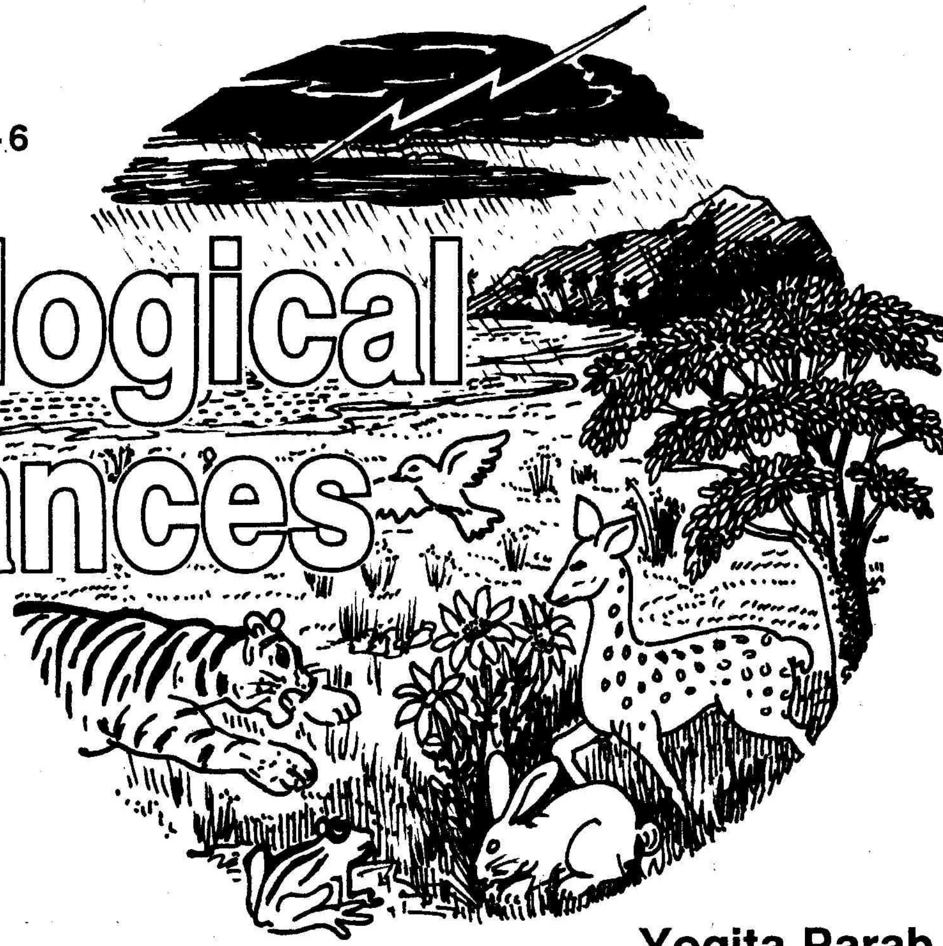
Activity Based Foundation course on Science, Technology and Society

Curriculum Book - 6

Ecological Balances



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Chitra Natarajan

Homi Bhabha Centre for Science Education
Tata Institute of Fundamental Research

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Foundation course
on Science,
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Yogita Parab and Chitra Natarajan

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1. The Population Problem
2. Resources: Energy
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4. Education
5. Global Climate Change
6. Ecological Balances

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The ‘Activity Based Foundation Curriculum’ has its genesis in the project for talent nurture among post-school students funded by the J.N. Tata Endowment Trust and conducted by Homi Bhabha Centre for Science Education (HBCSE) for three years since 1993. Besides providing adequate funds for the project intended for developing ‘good citizenship qualities’ among students of grades 11 and 12, the benevolence of the Late Mr. D.K. Malegamwala allowed the Centre both intellectual and economic freedom to select students and to experiment with innovative content and mode of interaction. After him, the project has received continued support from his successor, Dr. Suma Chitnis, Director of the J. N. Tata Endowment Trust.

The sensitivity to current issues and concern about education of young people evinced by Mr. V.G. Kulkarni, Founder Director of HBCSE, guided the project from its inception. Discussions with Dr. Phondke and Mr. Kulkarni have enriched the content of the series. Besides deriving the benefit of his rich experiences in the areas covered by the project, I have been inspired by Dr. B. M. Udgaonkar’s keen interest in the curriculum.

HBCSE Director, Dr. Arvind Kumar’s commitment to enriching students’ knowledge, and his participation and support in drawing up the content and format of the programme, contributed immensely to the success of the project. The series of books, of which this is one, is a direct outcome of the programme. Dr.Arvind Kumar has been actively involved in planning the overall content of the books. His encouragement and gentle nudges have been useful in bringing them out in print over a reasonable time span.

Besides Dr. Arvind Kumar, Drs. Bakhtaver Mahajan, Sugra Chunawala, G.C. Pal and Ms. Sandhya Karande conducted several sessions during the programme. Besides encouraging the project, Dr. H. C. Pradhan, through the programmes he has coordinated, has provided me opportunities to test some of the activities included in this book on selected students of secondary and higher secondary levels.

The participants of the programme in Mumbai were students from arts, commerce and science faculties of two junior colleges in the vicinity of the

Centre. The programme was also conducted at the D. B. F. Dayanand College of Arts and Science, Solapur, by Dr. N. S. Dhayagude and his team, where it was received well by the local participants. The participants of the Mumbai and Solapur programmes performed many of the activities included in the books, and enriched this endeavour by their enthusiasm and feedback. These young people's quest for meaningful activities is the *raison d'etre* for this activity based curriculum.

Yogita Parab, who had assisted me in every way in bringing out the first five books in this series played a crucial role in writing this one. It has been a pleasure working with her on all the books. Through her initiatives in the selection of material and organisation, and in generating new activities, she earned her coauthorship. Drs. G. Nagarjuna, Porus Lakdawala and K. Subramaniam have been of immense help in providing the needed human interface in all our computer interactions. Everyone at the Centre contributed to providing a problem-free working atmosphere.

