have more than one color. Record a maximum of two colors if necessary, and indicate (I) the Main (dominant) color and (II) the other (sub-dominant) color.

For reference, some soil colour categories are described here -

Black Soil:

These soils are often associated with high levels of organic matter (peats) that gives them their colour. Such soil has poor pH and are characterised with having poor drainage (not allowing much water to drain down) and hence mostly show waterlogging conditions above them.

White/Pale/Bleached Soil:

These soils are often referred to as bleached or 'washed out'. These soils exhibit light colour due to leaching out of nutrients like iron and manganese due to high amount of rainfall or heavy drainage. They are characterised with poor organic contents and leached nutrients.

Red Soil:

Red colour soils indicate good drainage. The red colour is because of oxidization of iron content within the soil due to oxygen rich conditions. This causes the soil to develop a 'rusty' colour. The colour can become darker with organic matter. This soil is rich in essential nutrients like phosphorus, iron and potassium and is considered fertile and good for agriculture.

Yellow to Yellow-Brown:

These soils have thin A horizon and are characterised with low pH and low level of oxides. This soil has more aluminium and iron than silica. The iron compounds in these soils are much in a hydrated form and therefore instead of producing rusty colour they exhibit yellow or yellow-brown colour. These soils have poor organic content and nutrients like phosphorus, therefore not very fertile.

Brown Soil:

These soils are characterised with good amount of decaying organic matter along with minerals like iron oxide and silica. The darkness of brown colour varies with amount of organic content and drainage of water and so as the fertility.

Gleyed / Grey/ Green Soil:

These soils are associated with waterlogging or poor drainage. Prolonged waterlogging and lack of air in these soils provides conditions for iron and manganese compounds to get reduced (that is responsible for the colour of soil). The iron and manganese compounds are either get removed from soil or get segregated as mottles or concretions in the soil.

A sample chart of soil color categories is given here

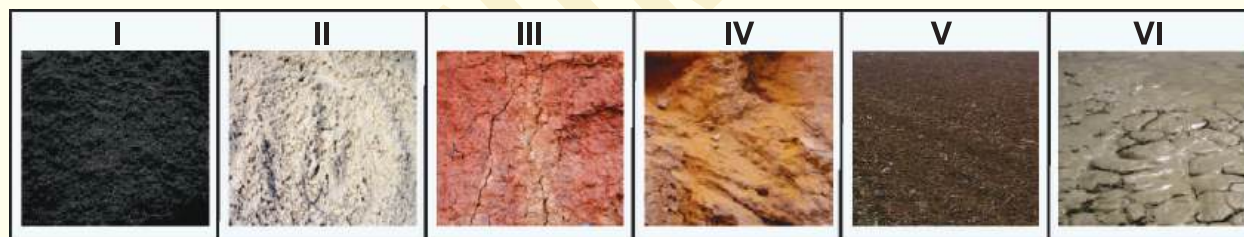


Figure: Soil Color Categories

Data collection and analysis –

- To make sample record the colour of the soil and other details like location (latitude & longitude), date & time, land use type, etc.
- In case you come across a new soil color, you can make your own soil colour category to record the observation (also continue your search through reference material and web resources to know more about that coloured soil).
- For compilation and tabulation of data a sample table as an example is given here, you can design your data table accordingly.

Site Details								
(place, geographical location, land use viz. agriculture land, query, under construction, orchard, grassland, forest, barren land, river side, flood plain, pastureland, roadside, wetland, garden, roadside etc).								
Soil Horizon	Depth of the Soil horizon (cm)	Soil Colour Category (Compared with Colour Chart) (Mark in the appropriate box)						New Colour Category
		I	II	III	IV	V	VI	
O								
A								
B								
C								

Results -

You can simply find out how many colour types of the soils are found in the referred area. Their external features and conditions can be understood.

After getting the basic data you can do mathematical and statistical calculations to draw appropriate results and conclusion.

Key points learned -

- Identification of soils on the basis of their colours and associated features.
- Skills of sampling, collection, observation, comparison and referencing with standards regarding color characteristics which are key tools for scientific explorations.

Open ended questions -

- Plastering and colouring of houses, palaces and other objects with different colour soils is practiced from ancient times. Even in many tribal communities the colouring sense is very excellent. How those people do were able to prepare permanent colours using soils?

Interesting facts -

Munsell Color System - It is a method of designating colours on the basis of a colour scheme. The scheme is based on three qualities or attributes namely Hue, Value & Chroma (HVC):

Hue - It corresponds to the dominant wavelength of color such as red, orange, yellow, etc;

Value - It corresponds to the brightness (lightness or darkness) of a color;

Chroma - It corresponds to the saturation or brilliance of a color.

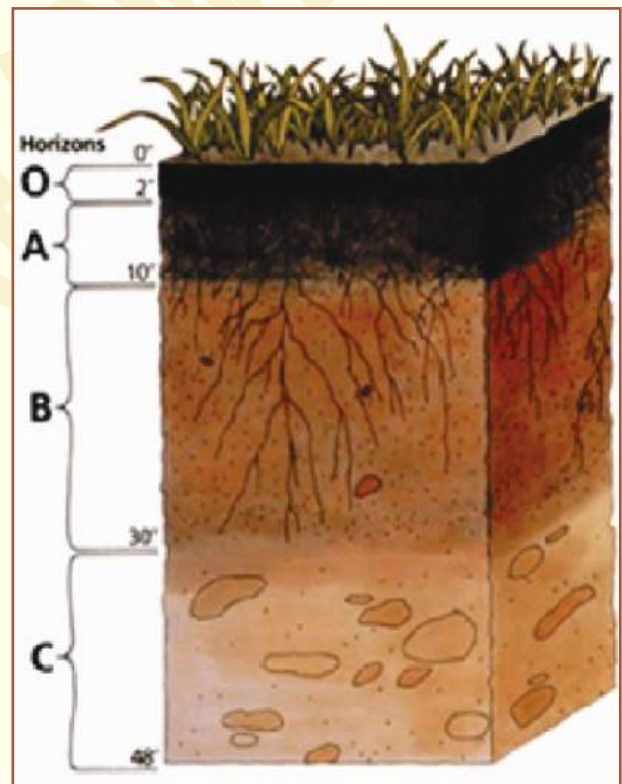
In the Munsell colour tool a collection of colour chips having varying degrees of hue, value and chroma is given and one can match the sample colour with the given colour chip and it's corresponding code.

For further details about Munsell Color System you may refer to the website <https://munsell.com>

Sub-Theme: Soil Horizons

At the time of soil formation process so many physical, chemical and biological activities occur simultaneously and ultimately after a long process of hundreds of years the soil having characteristic layers is formed. The vertical appearance of different layers parallel to the soil surface whose physical, chemical, biological characteristics differ from the layer above and below is called soil horizon. Soil horizons are classified according to their vertical sequence of distinct layers. Mostly the boundaries of soil horizons are zone of transition rather than distinct lines of division. The width of each horizon i.e. depth of the upper and lower boundaries of each horizon provide information of the soil forming processes that have formed the soil. Most of the horizons do not have a constant depth.

For describing and interpreting soil horizons in the field the master horizon codes that are assigned to the various soil horizons are H, O, A, E, B, C and R. 'H' horizon is the topmost layer of soil that is underwater and consists of undecomposed or partially decomposed organic material. 'O' horizon (humus or organic horizon) is composed of decomposed organic matter in wetlands and partially decomposed organic matter and litter at the surface of terrestrial soil. 'A' horizon (the mineral horizon or top soil) consists of decomposed organic matter and inorganic minerals. Living creatures in soil are also chiefly found in this horizon. 'E' horizon (eluviated horizon) is formed when compounds of iron, aluminium etc and organic matter are leached down from this layer. 'B' horizon (sub soil) consists of the iron, aluminium and humic compounds and clay leached down from A and E horizon. 'C' horizon (parent material) is the weathered zone of parent rock beneath and 'R' horizon is the bedrock from which the weathered inorganic material is coming from. Sometimes the top soil horizons are further categorized into sub-types if any distinct features of differentiation are found. Soil horizons can be seen by digging the soil deep down.



Activity: Understanding the formation of soil horizons

About this experiment -

Soil horizons are the vertical appearance of different layers of the soil whose physical, chemical, biological characteristics differ from the layer above and below. We can examine the soil horizons and their characters simply by digging the earth vertically and by examining different layers of the soil formed below parallel to the ground.

Mostly soils have three major horizons (A, B, C) and some have an organic horizon (O) at the top. O (Humus or organic) horizon is composed of mostly organic matter such as decomposing leaves. The O horizon is thin in some soils, thick in others, and not present at all in others. A (Topsoil) horizon is rich in minerals with organic matter incorporated. A horizon is important for plants and other organisms to live and generally 8 to 10 inch in depth. B (Subsoil) horizon is composed of minerals that leach (moved down) from the A horizon and accumulate here. C (Parent material) horizon is composed of the inorganic material that is coming from the bedrock. R (Bed Rock) horizon is the mass of rock such as granite, basalt, quartzite, limestone or sandstone that forms the parent material through weathering.

We can also examine the texture and composition of soil of different horizons to understand that their composition and respective depths vary from location to location and their physico-chemical characteristics also vary accordingly. The formation of horizons and their characteristics are also reflective of the environmental and ecological conditions of their area.

Material required-

Spade or shovel, notebook, colored pens or pencils, zip-lock soil sampling bag, measuring tape, magnifying glass.

Method -

1. Identify the locations where you wish to examine soil horizons (Presence of grasses, trees and other types of vegetation are usually a good indicator that you can dig a successful pit).
2. Using a spade or shovel dig a pit that is at least 1 meter (3 feet) deep. The pit should be wide enough that you can easily observe the different layers (horizons) of soil all the way to the bottom of the pit. Usually this means digging a pit that is as wide as it is deep.
3. Carefully observe the vertical profile and formation of soil layers above and below from each other.

4. Starting at the top of the profile and working your way down to the bottom of the profile, determine the types of soil horizons (O, A, E, B, C, R) present and the depths at which horizons are located. Sometimes the horizons do not show distinct boundaries therefore discuss as a group and decide the types and depths of horizons and mark them.
 5. Take depth measurement at the top and bottom of each horizon using the measuring tape or scale starting with 0 cm at the top of the profile.
 6. Make a sketch of the horizons types and depths in your field notebook.
 7. Take photograph of the pit in which all horizons are clearly visible. Take some photographs of the surrounding landscape to record the ecological conditions of the location.
 8. Examine each horizon in-situ for moisture, color, smell, texture, and structure and record in the field notebook.
 9. Collection of soil sample from each identified horizon will help in further identifying their physico-chemical characteristics.
- # You can also observe soil horizons where some digging is going on.

Data collection and analysis -

- In your field notebook, describe characteristics of the site that could influence the soil profile. This includes features like: vegetation types (percent of coverage and heights), land use (urban, agricultural, garden, forest etc), buildings or other artificial features, surrounding landforms and water bodies, approximate slope of the site and exposure to sun and shade.
- In order to determine the moisture, color, smell, texture, and structure of soil of each horizon you can examine directly at pit or after collecting the soil from each horizon and bringing the samples to the test facility, or you can attempt both in-situ examination as well as sample examination. Describe these characteristics for each horizon in your notebook -

Moisture - Take some soil between fingers and check whether it is dry (no feel of moisture), moist (feels damp), or wet (feels saturated).

Color and smell - If the collected soil is dry, you will need to spray some water on it to make it wet in order to best observe the color and smell. You can know more about soil colours through our activity on [Soil Colour](#).

Structure - With the help of magnifying glass examine the general structure of the soil

in each layer, consistency, presence or absence of rock, plant roots and animals seen etc.

Calcareousness - Put some drops of lemon juice or mild acid on the soil, watch the effervescence in terms of Nil, Low, Medium or High. Nil effervescence means the soil is not calcareous and whereas production of effervescence indicates calcareous nature.

Precautions - If the soil pit has been dug for the examination of soil horizons then before leaving refill the pit before leaving from the site. Take care that you have not forgotten any equipment at the site.

Results -

Present your results in the form of numerical data as well as qualitative characteristics. Various interpretations can be done through mathematical and/or statistical calculations.

Photographic evidences and sketches and diagrams of the studied soil horizons will be useful for further reference.

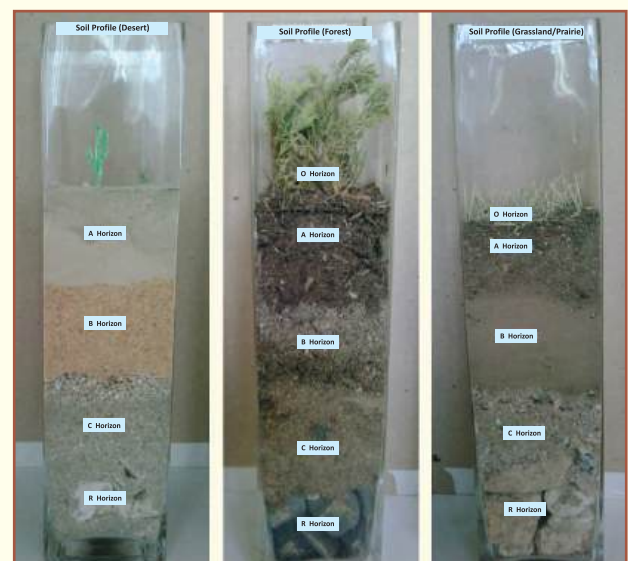
Key points learned -

This activity helps in finding and interpreting the facts like -

- What does soil profiles tell us?
- What effect does the soil type have on the amount of soil moisture it can hold?
- Observing the profile you are able to understand the newly-created soil and well developed soil.

Open ended questions -

- Explore in your area about different soil types and find the difference between soil horizons of an arid area, forest, grassland, agriculture fields etc?
- Make replica of soil horizons by collecting soil samples of different horizons and putting them in the same order and proportional depth in a glass container. Illustrative examples of soil horizon replicas are given here –



Sub-Theme: Soil Structure

Soil structure is the shape that the soil takes based on the arrangement of the solid parts and the pore spaces located between them. In other words it is the assemblage of the sand, silt and clay appearing in varying size of larger particles that are called aggregates. Soil structure is described in terms of grade (degree of aggregation), class (average size) and type (form or shape of individual aggregates). Five distinct classes (based on average size of individual aggregates) of soil structure are very fine, fine, medium, coarse and very coarse. The soil structure plays important role in moisture and water holding capacity of the soil as well as holding and leaching of inorganic and organic compounds in soil horizons.

Activity: Understanding the formation of soil structure

About this experiment -

Soil structure depicts the arrangement of solid particles of the soil and of the pore space between them. Apart from the natural aggregation of soil particles the soil structure also affected by its natural formation and also by the soil management practices. Each individual unit of soil structure is called a ped (aggregate of soil particles as a result of pedogenic process). The natural organisation of particles in the form of discrete units (peds) is separated by pores or voids.

Based on the aggregation of soil particles the soil structures are categorized as follows -

Granular - Granular structure is consists of the aggregates having equate and just about spherical shapes. Water circulates very easily through such soils. They are commonly found in the A-horizon of the soil profile.



Blocky - Blocky and subangular blocky structures are formed when soil particles cling together in nearly square or angular blocks having more or less sharp edges. Relatively large blocks indicate that the soil resists penetration and movement of water. They are commonly found in the B-horizon where clay gets accumulated.

Prismatic and Columnar - Prismatic and columnar structures are formed by arrangement of soil particles into vertical columns or pillars separated by miniature but definite vertical cracks. Water circulates with greater difficulty and hence drainage is poor. They are commonly found in the B-horizon where clay gets accumulated.



Platy - Platy structure is made up of soil particles aggregated in thin plates or sheets, piled horizontally on one another. Plates often overlap, greatly impairing water circulation. Such soils are found in forest in the A- horizon, and in clayey soils.

Massive – This type has no distinct structure. It is hard to break apart and appears in very large clods.

Material required-

Soil Structure leaflet,
Magnifying glass,
Shovel or trowel

Method -

1. Take out a sample of undisturbed soil from any soil horizon with the help of shovel or trowel.
2. Look closely at the soil and examine its structure (aggregation of soil particles) either by naked eye or with the help of magnifying glass.
3. Match the structure of the sampled soil with the keys shown in soil structure leaflet.
4. Determine the type of soil structure of the sampled soil and record in the data sheet.

Data collection and analysis -

- Record the soil structure of different samples in a data sheet. An example of data table is given below. You can modify or redesign the data table according to the need.

Table to record the soil structure categories of different horizons –

Site Details (place, geographical location, land use viz. agriculture land, query, under construction , orchard, grassland, forest, barren land, river side, flood plain, pastureland, roadside, wetland, garden, roadside etc).						
Soil Horizon	Depth of the Soil horizon (cm)	Soil Structure Category (Mark in the appropriate box)				
		Granular	Blocky	Prismatic & Columnar	Platy	Massive
O						
A						
B						
C						

Results -

Present your results in the form of numerical data in the form of quantitative and/or qualitative characteristics. Various interpretations can be done through mathematical and/or statistical calculations.

Photographic evidences of the landscape surrounding the sampling site will be useful for further reference.

Key points learned –

This activity helps in finding and interpreting the facts like -

- The unit of soil structure itself is composed of aggregated particles and each unit is called a ped.
- The presence of air spaces in the form of pores or voids in the soil structure regulates its moisture and water holding capacity.

Open ended questions -

- Examine the drainage (movement of water) in soils having different structures.

Sub-Theme: Soil Texture

Soil texture refers to the composition of sand, silt and clay sized particles in different proportions that make up the mineral fraction of the soil. Soil texture influences almost every aspect of soil use as well as in ecosystem services including the very important supporting services like biogeochemical cycles and soil formation etc. Soil texture greatly affects the soil-water relationships, gaseous exchange, retention of soil nutrients, mineral and humic compounds.

Soil texture is classified in various types according to the composition of differently sized particles. Major classes are Sandy, Loam, Clay, Loamy Sand (Silt), Sandy Loam, Silty Loam, Sandy Clay Loam, Silty Clay Loam, Clay Loam, Sandy Clay and Silty Clay.

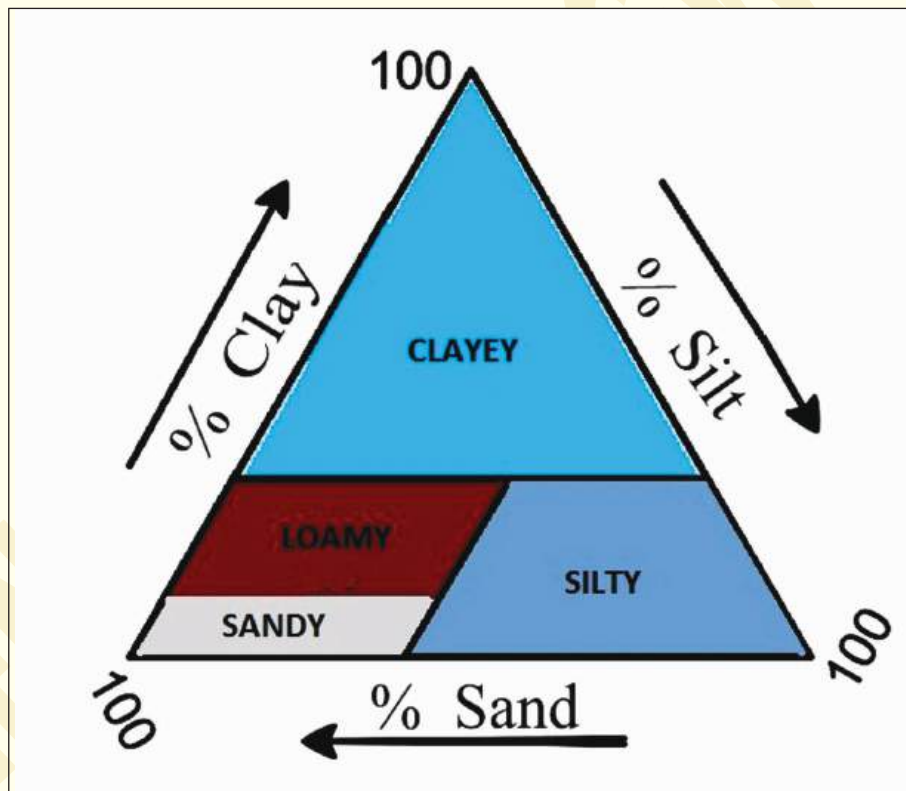


Figure: Major Soil Texture Groups

There are various simple methods to know the soil texture in the field. For example, by taking the soil in hand and squeezing it into a ball, throwing the ball at a hard surface, crushing the ball etc; by pushing the soil into a ribbon between thumb and forefinger; by

rubbing the soil; by mixing the soil in the water and after stirring the water letting the differently sized and weighed soil particles settle in different layers. There are other laboratory tests too to determine the soil texture, most common is the sieving of soil and estimating proportion of different sized particles to determine the texture class.

By collection of soil samples and examination of their texture one can prepare the soil texture map for an area. By understanding the soil texture types in an area one can also better understand the distribution of plant diversity, cropping pattern and nutrient status as well.

Activity: Examination and determination of soil texture by handling it.

About this experiment -

Soil texture refers to the amount of the sand, silt, and clay mixed in it in different proportions. This proportion influences almost every physico-chemical characteristic of the soil and its uses. Soil texture influences drainage and percolation of water, water holding capacity, circulation of air and gaseous exchanges, retention of nutrients in different layers, microhabitat of soil organisms and many more other aspects. Major soil texture classes are Sandy, Loam, Clay, Loamy Sand (Silt), Sandy Loam, Silty Loam, Sandy Clay Loam, Silty Clay Loam, Clay Loam, Sandy Clay and Silty Clay.

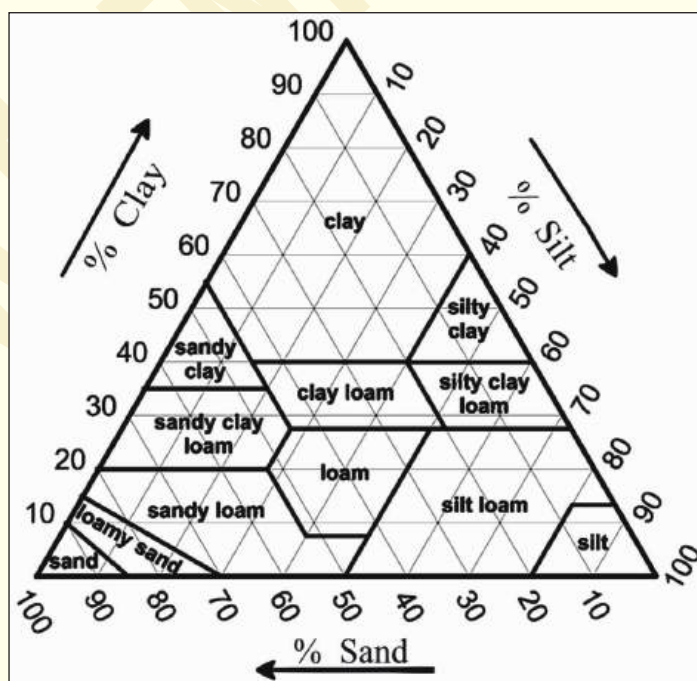


Figure: Soil Texture Classes According to Their Composition (Source – [USDA-NRCS](#))

We can easily examine the soil texture in the field and can primarily determine the texture of a sample at the site of sampling itself. For accurate determination of soil texture we can later on bring the soil sample to the lab. By examining different soil samples in an area one can prepare map of soil texture of the referred landscape. The knowledge of soil texture of an area would help understanding the adaptation of plants and agriculture varieties, cropping pattern and water & nutrient status as well.

There are various simple means to examine the soil texture in the field. For example, squeezing the wet soil in hand, making a soil ball and throwing it on a hard surface or crushing the ball, pushing the wet soil into a ribbon form between fingers, rubbing it etc. Here we are discussing some methods of examining the soil texture by using our hand.

Material required-

Soil texture chart, khurpi or trowel

Method -

Stage One - Soil Ball Test:

1. Collect the soil sample from different horizons of a soil profile. Mark the samples with the profile code and horizon code, depth, date & time.
2. From this take a handful of soil (about 25-50 grams) and spread the soil onto a tray and remove any pebbles and visible plant material like roots etc.
3. There might be lots of lumps and clumps (aggregates) of soil particles, these needs to be broken apart so that you can examine the soil texture conveniently.
4. Take a handful of soil and wet it slowly and gradually until it becomes like moist putty. Now shape this wet soil into a ball (see picture).
5. If the wet soil does not get shape of a ball that means it is very sandy soil.
6. If the soil sample can be shaped as ball then go for next stage test.



Stage Two - Ribbon Shape Test:

1. Take the wet soil ball and gently push it into a ribbon between your thumb and forefinger (see picture for help)
2. If the soil does not make ribbon and get broken down or fall apart that means it is Loamy Sand or Silt.
3. If the soil does form a ribbon you just keep pushing the soil out until the ribbon breaks from its own weight.
4. If the ribbon breaks into pieces less than 2.5 cm length then it is 'weak ribbon', if it breaks into 2.5 to 5.0 cm pieces then it is 'medium ribbon' and if it breaks into more than 5 cm pieces then it is 'strong ribbon'.



Stage Three - Rubbing Test:

1. Take a small amount of the soil sample in the palm and add some water into it for making a paste like mixture.
2. Using your finger rub the soil paste against your palm.
3. Find out how it feels by rubbing the soil paste – gritty or very smooth or sticky?
4. Derive inferences of the soil texture types based on the respective length of ribbon formed and rubbing test -



- A. For ribbon size less than 2.5 cm, test by rubbing -**
 - Whether the soil feels very gritty? If yes then it is 'Sandy Loam';
 - If the soil feels very smooth then it is 'Silt Loam',
 - If the soil neither feels gritty nor very smooth then it is 'Loam'.
- B. For ribbon size between 2.5 to 5.0 cm, test by rubbing -**
 - Whether the soil feels very gritty? If yes then it is 'Sandy Clay Loam';
 - If the soil feels very smooth then it is 'Silty Clay Loam',
 - If the soil neither feels gritty nor very smooth then it is 'Clay Loam'.
- C. For ribbon size more than 5.0 cm, test by rubbing -**
 - Whether the soil feels very gritty? If yes then it is 'Sandy Clay';
 - If the soil feels very smooth then it is 'Silty Clay',
 - If the soil neither feels gritty nor very smooth then it is 'Clay'.