Chitra Natarajan

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Chapter 1

The foundation curriculum

1.1 The need

The complex web of interactions between all spheres of human activity demand that prospective decision makers possess a repertoire of skills complemented by a reasonable capability to communicate their strengths, in oral and written form. Many of these skills are dependent on the domains of specialization: the study of biology may hone observational skills and the ability to classify and categorise; mathematics calls for logical skills, and the pursuit of sociological sciences calls for critical thinking and the ability to make complex linkages.

Both teachers and the taught readily acknowledge that science, technology and society are intimately linked. However, these linkages are complex. Hence, there is a need to adopt different methods in classrooms to encourage students to form such links. These pose problems for the teacher.

A factor that makes teaching issues at the interface of science, technology and society even more difficult is the proliferation of information. The information boom also comes in the wake of crumbling national barriers for trade and information exchange and a global notion of neighbourhood. Societies and individuals are reacting more rapidly to global changes than they ever did before. Changing environmental perspectives in Europe have led to migration of polluting industries into the developing countries. Tension in the Middle East or West Asia becomes an immediate cause for concern in Kerala. War, destruction, concern, recovery, rebuilding, and war again - cycles that used to take hundreds of years in previous centuries, now have a periodicity of less than ten years. Contemporary issues not only affect all citizens to some extent, but also call for a systems approach to its understanding and resolution, considering among other things, the technological, economic and socio-cultural linkages. This approach requires a certain attitude to problem solving.

Appropriate training can enable students to acquire problem solving abilities. However, increasing content specialization after grade ten, and lack of an integrated approach to learning before that, are hurdles to such a training. This situation can be partially remedied through intervention training programmes, be they at the level of higher education, or during professional on-the-job training.

1.2 A programme for post-school students

Such a training formed the principal objective of the programme funded by the J.N.Tata Endowment Trust, and implemented by HBCSE over three years at Mumbai and also for two years at Solapur. Developing a sensitivity to, and an understanding of, the complex linkages between science, technology and society, was the basis for the programme that aimed at promoting 'good citizenship' qualities among post-school students. The other vital input was strengthening the comprehension and communication skills of the students.

1.3 The curriculum

1.3.1 Genesis

The success of the programme, measured in qualitative terms — heightened sensitivity of the participating students, and their sustained interest — has inspired this Foundation Curriculum. The curriculum has been embodied in a series of books. The objectives of the curriculum preclude these books from being textbooks. Instead, these books outline a series of activities that lead from simple issues and ideas to complex ones, requiring the students to make the necessary linkages. The activities are also designed to develop the skills necessary for a practical understanding of issues at the interface of science, technology and society.

Most activities suggested in the books have been tried with post-school students during the programme. These could be used by any interested person — a teacher or leader of a forum — to develop comprehension and communication skills among members of a group of young people. They will be working on a broad canvas of issues at the interface of science, technology and society. Outlined below are the objectives of the curriculum, guidelines for interaction, and the topics, chosen for convenience, under which various issues will be discussed.

1.3.2 Objectives

The objectives of the curriculum can be summarised as follows.

- Offer guidance to students in improving their English comprehension, communication and analytical skills, besides quantitative reasoning. English has been chosen in the light of its being the language of global information flow.
- Integrate students' curricular knowledge with environmental and developmental issues of concern, thus giving a broad exposure to several disciplines.

1.3.3 Guidelines

Setting guidelines for interaction between the group of students and the teacher will go a long way in achieving the objectives stated above. A possible set of guidelines are listed below.

a. Sessions should be conducted in a participatory and interactive mode.

b. Sessions should involve thinking across disciplines, stretching the ability of participants to think beyond the obvious connections.

c. Relevance of the issues to daily life should be stressed, and participants should be guided in making decisions.

d. Weaknesses and lacunae should be assessed at intervals, through appropriate questionnaires.

e. Skills should be developed through suitably designed activities. These could include the following.

   - writing persuasive essays, poems, letters to local newspapers,
   - writing and staging street plays,
   - organised formal debates,
   - analysis of tabulated information,
   - comparison and quantification,
   - drawing charts and graphs,
   - designing games,
   - conducting interviews and surveys, and
   - visits to industries, research institutes.

1.3.4 Content

Activities designed to meet the objectives of skill development are grouped under issues of current concern. The issues are all interlinked and need to be treated that way. For convenience of presentation, these are discussed under the following topics.

- Survival of Humankind: Curricular Philosophy, and The Population Problem
- Education
- Health — Diseases, Drugs, and New Challenges
- Resources: Land and Air
- Resources: Food and Water
- Resources: Energy

- The Environment — Ecological Balances
- The Environment — Global Climate Change
- Information Revolution and the Media
- Social Conflicts, Gender Issues and World Peace

The present chapter, an introduction to the curriculum, is a part of each book, with a variation only in Section 1.4. It would be useful to revisit the discussion on *Survival of humankind* given in the book on “The Population Problem”, whenever in doubt about the goals of the session.

1.3.5 Duration and target group

The activity books are designed to be adequate in content for a 2-year course in Science, Technology and Society at the Higher Secondary level. The activities in the curriculum can be completed over a span of 200 contact hours. Some of the activities require the participants to collect data by library search or survey outside contact hours. However, many activities, mentioned in Section 1.4 of the respective books are essential for giving students a flavour of the issues. These may be covered over a span of 100 contact hours, about 10 hours per book. The large number of activities given in each book allow ample scope for a flexible and innovative approach to teaching.

The activities outlined in the books can, however, be used with any group of individuals with a minimum schooling of standard X (grade 10). It has been found to be harder to work with groups exceeding 30 members. This problem can be overcome by dividing the group into subgroups of smaller size. It would certainly help to have a common language of communication within the group. Since it is most likely that the books will be used in a classroom situation (say, higher secondary class), the participants are referred to as *students* in all the books.

1.3.6 The group leader

The objectives will be patently met if the group consists of a leader or coordinator, who has more than a cursory interest in the developmental issues of concern today, and enjoys making linkages. The students should be guided not only in making the obvious links, but also to go beyond them.

A coordinator with a formal training in cross-disciplinary thinking has a clear advantage, but a person with an open mind to the ideas of others, and one who feels that students cannot be all wrong, would do just fine. It would be useful for the group leader to be proficient in English, so as to be able to read and comprehend the proliferating information and communicate this to the group. It is most likely that the leader will be the teacher, and hence *teacher* in the books will mean the leader or coordinator of the group.

The leader plays a special role in all the activities outlined. The cardinal principles that govern the interaction of the leader with the group include the following.

i. Understand and value individual and group perceptions.

ii. Encourage listening by setting an example.

iii. While moderating discussions, support the apparently indefensible viewpoint.

iv. Attempt to raise the discussion from the level of free-standing personal statements —'I feel', 'I think', etc., with no accompanying justification — to coherent and logical arguments, with quantification wherever possible.

v. Allow for changing and evolving views during discussions and show a willingness to learn from the students.

vi. Encourage following firm rules during a debate.

vii. Facilitate and liven up discussions by introducing a new angle whenever possible.

viii. Use the 'let us find out' mode as often as is appropriate.

The role of the leader is far from a passive one. Encouraging the diffident student, guiding the overly confident one, finding loop holes in the arguments of a member without lowering self-esteem and being in control of the situation in a class full of thinking individuals is a challenging task. Yet, if viewed as an opportunity to improve one's skills of critical thinking, at the same time creating a generation of thinking individuals, the joy of such interactions can be infectious.

1.3.7 What this is, and what it is not

As already explained in Section 1.3, these books are not substitutes for textbooks, nor are they comprehensive. They are meant to give students a feel for 'real world' problems, without introducing the intractable complexities all at once.

There are very few problems of concern today that have either globally applicable, or locally unique, answers. As in any reasonable developmental approach, the answers to many questions must be sought within a local framework of society, politics and economics. In fact, increasing students' sensitivity to local needs and problems and putting these in the context of global concerns, constraints and opportunities, with examples of solutions arrived at in different contexts, is a tacit aim of the Foundation Curriculum.

Hence, it is an advantage for leaders and group members to have access to information, both local and global. The bibliography is indicative rather than exhaustive. Definitions and concepts can be sought and found in any relevant textbook available in a junior or senior college. Newspapers and locally available magazines could be additional and sometimes valuable sources of issues of debates. Many newsgroups and voluntary agencies provide information and clippings files free of cost or at a nominal charge. The group must, in the course of the interaction, generate and catalogue its own set of clippings files on issues of concern to the group.

The important, but rather difficult, questions of evaluation have not been addressed here. In this curriculum, more than in any other, evaluation of any form is a measure not only of participant's comprehension, but also of the effectiveness of the leader. Test questionnaires have been provided in some of the books as guidelines to assess the effectiveness of interaction in the course and to help take corrective measures.

1.4 This book

Sixth in a series of books planned on issues in *Science, Technology and Society*, this book deals with ecological balances. The environmental movement gained momentum in the 1970s following Rachel Carson's book "Silent Spring". Since then concerned people all over the world have been exchanging that human beings are upsetting the delicate balances in nature. This book is about balances in nature, and about how the matter, which Earth inherited during her formation, is being cycled through the living and non-living components.

The book provides a brief introduction to Ecology, in itself a vast area of study. It invites the students to a discussion of the nature of the growth and dependence of communities of organisms. Through activities in the 3^{rd} and 4^{th} chapters, students should become familiar with biomes, niches and species diversity. The last chapter raises questions about the role of human beings in the dynamic interdependence in nature through a discussion of some ecological disasters of the last few decades in India and elsewhere.

Like the others in the series, this book too requires participants to engage in a variety of activities, including staging dramas, poetry-writing, poster-making and debates and discussions. If some of these activities are carried out outside class hours, contents can be covered in 20 contact hours. For a shorter course of 10 contact hours, you could select Sections 2.1, 2.4, 2.4.1, 3.3.1, 3.3.2, 3.4, 3.5, 3.5.1, 3.5.3, 3.5.4, 4.2.1, 4.2.2, 4.3.1, 4.3.2, all subsections under Section 4.4 and Chapter 5.

Chapter 2

Balance

2.1 Ideas about balance

Nature manipulates all its components through a set of rules perfected over the years. No component is arbitrarily favoured for survival or extinction. Responses and adaptations of the components to every change in the environment generate new and dynamic patterns. Moving towards a balance — (not necessarily reaching one!) is the only dogma of nature.

This book is about recognising some of the pathways to balances in nature. In particular, this chapter will address the idea of balance.

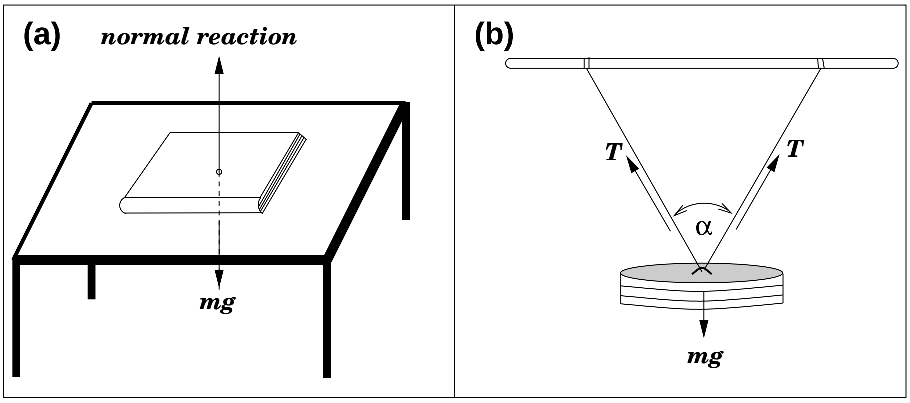
Context map

1. Do you read a newspaper? Recollect the word 'balance' in combination with other ideas in the newspapers and in your every day life. List the ideas.

2. In school science, you have drawn diagrams to depict the balance of forces on a material body. Draw some situations around you that show the balance of forces. For instance, the forces on a book on a table (a) and a weight hung by 2 threads at an angle (b) are shown in Figure 2.1.