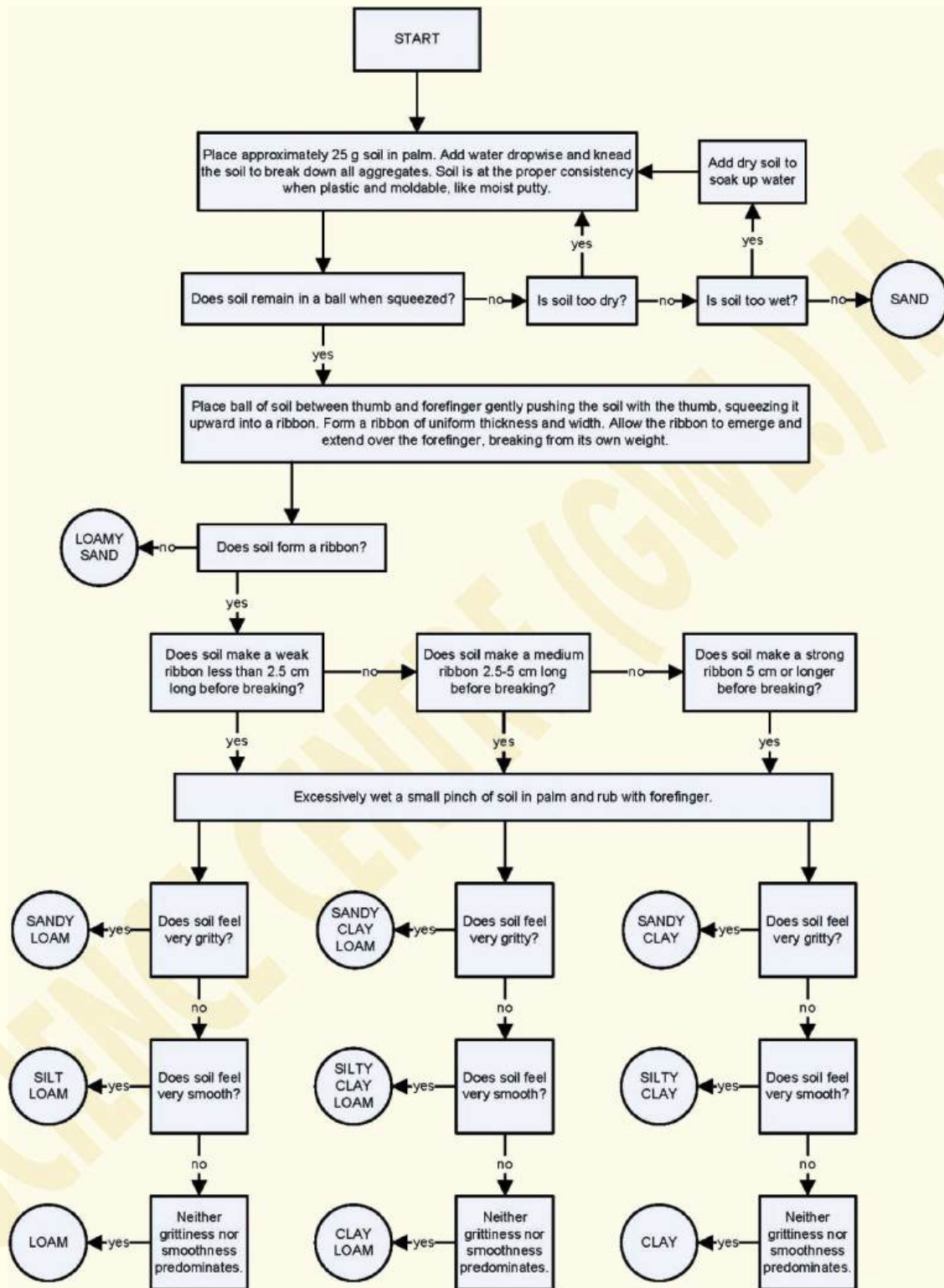


Figure: Flow Diagram for Determination of Soil Texture by Feel Analysis

(Figure reproduced from: Thien, S.J. 1979. A flow diagram for teaching texture by feel analysis. *Journal of Agronomic Education*. 8:54-55).

Data collection and analysis -

Record the soil texture test results in the designed table or data format. A sample data table is given for example –

Site Details -													
Place, geographical location, land use (viz. agriculture land, query, under construction, orchard, grassland, forest, barren land, river side, flood plain, pastureland, roadside, wetland, garden etc).													
Soil Horizon	Depth of the Soil Horizon (c.m.)	Soil Texture Class (Mark in the appropriate box)											
		Sandy	Loamy Sand	Sandy Loam	Silt Loam	Loam	Sandy Clay Loam	Silty Clay Loam	Clay Loam	Sandy Clay	Silty Clay	Clay	Other
A													
B													
C													
D													

Results -

Present your results in the form of numerical data in the form of quantitative and/or qualitative characteristics. Various interpretations can be done through mathematical and/or statistical calculations. Photographic evidences of the landscape surrounding the sampling site will be useful for further reference.

Key points learned –

- Texture classes of soil
- Classification / Categorization of soil based on texture

Open ended questions -

- Observe seed germination of different plant species in relation with soil texture classes.
- Observe and experiment to understand the relation between soil texture and water movement (Drainage, percolation, water holding capacity).
- Observe the conditions of soil erosion in your area in reference to existing soil texture types and try to find remedial measures for it.
- Try to find out interrelationship between different soil textures and associated plant species growing in the area.

Sub-Theme: Soil Consistency

Soil consistency is the strength with which soil materials are held together or the resistance of soil to deformation and rupture. Soil consistency is measured for wet, moist and dry soil samples. For wet soil the consistency is expressed as both stickiness (ability of soil to adhere to other objects) and plasticity (ability of soil material to change shape but not volume). The stickiness may be classified as 'non sticky' and 'sticky' whereas the plasticity can be rated as non plastic, slightly plastic, plastic, very plastic etc. By feeling the soil resistance to pressure & rupture it can be rated as loose, friable, firm, hard and their further subcategories.

Activity: Determination of soil consistency by testing its strength and plasticity

About this experiment -

Soil consistency is soil's expression of resistance to pressure and rupture, as well as its stickiness and plasticity. Different kinds of soils possess the strength with which soil materials are held together or the resistance to deformation. We can check the soil consistency simply by pressing it to rupture or get deformed. Feel of the soil consistency can be recorded as loose friable, firm, hard etc which is reflecting relative resistance to the applied pressure. By doing this activity one can understand the differentiation between strength of soils found in different landscapes as well as soil found in different soil profiles (horizons). This also helps in decision making for preparation of soil appropriately before using it for any purpose.

Material required-

- Leaflet of figures to test soil consistency

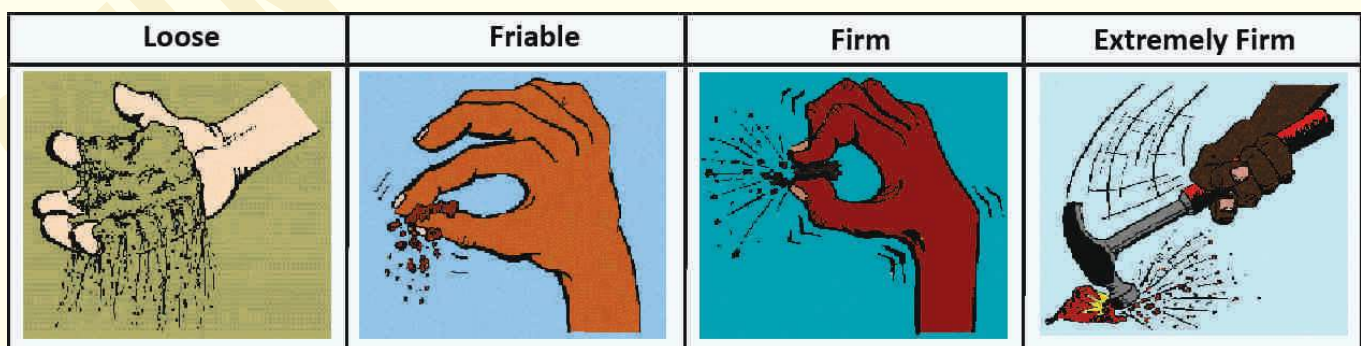


Figure: Soil Consistency Types

Method -

1. Take a ped from any soil horizon.
(If you are collecting the soil from top surface you may not dig the soil but if you are collecting the soil from different horizons then you have to dig the earth to see the soil profile. If the soil inside is very dry then moisten the face of the profile with mild spray of water using a water bottle and then remove a ped to determine the consistency).
2. Holding the ped in between your thumb and forefinger, gently squeeze the ped until it pops or falls apart.

Record one of the following categories of soil consistency in the data sheet -

- A. Loose Soil:** Trouble in picking out a single ped and the structure falls apart before it is taken out. Soils with single grained structure (in which individual particles do not stick together) always have loose consistence. For example, sandy soil is always a loose soil.
- B. Friable Soil:** The ped breaks with a small amount of pressure.
- C. Firm Soil:** The ped breaks when you apply heavy pressure that even cause dents on your fingers.
- D. Extremely Firm:** The ped can't be crushed with your fingers (you need a hammer).
Repeat this procedure for each horizon/profile in your area.

Data collection and analysis -

You may record the soil consistence type of different soil profiles (horizons). A sample table is given here, you may design your own data sheet to record your observations as per need.

Site Details - (place, geographical location, land use viz. agriculture land, query, under construction , orchard, grassland, forest, barren land, river side, flood plain, pastureland, roadside, wetland, garden, roadside etc).					
Soil Horizon	Depth of the Soil Horizon (c.m./Inch)	Soil Consistence Observation (Mark in the appropriate box)			
		Loose	Friable	Firm	Extremely Firm
A					
B					
C					
D					

Results -

Present your results in the form of numerical data and/or in the form of qualitative description. Various interpretations can be done through mathematical and/or statistical calculations.

Photographic evidences of the landscape surrounding the sampling site will be useful for further reference.

Key points learned –

- Observations of soil types, their horizons and consistency and their interrelationships.
- Categorization of soil types based on a certain criteria. For example, soil consistency of own area.
- Understanding why preparation of soil is important before its use for a purpose.

Open ended questions -

- Take seeds of your local cereals or plant varieties and try growing them in different soil (consistence) types.
- Try preparation of soil by mixing of soils of different consistence and experiment the seed germination in that and other tests of soil characteristics.

Sub-Theme : Soil pH

Soil pH is the measure of acidity or alkalinity of the soil. Soil pH directly influences the availability of mineral nutrients, nutrient dynamics and biological process in the soil as well as the soil structure. It is an important parameter that influences other soil factors and by influencing the availability of mineral nutrients it directly affects the plant distribution as well as growth. The neutrality, acidity or alkalinity of soil differ in different sources of soils such as alluvial soil, farm soil, road side soil and pond soil, forest soil etc.

The pH range in soil normally varies from 3 to 9. Generally, soil pH between 6.0-7.5 is considered optimum for most plants, as most of the nutrients are available in this pH range. However, some plants may have soil pH requirement above or below this range. The desirable soil pH range for optimum plant growth varies according to their varieties. The toxic elements in soil get highly mobile under acidic conditions and leach into ground water and consequently taken up by plants and accumulated in their parts. Some plants also show inhibited growth due to increased aluminium toxicity under acidic condition. Soils having higher pH may also deficient in phosphorus and most micronutrients.

Soil pH is normally measured in a soil water suspension. The simplest method for estimation of pH range of soil is testing it with pH strip or with litmus paper. For accurate estimation of pH titration method and electrode sensor methods are followed.

Activity: Determination of pH of soil by 'pH paper test'

About this experiment -

Soil pH is the measure of acidic or alkaline nature of soil. Soil pH is an important character that influences the nutrient dynamics and biological processes in the soil. Soil having pH less than 7 is called acidic and for more than 7 is called alkaline. Soil pH from 6.0 to 7.5 is considered optimum.

Soil pH is normally measured in a soil water suspension. The acidic or alkaline nature of soil can be easily tested in the field with the help of a litmus paper (which is a filter paper that is treated with natural-soluble dye obtained from lichens), whereas to ascertain the range or value of acidity or alkalinity standard pH paper strip (which is a paper treated with mixture of indicators) is used.

Basic Concept of pH:

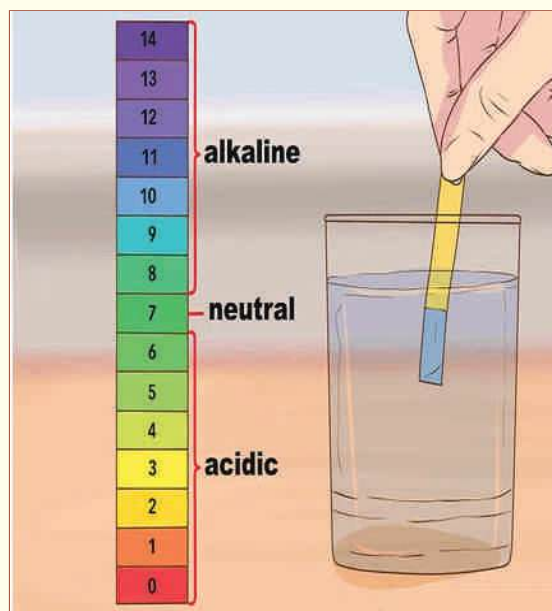
- pH of Neutral Solution : If the pH of a solution is 7, it will be a neutral solution. Such solution shall not react with litmus or any other liquid indicator.
- pH of Acidic Solution : All acidic solutions have pH less than 7. Therefore, whenever the pH of a solution is less than 7 it will be acidic in nature and it will turn the blue litmus to red, and will cause liquid indicators, methyl orange turn to pink and phenolphthalein to colourless.
- pH of alkaline solution : All alkaline solutions have a pH greater than 7. Therefore, whenever the pH of a solution is greater than 7 it will be alkaline in nature and will turn the red litmus to blue, and will cause methyl orange turn to yellow and phenolphthalein turn to pink.

Material required-

pH paper strip, graduated glass beaker (alternatively you can take any clean small vessel of glass or metal having at least 100 ml volume).

Method -

1. Take about 10 gram of soil sample in the beaker and add 50 ml of distilled water in it.
2. Shake the solution well for two minutes.
3. Place the beaker at a flat surface for at least 15 minutes to let its soil settle down.
4. After settling of soil, take out the supernatant (soil water suspension) in another beaker (or alternatively other container) in a way that the settled soil does not get moved and remains in the first beaker.
5. Take some amount of supernatant and dip a pH paper strip into it and take out immediately and let it dry for few seconds for any change of colour.
6. Observe the change in colour of pH paper and match it with the colour scale printed on the pH paper strip booklet.
7. The pH of sampled soil will be corresponding to the pH value printed on pH booklet with which the colours of tested pH strip matches.



Data collection and analysis -

Use reference range of pH to determine the nature of respective soil sample as following -

pH 7 - Neural,

pH less than 7 - Acidic,

pH more than 7 - Alkaline

Record the observed pH value of each sample and the inferred nature of the sample in the data sheet. A sample of data table is given here, you can design your data table according to the additional information you want to record with the pH values.

Sample Code	Place of Soil Sample (Either name of place or type of land)	Location (Latitude & longitude)	pH Range (mark in the appropriate cell)			Nature of Soil
			pH <7.0	pH = 7.0	pH > 7.0	

Results -

Derive your results regarding pH value observed for different samples and other interpretations based on additional data/information compiled. Photographic evidences of the landscape surrounding the sampling site will be useful for further reference.

Key points learned –

- Concept of soil pH and related acidic or alkaline nature.
- Classification of soils based on acidic, alkaline and neutral nature.
- The neutral, acidic or alkaline nature of soil differ in different sources of soils such as alluvial soil, farm soil, road side soil and pond bed soil, forest soil etc.

Open ended questions -

- Why distilled water is used in making soil solution? Why not water taken from any source is used?
- What is the reason for different pH value of soils?
- What would be the effect of variation of soil pH on crop pattern?
- Can you maintain or alter the soil pH? If yes, try out and present. For how long the altered pH can be maintained?

Sub-Theme : Soil Porosity

Soil porosity is the amount of space available between soil particles. Pore spaces are formed due to plant roots, movement of soil organisms, burrowing animals, expansion of gases within soil, dissolution of the soil parent material etc. Different sized pore spaces in soil directly affect the water holding capacity (i.e. ability of spaces to hold the water) of soil. More the porosity lesser will be the water holding capacity, consequently more loss of soil water through evaporation, dryness in soil and poor availability of soil water to plants. The seepage and recharge of underground water is also affected by the porosity of soil.

Water that is kept hold in soil pores against of gravity is called capillary water, is the main source of water to the plants. Soil pores also contain air that helps in availability of Oxygen to plant roots to perform respiration. Soil porosity supports plant growth and activities of living soil organisms in many ways.

Soil structure, soil texture and soil organic carbon directly affect the pore space. Well aggregated soil will have more spaces as compared to single-grain or less structured soil. Clay and clay loam soil will have greater pore space than sandy soil. Addition of organic matter increases the volume of pore space in soil. Intensive agriculture reduces the soil porosity as compared to fallow soils. Loam soil or loamy content in soil is best suitable for adequate soil porosity that retains capillary water, air and spaces for growth of plant roots.

Activity: Determination of soil porosity by 'Pore Volume'

About this experiment -

Soil porosity influences various physico-chemical and biological features of soil, like water drainage, water holding capacity, gaseous exchanges, microhabitat of soil organisms, penetration and growth of plant roots etc. Most importantly, the porosity is determinant of the availability of 'Capillary Water' that is primarily available to the plant roots. Porosity itself is determined by combination of other soil characteristics like structure, texture, organic carbon etc.

Soil porosity can be determined by estimating the pore volume i.e. volume of the space available between soil particles, and is expressed as a percentage of the total volume of the soil material. Soil porosity is an important factor in areas where drinking water source is groundwater and the ground has drainage issues.

Material required -

Glass beakers of 250 ml volume, measuring cylinder of 100 ml volume (Alternatively you can take any wide mouth vessel of known volume and another graduated vessel of known volume)

Method -

1. Fill the beaker with the collected soil sample to a definite volume (for example, let us fill it up to 200ml volume), keep stirring the beaker gently so that the soil sample gets filled properly up to the marked volume.
2. Take the measuring cylinder and fill it to 100 ml with water.
3. Now from the measuring cylinder slowly and carefully pour the water into the beaker in which soil sample is filled, keep pouring the water slowly until it reaches to the level of filled soil.
4. Pour slowly so no water spills out of the beaker. Record exactly how much water was used.
5. If the water level goes down from the level of filled soil then add more water to bring it to the same level.
6. Finally record the amount of water used to fill (saturate) the soil up to its top surface.
7. Follow the above process for every soil sample whose porosity has to be determined.

Data collection and analysis -

Record in the data table, the amount of water used to saturate different soil samples. Use the following formula to calculate the percent porosity of the sampled soil -

$$\% \text{ Porosity} = (\text{Amount of water added to soil sample} / \text{Volume of soil sample}) \times 100$$

A sample of data table and example of data entry is shown here; you can design your own data tool to record the observations

Sample Code	Source of Soil	Volume of Soil Sample (ml)	Amount of water added to Saturate the Soil Sample (ml)	Porosity %
X	Agriculture field	200	23.5	11.75
Y				

Results -

Derive your results regarding porosity of different soil samples and other quantitative and qualitative interpretations based on the data compiled.

Key points learned -

- Different soil types have different pore spaces between their particles and accordingly possess the ability to hold the water.
- The underground seepage and recharge of water is affected by the porosity of soil.

Open ended questions -

- Make a mixture by adding different soils together to make the soil having desired porosity and check whether it serves better in holding water and air and helps plants to grow better.

Interesting facts -

FAO Guidelines for Soil Description - <https://www.fao.org/4/a0541e/a0541e.pdf>

Theme - Biodiversity

Biological diversity (in short Biodiversity) is the term that is used to describe the types and combinations of the life forms on the Earth. There are life forms ranging from very minute microorganisms to multicellular small creatures to invertebrates to vertebrates among animals and unicellular photosynthetic organisms to multicellular algae to higher aquatic and terrestrial plants. Overall biodiversity consists of all types of life forms that are broadly differentiated into plants and animals, as well as those having both plants and animal characteristics and also those having different characteristics other than plants and animals.

In a time period of more than 3.5 billion years from early Precambrian era to till date different life forms have developed on the earth. Species that we see today are that have evolved from their ancestors and adapted to the current environmental conditions on the earth. We humans are also an integral part of the Earth's biodiversity. It is believed that there could be up to 10 crore life forms on the Earth; while from statistical inferences it is considered that there are about 1.3 crore species on the Earth; but in actual, till date we have been able to identify only about 17.5 lakh species on the earth.

Biodiversity includes different forms of plants, animals, microorganisms but its actual scope is much wider. Different forms of life also have huge diversity at genetic level, i.e. different species also have genetic variations within them and these genetic differences within species further leads to wideness of biodiversity.

Apart from genetic variations another aspect of biodiversity the variety of ecosystems in which the life forms live. There are geographical and climatic variations in different parts of the Earth which we classify into forests, wetlands, mountains, deserts and many more types of ecosystems. In each ecosystem different species have different types of occurrences and distribution where they interact with each other and also with the local air, water, soil, weather conditions, physical forms, chemicals and gases around them.

Biodiversity is the combination of life forms, their interactions with each other, their interactions with environmental conditions and their own evolutionary process. Biodiversity is a major source of ecosystem services to us that help in sustaining our life. Biodiversity resources are the pillars upon which human beings have build their civilization.

Under this theme different activities are described under sub-themes that would help us in understanding the characteristics and functions of biodiversity, different life forms in

different ecosystems, their forms and functions, their ecological characteristics and importance -

- Aquatic Bottom Organisms
- Fish Diversity – Different Types of Caudal Fins in Fishes
- Fish Diversity – Different Types of Scales in Fishes
- Aquarium – A Prototype of Aquatic Ecosystem
- Seeing Underwater from Outside
- Terrarium – A Safe House for Small Animals
- Vermicarium – House of Soil Worms
- Formicarium – The Ant House
- Butterfly Diversity
- Sampling of Small Insects
- Birds' Houses
- Pugmarks / Footprints
- Height of Tree
- Tree Crown and Canopy Cover

Sub-Theme: Aquatic Bottom Organisms

Organisms that live in the bottom zone of aquatic environment (standing or running, fresh water or marine) burrowing in the bottom mud or crawling over it or swimming or sedentary at a place are called Benthos. The bottom layer of aquatic environment where benthos are found is called the Benthic Zone. The benthic zone ranges from the shore area where water meets land, to the shallow depths and further to the extreme depths where even humans have not reached yet.

The term benthos was coined by Ernst Haeckel in 1891 and it comes from the Greek noun word that means "depth (of the sea)". Benthos life forms include plant forms (phytobenthos), animal forms (zoobenthos), and microbial forms (benthic microflora) that are the equivalents of primary producers, consumers, and decomposers, respectively.

Types of Benthic Organisms – Benthic organisms can be divided into three groups depending upon their habitat –

Hyperbenthos: Those have the ability to swim and live near the bottom but are not attached to it. e.g. Clams and Mussels, Snails, Star Fish, Sea Urchin, Benthic Diatoms etc.

Epibenthos: Those spend their lives attached to the bottom floor on rocks, or on shells etc. e.g. Corals, Sponges, Barnacles, Macroalgae, Sea Grasses etc.

Endobenthos: Those live within the sediments in burrows or creating underground tunnels. e.g. Oligochaete worms, Tubeworms etc.

Importance of Benthos :

Benthos are very important part of aquatic food chain. Mostly benthos tends to rely on food sources that sink down to the bottom, such as inorganic matter and dead organisms, but many of them also feed on one another. Many other organisms such as fishes, aquatic birds and other aquatic organisms also feed upon benthic organisms. They act in keeping balance in the environment. They break down the dead organic matter that sinks into the water thus keeping the aquatic environment cleaned up from waste and dead & decomposing material through their feeding process. They play important role in recycling of nutrients in the aquatic environment. Benthos also acts as a bioindicator of the health of aquatic environment through their presence or absence indicating the cleanliness/pollution of the habitat.

Activity: Let's explore the diversity of aquatic bottom organisms (Benthos)

About this experiment -

Benthic zone organisms (Benthos) live in the bottom zone of aquatic environment. The aquatic environment includes standing or running, fresh water or marine in the form of pond, lake, stream, river, sea, marsh etc. Benthos would be found in their various life forms that are categorized broadly in three types according to their distribution in the bottom as, Endobenthos (burrowing in the bottom mud), Hyperbenthos (crawling over it or swimming) and Epibenthos (sedentary at a place). Benthic organisms include plant species (phytobenthos), animal species (zoobenthos) and microbial forms as well.

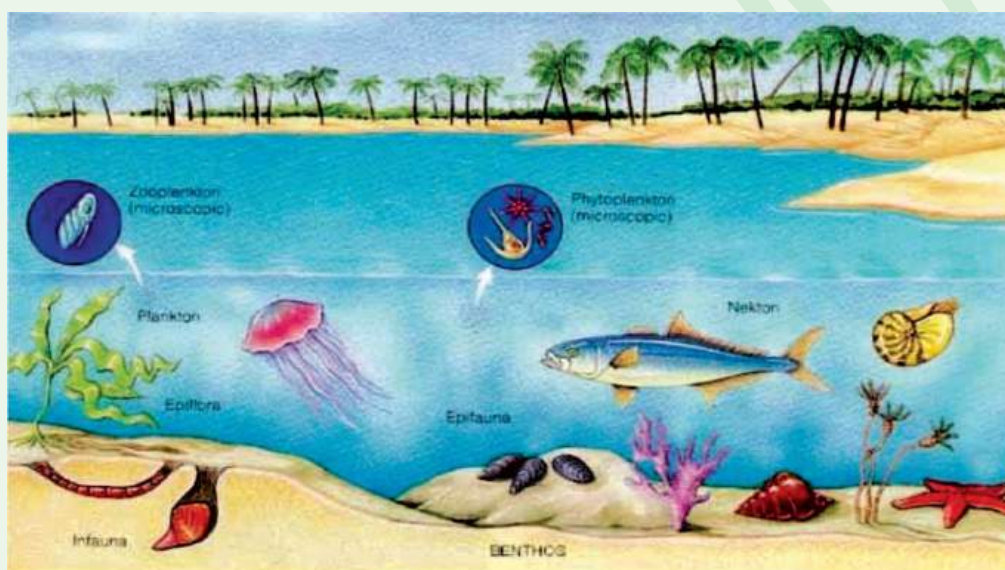


Image: Benthos in a Water Body

Why Benthos are important? Benthos are very important constituent of aquatic ecosystems making part of the food chain and food webs, biogeochemical cycles, trophic structures, energy flows and various other ecosystem functions. Benthic organisms living in deep zones tend to feed upon the dead organic matter that sinks down to the bottom and thus play important role in recycling of nutrients and keeping the aquatic environment clean.

Benthos as bioindicator: Benthos also acts as a bioindicator of the health of aquatic environment through their presence or absence indicating the cleanliness / pollution of the aquatic habitat.

Here we are describing the activity as how we can collect and examine various types of Benthos and understand their diversity in our water bodies.

Clean Water Bioindicator Benthos



Clean Water Body



Mayfly Larva



Dragonfly Larva



Aquatic Sow Bug



Pila



Oligochaeta Worm



Mussel

Polluted Water Bioindicator Benthos



Polluted Water Body



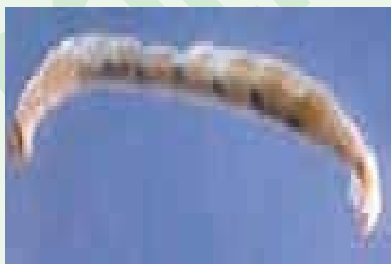
Dobsonfly Larva



Water Beetle



Snail



Oligochaeta Worm



Midge Fly Larva



Tubifex Worm

Material required -

- Mud sampler (Khurpi or shovel),
- Sieve (2.0mm & 0.5mm mesh size),
- Bucket,
- Magnifying Glass,
- Collection bottles,
- Forceps,
- 70% alcohol (Preservative)

Method -

1. Mark a measured spot in the bottom zone in a water body and collect sediment sample from it by a mud sampler.
2. Take the Sample in a bucket, note its volume and add water to it.
3. Sieve out the sample through 2mm & 0.5mm mesh size sieves, one after the other respectively.
4. Collect the micro and macro invertebrates from the sieves with the help of forceps and transfer them to a wide moth bottle containing 70% alcohol.
5. Transport residual organic materials retained in the sieve, to the laboratory and add 50ml - 100ml of water to it.
6. Dissolve 5 gm of sucrose in it (sucrose helps the benthic organisms to float on the water due to change in the density of the medium, that makes easy to collect them for further process)
7. Fix the organisms in 70% alcohol to preserve.
8. Identify the species and estimate the number of organisms species-wise, their total number, and make inference on the basis of quantitative and qualitative analysis.

Data collection and analysis -

- You can make a record of the benthic organisms collected from different water bodies, their identification, number in the sample, aggregate number of benthic organisms collected from respective water body etc.
- An example of data table is given here; you can design your own data table as per need.