3. You equate the number of atoms, and quantity of energy on either side of a chemical equation to balance it. The chemical equation for

Figure 2.1: Balance of forces: a book on a table (a), weight hung by 2 threads at an angle (b).



burning of coal could be simply written as,

$$C + O_2 \rightarrow CO_2 + 394\ Kilojoules\ energy\ per\ mole$$

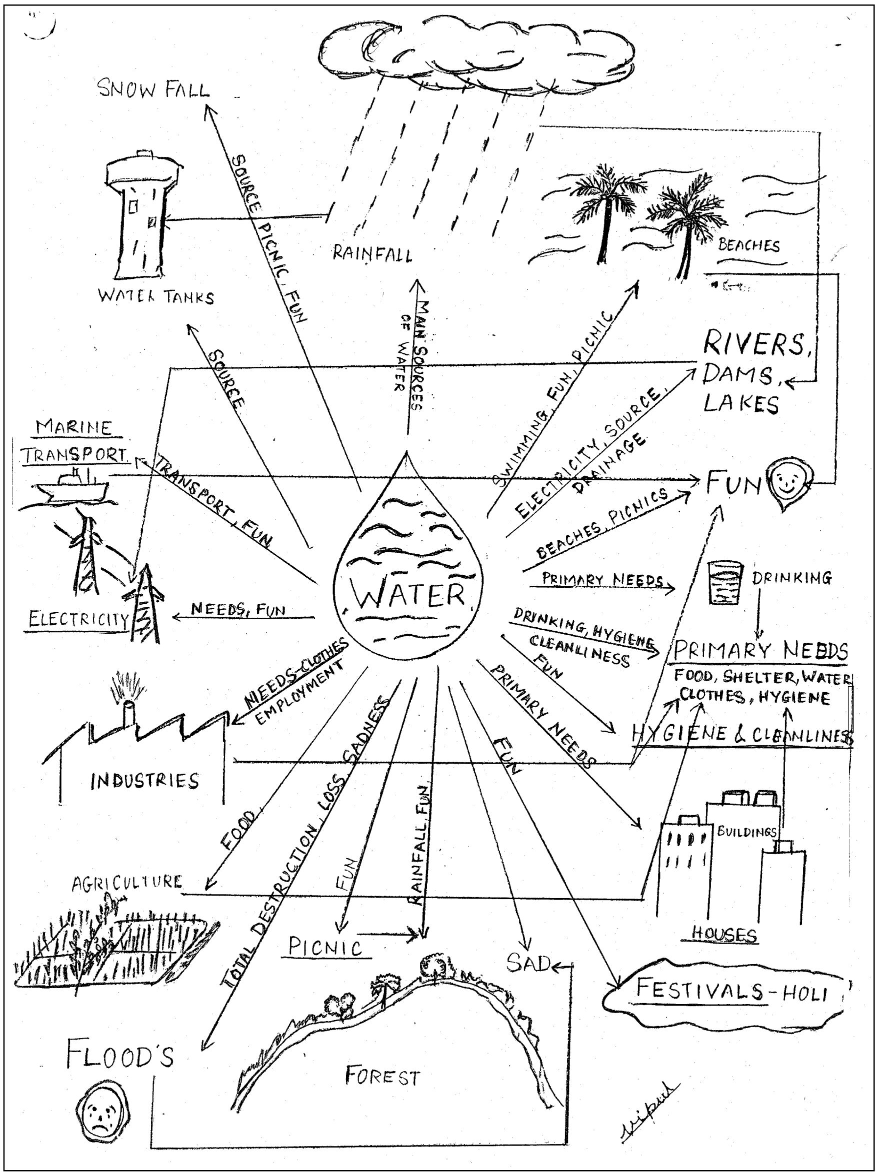
You are also familiar with mathematical equations, like $25 \times 4 = 100$ or $(a+1)^2 = a^2 + 2a + 1$. Write 5 examples of such balances that you have encountered.

4. List all the ideas that the word '*balance*' brings to your mind. It can be fun to use the technique of **context maps**. This is how you would go about mapping your ideas about *balance*.

   Write the word on a paper. Around the word, draw or write all words, phrases or events which you think relate to the notion of a balance. It can be an object (grocer's balance), or a concept from your school science. Represent these in your map. Include even those ideas that are remotely related to the notion of a balance, feelings and emotions too. After filling your sheet of paper with words and pictures, connect those ideas which you feel are related. On the connecting line, explain the link (why you think they are connected). Figure 2.2 gives a sample context map on *water* made by a student of grade 11.

5. Display your context maps around the classroom. You will be amazed at the variety of ideas that different members of your class came up with. Discuss the most common feature and the rare, but important features in all the *context maps*.

Figure 2.2: Context map of water.



2.2 Balance and equilibria

In mathematical terms, the relation between two quantities, A and B can be stated in one of the following ways,

- A is greater than B; $A > B$,
- A is less than B; $A < B$,
- A is equal to B; $A = B$.

The factors influencing 2 quantities A and B may be either common or completely different. Varying one factor may affect either of the quantities A, B or both. The effects may be similar or different.

Consider the number of tall trees, small shrubs, herbs, insects, birds, reptiles and mammals in an old reserved tropical forest. At any time these numbers bear a set of relationships with each other. It may happen that the number of insects are greater than the number of fruits available. It may follow that the number of fruit-eating birds are less than the number of insect-eating ones.

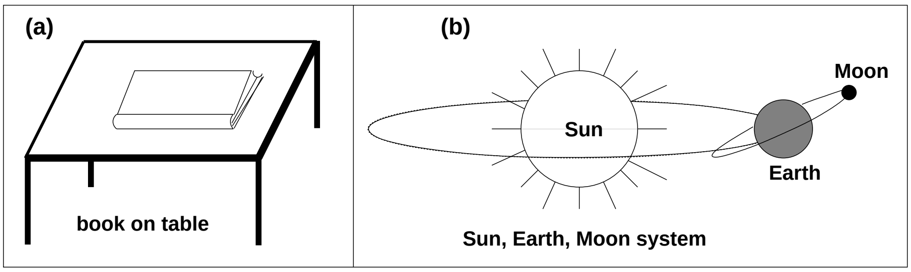
Insects, fruit trees and birds are also subject to changing conditions: factors like rain, temperature, natural disasters, human habitation nearby. As a result of such changes the relationships may either change or be maintained. If the changes lead to increased fruit trees, they may attract more insects and hence maintain the relationship among the birds. On the other hand, the fruits may be in tall trees and preferentially attract more fruit-eating birds.