Site description: Description of the type of water body (in terms of area, depth, expansion, health etc.), surrounding environment, geographical conditions etc.			
Location (Latitude & longitude):			
Date and Time of Sample Collection:			
Bottom Sampling Area (cm²):			
S. No.	Name of Species (Scientific name / General Name)	Total Number of Individuals	Number of Individuals per unit area
1			
2			

Qualitative and Quantitative Analysis:

- Identify the organisms using keys & monographs.
- Count their number species-wise in the sample and note down.
- Calculate the number of organisms per unit bottom area species-wise and for total benthos.

$$\text{Individuals of a Species per Unit Area} = \frac{\text{Total number of individuals counted from the sample}}{\text{Bottom sampling area}}$$

$$\text{Benthos per Unit Area} = \frac{\text{Total number of Benthos counted from the sample}}{\text{Bottom sampling area}}$$

Results—

Present your results regarding species of benthos identified from the sample and their individual populations as well as total number.

You can present your result through mathematical and statistical calculations of quantitative and qualitative data.

You can also analyse the data in reference to the spatial and temporal variations and habitat characteristics.

Key points learned –

- The bottom of aquatic bodies also hosts various life forms that are termed 'Benthos' (i.e. bottom dwelling organisms)
- Benthic organisms include plants, animals and microbial species
- Benthos have species-wise distribution pattern in the bottom (Hyperbenthos, Endobenthos, Epibenthos)
- Benthos are an important ecological indicator of the health of water body

Open ended questions -

- Do benthic organisms do respiration? How do they get the required gases?
- When it is very difficult for us to go under the sea beyond a limit because of the very heavy pressure of the water column, how do benthic organisms in deep sea zone able to bear the heavy pressure of the water column above them?

Interesting facts -

Studying Benthos (or benthic organisms) is important to understand how aquatic ecosystem works. Often these animals occur in high numbers and with biological diversity, which lead us to think they play an important role in the energy (food) flow through the aquatic ecosystem.

Sub-Theme: Fish Diversity- Different Types of Caudal Fins in Fishes

Caudal fin is the tail fin of a fish that is located at the posterior narrow end of the body (caudal peduncle). The word “Caudal” comes from the latin word “cauda” that means tail. Among all fins only caudal fin is connected to the vertebral column of the fish body. Caudal fin is used for propulsion as well as side-side thrust during forward movement.



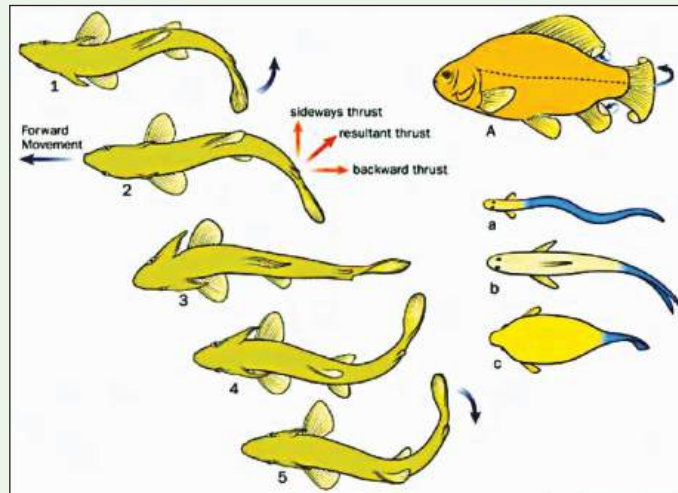
Caudal Fin (Fish Tail)

Types of Caudal Fin in Fishes –

Based on their shape caudal fins are categorized in different types, namely pointed, rounded, truncate (square), emarginated, forked, lunate and heterocercal etc. The shape of caudal fin corresponds to the power of propulsion; it also acts like a rudder to help in change of direction while swimming.

Caudal Fins as Indicator of Ecological Adaptations:

Fish shape and anatomy helps us discover information about how a fish moves, where and how the fish lives, and how it has adapted to its environment. The shape of a fish's caudal fin indicates how the fish moves and lives as well. Pointed caudal fin like that in Catfishes and Sharks are effective in making thrust and variable speed and acceleration. They also use the pointed caudal fin to stun the prey. A rounded or truncated caudal fin like that in Killifish, Minnow, Snakehead, Trout, Salmon etc is good for maneuverability and short bursts of speed. This kind of caudal fin is commonly found on fishes living in coastal embankments, river mouths and riverine systems. A forked shaped caudal fin like that of Catla and Striped Bass is good for maneuverability and speed over longer distances. Lunate or crescent shaped caudal fin like those found in Tuna and Swordfish allow for great speed over long distances and are usually found on fish that live in the open system.



Fish Movement with the Help of Caudal Fin

Activity: Identification of fish diversity based on their caudal fins

About this experiment -

Among all fins that a fish possess, only caudal fin is connected to vertebral column and this gives strength to the caudal fin to be used for propulsion and thrusts while swimming or changing directions or accelerated movements.



Caudal Fin (Fish Tail)

Based on their shape caudal fins are categorized in different types, namely pointed, rounded, truncate (square), emarginated, forked, lunate and heterocercal etc. The shape of a fish's caudal fin indicates how the fish moves and lives as well.

Here we are discussing how we can classify fishes found in our region on the basis of their caudal fins.

Types of Caudal Fins in Fishes

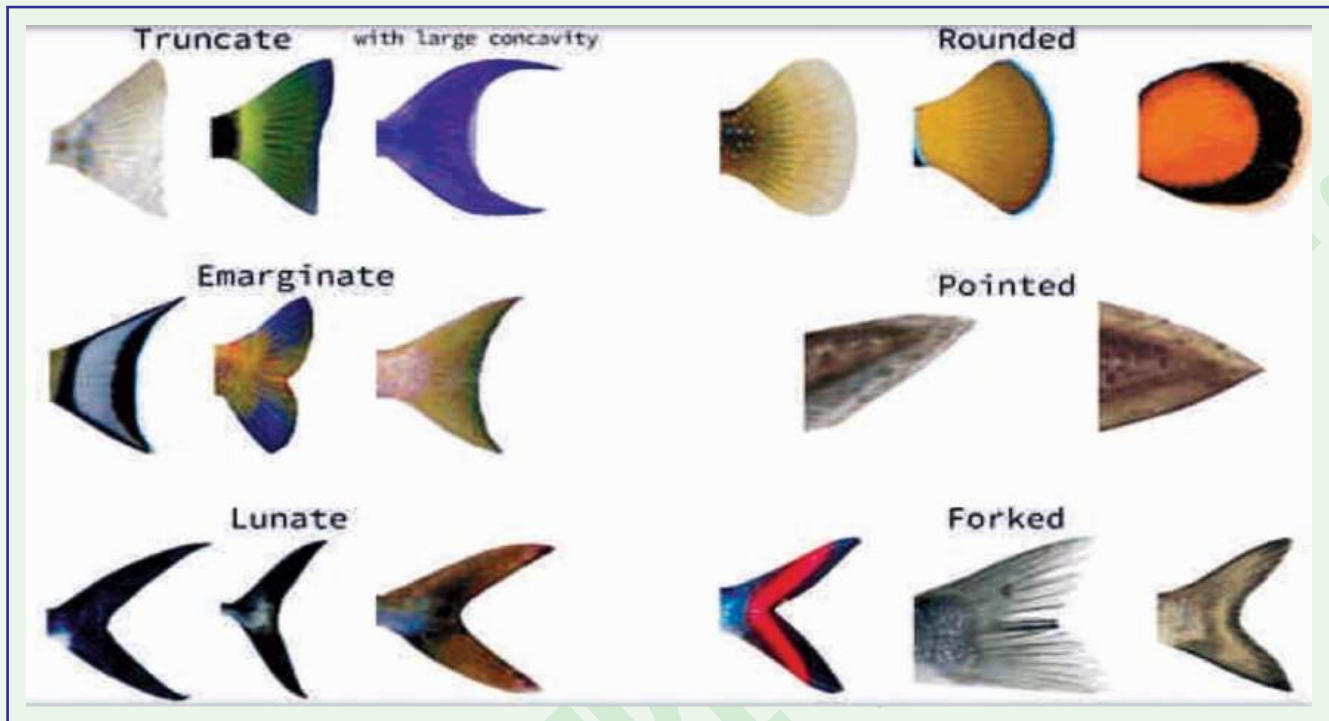


Image: Different Shapes of Caudal Fins in Fishes

Caudal Fin (Tail) Types

Shape	Type	Example	Fish	Characteristics
	Pointed		King Snake Eel	Slow, snake-like movements
	Rounded		Gulf Toadfish	Large amount of surface area creates drag, but effective maneuvering/acceleration
	Truncate (square)		Grey Snapper	Not as much drag as rounded shape, still effective maneuvering and acceleration
	Emarginate		Sheepshead	Not as much drag as rounded or truncate shapes, still effective maneuvering and acceleration
	Forked		Tomtate	Much better acceleration, still good maneuvering, less surface area means less drag
	Lunate		Crevalle Jack	Rigid fin with less surface area means great acceleration, but less maneuverability
	Heterocercal		Nurse Shark	Only found in primitive fishes like sharks, sturgeon, paddlefish

Image: Types of Caudal Fins with Examples

Material required-

Leaflet of caudal fins

Method -

1. Observe the caudal fins of fishes found in your region. Focus on a fish and observe its caudal fin and try to identify its fin type with the help of caudal fin leaflet.
2. While observing the caudal fin, also observe the fish movements and note how it is using its caudal fin in movements.
3. Draw the sketch of fish and mark characteristics of its caudal fin. You can also take the photograph of the fish or take a video of its movement.
4. If you are belonging to fisher family you can conveniently observe and examine the caudal fin of different fishes caught. You can also relate the fish habitat and fish behaviour in reference to their use of caudal fin.
5. Alternatively, you can visit the local fish market or fishing areas and can examine and document the caudal fins of different fishes.
6. You can distinguish fins on the basis of their morphology and anatomy (viz. Shape, size, dimensions, fin rays, colour, thickness etc.)

Data collection and analysis -

- Record the Name of Site of observation along with date and time.
- Make a list of the fishes observed and record its caudal fin type (using the caudal fin leaflet)
- Draw the sketch of caudal fin of respective fish
- Draw the sketch of respective fish
- Draw the sketch of fish's movement and orientation of caudal fin

Results –

You can present a record of the fish diversity on the basis of caudal fins; classification of fishes according to fin types, morphological characters of caudal fins.

You can present your finding numerically and/or qualitatively or through sketches, photographs and drawings.

Key points learned –

- Fish morphology
- Caudal fin morphology

- Use of caudal fin for fish movements
- Fish habitat and adaptations of caudal fins
- Categories of fishes on the basis of their caudal fins
- Fish behaviour and use of caudal fin

Open ended questions -

- Is it possible to design the oar of a boat like that of a fish fin?
- Can we make an oar having shape and corresponding propulsion power following the caudal fin of a fast swimming fish?
- Does there exist any fish that is devoid of caudal fin / or all fins? If yes, how do they swim without having fins?

Interesting facts -

Fish shape and anatomy helps us discover information about how a fish moves, where and how the fish lives, and how it has adapted to its environment. By studying the morphology of living things, humans have learned how to better design machines such as submarines, torpedoes, airplanes and automobiles. Body shape, mouth location and size, tail shape and color all give indication of how fish live and function.

Sub-Theme: Fish Diversity: Different Types of Scales in Fishes

A fish scale is a small rigid plate that grows out of the skin of a fish. Fish scale is rooted and develops in the mesoderm (layer between epidermis and the underlying tissues). The term scale is derived from the Old French word "escale", meaning a shell pod or husk. Primary purpose of scales is to act as armour/protective covering for fish and apart from that they help them in camouflaging through the use of reflection and coloration as well as hydrodynamic advantages. Genes responsible for the development of scales in fishes are same like that of genes responsible for development of hairs in mammals.

Scales grow on a fish in overlapping plates, in a pattern that the free end of the scale points towards the tail. If you slide your hand on the fish body from head towards tail it will feel like smooth skin whereas if you slide hand from tail towards head then free ends of scales will give you rough-textured feeling.



Overlapping Pattern of Scales on a Fish



Overlapping Pattern of Scales on Catla Fish

Fish scales are categorized in four major types – **Placoid, Ganoid, Cycloid and Ctenoid.**

Placoid Scales: Placoid scales are the most primitive form of scales. They do not grow in size as the fish size increases, instead more scales are added. The structure of placoid scale has 3 layers. The innermost is the pulpy vascular core over which middle layer is calcified tissue called dentine and outermost layer made of hard glassy, opaque or partially opaque, enamel-like substance, called vitrodentine. Cartilaginous fishes like Sharks, Rays, Chimaeras etc have placoid scales.



Ganoid Scales: Ganoid scales are slightly less primitive than placoid scales. These scales grow in size as the fish ages. The structure of ganoid scales appears like diamond shaped, hard and thick. Ganoid scale is formed from ganoine (shiny substance that is secreted by the deep



vascular inner layer of the skin called corium, and composes the outer layer of the scale). Fishes like Bichir, Paddle fish, Bowfins, Gars, Sturgeons etc have ganoid scales.

Cycloid Scales: Cycloid scales are the less advanced of the advanced scale types. These scales increase in size as the fish ages and the growth can be seen in the form of rings made in scale. The rings can be related to the age of the fish. Cycloid scales are thin, circular scales covered by a thin layer of epidermis and mucus. This gives the fish a slimy feel. Lower order bony fishes like Salmon, Carps, Minnows etc have cycloid scales.



Ctenoid Scales: Ctenoid scales are the most advanced of all the scale forms. These scales also increase in size as the fish grows and the growth is manifested in the form scale rings. The structure of ctenoid scale is similar to cycloid scale with the exception of tiny comb-like protrusions on the posterior (free end) of the scale. These protrusions in the scale help the fish to swim faster. Higher order bony fishes like Tuna, Perch, Drum, Sunfish etc have ctenoid scales.



The structure of scales is useful in broad classification of the fish groups. Thus, among the fishes, placoid scales are characteristic of Chondrichthyes (Fishes having cartilage, tough elastic tissue), ganoid scales are found in the primitive bony fishes, while the cycloid and ctenoid scales are found in the higher teleosts (bony fishes).

Like annular rings in trees, cycloid and ctenoid fish scales also have annual growth rings. By observation of pattern of scale rings one can infer the age and growth of fish as well as environmental conditions prevailing in their habitat.

Activity: Fish scales as identity of their growth and environmental conditions

About this experiment -

A fish scale is a small rigid plate that develops from the mesoderm (layer between epidermis and the underlying tissues) of fish skin. Scales are primarily meant for protection of fish body and apart from that scales also help them in camouflaging and movements in water. Scales grow on a fish in overlapping plates, in a pattern that the free end of the scale points towards the tail.

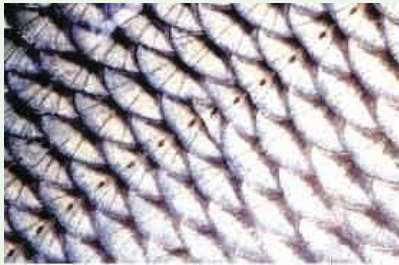


Image: Picture Showing Overlapping Pattern of Scales on a Fish



Image: Picture Showing Overlapping Pattern of Scales in Catla Fish

Fish scales are categorized in four major types – Placoid, Ganoid, Cycloid and Ctenoid. Placoid scales do not grow in size but grow more in number as the fish size increases. Ganoid scales grow in size as the fish ages. Cycloid scales increase in size as the fish ages and that is visible in the form of rings made in scale. Ctenoid scales also increase in size as the fish grows and the growth is manifested in the form scale rings. The pattern of growth rings made in the scale also reflects the environmental conditions in which the fish grows (See the figures given in the sub theme).

The structure of scales is useful in broad classification of the fish groups. Placoid scales are characteristic of fishes having cartilage (a tough elastic tissue instead of bones), ganoid scales are found in the primitive bony fishes, while the cycloid and ctenoid scales are characteristics of higher bony fishes that we have mostly at present

Here we are going to discuss activity through which we can examine the formation of scales and growth rings made in them and also try to infer the age and growth of fishes as well as environmental conditions prevailing in their habitat.

Material required-

- Leaflet of fish scales,
- Plain glass slides,
- Cello tape,
- Sticker for labeling,
- Marker,

- Forcep,
- Watch glass,
- Tissue paper.

Method -

A. Collection of fish Scales and slide preparation:

1. One can generally collect fish scales from the local market. For better scale sample select the lateral abdominal side of the fish body and remove scales with the help of forcep. Take at least 2-3 scales for better study and observations of scale characteristics.

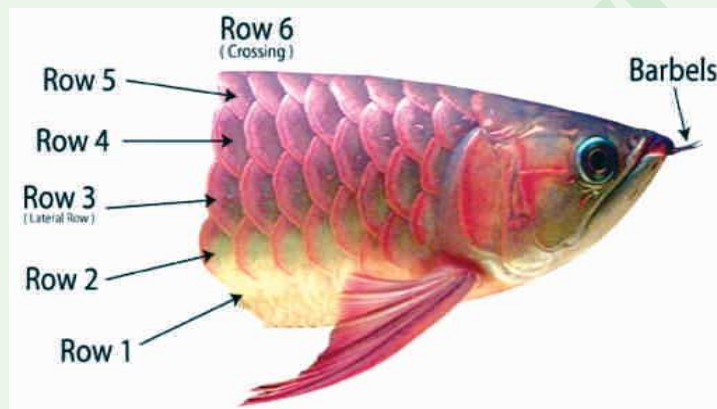


Image: Places on the Fish Body from Where Scales can be Collected

2. Wash the scale with water 2-3 times so that the mucous stuck to the scale is removed.
3. Take the glass slide and clean it with the help of tissue paper
4. Place the fish scale on the glass slide in horizontal position and cover it with another glass slide.
5. Wrap the slide ends with the cello tape so that the scale is fixed between the slides
6. Label the slide with date & time and place

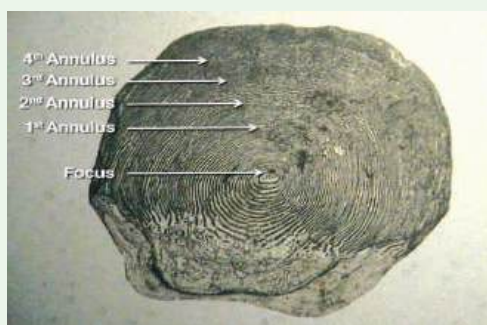
Note - The slide preparation can be done at the sample collection site (i.e. at the market shop or at the water body etc). If you find any recently dead fish at a natural site, you may also collect scale sample in the same way.

B. Age determination of fish by scale annuli counting:

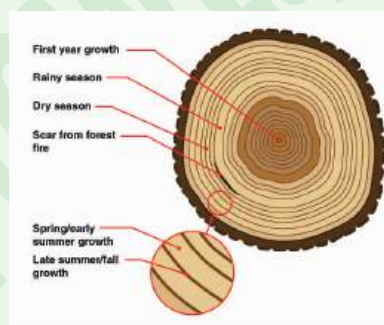
1. For age determination, few scales are removed from the side of the body just below the origin of the dorsal fin. In the fishes having soft-rays scales are taken from the region above the lateral line but in the fishes having spiny-rayed fins, scales located below the lateral line are preferred.

2. The scales are first soaked in a weak solution of caustic soda for 10-15 minutes. Subsequently, they are washed and mounted.
3. Temporary and permanent mounts can be made for age determination.
4. The temporary mounts of cleaned scales are made wet or dry. The mounts are best when the scales are held between two slides for some time in order to make them completely flat.
5. The wet process includes mounting of scales in glycerin.

Like tree stems fish scales also have annual growth rings and the formation of rings also indicates the environmental conditions. For example, closely crowded bands in scale indicate winter periods of slow growth just as do the similar bands of tree stump.



Annual Growth Rings in Fish Scale



Annual Growth Rings in Tree Stem

Note- Examination of fish scale can also be done for age and growth to determine and prepare records for maturity, age-related growth rates, survival/mortality rates (longevity), population age structure etc.

Data collection and analysis -

A. Age Determination of Fish by Scales – As shown in the picture below, carefully examine and identify the annuli formed in the scale, to determine the age of fish -

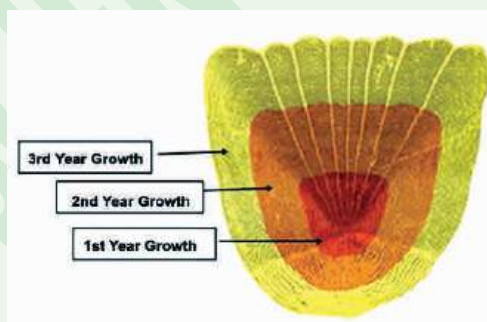


Image (A): Determination of Age of Fish by Examination of Scale Annuli

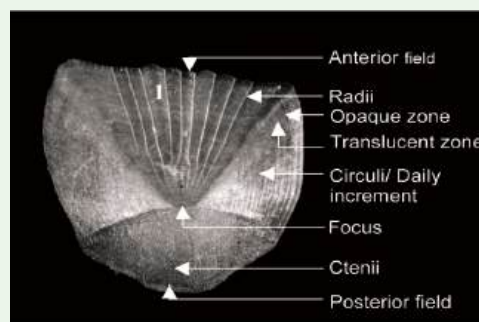


Image (B): Determination of Age of Fish by Examination of Scale Annuli

B. Record of Scale type and annuli rings count – A data table can be designed for recording the scale types and the number of annual rings formed in them. Here an example of data table is given -

S.No.	Name of Fish	Type of Scale	No. of Annuli in the Scale	Estimated Age

Results –

A general account of the fish diversity, species list, scale types, annuli count and age, and photographic or sketch illustrations can be prepared and presented.

You can make inference through mathematical and statistical calculations and present your data accordingly.

Photographic and/or hand-made sketches of fishes, their scale patterns, scale structure, annuli pattern etc can make a good impact.

Key points learned –

- Fish morphology
- Scale anatomy
- Scale annuli counting and age determination of fish
- Inference of stress condition by examination of scale annuli pattern
- Scales study for categorization of fishes in different ways

Open ended questions -

- Do all fishes have scales? How do fishes not having scales manage survival & activities?
- Why scales are peeled off before cooking the fish?

Interesting facts -

Uses of Scales: Fish scales can be utilized to make different kinds of items like jewellery items. Some examples of jewellery items prepared from fish scales are shown here



Dry Fish Scales for Making Jewellery



Fish Scales Earrings



Fish Scales Flower

Sub-Theme: Aquarium - A Prototype of Aquatic Ecosystem

It is always interesting to explore and know about the life forms living underwater. Apart from finding the species of aquatic organisms, more interesting is to know their morphology, body parts, and activities, how do they move, what they do round the clock, their behaviour etc. In natural water bodies like river, ponds, lakes and oceans it is not possible to see and know about aquatic life unless we get opportunity to go into them. From outside also, mostly it is difficult to see the aquatic organisms due to color, turbidity, depth and the time to be spent etc.

As an alternative an aquarium may serve as an aquatic system where the captivated aquatic plants and animals stay comfortably under the optimal conditions. In ideal way the aquarium serves as a habitat for them with conditions favourable to live and reproduce and perform lifecycle activities and interactions. In an aquarium one can easily see the aquatic organisms living in different zones of water (Zonation), their body parts, adaptive features, activities, movement patterns, behaviour and life cycle activities etc. One can see the producers, consumers, their interactions and can understand the concepts of food chain, food web, energy transfer, trophic structure, biogeochemical cycles etc that are characteristic features of an ecosystem.

The size of aquarium can be designed from even one cubic feet to several cubic meters or more in variable shapes, according to the available space and ability to manage.

Activity: Let's observe and understand the aquatic life through an aquarium.

About this experiment -

An aquarium may serve as an aquatic ecosystem where the captivated aquatic plants and animals stay comfortably under the optimal conditions and even can reproduce and perform lifecycle activities and interactions. One can easily see through an aquarium how various aquatic organisms distribute in different zones of water according to their microhabitat preference, how they use their body parts in different activities, their adaptive features, behaviour etc for the desired duration.

Here with the example of an aquarium as an ecosystem we can understand its components including producers, consumers, their interactions, food chain, food web, energy transfer, trophic structure, biogeochemical cycles etc that are characteristic features of an ecosystem.

We can make an aquarium of any size, even from one cubic feet to several cubic meters or more, in variable shapes, according to the available space to keep and ability to manage.



View of an Aquarium

Material required -

You can make an aquarium of glasses bound with each other. Alternatively, you can find prepared aquariums in the market. You can make a small aquarium using a glass container available at home. You can also take any box type container whose one side at least should be transparent.

Method -

1. Take an aquarium and cover its top open side with a gauzed cloth or a thin mesh like mosquito net such that you can open it at requirement.
2. Lay some gravel and coarse sand at the bottom of the aquarium.
3. Fill the aquarium with normal water (better collected from a river or a pond or lake and if not available then tap water will also work), leave it for few hours so that suspended particles in the water will settle down.
4. Fix some aquatic plants at the bottom of the aquarium (there might be free floating plants as well and you can put them as well).
5. Release the aquatic organisms in the aquarium carefully.
6. Observe the aquatic animals for the desired duration and record the observations.

Data collection and analysis -

- Data collected through observation may be recorded in the tabular form or in descriptive form.
- The data may be analysed quantitatively and/or qualitatively or in the narrative form in reference to a particular organism or different classes of organisms or as a whole.
- You can record different ecosystem functions of the organisms and also the ecosystem services of the aquarium (aquatic) ecosystem.

Results –

Present your data / observations in the basis of calculations or qualitative analysis in reference to species diversity, microhabitat requirements, behaviour, functions etc.

Key points learned –

- Understanding of an aquatic ecosystem from a well-managed aquarium.
- Distribution, zonation, feeding pattern and other activities of different aquatic organisms differ species-wise as well as individually.
- Aquatic organisms have different morphology and adaptations to live in the aquatic environment.

Open ended questions -

- Can you keep marine fishes in an aquarium? For that, what type of conditions you will have to make?
- What do fishes deliver in reproduction – eggs or juveniles? Can you identify fishes in your area accordingly?
- How do fishes take care and nurture their offspring? Watch and describe.

Interesting facts -

Marine World – India's Largest Public Aquarium:

India's largest marine aquarium 'Marine World' was opened in on 21st August, 2023 at the shores of the Panchavadi Sea in Chavakkad in Thrissur district of Kerala state. The marine aquarium houses more than 3 lakh fishes from 300+ species of oceanic life. The largest public aquarium is expanded on four acres of land that can normally occupy 150+ visitors at a time and up to 2000 people on holidays.

Sub-Theme: Seeing Underwater from Outside

In a water body like ponds, shallow water of lakes, oceans and rivers etc viewing aquatic animals gets disturbed by various factors including the turbidity of water, movement of the animals, hiding spaces inside water and also the distance of the viewer from the water level.

Viewing tube is the simple device that enables the naturalist to look inside shallow water and watch different life forms living in it up to the bottom. Viewing tube is a cylindrical narrow tube made of tough and light weight material with 2-3 inch diameter and length appropriate to dip it up to few feet under the water. Its one end (which is dipped inside water) is closed with transparent film or glass and the other end open outside water where the observer can fix eye and see the objects seen at the underwater end clearly. Viewing tube enables the viewer to reach closer to the aquatic life forms up to the bottom zone without disturbing them or handling them.



Image: Photo of Viewing Tube

Efficiency of the viewing tube can be further strengthened by attaching a convex lens at the dipping end which would further magnify the view of the objects being seen. This further helps the viewer to see the underwater life forms, bottom structures and functions in a more distinct manner.

Activity: Let's see underwater from outside using viewing tube

About this experiment -

In a ponds or other water bodies viewing the aquatic life forms is not easy due to various factors such as turbidity of water, continuous movement of the animals, hiding spaces inside water and also the distance of viewer (eye) from the water level.