The factors may vary continuously, like changes in average temperature of Earth — a fraction of a degree over several millennia. They may change in spurts and jerks — in discrete steps, like sudden floods.

For a system in **equilibrium**, the net effect of all the factors, affecting its components is zero. That is, the relationships between its components do not change with changing factors. Any system in equilibrium can be described being in **static** or **dynamic**, and **stable, neutral** or **unstable** equilibrium. You will learn to differentiate between different states of equilibria through the following activities.

1. Consider the two situations given in Figure 2.3: a book on table (a),

Figure 2.3: (a) book on table and (b) sun, Earth and moon system.



and the sun, Earth and moon system (b). Discuss the differences between them. Describe the relationship between the book and the table if left undisturbed. What is likely to happen if you pushed it lightly, or hard? Would you say that the book and table are in equilibrium with each other?

2. An equilibrium of a set of objects in which the objects maintain not only their relationship, but also their state (or value, in the case of quantities) is a **static equilibrium**. This is the situation obtained for the book on the table.

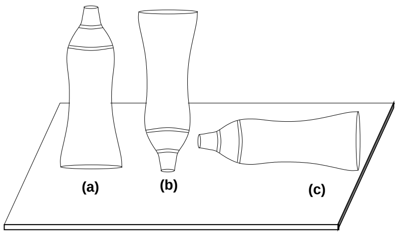
   Now, consider the sun, Earth and moon system. Earth and the moon together have been continually moving around the sun. This state of motion has not changed significantly over millions of years. Is this system in equilibrium? Explain. Are the Earth and the moon in equilibrium with each other?

3. A set of objects could be changing their state (or value) continually and yet maintain a steady relationship among them. In fact, these relationships characterise the system. Since the relations remain the same over time, you would say that the sun-Earth-moon system is in equilibrium. But the bodies or quantities are not static; they are *dynamic*. Such an equilibrium is called **dynamic equilibrium**.

   List 2 examples of objects in static equilibrium. Similarly cite 2 examples of objects in dynamic equilibrium.

4. Equilibria can be analysed in one more way. Consider these 3 situations (Figure 2.4): a soda bottle placed right side up (a); the same bottle placed upside down (b); or the bottle placed on its side (c). Push the bottle gently. Increase the force on the bottle until it topples over. In which position will the bottle topple with the least push? Why?

Figure 2.4: Stable and unstable bottles.



5. Consider bottles with broad bases and narrow mouths, empty bottles and bottles filled with water or sand, tin cans, both empty and filled. Place all these objects on a flat surface, some on its base, some upside down, and some on their sides. Which ones among all your objects are most resistant to push? You might say those are most stable with respect to push.

6. Consider an object or system of objects in equilibrium with its surroundings. If it is highly sensitive to some changes in its surroundings, and these changes, though slight, can upset its equilibrium, then it is said to be in **unstable equilibrium** with respect to those changes. On the other hand, when the object or system is almost insensitive to some changes (say, push) and resists them, the object is said to be in **stable equilibrium** with regard to those changes.

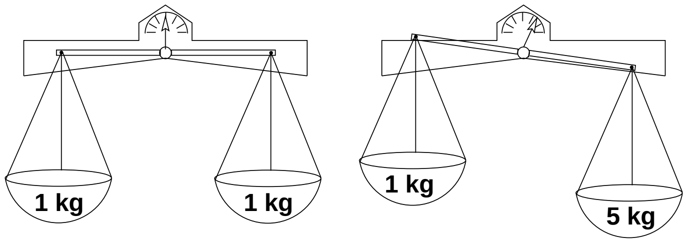
   Give five examples of stable equilibrium. Choose the examples from natural systems, social systems, economics and such varying areas.

7. A system of objects can be in either static or dynamic equilibrium; not both at the same time. Stability of the system on the other hand concerns a property relative to one or more specified factors that change. First, there was no push on the bottle. Then there was the push. The *push* factor changed. Write a page explaining the difference between ideas of *stability* and *equilibrium*.

8. With respect to a push with a certain force, a bottle, even an upside down one, is more stable than a steel pin on its head. Which is likely to change its state if you heat the two to high temperatures?

9. You have just discussed how one system can be more stable than another with respect to one change (push) and less stable than another with regard to another change (heat). Most inter-related set of objects around us can be described as being in static or dynamic equilibria which may be more or less stable under a specific change.

Figure 2.5: What makes me stable?



Against each situation given below, mark whether it is in equilibrium and if so, whether it is static or dynamic.

- A rock resting on a mountain peak (precipice),
- The same rock after it has rolled into a valley,
- Wickets in a game of cricket
- Stumps in cricket
- Floating piece of wood
- A swing in motion,
- Water in a sealed jar,
- A seed in the soil,
- A seed in a bottle in your kitchen,

10. The first four examples are actually 2 pairs of situations, each pair involving the same or similar objects under 2 different environmental conditions. For each pair, state which is the more stable situation. (*Hint: You will see that there is an assumption of a changing factor. Make it explicit in each case.*)

11. Each of you list ten more examples of systems in equilibria. Classify the items in your list as static or dynamic. How many examples of static equilibrium did you list? How many were dynamic? Compare your lists in the class. Which equilibrium – static or dynamic – was listed more often?

12. Figure 2.5 shows two double-pan balances used in a grocery store. One balance has equal weights of 1 kg each on its pans. The other has 1 kg weight in one pan and 5 kg in another. Are both these balances in equilibrium? Is the equilibrium static or dynamic? Which is the more stable system? To what change? Why do you think so?