Viewing tube is the simple device that enables a person to look inside shallow water and watch different life forms distributed in it from surface to bottom. Viewing tube is a cylindrical narrow tube having 2-3 inch diameter and length appropriate to dip it up to few feet under the water. Its one end (which is dipped inside water) is closed with transparent film or glass and the other end open outside water where the observer can fix eye and see the underwater objects. Efficiency of the viewing tube can be further strengthened by attaching a convex lens at the dipping end which would further magnify the view of the objects being seen. Additionally, an LED light may also be attached to the dipping end. The LED light may be used for viewing underwater during night hours or if the water is much turbid.



Material required-

Viewing tube

Method -

1. Dip the viewing tube in the water and move it down slowly and steadily so that the aquatic animals do not feel disturbed by the movement of the tube.
2. Once the dipped end reaches at a depth you decide or any animal or a plant is seen, stop further lowering of the viewing tube.
3. From the open end outside, see through the viewing tube in the water and observe the objects carefully.
4. By lowering the viewing tube further down you can stop at any point to see the objects inside the water.
5. Reach up to the bottom to see the bottom life forms and deposits and structures.
6. Move the viewing tube horizontally or slightly oblique to see underwater in different directions.
7. You may catch the planktons and other small plants and animal forms with the help of plankton net or tea strainer and bring them to home and put them in aquarium for further observations.
8. Note down your observations in the data tool.



Children Using Viewing Tube to See Underwater

Data collection and analysis -

You can present your data in tabular form or other form. A sample of data table is given here; you can design your own data table according to need.

Name of Aquatic Plant	Hand Drawn Sketch /Photo of Plant	Remark	Name of Aquatic Animal	Hand Drawn Sketch /Photo of Animal	Remark

Results –

You can present species lists of plants and animal life forms and their taxonomic classes. Distribution of different life forms in the aquatic habitat may be explained.

Description of nature and behavior of aquatic animals and plants may be given so it can provide insights about their habitats and inter-relationships.

Key points learned –

- Viewing tube is a simple and effective way to go closure to the aquatic animals and plants and study their body structure, behavior and living styles.

- Underwater life forms are diverse and they are distributed in different zones of water making their microhabitats.
- Observations of aquatic life forms at different time of the day give us more information about their diurnal behaviour.

Open ended questions -

- Is it possible to use viewing tube to see underwater in open waters of ponds / lakes / reservoirs / sea / rivers? If yes, explain how and if not then explain why not.
- What will be the behaviour of aquatic life forms in presence or absence of light?
- Also it will be interesting to study how animals respond to the presence of the approaching tube inside water.

Sub-Theme:

Terrarium - A Safe House for Small Terrestrial Animals

Terrarium is an artificial safe house for small terrestrial animals, particularly insects. The terrarium is a kind of box or chamber that is covered from top with a mesh to allow air circulation and walls of transparent material sheets. The walls may be made of opaque sheets having windows of transparent material to facilitate view through sides.

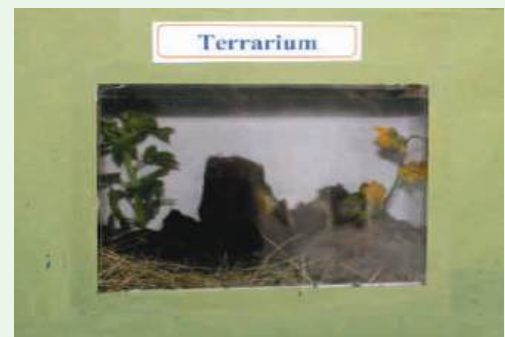
Ideally the terrarium is provided with small plants (especially those would provide host to the collected insects) for facilitating in-situ oxygen and fresh air generation, and water so that basic feed requirements of kept insects could be supported. Alternatively, natural food material can also be supplied timely. Small animals, particularly insects are collected from the local environment following the safe techniques and devices (e. g. butterfly net or pooter) and are released in the terrarium where they are free to fly, feed and rest. Terrarium is a good mean to observe the bodies and behavior of small animals like insects, keeping them comfortably till convenient time before releasing them back into the open.

Size of the terrarium can be determined as per the choice of keeper, keeping in mind the facilities required for captivated species.

Activity: How to keep small animals under observation in a terrarium

About this experiment -

Terrarium is an enclosure or artificial safe house for keeping small animals including insects, reptiles, molluscs, and small mammals etc. It contains soil, plants and water so that basic habitat and feed requirements of kept animals could be supported. Alternatively, natural food material can also be supplied timely. Small animals (for example butterflies or moths or snails) are collected from the local environment with suitable device and are released in the terrarium where they are free to move, feed and rest and perform their lifecycle activities. After observation, the kept animals are released back in the area from where they were caught. Size of the terrarium can be determined variably, as per the requirement.



In this exercise we are describing how we can make a terrarium and keep small animals safely in the terrarium for study purpose.

Material required-

A Terrarium

The terrarium is a kind of box or chamber that is covered from top with a mesh to allow air circulation and walls of transparent material sheets. The walls may be made of opaque sheets having windows of transparent material to facilitate view through sides. The floor is covered with soil in which living plants are fixed. These plants may be chosen according to host specificity (i.e. providing host to a particular species like a butterfly or other insect) or any native vegetation including moss, fern, grass, herbs etc. Water is kept in small pots, preferably earthen pots so that butterflies / bees / moths etc can take water from its wet surface.



Image: Making of a Terrarium

Method -

1. Assemble a terrarium with food and water facility
2. Release the animals to be kept under observation, in the terrarium and cover its top open part with mesh or perforated lid.
3. Observe the animals kept, for the observation purpose they are kept i.e. diurnal activities, food and feeding, movements, morphology, behaviour, life cycle activities, mutual interactions etc.
4. Prepare a diurnal time budget of the animal for its activities (i.e. types of activities the animal do for total respective duration in 24 hour time period. For example, resting: 5 hr., Feeding 0:30 hr.; Movement 2:45 hr. etc).

5. You can make sketches of the animals and/or take their photographs of various activities.
6. After required observation the captivated animals are released back to nature.

Data collection and analysis -

Data related to the body parts of animals and their behavior is recorded in the tables. This enables us to collect details about the animals. This also helps to compare the features of different animals studied in the terrarium.

An example of observation table is shown here; you can make any data format according to the purpose.

S.No.	Name of Animal	Hand Drawn Sketch of the Animal	Important Observation about the Animal

Results –

You can present your observations in the form of quantitative and/or qualitative data. Hand drawn sketches and photographs will be an additional record to display.

Key points learned –

- Terrarium is a very convenient, easy to assemble and easy to operate device to keep small animals for observation.
- Terrarium provides convenient environmental conditions to the captivated animal and the keeper can maintain the conditions as per the need of a particular animal.
- One can easily study the morphology (external body parts), morphological adaptations, activities and behavior of small animals using this method.

Open ended questions -

- Do the insects or other animals react to or respond to different colour lights? Examine by illuminating with different artificial lights in the terrarium.
- Observe the housing requirements (dwelling place) of different animals and explore which animals you can keep in the terrarium and which you can not.

Sub-Theme: Vermicarium - House of Soil Worms

Vermicarium (wormery) is an artificial safe home for worms, like earthworms. The structure of vermicarium is a kind of container having variable height, width and length with its top open for transferring worms, soil, water and other required material into this. To see the activities of worms at least one side of the container is kept transparent. Through the transparent wall of vermicarium one can see the activities of worms, their burrowing style and pattern, feeding style, underground movement, excretion, interaction etc. Since worms avoid light, the vermicarium needs to be kept either covered or at a dark place so that worms are not forced to hide and they can perform activities naturally.

With the help of vermicarium one can understand the habitat conditions of soil worms (e.g. earthworms), their behavior as well as can understand their role in maintenance of soil characteristics. The role of earthworms in different soil environments and in different seasons can also be understood. Through vermicarium we can see how efficiently and effectively earthworms play role in transforming the soil and maintain soil environment.

Activity: Making a vermicarium for nurturing and observing earthworms

About this experiment -

Vermicarium (wormery) is an artificial safe home for worms. The vermicarium is a kind of container having variable height, width and length with its top open for transferring soil, earthworms, water and other required material into this and at least one side transparent. With the help of vermicarium one can understand the habitat conditions of soil worms.



Here we are describing how we can make a vermicarium for keeping earthworms and understand their lifecycle by closely observing them. Earthworms play very important role in maintenance of soil characteristics through transforming the soil nutrients and organic matter. They also play important role in turning the soil to-down and also influence its porosity, water holding capacity, drainage of water and movement of minerals.

With the help of vermicarium we can see how earthworms make their burrows, how do they feed, what they feed upon, how do they do movements, how do they excrete and how do they interact with each other and other etc. excretion, interaction etc.

Material required -

A Vermicarium

It is a closed container where the top is kept open for aeration and transferring soil and organic material for earthworms.

Method -

1. Collects different types of soils (sand, silt, clay etc) having different colours and decomposing plant products.
2. Puts the soil types one by one in the form of layer in any order in the container (This is basically meant to see later on what changes occur in the soil when earthworms transform these soils).
3. Put the decomposable plant products such as dry leaves, roots, vegetable and fruit peels, little cow dung or fecal pellets of goat etc in the top layer.
4. Spray little water to moisten the material filled inside the container.
5. Release some earthworms (you can count their number) on the top layer in the container.
6. Since earthworms avoid light, the vermicarium needs to be kept either covered or at a dark place so that earthworms are not forced to hide & they can perform activities naturally.
7. From time to time the naturalists can bring the wormery for short time to a lighted area and observe the behavior of the earthworms.
8. The transparent walls of vermicarium allow you to observe the inside physico-chemical and biological changes as if you were seeing in the vertical section of the ground.
9. At weekly intervals see how much deeper the earthworms have reached and how are they transforming the organic matter and soil.
10. At weekly intervals see the changes occurring in soil structure and colour (also observe which layer of soil is transforming first)
11. See if the number of earthworms has increased; can you see their eggs & juveniles too?
12. Over a month or, two one can observe the transformation of the decomposable material as well as soil into vermi-compost (also called organic manure) which is highly fertile and good for plant growth.
13. Record the transformation of soil and organic material into vermi-compost over a time period (Journey towards vermi-compost).

14. You can bring out the material after its complete transformation and separate out the earthworms (now they are more in number and with them you can make multiple vermicarium or release some of them in your garden soil).

Note – There are different earthworm species occur in the environment. You may try experiment with different species and make a comparative record of each. Remember, each species of earthworm irrespective of their comparison is important for the nature as well as to us.

Data collection and analysis -

● You can record the observations of earthworms in a data format. A sample of data sheet is shown here; you can design your own data sheet as per requirement.

Number of Week	Changes in Soil Structure	Changes in Soil Colour	Vertical Depth of Earthworms	Journey Towards Vermi-Compost
1				
2				

- You can set the experiment in different seasons and can see what differences you get in the same parameter of observation during different seasons.
- You can test the physico-chemical characteristics of the soil before release into the vermicarium and again after it gets transformed into vermi-compost.

Results –

You can analyse your data quantitatively and qualitatively and make interpretations accordingly.

Key points learned –

- Earthworms perform very important role of transforming organic matter and soil into nutrient rich compost.
- Earthworms also require certain conditions to live in the soil. Without that they can't survive in the soil.
- Earthworms are sensitive to temperature and light, hence we have to be careful for them while doing any lightening or heating on to the ground.
- Absence of earthworms or, decrease in their number in any soil is an indicator of the poor quality of soil.

Open ended questions -

- Have you seen whether the earthworms have eyes or not? How do they see and change the direction during movements?
- Do the earthworms have lungs? How do they breathe?
- What is vermi-compost? How it is produced? What does it is composed of?
- Test the vermi-compost for its texture, consistency, porosity, water holding capacity, and nutrients and compare with same parameters of your local soil sample.
- Find out whether growing a plant only in vermi-compost is good or growing it in vermi-compost mixed soil? What should be the proportion of vermi-compost and soil to grow a plant?

Interesting facts -

Earthworm diversity in India:

In India, including the islands of Andaman & Nicobar and Lakshadweep, 452 species / subspecies of earthworms belonging to 71 genera are known. Out of them 89% of species/subspecies and 71% of genera are endemic (i.e. they are confined to Indian parts where they occur and nowhere in the world). 57 species of earthworms in India are exotic (i.e. brought from other geographical areas other than India). The scientific exploration of earthworm's diversity in India began in nineteenth century)

Are there specific species of earthworms used for vermi-composting?

Earthworm diversity varies with soils and choosing a native species for vermi-composting is best. Your native species are best suitable to your local environment and adapted to survive. There is no need to import any particular species for making vermi-compost. In India local species mostly used in vermi-composting are *Perionyx excavatus* and *Lampito mauritii*.

To know more about earthworms of India you can visit the following website - <https://earthwormsofindia.com/>

Sub-Theme: Ant House (Formicarium)-The House of Ants

Formicarium is an artificial secured house for ants that provides a good opportunity to us to observe and understand the social structure, activities, behavior and ecological role of ants. Usually, the artificial ant house is made with plaster of paris. The internal design is made in the pattern that ants make inside soil.

For convenience of observation one side of ant house is kept transparent through which one can observe what is going on inside. Transparent side of the ant house allows the observer to look at the body and behavior of the ants from time to time and keep record of ant behavior over time.

Activity: Making a formicarium (Ant House) for lodging and observing ants

About this experiment -

Ants are an integral component of terrestrial ecosystems. Formicarium is an artificial lodging structure made for ants in which we can keep them to observe and understand their social structure, activities, behavior etc. The formicarium is made of plaster of paris (PoP). Its internal design is patterned according to that ants make naturally and it is seen like a vertical cross section of the ant house in the ground. The door of formicarium remains the gateway for the ants. Inside this small house the small cavities are formed that are connected to the main entry road for ants to move inside and live in the cavities for some time. The visible side of the ant house is covered with a transparent material through which one can observe what is going on inside.



Material required -

A formicarium (Ant House)

How to make a formicarium :

- i) Take a rectangular box of cardboard or plastic having dimensions at least of 6 X 3 X 2 inches in length, width and height/depth respectively. Alternatively, you can take an empty box of sweet or chocolate box.

- ii) Take some wheat flour and make a bit tight dough of it and then make its shape having a long stem to which small balls are attached through small stalks in its length. The thickness of this shape should be lesser than the height/depth of the box in which it has to be placed. This shape should not be longer more than $\frac{3}{4}$ length of the box.



Making of Wheat Flour Cast to make Ant House

- iii) Place the figure made of dough in the box in its length such that its main stalk (long stem) is touching to an end of the box in length.
- iv) Now make thick slurry of plaster of paris (PoP) and fill it in the box such that the structure made of dough is covered completely by the slurry.
- v) Place it to get solidify for 5-6 hours and after that remove out the dough from the solidified structure of plaster of paris.
- vi) Your formicarium (Ant house) made of plaster of paris is ready (see above diagram).

Note – You can make ant house even bigger, having more branches and sub-branches and cavities, provided you should have facilities to keep it at secured place.

Method -

1. After making of Ant House, place some food for ants, such as jaggary or sweet or grains, inside the cavities of the ant house.
2. Place the ant house in a corner at a shaded place.
3. Gradually, ants from nearby area will start reaching the ant house. Initially the ants will come, eat and move out. Each time you have to refill the food stuff so that the ants feel secured and prefer to settle in the cavities in course of time.
4. Once the ants are accommodated in it, start your observations of them.

5. At different time intervals observe and record the social structure, behaviour, feeding habit etc of ants. How they collaborate with each other to carry materials, how they manage different activities in collaborative manner, how each ant has a unique role, what sort of food materials ants prefer etc.
6. You can use formicarium to study ants during different seasons as well.

Data collection and analysis -

Record your observations systematically in a data format. An example of data table is given here; you can design your own data table according to the need.

Date and Time	Behaviour of Ants with respect to Food	Behaviour of Ants with Each Other	Factors Affecting Behaviour of Ants	Any Interesting Observation

Results –

You can analyse your data quantitatively and qualitatively and make interpretations accordingly.

Key points learned –

- Formicarium is an easy tool to observe and know about ants' social structure and behavior.
- Ants do not feed upon any food and they also have food preference.
- We can protect ant diversity in our area by making such ant houses.

Open ended questions -

- How do ants maintain the temperature and air circulation inside their house?
- Do ants also sleep? Or whether they remain awake all times? What they do during night?
- Do ants also have day-night cycle of activities?
- Sometimes you see ants moving on a trail and do not deflect from the path, how do they manage it?
- Do ants smell? How do they find food material even from tightly packed bags?
- Do ants act as bioindicator? Give one example from which we know what they are indicating.

Interesting facts -

Diversity of Ants on the Earth:

There are more than 15700 species and subspecies of ants on the Earth. Ants make up $2/3^{\text{rd}}$ of the biomass of all insects on the Earth.

For more details you may see the following link -

<https://www.pnas.org/doi/full/10.1073/pnas.2201550119>

Diversity and Endemism of Ants in India:

In India there are 828 known ant species from 100 genera. 256 (31%) of species are endemic to India (i.e. they are found only in certain parts of India and nowhere in the world). Whereas, 24 species are non-native (i.e. they are from other territories other than India). The endemism of ant species in India (31%) is much higher than endemic species of mammals (11%), fishes (8%), birds (4.3%) and flowering plants (10%). That means, one of every three ant species in India is endemic.

For more details about ant diversity in India you may see the following link –
<https://zookeys.pensoft.net/article/6767/>

Sub-Theme: Butterfly Diversity

Butterflies are one of the most active insects that do not remain stable and keep moving here and there. Hence it becomes difficult for a person to observe butterflies at one place for more than few seconds. One is forced to chase them continuously to observe their behavior. **Butterfly net** is a useful tool to catch butterflies and observe them for the required time without doing harm to them. The butterfly net consists of a metallic or wooden handle with removable or fixed rugged metallic ring or wire hoop. An elongated mesh bag (usually made of nylon) is attached to the ring in a manner that its broad mouth is fixed to the ring/hoop and the elongated part ends in a narrowing closed distal end. To catch the butterfly the net is swung in the air such that the flying butterfly is caught in the mesh bag without causing any harm to its body.

One can easily catch butterflies with the help of butterfly net and can keep them in the terrarium for some time where they get basic requirements fulfilled such as air, water, food and security. After their unhandled observation and examination butterflies can be released into the area from where they were collected.

Activity: Let's make butterfly net and catch butterflies for study

About this experiment -

Butterflies are hyperactive insects that keep on flying and moving during daylight. Hence it is very difficult to observe them closely at a static position. One can easily catch butterflies with the help of butterfly net and can keep them in the terrarium for observation along with providing basic requirements fulfilled such as fresh air, water, food and security. After observing and studying the butterfly it is released back into its natural environment.



Material required-

A butterfly net

The butterfly net consists of a metallic or wooden handle with removable or fixed rugged metallic ring or wire hoop. An elongated mesh bag (usually made of nylon) is

attached to the ring in a manner that its broad mouth is fixed to the ring/hoop and the elongated part ends in a narrowing closed distal end. To catch the butterfly the net is swung in the air such that the flying butterfly is caught in the mesh bag without causing any harm to its body.

Method -

1. First assemble the butterfly net and practice is how to use it.
2. Hold the handle and move the face of the net in a horizontal manner in one direction.
3. Always keep in the mind that the butterfly is moving in front of you and you are moving the net towards the butterfly in a careful manner so that you manage to catch the butterfly without causing any harm to it.
4. Once the butterfly gets inside the net, slowly lock the face of the net by rotating the handle of the net. This does not allow the butterfly to come out of the net.
5. Take an appropriate size container to transfer the butterfly into it from the net.
6. Transfer the butterfly to the terrarium.
7. Once the butterfly finds air, water, food and security inside the terrarium and moves freely inside the terrarium, start your observations in systematic manner and record in the data format.
8. After observing for the desired time, release the butterfly back to its natural habitat.
9. Make sketches of butterflies and if possible take their photographs as well for display.



Catching of Butterfly using Net

Data collection and analysis -

- You can catch and study a wide range of butterflies and make records of their morphology, behavioral pattern in a systematic manner.

- Comparative analysis of the collected information can be used to make numerical inferences and illustrative records like charts and posters.

Record your observations systematically in a data format. An example of data table is given here; you can design your own data table according to the need.

S. No.	Name of Butterfly	Sketch diagram of Butterfly	Comments

Results –

You can present your observations in the form of quantitative and/or qualitative data. Hand drawn sketches and photographs will be an additional record to display.

Key points learned –

- Butterfly net is an easy tool to catch butterflies without harming them.
- Butterflies also sit and rest on different objects and surfaces besides doing their diurnal activities.
- Different species of butterflies have different types of morphology and body coloration.
- Butterflies also possess sexual dimorphism and by practice one can distinguish male & female of a species.

Open ended questions -

- How do butterflies identify colours of flowers and plants?
- Why not butterflies seen in the night? Are they night-blind or else?

Interesting facts -

What is Butterfly Stroke?

The 'butterfly stroke' is a swimming stroke swum on the chest, with both arms moving symmetrically, accompanied by the butterfly kick along with the movement of the hips and chest. This style evolved in the early 1930s and while performing the breaststroke style. If you look at the arm (wings) and leg movements of a mature butterfly, you'll see the arms (wings) make a semicircular motion in the front on the sides of the body, and the legs make the same motion at the rear on the sides of the body. Those semicircles look like butterfly wings.

Sub-Theme: Sampling of Small Insects

Pooter is a simple equipment to catch small insects in a safe manner. It enables the person to catch small insects, which later can be kept in the terrarium and observed for their morphology, body parts and behavior. Pooter consists of two (transparent) tubes connected to a closed container. Free end of a tube (which is comparatively wider than the other) is fitted with a funnel through which the insect can be trapped and sucked into the container. The suction is created through free end of another tube. The mouth of this suction tube which is fitted in the container is covered with a fine mesh so that the insect is not dragged in it during the suction. Mostly the container and tubes are kept transparent so that movement of insect through funnel and tube towards the container can be seen and any possibility of physical harm could be minimized. With the help of pooter, the insect is slowly pulled (sucked) into the container. There remains no way for the insect to move out of the container. After a few insects are drawn into the container, they can be transferred into the terrarium for observation. After observation they can be released back conveniently into the ambient environment.



Activity: Pooter (Insect Collector) - A device to collect small insects

About this experiment -

Pooter is a simple technique to catch small insects in a safe manner. It enables the person to catch small insects, which later can be kept in the terrarium and observed for their morphology, body parts and behavior. With the help of pooter, the insect is slowly pulled (sucked) into its container. There remains no way for the insect to move out of the container. After a few insects are drawn into the container, they can be transferred into the terrarium for observation. After observation they can be released back conveniently into the ambient environment.

Material required -

A pooter

- The assembly of pooter consists of two (transparent) tubes connected to a closed container. Free end of a tube is fitted with a small funnel through which the insect can be

trapped and sucked into the container. The suction is created through free end of another tube. The tube which is connected to the funnel is kept broader than the other tube through which suction is created. The mouth of suction tube fitted in the container is covered with a mesh so that the insect sucked in the container is not pulled in the suction tube and remain in the container. Mostly the container and tubes are kept transparent so that movement of insect through funnel and tube towards the container can be seen and any possibility of physical harm could be minimized. You can make your own pooter device.

Method -

1. Locate the small insect you want to collect and quickly put the funnel of pooter on it such that it is trapped in the funnel.
2. By another tube connected to the container, suck the air out so that an air suction would be created in the container and through it in the tube connected with funnel, so that the insect trapped in the funnel would be pulled in the container.



Use of Pooter for Collection of Insects

3. Transfer the insect from the container of pooter to the terrarium for further observation, where it is kept with provisions of food, water and safety.
4. Observe the insect in the terrarium without handling and disturbing it and record your observations of in the data format.
5. You can make sketches of the insect and also take photographs of it for making further purpose.

6. After the study the trapped insect is released back into its habitat.
7. You can collect more numbers of an insect species or many insects of different species for observation & study purpose.

Data collection and analysis –

- You can catch and study a wide range of insects and make records of their morphology, behavioral pattern and other characters in a systematic manner.
- Comparative analysis of the collected information can be used to make numerical inferences and illustrative records like charts and posters.
- Record your observations systematically in a data format. An example of data table is given here; you can design your own data table according to the need.

S. No.	Name of Insect	Sketch Diagram/ Photo of the Insect	Food & Feeding of Insect	Important Observation

Results –

You can present your observations in the form of quantitative and/or qualitative data. Hand drawn sketches and photographs will be an additional record to display.

Key points learned –

- Pooter is an effective and safe tool to catch small insects for study.
- Body structure and behavior of small insects can be studied through the pooter and then in terrarium.

Open ended questions -

- How do insects communicate with each other? Do they have any language in any manner?
- How do grasshoppers produce clattering (stridulating) sound?
- How do insects visualize the size and distance of any object?

Sub-Theme: Birds' Houses

Most of the birds live in their natural houses, that they build with natural material and in different forms and patterns according to their requirements and habitat adaptability. We call their houses as 'nests'. It is always interesting and informative to see the birds' houses, their architecture, patterns, materials used etc. By studying birds' houses (nests) we learn many facets of science including architecture, physics, biology, chemistry, climate adaptability, habitat selection, aeration, symbiosis, and many aspects of animal (bird) behavior.

Many bird species (some of them are on the verge of extinction or are threatened) are adapted to coexist with human beings and make their natural houses in human settlement areas at safe refuges. But with anthropogenic disturbances, the safe refuges for birds to make nests are disappearing from human settlements. Now is the time to understand the habitat needs of birds, understand their house (nest) making methods and make efforts to provide them safe housing options.

Activity: Let's protect and conserve birds through artificial bird nest houses

About this experiment -

When populations and diversity of bird species is declining in the urban environment, artificial bird nest is a good option to offer safe refuge to birds in urban environment and even in natural areas where nesting sites of birds are reducing. Although it is not an alternative for all bird species but it can be very useful for birds that are well acquainted with human beings. Artificial bird houses of different sizes, materials and shapes are designed by bird lovers for attracting different types of birds to their locality. Apart from offering the refuge to birds, bird lovers also know their (birds) nest preferences in terms of nesting material, design and size and also learn about position of installation of the artificial nest. Besides this, by offering different feed material we know about their food requirements, food preference and feeding habits. Through least artificiality and more naturality we can facilitate bird diversity to survive along with human beings.

Artificial bird house provides an opportunity to bird lovers to keep track of the life-styles and behavior of different bird species. Children in particular find it highly fascinating when they find birds coexisting with them and interacting with them. A bird lover can make bird house and hang it at a safe place in a building, or onto a nearby tree, or can place it at a

safe platform in house or even at the work place. Small birds like, House Sparrow and other sparrows, Myna, Pigeons, Parakeets, Bulbul, Owlets etc easily adapt to artificial bird nests. Good and durable artificial bird nest house can also be made from cardboards made of recycled cloth and paper.

Here we are discussing how we can make artificial bird nest house and help our avian friends get safe refuge and remain coexist with us.



A bird nest house made of handmade sheet of recycled papers

Material required-

A bird nest house

A bird nest houses is basically a housing structure of different size, materials and shapes, designed for attracting birds to adapt it for nesting purpose. A bird nest house may be simply a shoe box having a small entry hole at one side, or a cardboard box, or an artificial grass woven hollow chamber, or a wooden box or a metallic container with a small entry hole in it, or a well-designed wooden or clay structure etc. Food and water facilities are also arranged to facilitate birds.

Method -

1. Hang or place the bird nest house at an appropriate place.
2. Place water and food material (like unprocessed grains or fruits) nearby.
3. Initially birds such as Sparrow, Crow, Maina, etc would come to the bird house and eat the food placed nearby.
4. After some time, realizing that the bird house is suitable to modify as nest, birds will bring the nesting material like grasses, fibers, cotton, leaves etc and will make bed and side lining in the nest house.
5. After the bird adapts your nest house you can start systematic observations of it and record the observations in the data format.
6. You can also make their sketches and/or take photographs for further reference.