In nature, it is very hard indeed to find a system which is not subjected to any change. It is even harder to find a system that is static, that is, constant despite changing factors. Nature is dynamic. The rest of this book is a joy ride through a study of some natural, interesting, interdependent systems in dynamic equilibrium.

2.3 Cycles in nature

School biology has taught you that some needs are common to all living organisms — be it an ant, amoeba or elephant. All living beings use solar energy directly or indirectly. Besides, they need gases from the air, and minerals that make up their bodies. In short, they depend on soil, water, and air. Bodies of living organisms are largely constituted by elements like carbon, hydrogen, nitrogen, oxygen, calcium and smaller amounts of phosphorus, sulphur and some metals. Many of these elements are essential for life processes. These are needed in different proportions at differing stages in the life cycle of a variety of organisms.

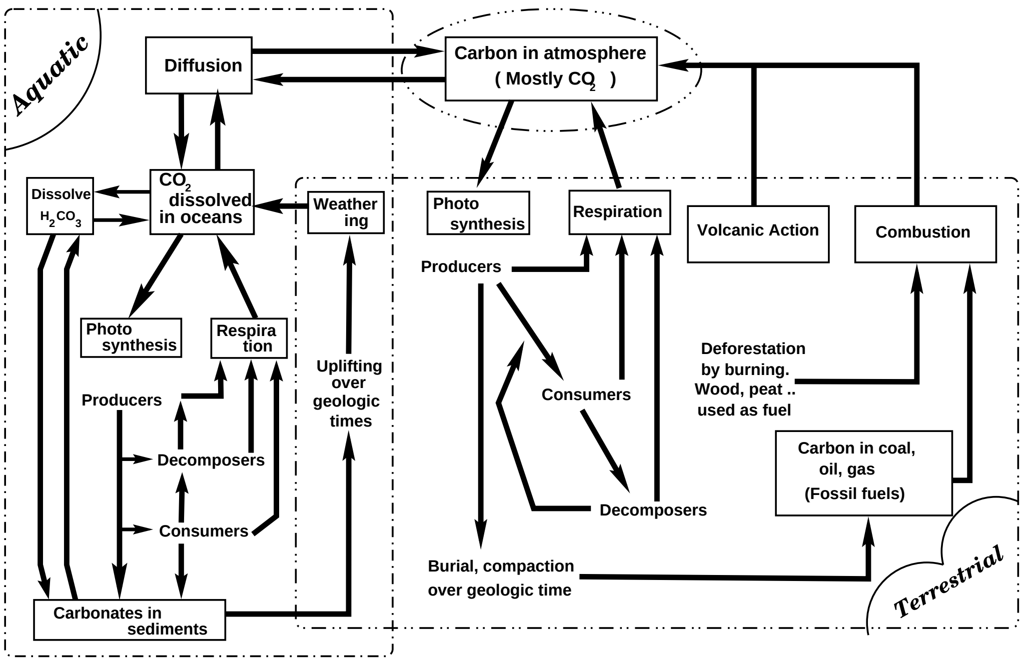
The elements needed for life are not *used up* permanently. Nor do they get replenished from outer space. Several generations of organisms have used the existing quantities of elements. These have been **cycled** in the Earth and its atmosphere for billions of years. Starting out in one compound, each atom moves through several compounds, as each transforms through processes in nature, until it is found in the starting compound again. Perhaps, several carbons in your body were once part of a Brontosaurus 65 million years ago! They may have passed through successive **cycles** through land, air and water.

The cycles of chemical elements used in the life processes are called **bio-geo-chemical** cycles. The time for each step in a cycle is, however, different, depending on the abundance and location of that element, and the role of living organisms in the cycle. In the following sections you will discuss the carbon, water, nitrogen and phosphorus cycles.

2.3.1 The carbon cycle

Figure 2.6 shows a global carbon cycle. [1] There is, in fact, no life without carbon. Carbon is so much a part of everything around you that you

Figure 2.6: Carbon goes around.



will find it harder to pick a carbon-free object in your surrounding than a carbonaceous one. It occurs in combination with other elements, notably, with hydrogen, oxygen, and nitrogen. The carbon cycle involves transformations of carbon compounds. These include simple molecules like CO_2, as well as chains of many carbon atoms with hydrogen and other atoms. Through the activities below, you will construct the carbon cycle.

1. Every cell in your body has carbon. Name two components that contain carbon within any cell in your body.

2. Where did that carbon in your cell come from? Trace where that carbon may have been in the past.

3. Imagine that you are a carbon atom. For this and the next few activities *you* are a carbon atom. *Your* life starts from a stage some 50 to 100 million years ago in the body of some interesting plant or animal of that time (find out what lived on Earth then, and choose *your* life form). Write a couple of pages on *your* transformation till today, when *you* find yourself in the skin cell of a human body. (*Hint: You may look up the evolution of life on Earth from a book, or refer to the*

book in this series titled "Global Climate Change".)

4. Compare the autobiographies of different carbon atoms (all your friends in the class!). How many of *you* (as carbon) were part of a fossil fuel? Assume that it would take at least 100,000 years for a dead tree to become part of a fossil fuel. How would *you* become a part of the fuel?

5. How many of *you* ever became carbon dioxide in the atmosphere? How did *you* get there? List the ways in which *you* could.

6. Did any of *you* get into the body of a fish? How? Was anybody dissolved in the oceans or any water body?

7. Were any of *you* compressed into a bottle of Cola? CO_2 in the atmosphere could react with rain water, form a mild acid (carbonic acid) which may react with rocks, forming salts containing carbon. Can you weave this aspect into *your* story?

8. Volcanic eruptions spew a lot of CO_2 and carbon salts. Where could this have come from?

9. Among all the passages that the carbon atom in your stories went through, how many could not have happened without the intervention of humans? List them. In what ways can humans affect the global carbon cycle?

10. Consider 2 forests in similar climates and soil and of the same area: one is a newly forming one and the other is an old forest. Which one would be a better sink for carbon? Why?