Data collection and analysis -

- You can collect observational data of one species for different seasons, or of different species for same seasonal period, or as you wish.
- You can also record the diurnal time budget of a bird (i.e. calculation of time period the bird spends in doing different activities like feeding, resting, singing, brooding, feeding chicks, nest making, flying, wing and body care etc in 24 hours duration).
- You can observe the food preference of different species of birds and can classify them in different feeding classes like granivorous, frugivorous, carnivorous, omnivorous, molluscivorous, piscivorous etc.
- Observations of their mating, egg laying, brooding, feeding, nesting, and maintenance of the nest house etc provides a good opportunity to us to know about their life cycles.
- You can record their calls and other sounds and can make an album of bird sounds. This record may be used as a key to identify a bird by its sound.
- The observations may be recorded at daily basis or periodically as per the study plan, for a bird or for different birds.

Results –

You can present your observations in the form of quantitative and/or qualitative data and inferences based on mathematical and statistical analysis.

Hand drawn sketches and photographs will be an additional record to display.

Key points learned –

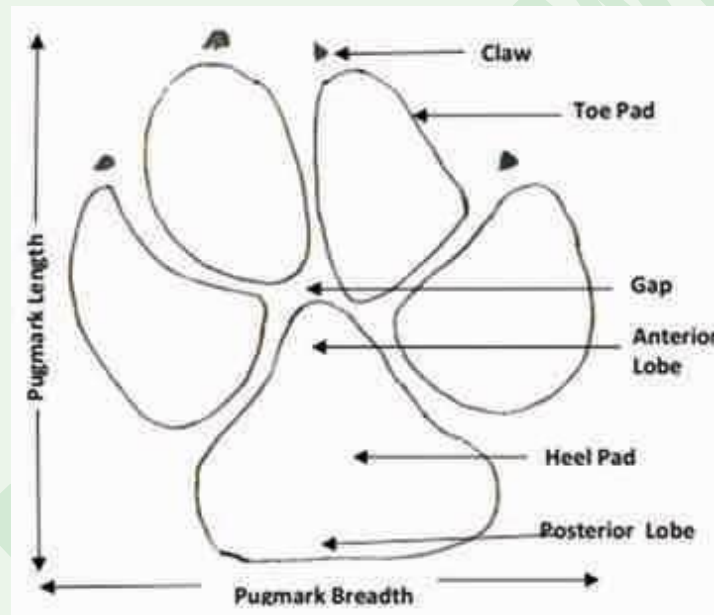
- Artificial bird house is a good option to offer safe refuge to birds.
- It is very easy to make a bird house with locally available material. Birds will make beds and linings in it with their nesting material.
- Birds are an integral part of our ecosystems and they perform important ecosystem functions.
- Most of the bird species have sexual dimorphism and one can identify male and female of a species distinctly.
- Birds produce calls and sounds that are specific for specific purpose. One can know many aspects of birds from their calls.

Open ended questions -

- Do birds also show parasitic nature? Explore and describe with examples.
- How do birds navigate (i.e. find directions) in the air, especially during long migration flights?
- Do birds mimic human sounds? If yes, give examples.
- Give example of birds whom the humans have not been able to domesticate.

Sub-Theme: Pugmarks / Footprints

The word 'Pugmark' means the mark left by the foot of the animal during locomotion, therefore normally it is called 'footprint'. Sometimes we are unable to see many animal species that exist in an area, due to many reasons like our own timing of visit, their timing of movement in their territory etc. In case of wild animal species like that of cat family, dog family, rodents, small mammals, birds and reptiles etc sometimes we find only their indirect evidences i.e. footprints, fecal matter, urine marks, body parts, markings on trees and ground, hairs, ground digging, and calls. Footprints are one of the easy indirect evidences of the presence of an animal species in the area. We can infer many aspects about animal species based on their footprints.



Morphology of a Footprint

Investigating the presence and identification of animal species in an area by their Pugmarks (footprints) follows the process of indirect evidence. The exercise involves tracing the pugmark found in the area on the paper and identification of animal species with the given key of pugmarks of different species. The collection of pugmark tracings can be used as a reference key to identify the unseen animal species by their pugmarks. Through practice of pugmark documentation and analysis we can also infer their population, sex, age, behavior, activities and role in the local ecosystem. This exercise is not only helpful in generating awareness and creating knowledge base about diversity of animal species in an area, but

also to understand their demographic features (i.e. male-female-juvenile counts), population size, behavior (movement, direction, speed, frequency etc). Through this exercise one can understand how different species play their role in an area and why it is important to conserve them to maintain the ecological health of the area.

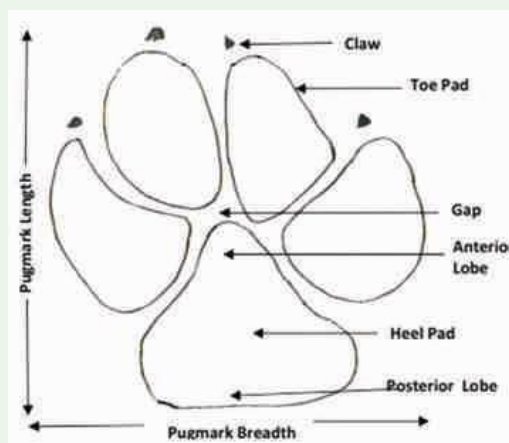
A key of pugmarks of some animal species is given for reference in the Prakruti Media Shala Website <https://prakrutishala.org/> (See Resource Material - Documents).

Activity: Identification of animal species by their Pugmark (Footprint) Tracings

About this experiment -

Pugmark or footprint means the mark left by the foot of an animal during standing or moving state. Sometimes while looking for wild animals in an area, we are unable to see many animal species due to many reasons like mismatch of our time of visit and their time of movement. Even sometimes while searching the lost domesticated animal we are unable to see where the animal has gone. We can identify them or trace them where they have gone, by their pugmark (footprint).

Pugmark (footprint) is easy indirect evidence to find the presence of a species or to find out the direction where the animal would have gone. Pugmarks (footprints) are distinct species specific and are made by almost all terrestrial animal species whether it is a snail or a spider or an ant or a lizard or a tortoise or a bird or a mammal or any other. The pattern of pugmarks (footprints) of an animal is not always made same except for its morphological characteristics; they vary under different environmental, physical and mental conditions. For example, if the animal was walking slowly or roaming normally, its footprint will be complete, clearly marked and easily noticeable; but if the animal was walking hurriedly or running fast, either chasing someone or running for safety, then its footprint would be incomplete, partially marked and difficult to notice. Further by practicing, we can also distinguish the footprints of female and male individuals of a species (especially in Cat family). Apart from telling the occurrence of an animal in an area, its footprint tells us many things about it, for example, extent of distribution, diurnal behaviour, habitat preference, coexistence with other species, population estimation etc.



Here we shall discuss how we can identify the pugmarks/footprints of different animal species with the help of available keys; and how we can make tracing of the pugmarks on the paper. The pugmark tracings prepared by you will further help others as reference keys in identification of animal species indirectly (i.e. without seeing them). Through practice you will learn how to infer the population, sex, age, behavior, activities and role of animals in the local ecosystem. This exercise is not only helpful in generating awareness and creating knowledge base about diversity of animal species in an area, but also to understand their demographic features (i.e. male-female-juvenile counts), population size, behavior etc. Through this exercise one can understand how different species play their role in an area and why it is important to conserve them to maintain the ecological balance of the area.

A key of pugmarks of some animal species is given for reference in the Prakruti Media Shala Website <https://prakrutishala.org/> (See Resource Material - Documents).

Material required-

- Glass or transparent plastic tracer (10 inch length & 8 inch breadth)
- Measuring scale or tape
- Fine point temporary marker pen
- Pencil & Eraser
- Butter paper and White Paper
- Transparent OHP sheet

Method -

1. Select the pugmark on the ground which is clear and complete and remove pebbles or any other such material surrounding it.
2. Place four equal size pebbles outside the four corners of the pug mark and place the tracer glass on them so that the pug mark is visible through the tracer.
3. Using marker pen mark the outer lines of the pugmark including claws, toe pads, heel pads and lines of the sole (see above diagram – morphology of a pugmark), on the tracer glass in dotted lines.
4. You can lift the tracer glass and bring to your table for further work or keeping it as such at the site, continue further work.
5. Take the butter paper and place it over the tracer glass, so that the drawing on the tracer is visible through the butter paper and using the pencil and eraser, copy the tracing of pugmark on the butter paper as seen from the tracer glass; draw the figure now with complete lines.

6. Also write the name of animal (if known), date, time, place & location at upper right corner of the butter paper. Remember this is the original size of the pugmark hence you should write size scale as '1-X' in the tracing details.
7. You can repeat the tracing on the white paper and /or OHP transparency (from the butter paper) with pencil or fine point pen for keeping the record and further use. Write all details on the final sheet the way it was written on the butter paper.
8. If possible, the tracings can be scanned and their digital copies can be stored in computer. If you process the digital copies of pugmark tracings in different size resolution then accordingly mention the proportion of size.

Data collection and analysis -

- Note the details like date, time, place & location and the name of person who did the tracing work in a diary for each pugmark.
- The measurement details of pugmark parts (e.g. total length & breadth, each toe pad length and breadth, heal pad length & breadth, gaps between toe pads & heal pad, comparative size of the toe pads & heal pad) should also be noted in the same manner.
- Apart from tracing the pugmark, also note the direction of the pugmarks, distance between pugmarks and comparative size of pugmarks of adults and juveniles of the same species.
- Make a record of animal species that occur in your area but you could not see them and now you have identified them through their pugmarks
- Make a record of animal species whom you know and their pugmarks have been recorded (this may include all domestic species and known wild species).
- Classify your record of species on the basis of different categories and criteria.

Results –

You can present your observations in the form of quantitative and/or qualitative data and inferences based on mathematical and statistical analysis.

Hand drawn sketches and photographs will be an additional record to display.

Key points learned –

- Pugmark (Footprint) is easy indirect evidence to find the presence of a species
- Pugmarks (Footprints) are distinct species specific
- Pugmarks (Footprints) are made by almost all terrestrial animal species ranging from crawling snails to birds and mammals.

- The pattern of footprint of an animal is not always made same except for its morphological characteristics; they vary under different environmental, physical and mental conditions.
- We learn distinguishing the footprints of female and male individuals of a species (especially in Cat family).
- Apart from telling the occurrence of an animal in an area, its footprint also tells us about its distribution, behaviour, habitat, population and community characteristics.
- We can easily make tracings of pugmarks (footprints) of various animal species found in our area and make a record of species-wise keys for different animal classes.
- By tracing work, we understand the morphology, dimensions, comparative sizes, patterns of markings of the pugmarks (footprints) of different animal species.

Open ended questions -

- Why the left hind leg pugmark is compared in the identification of male and female leopard or tiger?
- How do snakes mark their footprints? How can you distinguish the footprints of snakes?
- What is Ecological Footprints? Explain with example.

Interesting facts -

How to get good pugmark?

For getting clear and complete pugmarks in the field you can select a path where wild animals are supposed to move. Take dry fine soil and spread it on the path in some length and width so that if any animal would walk over it then clear impression of pugmarks will be made on the fine soil layer.

How to differentiate pugmarks of canidae (dog family) and felidae (cat family)?

- In both families the pugmark is formed having four toes with a heel pad.
- In Canidae (the dog family, e.g. Wolf, Wild Dog, Domestic Dog, Jackal, Fox, Hyena etc) animals the toe pads are larger than the heel pad (as an adaptation for easily running down the prey) whereas, in Felidae (the cat family, e.g. Tiger, Lion, Leopard other wild cats and domestic cat) hunting is done mostly by stealth and to facilitate that, the heel pad is larger than the toe pads.
- In canids the claws marks are formed in front of the toe pads whereas in felids the claws are retractable hence (except in defense or attack mode) under normal conditions the claw marks are not formed in the pugmark.

- In canids the middle toe pads in all four legs are at different level whereas in felids the two middle toes occur side by side (aligned) in the front legs and at different level in hind legs.

How to distinguish front leg and hind leg pugmarks?

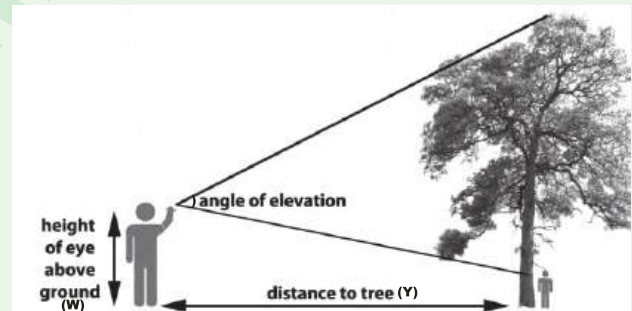
- In dog and cat family the hind leg pugmarks are smaller than the front leg pugmark
- In cat family the two middle toes occur side by side (aligned) in the front legs and at different level in hind legs.
- The front legs are used in hunting and holding the prey therefore pugmark breadth of front legs is generally more than pugmark breadth of the hind legs.
- In cats the pugmark breadth of front legs is more than pugmark length.

Sub-Theme: Height of Tree

Tree height is the vertical distance between the base of the tree and the tip of the highest branch on the tree. Measurement of height is also an important component in measurement of tree volume. There are different methods of measurement of tree height, that includes non-instrumental methods (e.g. Ocular Estimation method, Shadow method, Single Pole method etc), and Instrumental methods (e.g. two-point measurement function and three-point measurement function using measuring scales and tangent method, altimeter, hypsometers, relaskop, clinometer etc). The accuracy of measurement varies with the method and means applied.

Clinometer is a convenient tool used for measuring angle of elevation or angle from the ground in a right-angled triangle. Clinometer can be prepared very easily and handy in use. Clinometer is useful in measuring the height of tall things like buildings, poles and trees etc. By the angle of elevation (measured with the help of clinometer), your eye height, and the distance between you and the object you can calculate the height of a tree using a simple equation. The calculations work by applying the principles based on the properties of right triangle.

The height of different trees in an area reflects different stories of vegetation. Using the clinometer and simple calculation method we can also track the growth of trees by periodical estimation of their height and through that we can also determine the comparative growth rate of different trees.

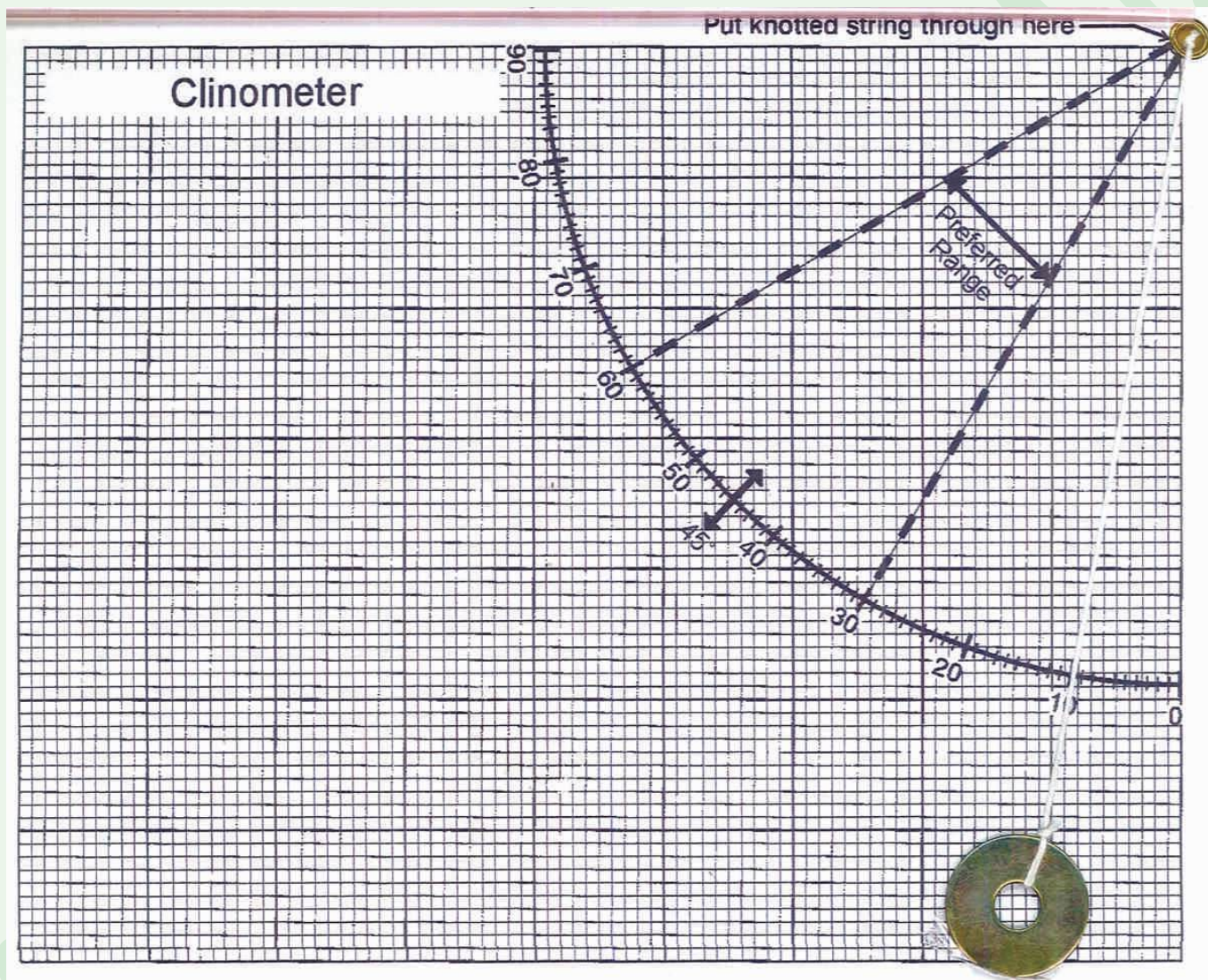


Activity: Measuring the tree height using clinometer

About this experiment -

Tree height is the vertical distance between the base of the tree and the tip of the highest branch on the tree. The height of different trees in an area reflects different stories of vegetation. On the basis of different stories of trees in a forest it is designated as multi-storied forest. There are different methods of measurement of tree height that are broadly classified into non-instrumental methods (i.e. without using any instrument) and Instrumental methods (i.e. using instruments).

Clinometer is an instrument used for measuring angles of any tall objects. The measured angle is used to calculate the height by applying the principle of a right-angled triangle. Using the clinometer and simple calculation method we can also track the growth of trees by periodical estimation of their height and through that we can also determine the comparative growth rate of different trees.



An image of a Clinometer

Material required-

- Clinometer
- Measuring tape
- Tangent table (you can stick it to the backside of the clinometer or keep separately)

Angle (°)	Tan.	Angle (°)	Tan.	Angle (°)	Tan.	Angle (°)	Tan.	Angle (°)	Tan.
1	.02	17	.31	33	.65	49	1.15	65	2.14
2	.03	18	.32	34	.67	50	1.19	66	2.25
3	.05	19	.34	35	.70	51	1.23	67	2.36
4	.07	20	.36	36	.73	52	1.28	68	2.48
5	.09	21	.38	37	.75	53	1.33	69	2.61
6	.11	22	.40	38	.78	54	1.38	70	2.75
7	.12	23	.42	39	.81	55	1.43	71	2.90
8	.14	24	.45	40	.84	56	1.48	72	3.08
9	.16	25	.47	41	.87	57	1.54	73	3.27
10	.18	26	.49	42	.90	58	1.60	74	3.49
11	.19	27	.51	43	.93	59	1.66	75	3.73
12	.21	28	.53	44	.97	60	1.73	76	4.01
13	.23	29	.55	45	1.00	61	1.80	77	4.33
14	.25	30	.58	46	1.04	62	1.88	78	4.70
15	.27	31	.60	47	1.07	63	1.96	79	5.14
16	.29	32	.62	48	1.11	64	2.05	80	5.67

Example: Assume you have established a baseline distance of 60.0 meters. Assume that you have measured the tree top to an angle of 34°. From the Table, you will see that the tangent of 34° is 0.67. Therefore, the tree height above your eye height is 60.0 m x .67 = 40.2 meters. By adding your eye height above the ground (1.5 m), the total tree height is 41.7 meters.

Make your own clinometer referring the figure above –

- Take a graph paper and make an arc on it from a corner such that the arc joins two right-angled sides.
- Mark the arc from zero to 90 degree like a protector.
- Take a coloured straw and stick it to the edge where right-angled arc is ending.
- At the corner of the arc make a small hole and tie a strong cotton string to it.
- Take a small weight (a small stone or metal bolt) and tie it to the free end of the string.

Alternatively, you can take out the printout of the above figure and fix the coloured straw, string and the weight as shown.

Method -

1. Select a tree whose height has to be measured.
2. Locate a spot from where the top of the tree can be seen.
3. Sight the top of the tree through the clinometer drinking straw.
4. Read the degrees of angle by noting the number where the thread crosses the arc on the clinometer sheet.
5. Measure the horizontal distance from you to the tree whose height is being measured.
6. Measure the height of your eyes from the ground.
7. See the tangent value of the angle in the tangent table.
8. Calculate the height of tree by applying the principle of a right angled triangle.

Data collection and analysis -

By the angle of elevation, your eye height, and the distance between you and the tree you can calculate the height of that tree using a simple equation -

$$X = Y \times \text{Tangent } Z + W$$

Here, X = Height of the tree

Y = Distance from you to base of the tree

Tangent Z = Tangent of angle where the thread crosses the arc on the clinometer

W = Height of your eyes from the ground

You can record the field observations and results of respective calculations for different trees in a data format. An example of data table is given here; you can design data table as per your convenience.

S. No.	Name of tree Species	Your Distance from the Base of tree (Y meter)	Height of your eye from the ground (W meter)	Angle of string noted in the clinometer in degrees	Tangent value of the angle (Z)	Height of the tree $X = Y \cdot \text{Tan. } Z + W$ (meter)
1	Neem Tree (<i>Azadirachta indica</i>)	60	1.5	34	0.67	$60 \cdot 0.67 + 1.5 = 41.7$

Results –

You can calculate the height of different trees and present your finding in the form of mathematical or statistical analysis.

By calculating height of various tree species in an orchard or forest you can also make inferences of the average story classes in it.

You can also make inferences which tree species commonly have very high height and which have short height. You can also categorize tree species into different height categories.

Key points learned –

- Clinometer is an easy assembled tool that is useful to find height of trees.
- The height of different trees in an area reflects different stories of vegetation.
- We can also track the growth of trees by periodical estimation of their height with the help of clinometer.

Open ended questions -

- If you cannot be on the same level to which the tree is standing, then how will you estimate the height of the tree?
- How would you find the height of a tree if the tree is leaning?

Sub-Theme: Tree Crown and Canopy Cover

The tree crown is the top part of the tree, which features branches that grow out from the main trunk, it includes branched stem, leaves, flowers and fruits all together. While all trees individually feature a crown, several types of tree crowns adorn an area. Based on the tree types the crown types can be several types, viz. pyramidal crown, full crown, vase crown, fountain crown, spreading crown, layered crown, columnar crown, weeping crown etc.

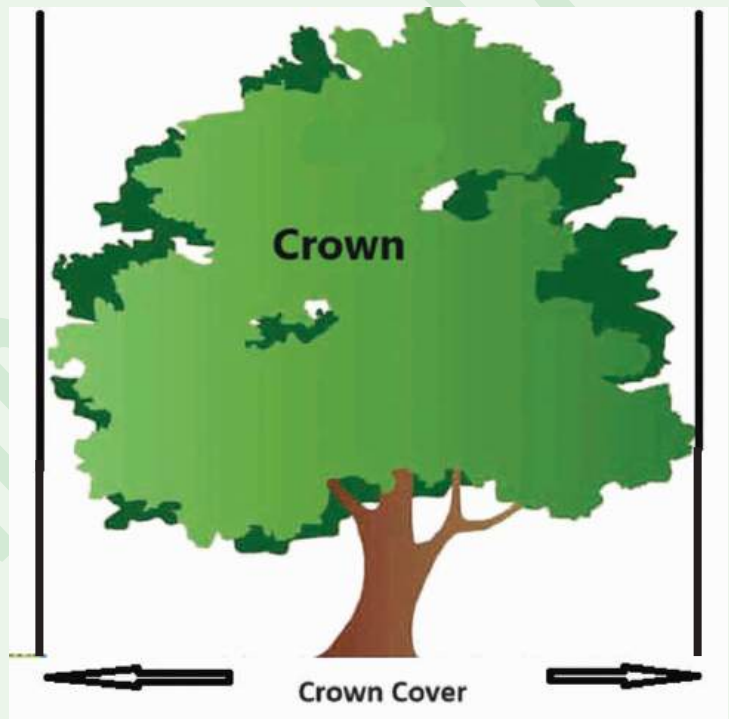
The area of land surface that is under the tree crown by its vertical projection is termed as Canopy Cover. In other words, canopy cover in a landscape is the proportion of the ground surface covered under the vertical projection of tree crowns. The canopy cover in a forest is expressed as percentage or proportional area in reference to the total area referred.

The crown is the branchy part of a tree on the stem while the canopy is the roof-like covering on the forest floor. Crown refers only the branched part of a tree while the canopy includes the stories of crown made by trees and even by shrubs and herbs. Crown or crown cover refers a tree while the canopy or canopy cover refers the assemblage of tree crowns.

The canopy architecture in a forest or landscape is determined by the arrangement of individual tree crowns found in the forest, thus there can be several types of canopy architecture in different landscapes. Different species of trees or even different individuals of same species have different canopy cover according to their growth. The canopy cover also reflects the dominance of a species in occupying space in an area.

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Trees are also classified into different crown classes when they compete for spreading their crowns and in a forest canopy. For example, dominant trees extend their crown above



the level of the canopy; their crown receives light from above as well as some light from sides as well. Codominant trees make their crowns up to the level of canopy and their crown receives light only from the top and not from sides. Intermediate trees extend their crown below the canopy cover and their crown receives some light only from the above. Suppressed trees crown is made below the level of the canopy and they do not receive any direct light.

Activity: Determination of the crown cover of a tree through graphical drawing method

About this experiment -

The tree crown is the top part of the tree, which features branches that grow out from the main trunk. Thus, crown of a tree includes all its branches, leaves, flowers and fruits. The crown of a tree is made according to its growth and spread; therefore, every tree individually features different crown from the other. Based on their spread, broadly crown types can be distinguished into several types, viz. pyramidal crown, full crown, vase crown, fountain crown, spreading crown, layered crown, columnar crown, weeping crown etc. The area of land surface that is under the tree crowns by its vertical projection is termed as Canopy Cover. In other words, canopy cover in a landscape is the proportion of the ground surface covered under the vertical projection of tree crowns. The canopy cover in a forest is expressed as percentage or proportional area in reference to the total area referred. The crown is the branchy part of a tree on the stem while the canopy is the roof-like covering on the forest floor. Crown is the structural character while canopy is the functional character.

By determination of the crown cover of trees we can infer many aspects like dominance, competence, association, density, foliage, branching, stratification etc. The most important function of the crown of a tree is to expose its leaves to the sun for performing photosynthesis. The variations in crown cover of a tree species at different time and different places (i.e. temporal and spatial variations) reflects its competitive ability during growth and adaptive capability to withstand weather and climate changes. Poor crown cover of trees or poor canopy cover of the stand of trees is an indication of the degradation while dense crown and dense canopy cover is the indication of rich and healthy tree diversity. In this exercise we shall learn how we can estimate the crown cover of a tree.

Material required-

- Plane Mirror,

- Marker,
- Ruler,
- Graph Paper,
- Coloured pencil,
- Compass

Method -

1. Taking a plane mirror horizontally in your hand (so that the reflection of tree above, is seen in it), walk away from the tree towards a direction (let it be north).
2. Stop where the leaves or branches of the tree are no longer visible in the plane mirror.
3. Ask a friend to call out when you reach the edge of the area covered by the leaves above.
4. Place a marker at this point.
5. Repeat the above process for other directions viz. North-East, East, South-East, South, South-West, West, North-West).
6. Measure the distances from the markers to the tree trunk with a meter ruler and note in the data sheet.
7. You may make sketches of trees and/or take photographs for further reference.

Data collection and analysis -

You can tabulate the distance of crown cover in different directions in a table, for example, as shown here -

S. No.	Tree Species	Distance (in meters) crown cover in different directions from the tree trunk							
		N	NE	E	SE	S	SW	W	NW

- Plot your result on a graph paper. First decide a scale, let's take 1 cm on the graph for 1 meter on the ground.
- From the center of the graph paper, first mark eight directions (that you have determined) and in each direction draw line proportional to the distance recorded in your table (i.e. distance of each marker from the stem of the tree).
- Join the outer ends of the lines that were drawn from center, with straight lines (you get a polygon like diagram)

- Count the squares and half squares of the graph paper that come within the polygon diagram
- You may avoid less than half parts of squares.
- Now adding the number of complete squares and half squares separately, calculate the approximate area covered within the polygon figure, in square centimeters.
- Each 1cm square represents 1m square; accordingly calculate the approximate area of crown cover in meter squares.
- Find out and compare the crown cover of different trees occurring in your area.
- You may calculate the approximate canopy cover of the landscape by adding all crown covers.

Results –

You may present the crown cover for each tree species or may interpret the data through mathematical and statistical analysis.

You can present your data species-wise or crown cover class-wise or in any other form as per requirement.

Sketches of the tree shapes and photographs would help in making better inferences.

Key points learned –

- Different species of trees or even different individuals of same species have different crown cover according to their growth.
- The crown cover reflects the dominance of a species in occupying space in an area.
- Crown structure and cover influences the foliage (leaves) in trapping the sunlight for photosynthesis.

Open ended questions -

- How do different species influence each other in an area through their crown cover? Explain with example.
- Can you determine crown cover of a shrub? Try yourself and find out.
- Observe the changes in the crown cover of a tree during different seasons.
- What is crown fire?

Theme - Earth And Atmosphere

Earth has conditions suitable to support life and thus is our home and we rely completely on it for our existence. The atmosphere surrounding the Earth contains the air that we breathe, it also controls the solar and cosmic radiations, plays role in maintaining planet's heat balance and biogeochemical cycles. Many physico-chemical phenomenon happen in the atmosphere like formation of clouds, formation and breaking of Ozone gas molecule, control of ultraviolet radiations, atmospheric circulation (atmospheric winds), pressure; production, transportation and release of electric charge, temperature variations in different heights, condensation of moisture, different forms of precipitations, aerosol transformation and gas-gas, gas-particle interactions etc. Most of the atmospheric phenomenon are influenced by the gravitational force and rotational and linear movements of the Earth.

Some of the important phenomenon which happen in the Earth's atmosphere that we need to understand and ways and means to study them have been discussed under this theme.

- **Observation and Identification of Clouds**
- **Rainfall Measurement**
- **Wind Speed and Wind Direction**
- **Green House**
- **Eco Mapping**

Sub-theme: Observation and Identification of Clouds

Clouds are formed when water vapour from the earth rises in the atmosphere and during rise, due to drop in air pressure and temperature it gets condensed on very small particles in the air (aerosols), eventually the condensed vapour gets denser and according to its weight, gets distributed in different heights of atmosphere in the form of clouds. Millions of very small water droplets collect to form cloud. The distribution of clouds in the atmosphere is also influenced by the rotational movement of the Earth as well as other atmospheric phenomenon like temperature, pressure and atmospheric circulations. Clouds formed in a part of the Earth may shift in the atmosphere in different directions, get condensed and fall as rain in other far off parts of the Earth. For example, during monsoon season in India, clouds that are formed mostly above the oceans travel in the atmosphere and enter above the Indian subcontinent, circulate differently with time and fall in different forms of precipitation.

Cloud formation is an interesting natural phenomenon that people are generally not aware of. By keenly watching the clouds and their types we learn to understand their types and distribution in the atmosphere. By practicing we can also anticipate weather conditions during different times/seasons according to the cloud formations. When the water droplets are not collecting and remain in scattered form the amount of sunlight reflected through them is more, and from the Earth these clouds look light coloured/white (non-rainy clouds) whereas when water droplets collect together into large drops, the amount of sunlight reflected from them is less and they look dark (rainy clouds).

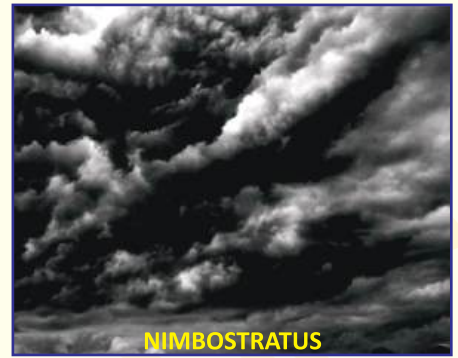
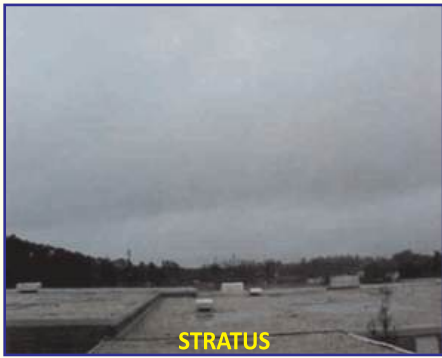
Basic cloud conditions that are referred in the classification are –

- 1) Strato – layer
- 2) Cumulo – heap, cotton ball
- 3) Cirro – high, curl of hair
- 4) Alto – mid
- 5) Nimbo – precipitation, mist, vapour or fog

The knowledge about clouds may serve very useful in broadcasting information and alerts to farmers and common masses for possible weather conditions like rain, storm, thunder etc especially during monsoon season.

Clouds are classified according to their vertical distribution in the atmosphere from the ground as low level clouds, middle level clouds, high level clouds and clouds with vertical development. The vertical categories are further classified according to their composition and formations.

Low Level Clouds:



Middle Level Clouds:



High Level Clouds:



Clouds with Vertical Development:



A. Low Level Clouds:

Low level clouds form in **stratus** (develop horizontally) pattern in lower atmosphere up to 2 km from the Earth's surface. Their distribution heights are same in polar, temperate and tropical zones. These are classified further in three types -

- i) **Stratus Clouds:** These Clouds are grey and lie very close to the Earth's surface. They usually look like a sheet layer but sometimes are also found in patches. They rarely produce precipitation.
- ii) **Stratocumulus Clouds:** These clouds are of grey or whitish colour. The bases of clouds tend to be more round than flat. They can be formed from old stratus clouds or from cumulus clouds that are spreading out. They appear like cloud clumps with thin and thick areas.
- iii) **Nimbostratus Clouds:** These clouds are named from the Latin word 'nimbus' that means rain cloud. These are dense, dark, grey, featureless layers of cloud which are thick enough to block the Sun and produce precipitation in the form of persistent rain and perhaps snow as well.

B. Middle Level Clouds:

Middle level clouds form in the atmosphere from 2 to 8 km altitude above the Earth's surface. Their heights in different latitudinal zones are different. In polar zones these are formed from 2 to 4 km altitude, in temperate zone these are formed from 2 to 7 km altitude and in tropical zones these are formed from 2 to 8 km altitude from the Earth's surface. These are classified further in two types -

- i) **Altostratus Clouds:** These clouds appear like flat and uniform type texture having bluish or grayish veil that totally or partially covers the sky. The light of the sun can be seen through them but there is no halo effect. They themselves do not produce significant precipitation unless they lower into stratus and become thicker.
- ii) **Alto cumulus Clouds:** These clouds exhibit 'cumulo' type characteristic and align like rows of clouds, like waves of the sea with white and grey coloring and shadows. These clouds contain mostly water droplets and perhaps some ice crystals too.

C. High Level Clouds:

High level clouds form in the atmosphere from 3 to 18 km altitude above the Earth's surface. Their heights in different latitudinal zones are different. In polar zones these are formed from 3 to 8 km altitude, in temperate zone these are formed from 5 to 14 km altitude

whereas in tropical zones these are formed from 6 to 18 km altitude from the Earth's surface. These are classified further in three types -

- i) **Cirrus Clouds:** These clouds look like white delicate feathers. They are generally wispy forms and are composed entirely of ice crystals.
- ii) **Cirrostratus Clouds:** These clouds appear as a thin, almost transparent, whitish veil like layer composed of ice crystals. When moonlight or sunlight passes through their ice crystals the light is dispersed similar to when light passes through a prism, and that result into formation of a halo.
- iii) **Cirrocumulus Clouds:** These clouds are thin white layers with a texture giving them the look of patches of cotton or ripples without shadows. These contain primarily ice crystals and perhaps some very cold water droplets too.

D. Clouds with Vertical Development:

These types of clouds form in **cumulus** (develop vertically) pattern in the lower atmosphere near to the Earth's surface and move upward through higher altitude up to high level. These are classified further in two types -

- i) **Cumulus Clouds:** These clouds have a flat base and a dense, mound-shaped top that resembles a large cauliflower and grows vertically. Where the sun hits these clouds, they are a brilliant white. The base tends to be a darker grey. They generally do not produce precipitation.
- ii) **Cumulonimbus Clouds:** These are large, heavy and dense clouds. They have a generally flat, dark surface with very tall and large tops like the shape of massive mountain or block. These clouds are often characterized with lightning and thunder due to collision between charged water droplets, and sometimes hail. They may also produce tornadoes.

Activity: Knowing about cloud formations and their distributions

About this experiment -

Cloud formation is an important phenomenon that is not only an intrinsic part of the Earth's water cycle but also an important characteristic of the weather too. Clouds are formed by condensation of the water vapour that rises in the atmosphere. Although the water vapour is generated from every object that is wet or saturated with water, but the water vapour that generates from the vast oceans contributes major part of the world's clouds. Clouds circulate in the atmosphere differently with time and place and fall in

different forms of precipitation. The water in the cloud interacts with the gases and particulates/aerosols present in the atmosphere and as a result clouds acquire modified chemical nature accordingly. The modified chemical nature of clouds varies according to the type of gas / particulate they interact with.

Clouds are classified according to their composition and formations as stratus, cumulus, cirrus, alto, nimbus etc. These formations are further classified according to their vertical distribution in the atmosphere from the ground as low level clouds, middle level clouds, high level clouds and clouds with vertical development.

The knowledge about clouds may serve very useful in broadcasting information and alerts to farmers and common masses for possible weather conditions like rain, storm, thunder etc especially during monsoon season. By practicing we can also anticipate weather conditions during different times/seasons according to the cloud formations.

In this activity we are helping learners to know about various types of clouds based on their formations and their atmospheric distribution.

Material required-

Cloud Card with description

*For reference you may see the cloud card given in the Prakruti Media Shala Website - <https://prakrutishala.org/adminpms/gallery/gallery225610.jpeg>

Method -

1. Look up in all direction in the sky through the window of cloud card,
2. See the clouds, their formations, shape, size and approximate height at different times of the day,
3. Identify the types of clouds that you see with the help of cloud card provided.

Data collection and analysis –

Note down the information of different types of clouds that are seen during different times of day as well as during different seasons.

A sample data table is given here for help, you may design own data table according to the need.

Date and Time	Name of place	Geographical Location of Observation (Latitude & longitude)	Type of Cloud Observed (Yes/No)	Any Prediction about Rain

Results –

Present your observations about the clouds in the form of categories, duration, vertical distribution and other interpretations based on quantitative and qualitative analysis.

Key points learned –

- Clouds have different formations and they are distributed in the atmosphere at various heights according to the weight and gravity.
- By keenly watching the clouds and practice we can anticipate weather conditions during different times according to the cloud formations.
- By observation of clouds it is possible to predict the weather conditions and broadcasting the weather alerts to farmers and other masses about rain, storm, thunder etc especially during monsoon season.

Open ended questions –

- Can you know about cloud cover in the sky above you? Explore How.
- During the day and night times we see the formation of light and shadow of moonlight and sunlight on landscape, how it happens? Do the shadows differ in density as well?
- During monsoon time when clouds appear to be covering the hills and high buildings, try to visit the cloud laden parts of hills / buildings and check whether you can see or feel the clouds.
- What is the cause of lightening in the sky and where does that ultimately goes?

Interesting facts –

Acid Rain:

The water vapour that rises in the atmosphere is pure water form but when it moves through the gaseous column of the atmosphere and also interacts with the aerosols and particles in the air (including suspended particulate matter and toxic gases) the pure form water gets changed into having polluting / harmful substances mixed in it. Acid Rain is one such phenomenon in which gaseous compounds of Nitrogen and Sulfur react with the water vapour and make that acidic. When such acidic water vapour condensed in the form of

clouds, falls on the Earth in the form of rain, it is called Acid Rain which affects negatively various life forms and other substances on the Earth.

Clouds contribute to the Earth's Greenhouse! :

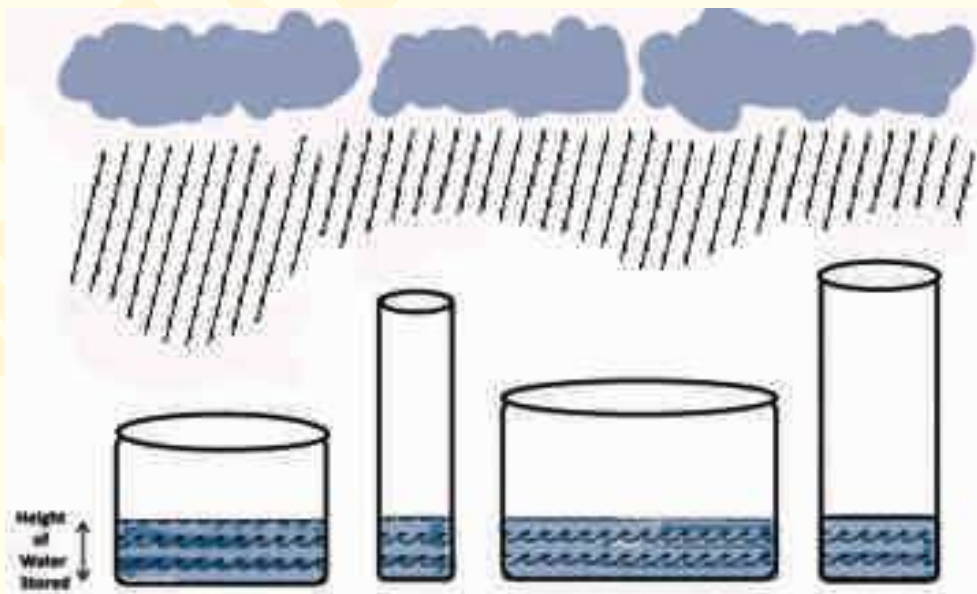
Water vapour in the atmosphere is one of the factors that cause natural greenhouse effect on the Earth. Like other gases, water vapour also traps the heat radiations in the lower atmosphere of the Earth and helps in maintaining the Earth's atmospheric temperature. But now a day the excessive release of the harmful gases and particulates in the atmosphere by anthropogenic activities is causing excessive trapping of the heat in the lower atmosphere and the resulting anthropogenic greenhouse effect which is associated with the global warming and climate change.

Sub-theme: Rainfall Measurement

When the temperature in clouds drops down to a degree that it triggers conversion of condensed vapour into liquid drops or frozen form that fall down on the earth, which is called precipitation. The precipitation may occur in various forms like drizzle, rainfall, snow, hail and sometimes cloud burst. Rainfall is one of the major forms of precipitation. Rainfall occurs in various parts of the earth during different times of the year.

Rainfall is one of the important environmental factors that influences occurrence and distribution of species and ecosystems, feeds the surface water bodies, helps in groundwater recharge. Rainfall is a major component of the water cycle on the Earth that helps in cycling of water from oceans to terrestrial areas and vice versa. Rainfall is an important indicator of vegetation types, animal types, ecology and most importantly, the weather & climate of an area.

Monitoring of rainfall is an important aspect to understand the weather and climate of an area and the simplest tool to monitor rainfall is the **Rain Gauge**. Rain gauge consists of a circular funnel which collects the rain into a graduated measuring cylinder. The graduated measuring cylinder is kept in a cylindrical vessel and the funnel is fitted on its mouth such a way that its tubular end portion put inside the graduated cylinder. A standardized design of rain gauge is used throughout the world for rainfall measurement and according to that the funnel of 203 mm (8 inch) diameter is used. One can easily assemble own rain gauge with the locally available material.



Depth of rainfall is height of water collected in a flat bottom container

The amount of rainfall is expressed in millimeter (mm) and is normally measured for 24 hrs for calculation. This means that if the rainfall at a particular place stands there without seepage in the ground and evaporation, then the total millimeters of the standing water is the measure of the rain fall. Normally 1 mm of rainfall (collected in the graduated cylinder) is equivalent to 1 ltr of rain water volume per square meter area. With average annual rainfall of an area (i.e. total rainfall in a year) one can estimate the potential of rain water collection in reference to any building or area.

Since wind is one of the greatest causes of error in rain gauge measurements, the best placement for the rain gauge is on a post as low to the ground as possible. Wind blowing across the top of the gauge creates an effect that causes raindrops to be deflected around the gauge. Because wind speed generally increases with height above the ground, the lower the rain gauge, the less effect the wind should have on it. In standard way, the top of the rain gauge is kept about 0.3 meters above the ground with no objects nearby that may affect its operation. The rain gauge is installed in the open area, at an adequately open place.

Activity: Measurement of rainfall using Rain Gauge

About this experiment -

Rainfall is an important phenomenon in the natural water cycle. It is an important parameter to know and interpret the weather conditions of an area. By knowing about rainfall on different scales like average annual rainfall, seasonal rainfall, monthly rainfall, areas of different rainfall etc one can interpret the kind of vegetation, the kind of landscape and the kind of local weather conditions the respective area would have. Rainfall is an important parameter in preparing the agriculture contingency plans, afforestation plans, grassland & pastureland development plans, watershed management plans, wetland conservation plans, fisheries development plans etc. At a laymen's level rainfall is an important weather parameter by which a person plans for cropping, housing and water supply needs.

Rainfall is an inevitable parameter to understand the weather and climate of an area and the simplest tool to monitor rainfall is the **Rain Gauge**. The rain gauge



consists of a cylindrical jar, a funnel and a graduated measuring cylinder. The cylindrical jar is placed on a flat surface and the measuring cylinder is placed in it and the funnel is fitted on top of the jar such that its tubular end hangs in the measuring cylinder. The funnel acts as the collector and collects the rain water which is falling over its area and the collected water is stored in the measuring cylinder. Later on, the collected rain water is measured in height (millimeter).

A standardized design of rain gauge is used throughout the world for rainfall measurement, and according to that the funnel of 203 mm (20.3 cm or 8 inch) diameter is used. But if you are using the funnel of another diameter then you have to calibrate it accordingly. Normally 1 mm of rainfall (collected in the graduated cylinder) is equivalent to 1 liter of rain water volume per square meter area. One can easily assemble own rain gauge with the locally available material.

The amount of rainfall is expressed in millimeter (mm) and is normally measured for 24 hrs for calculation. With average annual rainfall of an area (i.e. total rainfall in a year) one can estimate the potential of rain water collection in reference to any built area or an open area.

Rain gauges can be installed at any place having area of at least 5 to 10 meters diameter open around it. The more open place, the better it is.

Material required-

Rain gauge assembly (cylindrical jar, funnel, measuring cylinder), note book, pen/pencil

Method -

1. Dry the cylindrical jar and keep it on a flat surface in an open space,
2. Fix the funnel on top of the cylindrical jar,
3. Leave the set up for 24 hours rainfall collection,
4. After 24 hours, take the funnel out and pour carefully the water collected in the jar directly into a measuring cylinder,
5. Record the reading of water level in the measuring cylinder in millimeter (mm),
6. Calculate the rainfall in mm for the sampling period,
7. Dry the cylindrical jar and keep it for recording of rainfall for the next 24 hours.

Data collection and analysis –

- If you have made a local rain gauge taking the funnel (collector) of different diameter then you will have to calibrate it as follows –

- Radius of your rain gauge collector (funnel) – ‘r’ cm
- Area (A) of the mouth of your collector = πr^2 i.e. $3.14 \times r^2$ (suppose A cm²)
- Area (B) of the collector of standard rain gauge (having 203 mm or 20.3 cm diameter or 10.15 cm radius) = πr^2 i.e. $(3.14 \times 10.5 \times 10.5) = 323.65 \text{ cm}^2$
- Multiplying factor for your rain gauge (F) = B/A
- Calculate the amount of rainfall measure in your rain gauge = **water collected in measuring cylinder** x F (mm)

- Suppose the collector in your rain gauge has a diameter of 123 mm which corresponds to an area of 119 sq. cm. The collector of 119 sq.cm area has to be calibrated against the standard funnel of 203 mm (323.65 sq cm area). Hence the rainfall measured in your rain gauge has to be calculated by multiplying with a factor of 2.72.
- Suppose the reading of rainfall in your rain gauge is measured 9 mm then the actual reading will be calculated as follows -

Rainfall (mm) reading in the measuring cylinder x 2.72

This will be $9 \times 2.72 = \mathbf{24.5 \text{ mm}}$

For record of the rainwater collected in the rain gauge and calculation of the rainfall you may design a data table. A sample data table and sample calculation is given here –

Place – Science Centre, Bhopal				Geographical Location - 23.1719° N, 77.4169° E		
S. No.	Date & Time of Start of Reading	Date & Time of End of Reading	Duration (hours)	Rainfall measured in the Rain Gauge (mm)	Multiplying factor (F)* (mm)	Rainfall calculated
1	15.05.2023 8:00 am	16.05.2023 8:00 am	24 hrs	9	2.72	24.5
2	-	-	-	-	-	-

*Determine your own multiplying factor and use that in calculation.

Results –

The daily or monthly or yearly rainfall data can be presented in simple tabular form or as per need. Various interpretations of rainfall can be done through mathematical and statistical calculations.

Key points learned –

- Amount of rain fall in an area can be measured using the rain gauge.
- Record of amount of rainfall over a rainy season in a year will help to find out how much it rained in different parts of the season.
- Record of amount of rain fall in several years will help to understand the pattern of rain fall in different years.
- A comparison of rain fall data over a period can educate us about the change of pattern of rain fall in different seasons. This can also be correlated with the change of other ecological factors related to the rain fall to understand the impact of rain fall on ecology in a particular area.

Open ended questions –

- What is Rainwater Harvesting? How do you find the rainwater harvesting potential of your house?
- Rainwater can be considered like distilled water, True or False? Give reason in support of your answer.
- Why it is not recommended to bath in the first rain?
- Normally we see rainbow during the rainy season. Why can't we see it throughout the year?

Sub-theme: Wind Speed and Wind Direction

Winds are an important phenomenon on the Earth both in terrestrial areas as well as in the gaseous envelop (atmosphere) around the Earth. Occurrence of winds and their patterns are caused by the Earth's own rotation and uneven heating of the Earth by the Sun. Pressure and temperature differences in the atmosphere are primary conditions leading to generation of winds. Anthropogenic activities also cause uneven heating of the Earth as well as lower atmosphere and contribute as unnatural factor in influencing the natural wind pattern. Wind types are classified into several categories depending on their geographical location, direction, time period, seasonality and regional conditions. For example, planetary or primary winds, monsoon winds, westerlies, trade winds, local winds, mountain breeze, valley breeze, land breeze, sea breeze etc. Extreme weather events like storms, hurricanes and cyclones etc are also associated with winds.

Winds possess magnitude, force and direction and thus are important factors that apart from directly affecting the living and non-living components, also affect other environmental characteristics and pattern. Winds transport moisture, heat, particulates, gases etc from one place to another. Even dispersal of many pollutants from their source to other areas is also caused by winds. Different ecosystem conditions undergo daily changes in wind direction and speed. We can explicitly see the diurnal change in wind pattern in coastal areas, valley areas, desert area, high mountain areas etc.

Wind Vane is a useful tool to record the direction of wind. It consists of an arrow-shaped structure called the 'vane' which is fixed on a pivot. The vane has two ends, one of which is arrow form and points in the direction of wind while the other end which is wider, catches the air. A record of wind flow direction each day can be maintained using the wind vane.

To measure the wind velocity **Cup Anemometer** is the simplest device that consists of hemispherical cups on horizontal arms mounted on a vertical shaft. The air flow in any horizontal direction turns the cups and causes the shaft to rotate. Under absence of other factors influencing the shaft's rotation the rotation speed of anemometer is proportional to the speed of wind. By counting the rotations over a period of time one can calculate the wind speed in distance per hour (e.g. kilometer per hour) unit.

Wind direction and speed recorded over a period of time can be depicted in the form of a diagram called windrose. The study of wind direction and wind speed of an area helps in

scientific research, monitoring, predictions and planning, development of urban areas and industries, management of agriculture and other natural resources etc.

Activity: Determination of wind speed and wind direction using Wind Vane and Anemometer

About this experiment -

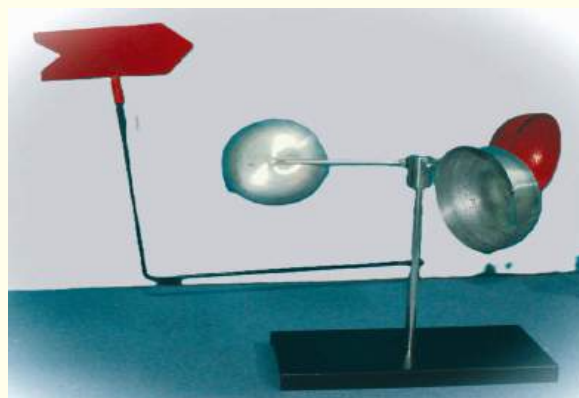
Winds are an important factor influencing the living and non-living components by virtue of their force and magnitude. Winds also play important role of transportation of pollens, seeds, moisture, heat, particulates, gases etc from one place to another. Winds can show diurnal variations (i.e. changeable patterns in daily duration) as well as can have a characteristic long-term pattern. Winds are one of the important weather parameters that possess significance in sectors like agriculture, aviation, navigation in marine and high mountain areas, sailing and meteorology etc.

The study of wind direction and wind speed of an area helps in scientific research, monitoring, predictions, planning, development of urban areas and industries, management of agriculture and other natural resources etc.

Wind speed and wind direction are primary characteristics of winds that one can easily understand through simple and easy observations. **Wind Vane** is a useful tool to record the direction of wind at a time. To measure the wind speed Cup **Anemometer** is the simplest device that is used to monitor and calculate the wind speed. Both wind vane and anemometer can be installed together at a place. The ideal sites for taking wind measurements must be open, away from trees, buildings and other structures which can obstruct natural wind movement. If the site is surrounded by trees or buildings, keep the instrument on top a building which is quite away from a tree or structure taller than the one on which it has been kept.

Material required-

- Wind Vane and anemometer,
- Compass

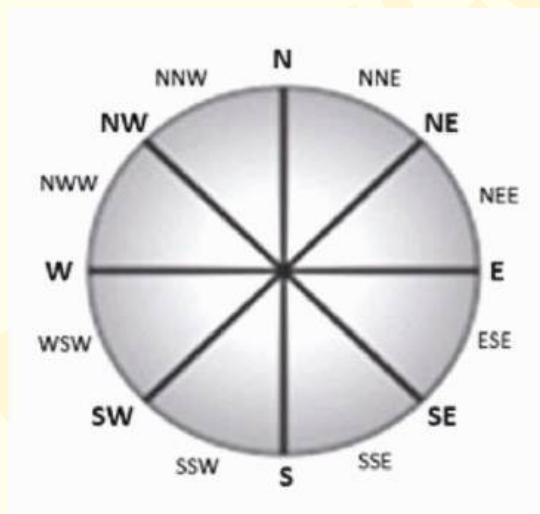


Method -

The assembly of wind vane and anemometer can be installed at one place. For recording direction a compass is placed at the base plate of the assembly.