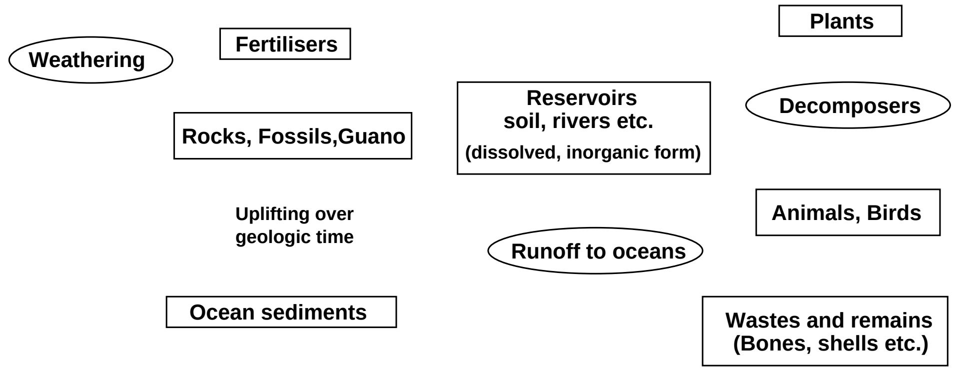
11. In what ways might pollution affect the carbon absorbing capacity of water bodies?

2.3.2 The phosphorus cycle

Phosphorus, found largely in the Earth's crust, is another element essential for life. The quantities in which it is consumed by life forms makes a difference to their growth. Certain life forms thrive in increased quantities of phosphorus, upsetting the variety of organisms there.

Phosphorus cycles are rather slow in nature, in contrast to the carbon cycle. Most of the reservoirs keep carbon for a short time. Phosphorus

Figure 2.7: Steps in the phosphorus cycle.



stays in a reservoir for longer times, partly because most of its compounds are relatively less water soluble. Besides, it is rarely found as a gas. It is found in the atmosphere as small dust particles.

Some steps in the phosphorus cycle are listed below. Using these steps (in any order you like) and the information in Figure 2.7 describe the phosphorus cycle. [1]

1. Phosphorus is washed from land into water bodies by rain and irrigation (run off), and as industrial wastes.
2. Phosphorus may stay in oceans for a few million years. The sediment at the bottom of the ocean are converted into rocks.
3. Geological changes like uplifting of sea beds expose deep ocean rocks.
4. Birds consume aquatic creatures with phosphorus and nitrogen in them. Excreta of birds bring the phosphorus back to soil.
5. Phosphorus is stored in the soil mostly as phosphates and in combination with iron, calcium, potassium, etc.
6. Phosphorus from the soil is taken up by plants. Animals get phosphorus from eating plants and other animals.
7. Decay of organisms returns phosphorus to the soil.
8. Fertilizers, natural and human made, increase the phosphorus content of the soil.

9. Phosphorus in larger amounts in lakes and ponds, triggers the growth of photosynthetic bacteria (that can use light to form food) and green algae (a microscopic green plant floating on water in large numbers). Blocking of light from deeper waters by surface growth of bacteria and green algae destroys aquatic life. This is called **eutrophication**.

2.3.3 The water cycle

Water is one of the basic needs of living organisms. Over two third of Earth's surface being water, it takes part in most of the cycles of matter. You will now construct the water cycle, the one you are most familiar with. Water cycle is divided into two distinct processes regulated by solar energy:

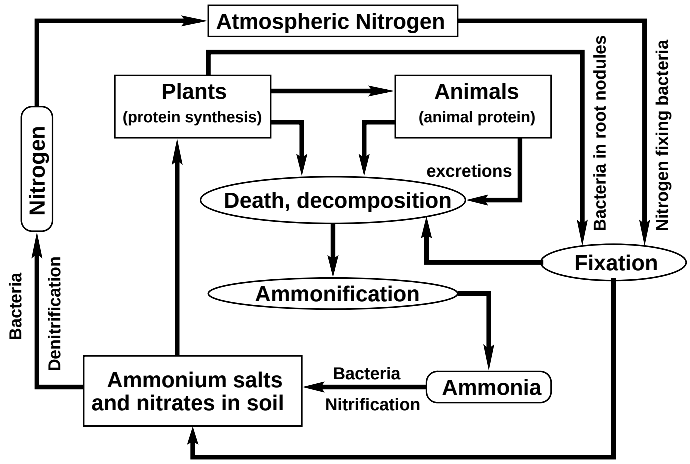
Evaporation : conversion of liquid water to water vapour.

Condensation : conversion of water vapour to liquid or solid form. This is familiarly known by many names depending on the final form. Snow is loosely bound, light, crystals of water, while sleet is rain as cold as ice. When there is a hailstorm, you can collect ice cubes in an inverted umbrella. Fresh dew drops on clean leaves on a spring morning are a pleasure to behold.

The steps in the global water cycle are listed below. State whether each one involves the process of evaporation, condensation or neither. Depict each scene below through a simple labelled illustration. Use your imagination to make it meaningful. Then put all your scenes together to form a picture of the water cycle. Describe the parts of the water cycle that affect the people in your town the most.

1. It rains on land and water.
2. Streams and rivers flow into lakes or oceans.
3. Water evaporates from surfaces of land, canals, streams, lakes, rivers, and oceans, to form clouds.
4. Floating clouds cool, and rain.
5. Water seeps into land and forms under-ground water reserves.

Figure 2.8: The nitrogen cycle.



6. All life forms consume ground water and surface water. Ground water is tapped by humans through wells.

7. Geysers are formed from ground water by geological pressures.

8. Respiration releases water in animals and plants into the atmosphere. Transpiration of plants also releases water into the atmosphere.