For Wind Direction:

1. Observe the wind vane, the arrow part of it will point to the direction the wind is blowing from. If the arrow is pointing to the east, it means the wind is coming from the east.
2. Monitor the wind vane at different times for observation of direction wind and record the directions.
3. The wind direction is normally observed in eight directions namely East, West, North, South, North East, North West, South East, South West. For more explicit data the directions can be sub-divided further as shown in the figure -



Windrose (Wind Direction Image)

For Wind Speed:

1. In the cup anemometer mark or colour a cup with different colour (for example Red) than other cups.
2. Count the number of times the cup having different colour/mark rotates on its vertical shaft in a time period (duration).
3. Measure the distance travelled by the cup around its axis as follows –
Distance travelled in one round by the cup (D) = $R \times 2 \times 3.14$
(Where 'R' is the distance of the cup's centre from the centre of the shaft to which it is attached by a horizontal arm)

4. Record the rounds done by the marked cup in a fixed duration
5. Convert the time in minute or hour and distance in meter or kilometer
6. Mention the wind speed in meter per second or kilometer per hour or likewise.

Data collection and analysis –

You can design a data table to record the wind direction for certain times and another data table to record the observations of wind velocity for certain durations. A sample of data tables with examples of data entry is shown here for example-

Table for recording the wind directions recorded at different times in a day -

Date: 13.05.2024		Place: Science Centre, Kolar Road, Bhopal	
Geographical Location: 23°10'34.5"N 77°25'25.1"E			
S. No.	Time	Wind Direction From	Wind Direction To
1	06:30 am	North-East (NE)	South-West (SW)
2	12.30 pm	North-North-East (NNE)	South-South-West (SSW)

Table for recording the wind speed for different durations -

Date: 13.05.2024		Place: Science Centre, Kolar Road, Bhopal		
Geographical Location: 23°10'34.5"N 77°25'25.1"E				
S. No.	Time	Duration of Observation	Rotations of Cup Anemometer	Wind Speed (km/Hr) or (meter/s)
1	6:30 am	10 seconds	30	6.8 km/hr Or 1.9 m/s
2	12:30 pm	10 seconds	18	?

Calculation of Wind Speed –

- Distance travelled in one round by the cup (D) = $R \times 2 \times 3.14$
(Where 'R' is the distance of the cup's centre from the centre of the shaft to which it is attached by a horizontal arm)
- If the radius (distance of the cup's centre from the rotational shaft) is 10 cm then the distance travelled by it in one round = $10 \times 2 \times 3.14$, i.e. 62.8 cm or 0.628 meter.

- If the cup makes 30 circles in 10 seconds then it will be taking 180 rounds per minute or 10800 rounds in one hour.
- Therefore the distance travelled in one hour will be $0.628 \times 10800 = 6782.4$ meter (Or $6782.4/1000 =$ approx 6.8 km) and the speed will be calculated as $(6782.4/60 \times 60)$ as 1.9 m/second or 6.8km/hr.
- Calculate the wind speed yourself if the cup anemometer rotates 18 times in 10 seconds.

Results –

The wind speed and wind direction can be described both quantitatively as well as qualitatively through different analysis and interpretations.

Key points learned –

- Wind speed and wind direction are ever changing phenomenon that influence other weather events as well as our lives significantly.
- Wind vane and anemometer are easy to assemble and portable devices that can be installed at suitable place for short-term / long-term wind monitoring.
- Long-term data of wind speed and wind direction is used in interpreting climate characteristics of an area.
- Study of data for a decade or more can provide us information about wind flow in the area and its impact on ecology and society.

Open ended questions –

- What are trade winds? How do they occur and what is their significance?
- What are atmospheric winds? Where do they occur? What is their significance?
- How do birds fly from one continent to another through very long distances without getting exhausted with energy?
- Is it possible to install the wind mills at any place? Yes or No, explain.

Interesting facts -

Windrose:

Wind direction and speed recorded over a period of time can be depicted in the form of a diagram called windrose. Windrose is a kind of weather map showing the frequency and strength of winds from different directions. It has immense significance in industrial environmental management, assessment and management of gaseous and particulate pollutants, monitoring of stack / chimney plumes and dispersal of emissions, maritime, aviation, wind energy establishments, agriculture etc.

Sub-theme: Green House

Green house is a technique to maintain temperature and humidity of the inside environment of an artificial chamber which is meant for growing vegetables, flowers and other type of plants under regulated conditions. The walls and roof of greenhouse are made of glass or transparent sheets so that it allows the sunlight to enter but obstruct them to reflect back, at the same time it traps the geothermal radiations emitting from the earth inside it and hence helps in maintaining the optimum temperature and humidity inside when the conditions in the outside environment are not stable. Green house is also useful as a nursery for germination of seeds and healthy growth of their saplings. It provides the required light, air, warmth and humidity to the little plants. Humidity inside the greenhouse remains much higher than the surroundings which works very favorable for the growing saplings. Also, it provides a consistent salubrious environment for the little plants to grow comfortably and consistently.

The working principle of the green house is quite interesting. The transparent walls and the roof of the greenhouse allows sunlight enter inside. The entering solar radiations are of high energy (i.e. short-wave radiations – having high frequency and short wavelength) whereas after striking the inside surfaces they lose some part of energy and therefore the reflected radiations possess lesser energy (i.e. long-wave radiations – having low frequency and long wavelength). The reflected radiations are unable to cross the transparent walls to escape outside and are reflected back into the chamber. This results in warming of the soil and air inside the green house. Simultaneously, the geothermal energy (i.e. heat liberated from the Earth itself) is also trapped in the greenhouse and consequently because of the trapping of thermal energy it leads to warming inside. The warming causes evaporation of water from the soil and enhances the humidity inside the house which helps seeds to germinate and sprouts to grow well.

In the Earth's atmosphere the water vapour, carbon-di oxide, methane and other gases are easily travelled through by the Sun's incoming radiations (which are high energy / short-wave radiations) whereas the radiations that reflect back the Earth become s weaker (low energy / long-wave radiations) and cannot escape out through this water vapour and gaseous envelop. As a result, the heat energy is trapped in the atmospheric blanket of the Earth. The trapped heat energy causes warming of the air and distribution of temperature to different mediums across the globe. This way the Natural Green House of the Earth is maintained which is vital for existence for the present life forms on the Earth. However,

because of the anthropogenic activities that lead to generation of more carbon-di oxide, methane and other such gases that are heavy and tend to remain in the lower atmosphere augment the trapping of heat over the Earth's surface and results into more warming of the earth and harmful consequences. This phenomenon is called the 'Green House Effect' which is major cause of the global warming and climate change.

The principle of greenhouse helps to understand the natural greenhouse of the Earth and also the greenhouse effect. One can make a small greenhouse to observe and understand the greenhouse effect. By this we can also understand our roles and responsibilities to minimize the anthropogenic greenhouse effect.

Activity: Knowing about the 'Greenhouse Effect' through a small greenhouse

About this experiment -

Greenhouse is primarily a man-made technique to grow vegetables, flowers and other type of plants under regulated conditions. But the principle of greenhouse is based on the Earth's natural greenhouse effect that helps in maintaining the temperature and various other natural processes to support the life on the planet.

In the Earth's atmosphere the water vapour, carbon-di oxide, methane, and other gases act as barrier for the Sun's radiations that reflect back after striking on the Earth's surface and also for the Earth's geothermal energy. As a result, the heat energy trapped in the atmospheric blanket of the Earth causes warming of the air and distribution of temperature across the globe which is supporting life on the Earth.

The natural greenhouse is getting severe due to anthropogenic release of Carbon-di-oxide, methane, compounds of sulfur, chlorofluorocarbons, ozone in the lower atmosphere etc that is augmenting the trapping of heat in the Earth's atmosphere. One can make a small greenhouse to observe its inside environment and understand the greenhouse effect. Even a small greenhouse made of transparent material sheets will demonstrate the temperature differences if kept in sun or even under the shade.

Material required-

- Few small rods of metal or wood or a stiff material
- Transparent material sheets
- Thermometer

We can make a small greenhouse by assembling few rods in the form of frame of a house and covering its sides (walls) and top by a transparent cover. A small opening in the greenhouse is kept to place the objects inside it or remove from it.

Method -

1. Assemble the greenhouse,
2. Place the greenhouse at an open place where sunlight reaches.
3. Place some seeds and small saplings of plants in the greenhouse as well as place similar types of seeds and samplings outside of it in the ambient environment.
4. A thermometer is fixed inside the greenhouse to monitor inner temperature. Another similar thermometer is placed outside to monitor temperature of the outside area where seeds and saplings are placed.
5. The seeds and saplings placed inside the greenhouse as well as those placed outside are monitored daily for tracking their germination & growth for a week.
6. The observations on seeds and saplings along with the temperature records when compared give us idea of the conditions inside the greenhouse that differ from the conditions of ambient environment and the effect on seeds and saplings.
7. Just like the large greenhouses this small greenhouse will also have difference in temperature, humidity etc in comparison of the ambient environment.
8. We can also compare difference in greenhouse conditions by placing our small greenhouse at different locations.



Field Experiment of Artificial Greenhouse and Greenhouse Effect

Data collection and analysis –

The record of changes observed in temperature, germination of seeds, growth of saplings etc inside the greenhouse and outside as well is kept on daily basis for a week.

This provides useful data related to the difference in the inner temperature and outside temperature and its effect on the seeds and saplings kept in both mediums.

One can even feel the difference in the humidity and temperature inside the greenhouse by simply putting her/his hand inside it. This procedure also can be done under various conditions like in the open sun, under tree shade, under a building's shade, in a garden, on the road, on the rocky surface etc. Under every condition the inner temperature and humidity of the greenhouse will differ from the outside ambient environment.

Results –

The observations and data can be presented through qualitative and quantitative interpretations.

Key points learned –

- Green house is a man-made technique that is based on the Earth's natural greenhouse system.
- Earth's natural greenhouse supports the life forms on the Earth.
- Anthropogenic greenhouse is harmful to the life forms on the Earth.
- Atmospheric water vapour, gases and aerosols etc greenhouse factors are good for the Earth when they are within the natural balance, however they become harmful if augmented, altered or disturbed by the anthropogenic factors.
- One can make greenhouses of different shapes, sizes and material and can understand the principle of greenhouse through experiment.

Open ended questions –

- What would happen if you change the transparent covering of your greenhouse with opaque or non-transparent covering?

Sub-theme: Eco Mapping

There are different technological tools by which one can determine location of living beings, species or ecosystems or natural habitats on the Earth. The locations can be depicted in the form of map in reference to spatial attributes like geographical distribution, natural organization, ecological setup and structure of the landscape and / or temporal attributes like time or seasons or duration. Conceptualization and generation of maps based on spatial and temporal attributes of a species or community or ecosystems is called **Ecological Mapping or Eco Mapping**. Ecological mapping represents the natural organization of a landscape. It offers suitable resolutions, based upon a regionalized process, and provides an ecological basis for planning activities that may impact upon the environment.

A layman can do Eco-Mapping in own area using two basic tools & techniques – ‘Global Positioning System (GPS)’ and ‘Google Earth Pro’.

I. Global Positioning System (GPS)

The Global Positioning System is a space-based radio navigation system. It is comprised of three parts – the space segment, the control segment and the user segment. The space segment is composed of more than 30 operational satellites distributed in six orbital planes inclined 55° from the equator at 20,200 km above the earth's surface and circling the Earth every 12 hours. The control segment is the station on the Earth that is maintaining and monitoring the GPS satellites. The user segment is the receiver (device) that receives and processes navigation signals from the GPS satellites and calculates position and time.

The GPS satellites can pinpoint a three dimensional position to meter-level accuracy. To pinpoint the 3D location of any receiver on the Earth at least four satellites are available at a time anywhere in the world. The GPS system has wide range of applications in different fields like agriculture, biology, geology, marine, ecology, navigational, military, war, land use, natural resource management, tracking of movements and social applications and many more.

II. Google Earth Pro

Google Earth Pro is a computer program that displays the entire world on a computer screen in 3D using satellite imagery. Users can view different features on Google Earth from various angles by layering satellite images, aerial photographs, and additional information like roads, railways, cities, and landmarks onto a 3D model of the Earth. This application is helpful for locating geographical positions (latitude and longitude), obtaining directions

from one place to another, creating maps with high-resolution satellite images, marking and saving routes, landmarks, and features, as well as analyzing land use and cover.

Scientists and others use specialized devices called GPS handheld instruments for precise navigation in important national and international operations. However, advancements in technology have made GPS applications accessible to the public too. Nowadays, GPS applications are available on mobile devices, allowing people to easily determine their location or navigate for various purposes using a GPS satellite signal receiver device. Similarly, Google Earth is also accessible on desktop and mobile devices and serves the purposes of mapping. Both GPS and Google Earth Pro applications are user-friendly tools for eco-mapping that can be utilized by ordinary individuals. They enable the creation of various digital records associated with specific locations and times for diverse purposes.

Activity: Know your geographical location on the Earth

About this experiment -

Maps are important tools to depict the spatial distribution of the places, objects, phenomenon, activities, and their information. Having a map of the spatial information of anything that we want to explore / visit / document is an advantage using which can perform our work more efficiently. Maps have importance in all kinds of streams, whether it is research & study or defense or social survey or business or politics or any branch of knowledge. In the modern time when we have digital technology available and accessible to everyone, use of maps has also become very common in travel, transport and sharing the location of someone or something. The best advantage of having maps in the digital gadgets in our hands is that it helps in reducing the chances of getting lost or wandered.

Ecological mapping or Eco mapping is the mapping technique by which One can determine location of living beings, species or ecosystems or natural habitats, their attributes and functions on the Earth, in reference to their spatial and temporal variations. Eco mapping offers suitable resolutions, based upon a regionalized process, and provides an ecological basis for planning activities that may impact upon the environment. Now a day eco mapping is an important technique applied in the natural resource management, apart from being useful in prediction of the natural phenomena eco mapping is immensely useful in prospecting of natural resources and policy frameworks as well.

A layman can do Eco-Mapping in own area using two useful tools & techniques – Global Positioning System and Google Earth Pro.



(i) Global Positioning System (GPS)

Global Positioning System (GPS) has revolutionized positioning concepts, though it stated primarily as a navigation system. It has wide range of geodetic, geophysical, navigational, marine, military and social applications. GPS is a space-based radio navigation system. It is comprised of three parts – The space segment, the control segment and the user segment. The user in her/his device receives the navigation signals (viz. location, movement and direction etc) and can perform movements and record location / position and other observations.

Applications of GPS

- Location : Determining a basic position (Latitude, Longitude and Altitude).
- Navigation : Getting direction from one location to another.
- Mapping : Creating maps.
- Timing : Providing precise timing.
- Other Applications : Application in agriculture, Mobile mapping, Eco-mapping, Marine application, Military application, Space application etc.

What is GPS device?

<p>Offline GPS device, used for gathering required information for navigation, location and mapping.</p> 	<p>Offline android mobile based GPS (GPS app application available for use in mobile device)</p> 
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Scientists and others use specialized devices called GPS handheld instruments for precise navigation in important national and international operations. However, advancements in technology have made GPS applications accessible to the public. Nowadays, GPS applications are also available on mobile devices, allowing people to easily determine their location or navigate for various purposes using a GPS satellite signal receiver device.

(ii) Google Earth

Google Earth Pro is a computer program that displays the whole globe on a computer screen in 3D visualization of the Earth's satellite imagery. Users can view different features on Google Earth from various angles by layering satellite images, aerial photographs, and additional information like roads, railways, cities, and landmarks onto a 3D model of the Earth. Google Earth is also accessible on desktop and mobile devices and serves the purposes of mapping.

Everywhere is at somewhere

Google's geo tools aren't just about geography. You can use them to trace routes from Shri Nagar to Kanyakumari, Marco Polo's journey through Asia, to explore the architecture of Barcelona or Delhi, to measure how glaciers of Alaska and Himalaya are receding, or to analyse the habitats of the animals and plants. Geospatial thinking has transformed our perceptions of the world around us, and how we address issues such as climate change and the protection of wildlife and environment.

Applications of Google Earth

- Location : Find spatial details of place on one click (Latitude, Longitude and Place Name, previous images of the same point too)
- Navigation : Getting direction from one location to another.
- Mapping : Compose map with the background of high resolution satellite imageries.
- Other Applications: Mark and save track, place and features, Land use and Land cover mapping (different land features like forest, agriculture, water bodies, river, elevations, drainage, human settlements, city, road etc)

Both GPS and Google Earth Pro applications are user-friendly tools for eco-mapping that can be utilized by ordinary individuals. They enable the creation of various digital records associated with specific locations and times for diverse purposes.

In this exercise we shall know and understand how we can mark and record geographical location on the Earth.

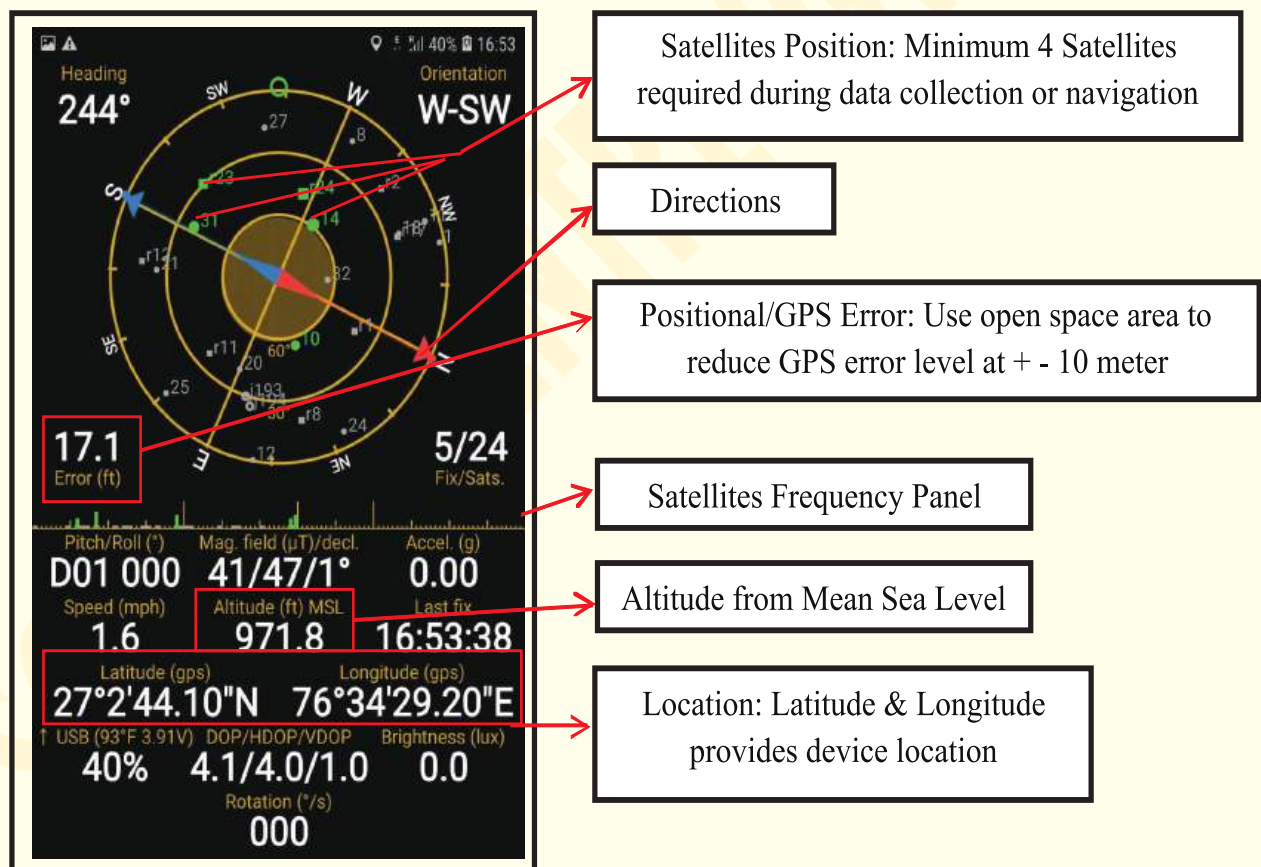
Material required-

- GPS handheld instrument or GPS application in the android mobile,
- Google Earth application either installed in mobile or in desktop computer,
- Color leaflet

Method-

How to use Android Mobile Base GPS?

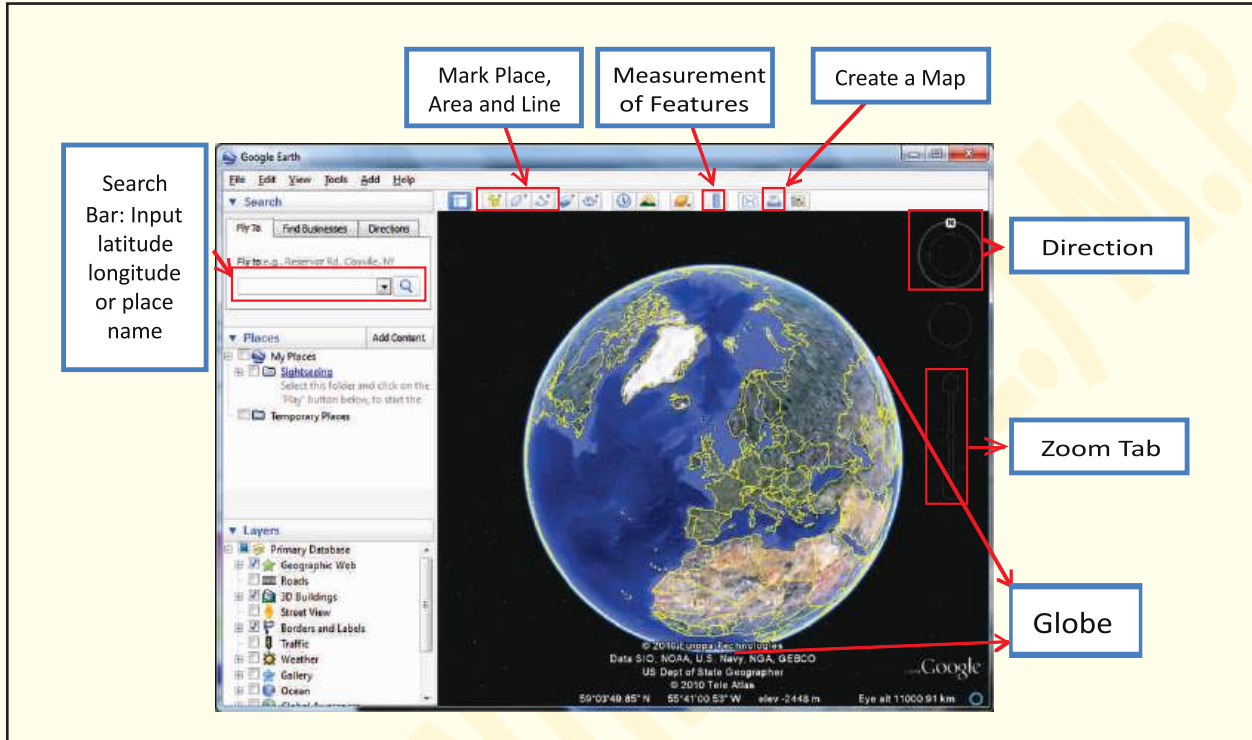
1. Download 'GPS Status' android mobile application through Google play store and install this application.
2. Open location service from mobile, then open 'GPS Status' application.



Example showing installation and use of GPS android mobile application

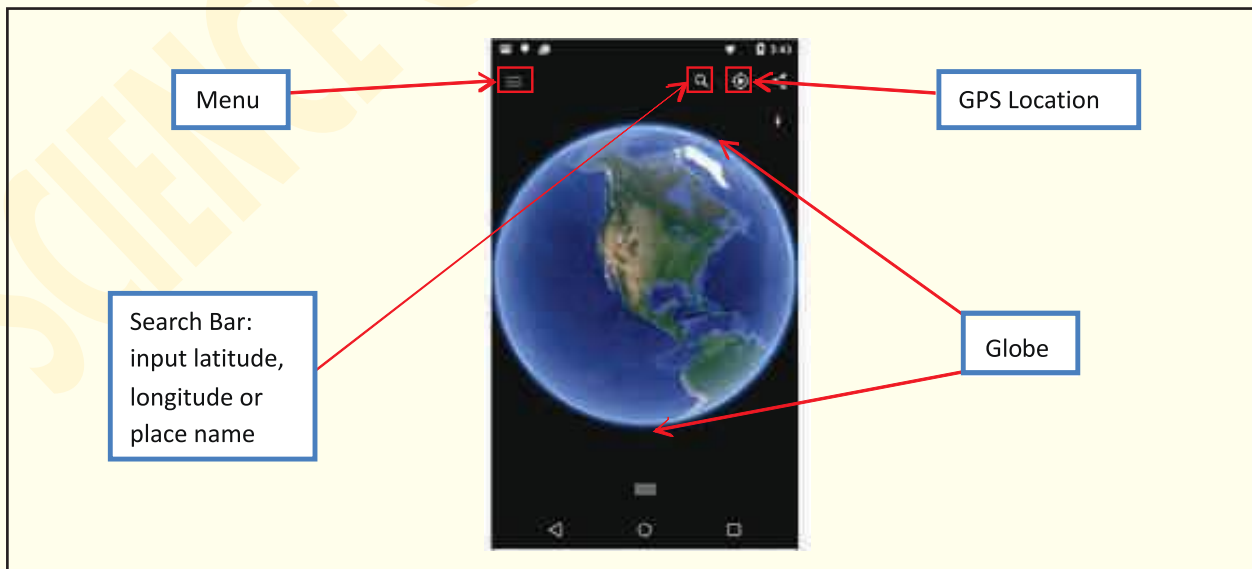
How to use Google Earth?

1. **Computer/Web Based Google Earth** - Download Google Earth from given link for desktop: https://www.google.com/intl/en_in/earth/versions/#download-pro



Installation and use of Google Earth Pro Application in Desktop

2. **Android Mobile Based Google Earth-**
Install Google Earth application from Google play store.



Installation and use of Google Earth Application in Android Mobile

Data collection and analysis –

- Record your GPS location (i.e. Latitude and Longitude), it is your current location on the Earth.
- Move around in your area (or if you travel to a far place) and record your location at that place (i.e. your location on the Earth at that time).
- You can make a list of locations (your location on the Earth, based on your movement from one place to another).
- Now later on using Google Earth application which is installed in your mobile or desktop computer, you can paste your recorded location in the Google Earth's 'Search' bar and see where you were on the Earth.
- You can put many locations on the Google Earth in this way and then can capture / save its image for depicting distribution of your recorded locations (distribution of any other thing that you record in different locations).
- You can save Google Earth file of your own location/distribution for future reference and use in making maps etc.

Results –

You can present your location data along with name or description of place, latitudinal and longitudinal location recorded and other features. Similarly, you can present the location data for any purpose. Simultaneously you can depict your locations on the maps using Google Earth application. Both location data and map depiction can be accompanied with other primary or secondary data and/or information.

Location data and map depiction can be used in data documentation and analysis of information collected related to parameters of water, soil, biodiversity and any other entities & their attributes.

Where We Are: An Exercise for Eco-Mapping

There are two steps for mapping -

- I. Collection of spatial and temporal field data,
 - II. Mapping through Google Earth
- I. Field data collection:** Follow the below steps for field data collection
- i. Open 'GPS Status' android application (Internet connection is required) to get the geographical information (viz. latitude, longitude, time, altitude etc.) displayed on application.

- ii. Open 'Location' service in the android mobile.
- iii. Go to that place which you want to map.
- iv. Identify the different geographical features seen in the application.
- v. Then, start to collect locations of your selected study area and fill in the data sheet. An example of data sheet is given here, you can design your own data format according to need

S. No.	Feature / Object	Name of Place	Latitude	Longitude	Remarks
1.	River / Drainage				
2.	Water body				
3.	Forest				
4.	Agriculture				
5.	Mountain / Hill				
6.	Road				
...

- I. **Mapping through Google Earth:** Follow the below steps for mapping on Google Earth;
 - i. Open 'Google Earth' on desktop.
 - ii. Identify the different geographical features seen in the Google Earth application.
 - iii. Type place name or latitude & longitude in search bar of Google Earth which you have saved in data sheet.
 - iv. Start editing on Google Earth map for location, boundary, route, area, marking additional points etc and other options to generate and save the picture as desired.

Key points learned –

- Concepts of geographical locations, distance and direction,
- Marking/recording geographical locations in the form of latitude and longitude as reference points of location on the Earth),
- Idea of different locations in reference to the whole Earth;
- Recording locations of different places, things, organisms, incidents and storing them in own data bank for further reference.
- Marking of recorded locations in Google Earth application and making location maps (distribution maps of desired object)

Open ended questions –

- What is the meaning of degree, minute, second in reference to geographical location?
- Is it possible to record location of an airplane while flying?
- Does the point of location is seen changing itself if we tilt the globe on Google Earth?
- How do guided missiles find their target far from hundreds of kilometers distance?
- What would happen while recording the location if the sky is covered with clouds or you enter a valley area or a dense canopy forest or enter a cave?
- Can you record the location of different public gardens of your city, or water bodies in and around your village, or locations of a rare tree species found in your region, or locations of shops in your village and so on?
- Can you prepare a location and distribution map for your village or city to depict the places where waterlogged conditions develop during rainy season, and solution for channelizing that water to nearby drain or percolate in the ground?

Theme – Astronomy

Astronomy is the natural science that includes study of celestial objects and all phenomena that occur in the cosmos beyond earth's atmosphere. The celestial objects include stars, planets, comets, asteroids etc and their larger clusters like galaxies or constellations etc. We are able to see many celestial objects by naked eyes whereas to see the rest of distant objects we require telescopes.

The celestial objects influence each other with their gravitational force, radiations, relative motions and own motions. Thus their position in the sky above us is seen changed due to regular relative motions. That is why we see changed positions of different constellations on daily basis and also cyclic in intervals. Other phenomenon like transits of comets, asteroids and planets are also associated with relative positions of celestial bodies. Even the biological processes of living beings on the Earth are influenced by the relative position and forces of other celestial bodies. Sun is the best example which is the only source of energy to support life on the Earth.

In our solar system our planet Earth is placed in an orbital path around the Sun and moves around it under its gravitational force (revolution), as well as rotates on its own axis (rotation). On the other hand, Earth's only natural satellite is the Moon, which revolves around it under the influence of its gravitational force, but only the same side of it is always visible towards the Earth because its rate of rotation is tidally locked, so that it becomes synchronous with its rate of revolution (the time required to complete one orbit). In other words, whenever the Moon revolves around the Earth, it rotates once in exactly the same amount of time and hence only one side of it is visible towards the Earth. The same forces that create tides in Earth's oceans from the Moon's gravitational pull, also act on the Moon's solid body.

We see daily rise and set of Sun and Moon because of relative motions of the Earth with them, so is the case with between other celestial bodies. The solar and lunar eclipses are also associated with the relative position of the Sun, the Moon and the Earth.

Different celestial objects including our own planet exert gravitational force according to their mass and size and even influence each other by that. The Moon is positioned and moves under the Earth's gravitational pull but its own gravitational force along with movement and changes in relative distance with the Earth influence the natural phenomena on the Earth. The daily tidal movements in our ocean waters are an excellent

example of Moon's gravitational influence on the Earth's natural phenomenon. Our traditional time keeping and calendar and weather forecasts and other miscellaneous information like positions of constellations and planets and their predicted effects are based on the knowledge of astronomy.

Night sky watching or day time observations of celestial objects always fascinate us. Likewise, is our curiosity for eclipses, identifying planets and constellations and their positions. Sometimes we need to be cautious about ways and means of watching the celestial objects and their phenomenon like watching the eclipses and watching the sun, and we require certain tools and follow methods for safe watching.

In this section we shall learn about celestial bodies, planets, constellations, sky and space phenomena through various activities.

- **Solar Eclipse**
- **Stars In the Sky**
- **Changing Positions of Planets**

Sub-Theme: Solar Eclipse

A solar eclipse occurs when the Moon passes between the Sun and Earth, casting a shadow on Earth that partially or fully blocks the sunlight in some areas. Solar eclipse only happens occasionally because the moon doesn't orbit in the same plane as the Sun and Earth do. The time when all these three are aligned is called the eclipse season which happens twice a year. Solar eclipses are classified into total, annular, partial and hybrid types according to the position of the Moon between the Sun and Earth. Total Solar Eclipse happens when the moon is aligned in such a way that it completely blocks the face of the Sun. Annular Solar Eclipse happens when the moon is at the farthest point from the Earth and appears smaller than the Sun, thus not covering it completely, as a result the moon appear like a dark disc on a larger bright disc. Partial solar eclipse happens when the Sun, Moon and Earth are not perfectly lined up and only a part of the Sun is seen in the form of crescent shape. During a total or annular solar eclipse people outside the shadow zone of moon (area on the Earth that is covered by the Moon's shadow) see a partial solar eclipse. Hybrid solar eclipse appears as interchange of an annular and a total solar eclipse where the former becomes the latter and then usually reverts back. It happens because of the curved surface of the Earth and resultant changes in the Moon's shadow moving across the Earth's surface.

During the solar eclipse it is not safe to watch it directly because the direct solar radiations may cause serious injurious to eyes. Even it is not safe to watch solar eclipse using a camera lens, telescope, binocular or any optical device because the concentrated solar rays will cause severe injuries to eyes or even loss of vision. Therefore it is recommended to watch solar eclipse through indirect viewing methods like pinhole projection and mirror projection.

Under the pinhole projection the sunlight is passed through a small opening and is projected onto a nearby surface as solar image (you can also do this activity just by crossing your fingers or by a hole punched in a paper or card). There are different ways of making the pinhole projector, either using a plain card or paper or a box.

Under the mirror projection a plain mirror is covered with a black paper sheet having a small hole at the center. The sunlight falling on the mirror is reflected only from the center hole and the solar image is focused onto a nearby surface.

Activity : How to watch solar eclipse safely

About this experiment –

A solar eclipse occurs when the Moon passes between the Sun and Earth, casting a shadow on Earth that partially or completely blocks the sunlight in some areas. Solar eclipses are classified into total, annular, partial and hybrid types according to the position of the Moon between the Sun and Earth.

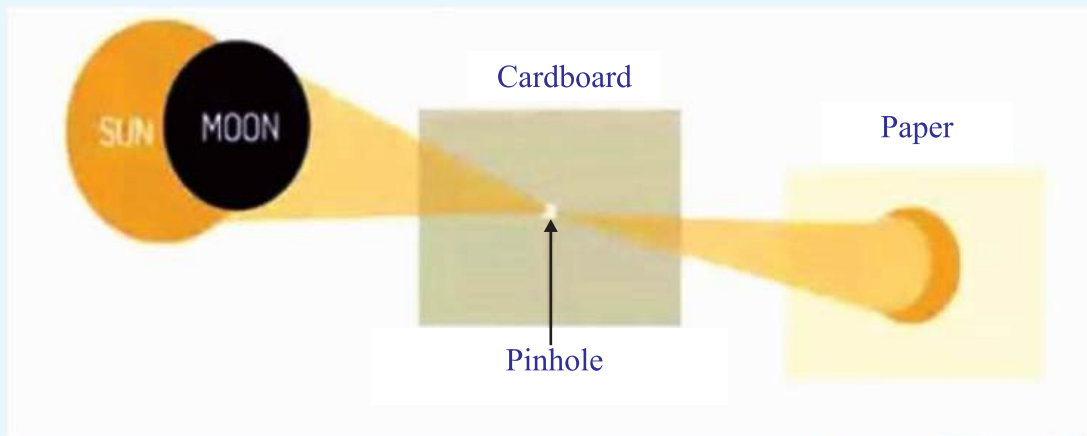
Watching the solar eclipse directly with naked eyes is harmful because the direct solar radiations may cause serious injurious to eyes. Even it is not safe to watch solar eclipse using a camera lens, telescope, binocular or any optical device because the concentrated solar rays will cause severe injuries to eyes or even loss of vision. Therefore it is recommended to watch solar eclipse through indirect viewing methods.

Here we are helping you to watch solar eclipse safely using simple handy devices without any direct watching. Here two simple techniques namely, **Pinhole Projection** and **Plain Mirror Projection** are described that are easy to assemble and also easy to be used in watching the Solar eclipse.

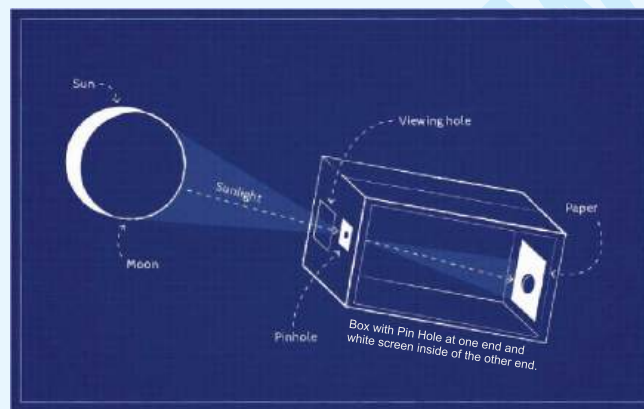
Pinhole Projection: In this technique the sunlight is passed through a small opening (just by crossing your fingers or by a hole punched in a paper or card) and is projected onto a nearby surface. There are different ways of making the pinhole projector, either using a plain card or paper or a cardboard box.



Creating Pinhole by Overlapping Fingers



Simple Pinhole Projector made of Card Boards



Box Type Projector

Under the **mirror projection** a plain mirror is covered with a black paper sheet having a small hole at the center. The sunlight falling on the mirror projector is reflected only from the center hole and the solar image is focused onto a nearby surface.

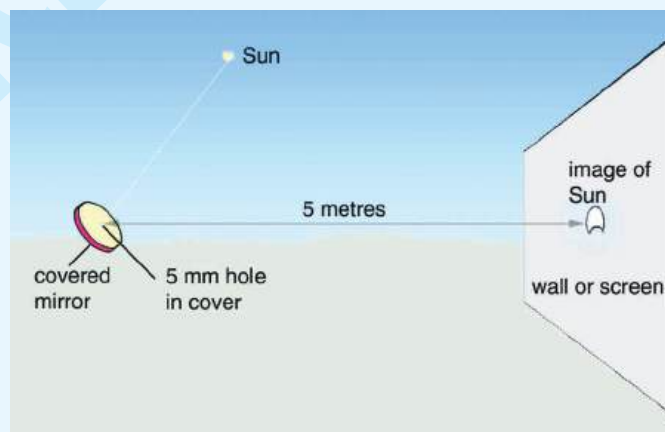


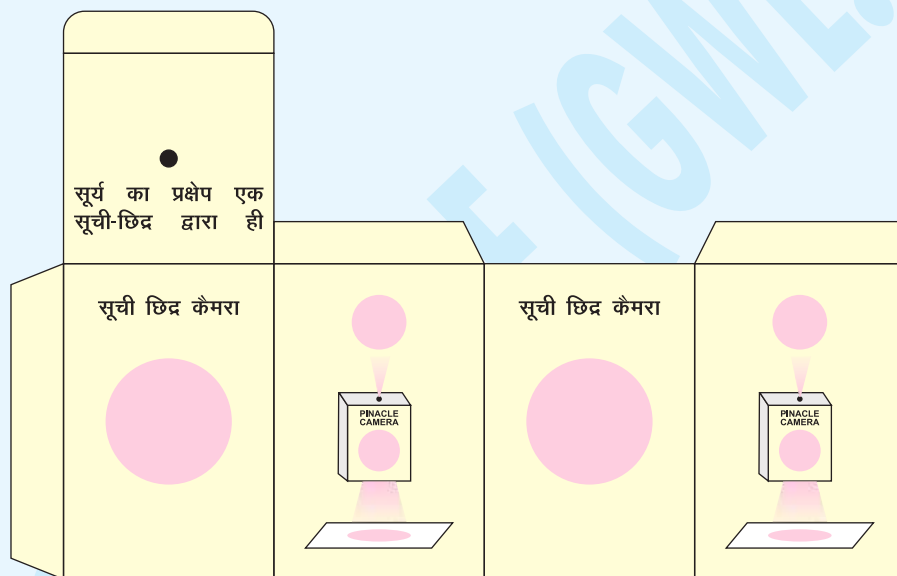
Diagram of Using Mirror Projector

Material required –

Plain card or thick paper sheet, cardboard box, plain mirror, black paper sheets

Pinhole projector Making -

- Take a card or thick paper and make a small hole of 1-2 mm diameter at its center (alternatively, you can take a cardboard box and at its one side make a small hole of 1-2 mm diameter).
- When pinhole side is oriented towards the sun, the sunlight enters through it and, in the box the reversed image of the sun is formed on the inside wall of the opposite end, whereas if a card or thick paper is taken then the projected image may be formed on the ground or on the wall.



A handmade pinhole projector

Plain Mirror Projector Making -

- Take a plain mirror and cover it with a black sheet of paper which has a hole of 1-2 centimeter diameter at the centre. The sunlight falling on the mirror is reflected only from the hole of black paper and its reflection can be focused on a wall or ground surface, based on the angle of falling sunlight.

Method -

Method-1 (Pinhole Projector):

- In case of a box type pinhole projector, align the projector such a way that its pinhole side faces towards the sun and the opposite end faces the ground.

- In case of the card/paper projector, place a black paper on the ground and align the pinhole projector such that it points towards the black paper (this way you will be able to see the Sun's reflected image more clearly).
- Carefully observe the projected image of the Sun formed on the black paper.
- You can fix the device before the start of eclipse and record the time and change in the projected image of the sun till the end of eclipse.

Method-2 (Plain Mirror Projector):

- Take the plain mirror projector and orient it towards the sun such a way that the sunrays falling on its centre hole are reflected on a dark surface.
- Carefully observe the projected image on the dark surface and record the change in the projected image during the eclipse period with a time scale.
- Both of the above methods may be carried out by an individual or in a group. In fact, both methods can be used for the public demonstration of the ongoing solar eclipse.

Data collection and Analysis –

- You can mark the progression of the eclipse on the paper with a pencil or marker at the regular time interval (i.e. phases of eclipse at time scale), alternatively you can use a paper marked with the time scale.
- The sketch of the eclipse phase along with time scale may be drawn on the white paper for the record and further interpretation.
- The eclipse phase may be recorded in the tabular tool. A sample table is shown here, you can make your own data table according to need.

Table – Time period of different phases of the solar eclipse				
Time of start of the eclipse (Contact Phase)	Time before complete coverage of the Sun (Second Contact)	Time of complete coverage of the Sun (Total Phase)	Time of the reappearance of the Sun (Third Phase)	Time of the end of coverage of the Sun (Fourth Contact)
A	B	C	D	E

- You can calculate the total time period of the eclipse by deducting time of start (A) from time of end (E) and can record the total time period of the eclipse in minutes or hours.
- Similarly, you can calculate time interval between different phases of the eclipse.

Results -

You can present your observation on the eclipse time period and duration of different phases and make inferences accordingly.

You can also determine the best distances where reflected sunlight from the pin-hole or mirror-hole makes clear images on the ground or the surface.

Key points learned –

- You will be able to watch the solar eclipse by alternative means without directly watching the Sun.
- You can make the tools described in this activity yourself to watch the solar eclipse.
- Common masses may also be demonstrated the live solar eclipse, to watch & understand the celestial phenomenon.
- Learners will be able to watch and record the eclipse; by doing this they shall be able to derive various inferences about the eclipse phase, its time scale, stages of the eclipse.

Open ended questions -

- Does our biological cycles and behavior get influenced with the solar eclipse? You may try observing behavior of other organisms (including certain plants) during the eclipse phase.
- Is it possible to make a pin-hole or mirror projector from metallic items or from other alternative materials?
- Why it is said not to have food or do outside activities during the solar eclipse?

Interesting facts -

Is directly watching of solar eclipse harmful?

There are different concerns regarding watching the solar eclipse. Because of the high energy radiations of the Sun, watching the sun directly with naked eyes or through telescope or plain glass may lead to permanent injury to the retina of eye or even blindness. The intensity of solar radiations increases during the solar eclipse and watching it directly by any means may lead to severe injuries or/and blindness.

What is diamond Ring during Solar Eclipse?

Diamond Ring or the 'Baily's Bead Effect' occurs at two times during the total eclipse phase, i.e. just before the complete coverage of the sun and just when the complete coverage ends up. During diamond ring stage last bits of sunlight pass through the valleys on the moon's limb, and the faint corona around the sun becomes visible. The faint corona looks like a ring with glittering diamonds on it.

Sub-Theme: Stars In the Sky

The Sun, Moon and planets show a perceptible movement to the background of stars while the stars are so distant that they look stationary. Because of the Earth's rotation we see the sky scrolling as if we are moving and the whole sky seems to turn the hours around. By this phenomenon we see the rise and set of the stars. In addition, the movement of the Earth in its orbit around the Sun also shows different portions of the sky round the year.

Every day the stars in the sky return to the same place 4 minutes early because the Earth's orbital movement around the Sun gives a slightly different background of stars each night. This 4 minutes difference every day is because of the difference between the length of a day (24 hrs) and that of an Earth's rotation (23 hours and 56 minutes).

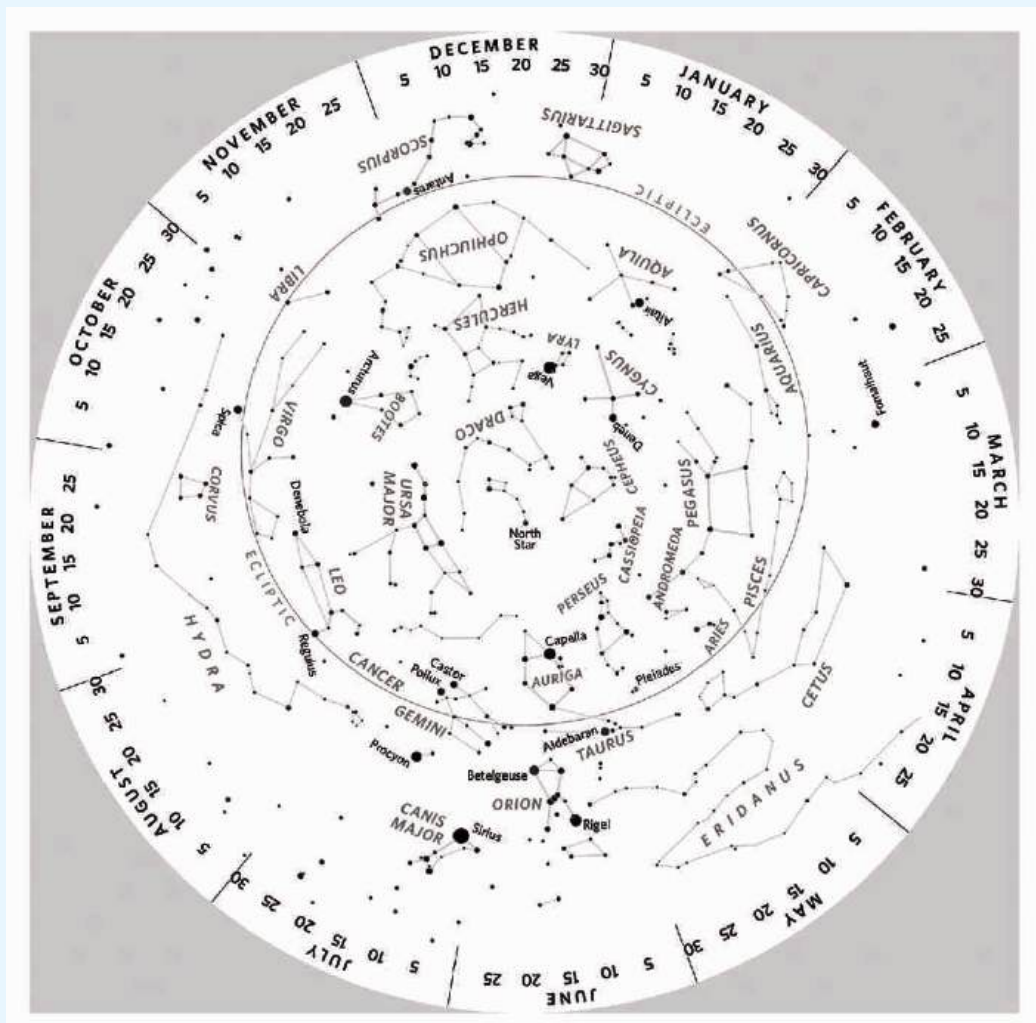
The daily position of the stars in the sky over a static position on the Earth can be seen using manufactured or digital version of the 'Tara Ghadi' (Star Watch), which is designed for locating the position of stars above us in the sky. The Star Watch device consists of two major components – Star Wheel and Star Dial. Star wheel is fixed in the star dial in such a way that it can be rotated in the star dial. The star wheel is having the position of stars inscribed which is surrounded by the monthly calendar. Star dial is a time displaying tool with which the star wheel can be adjusted according to the particular day and time.

Activity: Seeing stars above my head using Tara Ghadi (Star Watch)

About this experiment –

When we look at the sky in the night we see the sky scrolling as if we are moving and the whole sky seems to turn the hours around. This is because of the Earth's rotation and by this phenomenon we see the rise and set of the stars. Earth's movement in its orbit around the Sun also shows different portions of the sky round the year. We can understand this by watching daily changing position of stars above our head by standing at a static position on the Earth. A simple and handy device designed to watch the relative position of stars from a static point on the Earth is 'Tara Ghadi' (Star Watch).

The Tara Ghadi (Star Watch) consists of two major components – Star Wheel and Star Dial. Star wheel is fixed in the star dial in such a way that it can be rotated in the star dial. The star wheel is having the position of stars inscribed which is surrounded by the monthly calendar. Star dial is a time displaying tool with that the star wheel can be adjusted according to the particular day and time.



Representative Image of Tara Ghadi (Star Watch)

Material required -

- Tara Ghadi (Star Watch),
- Compass,
- Clock

Method -

1. First of all fix the calendar of star wheel with the time of the star dial
2. Hold the Star Watch above your head such a way that its north pointer projects outside and south pointer above your head
3. Now see the names and positions of stars visible in the star wheel and then watch the sky above your head to find stars and their similar position in the space.

4. Try the same activity in your region at different locations (different locations must be few kilometers away from each other) and try to derive inference regarding positioning of stars in the sky.
5. You can make a network of friends living in different cities and share the findings of star watch with each other.

Data collection and Analysis –

- You can record position of the stars seen above head in respect to time (hourly or daily basis).
- By compiling the monthly record you can categorize the stars most seen, least seen, longest seen, shortest seen etc.

Results -

You can make a record of the stars and planets seen in the sky in respect to time and place on the Earth. A record of constellations seen at different times and other celestial events can also be prepared to understand their timing and positions in the sky.

Key points learned –

- Positions of stars above us at a time
- Timing & Frequency of appearance of a star in the sky
- Direction of stars visible from a point location
- We can find directions by observing position of stars
- By practicing with Tara Ghadi now try estimating time (without a clock) by looking at the position of stars on a day. You can try estimating direction in the same way.

Open ended questions -

- When compass or any other instruments were not available, how could sailors and travelers determine the directions for movement? Explain to your peers with example.
- Why do stars in the sky seen blinking? Why not the Sun and the Moon are seen blinking same way?
- Do the position of stars and their constellations affect us in any way?

Interesting facts -

Cropping Calendar : Our traditional agriculture practices involve planning of crops and cropping cycles based on star navigation (i.e. deciding the cropping calendar). You can interview the village elders to know about how they used to plan their activities based on star navigation and with your observations using Star Watch those practices can be verified and documented.

Sub-Theme: Changing Positions of Planets

In our solar system the relative position and movement of the planets around the sun is different. Their own rotational movements are also different. By knowing the orbital paths and relative position of planets around the Sun we can understand the relative position of planets in reference to the location of the sun (placing the Sun at the center). Similarly in reference to our own location (placing ourselves as the Earth placed at the center) we can easily perceive relative motion of the planets that are visible in the sky above us. The planets appear changing their position in the sky every night but they move in a linear path and do not deflect.

There are different online websites and mobile app applications to see the position of planets on a particular day keeping us at a static location. This concept has been explained and demonstrated by a sky umbrella tool.

Activity: Let's understand changing positions of our planets

About this experiment –

We know that the planets in our solar system are arranged around the sun and without deflecting from their linear path they revolve around the Sun (which is at the center). In the same way placing ourselves as the Earth placed at the center, we can easily perceive relative motion of the planets that are visible in the sky above us, in reference to our own location. There are different online websites and mobile app applications using which we can understand the position of planets above us on a particular day, keeping us at a static location.

Here we are explaining a handy tool named, **Sky Umbrella**, using which we can understand the relative position of planets in reference to the location of the sun (placing the Sun at the center) and/or in reference to our own location (placing ourselves as Earth placed at the center).

This activity involves use of online websites & mobile app applications to see the position of planets on a particular day and replicating the position of planets in the 'Sky umbrella' using magnetic planet cards. This would help understand the position as well as direction of planets and their timely changes.

Material required -

- Umbrella,
- Small magnets,
- Iron Discs,
- Planet cards (Cards bearing photo of sun and planets),
- A hollow ball.

Stick the iron discs to the backside of the planet cards.

Method -

1. There are different websites and mobile apps that release the live/updated position of celestial bodies. We can refer these websites or mobile applications to see the position of our planets on a particular day.
2. Open the online site to see today's position of our planets.
3. Take the umbrella and on its outer pointed end fix the hollow ball (making a hole in it), considering it as the Sun at the center.
4. Now referring the outward sequence of planets from the sun, their direction and relative positions (as seen today in the online website or mobile app) arrange the planet cards on the sky umbrella
(**Note** - The size and respective distances of the Sun and Planets are not according to scale)
5. Place the planet card on outer side of the umbrella and from inner side place the magnet so that through its magnetic force it sticks the iron disc of the planet card to a fix position. This way you can fix the planet cards on the umbrella according to their relative positions and direction from the sun.
6. Now taking yourself (at the earth) as the center, arrange the position of the Sun and planets on the sky umbrella.
7. Now referring the sky umbrella, draw the diagram of the relative positions of planets on a paper to keep the daily record.
8. By repeating the exercise continuously, you will have daily record of observations and diagrams in the record.

Data collection and Analysis –

- For each planet observe and record the direction of movement and relative positions from the Sun and from each other.

- Find the linear (orbital) distance travelled by each planet in a period of time with the help of online website/mobile app.
- Find the actual distance of the Planets around the sun and also from each other, with the help of online website/mobile app and mention that in the Sky Umbrella diagram that you prepare.
- Compile the record in the way you find appropriate.

Results -

You can present your observations related to changing position of the planets relative to the Sun and relative to your position (placing you as the Earth at the center).

Key points learned –

- This activity helps in generating awareness about our solar system and positioning of the planets in it.
- The exercise helps in learning proportional distance, direction, measurement and calculations based on observations.
- Children can replicate the sky umbrella using local material and alternative ways of depiction of figures / diagrams

Open ended questions -

- How do planets in our solar system maintain a linear path (without deflecting) around the Sun? Why don't they deflect and change their positions and distances from the Sun as well as from each other randomly?
- With the help of Sky Umbrella can you make arrangements of various constellations as they are seen in the sky?
- There are various mythological facts related to the nature and effects of the planets. For example, the Saturn's predicament, reprobation of the Mars etc. Is there any scientific basis of all these?
- Does the celestial position of planets affect the life cycle or physical or mental status of a person?