9. It snows at high altitudes (heights) and in high latitudes (farther from the equator).

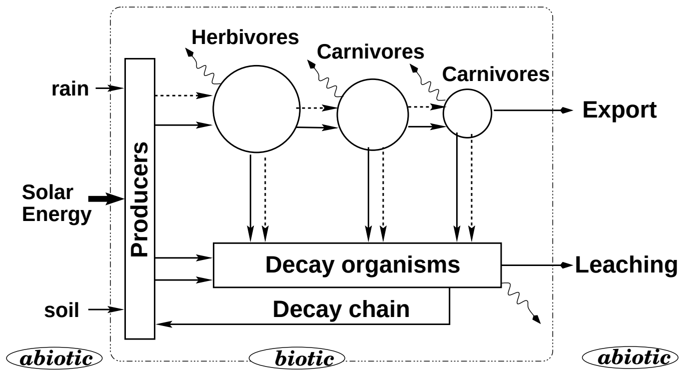
10. Ice caps form on mountain tops and there are land-masses of ice closer to the poles.

11. Ice melts because of a slight increase in temperature. Melted ice and glacier flows into water bodies.

2.3.4 The nitrogen cycle

Nitrogen constitutes almost 80% of the atmosphere we live in, it is highly mobile and is rapidly recycled. Figure 2.8 shows a nitrogen cycle. [1] Nitrogen begins its cycle as a molecule in the atmosphere. Through various processes indicated in the figure, this molecule passes through life-supporting compounds, soil, bacteria, bodies of living organisms, water and back to gaseous molecule again.

Figure 2.9: Net flow of energy and nutrient.



Describe the nitrogen cycle giving as many specific examples of each process shown in the figure as you can. For instance, for *biological fixation*, you could say that bacteria in the nodules of groundnut plant convert (fix) nitrogen from the atmosphere into nitrogen compounds useful for the plant.

2.4 Energy and nutrient flows

Life processes consume some energy and matter, and release some too. Materials, in the form of gas, liquid or solid which is used by living organisms for their growth and repair are commonly known as nutrients. In that sense, all life processes are merely steps in a continuous flow of energy and in the cycling of nutrients. Figure 2.9 is a symbolic representation of the relationship between the non-living (abiotic) components and living (biotic) components of the world. Arrows show the direction of flow of matter and energy. [9]

1. What is the primary source of all energy? Explain why you think so. What are the primary sources of nutrients? Who (among the living world) use these primary sources directly?

2. In what form do the herbivores derive their energy and nutrients for growth? Name some herbivores and list their source of energy and matter.

3. Is energy cycled? In other words, does the energy from a source get back to the same form, even after a long period of time? Justify.

4. The wavy lines in Figure 2.9 indicate *loss* of energy. In what form is this energy? What role does this energy play?
5. There is no equivalent wavy line indicating loss of matter or nutrients. Should there be one? Explain your stand and discuss in the class.
6. *Leaching* in the figure refers to the process by which a part of the material reaches the soil. It is usually dissolved in a solvent like water or acid. *Export* refers to the matter that mixes with soil. What roles do these have in the flow of matter and nutrient?
7. Are nutrients cycled? For instance, will an amino acid in an animal's body, after passing through several processes become an amino acid again, even if this is in another animal's body? Whether you agree or not, illustrate your point by describing one possible route that it could take. Which organisms did you include in your route? Discuss your route with others in the class. Did anybody include routes and organisms different from your own?
8. Which organisms, according to you, are absolutely essential in order to maintain the processes of energy and nutrient flow? Discuss your answers in class.
9. Form groups of 5 members. Draw the flow of energy and nutrients for a familiar community of living organisms, say an agricultural field. Give the names of the various organisms involved. Make a poster on this theme.

Solar energy is stored on Earth in the chemical bonds of compounds. All life forms need energy to live. Yet, they need it in different forms. For example, though solar energy is available in large quantities, it cannot directly give you the energy to do your daily work, or for that matter, propel the housefly through the air. Plants are the special organisms which convert solar energy into a form that is easy to store, transfer and reconvert for the use of all other living beings. They are said to be at the first **trophic level**. Animals need to consume plants or other animals as food to satisfy their energy needs. Herbivores are at the second trophic level. Carnivores occupy the third or higher trophic levels depending on whether they consume herbivores or other carnivores. The decay organisms are essential for converting the flow of nutrients into a cycle. They are nature's recyclers.

The food you eat

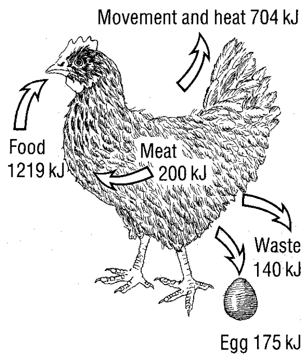


Figure 2.10: Energy balance in a hen.

Whenever you *feel* hungry, you realise it is time to eat. Food helps you to do all the things you can. In fact, you know that it is essential for your life. How is the food used by your body? If you added up the weight of food intake over a period, and subtracted the weight excreted in the same period, would you arrive at the increase in your weight during that time? Following the steps given below, estimate the amount of food consumed by your family over a month and discuss what it was used for.

1. Note the age and weight of each person in your family at the beginning of a month.
2. Note the total quantity of food bought by the family for the whole month. You could estimate the food in the house on the first day of the month (x) in kg. Keep account of food items bought each day for a month (y), including grains, fruit, vegetables, milk, snacks or drinks. Estimate the food remaining at the end of the month (z). The food used up would be $w = x + y - z$.
3. Note the approximate quantity of food material (either liquid or solid, in kg) that is thrown out as garbage each day, say g. Continue this for a month.
4. At the end of the month, calculate the quantity (in kg) of food consumed by your family, say w-30g. Try this during a month when you had least number of visitors.

5. At the end of the month, note the weight of each member of the family. Find the net change in the weight of your family, all members together.

6. Is the difference in weight equal to the food eaten by the family? Compare the results in the class. How does the change in weight compare with the food intake of the family?

7. How would you account for the difference between the food intake and the gain in weight? List all possible ways in which the food you eat may be used by your body. Divide the list into (i) excretion, (ii) growth and reproduction, and (iii) respiration. Estimate the quantity of each for an average person like you. Also estimate your average food intake over the month.

8. Were there members of your family or those of your friends' whose weight has changed significantly? Is the difference in weight related to the age of the person? Explain how.

2.4.1 The food flow

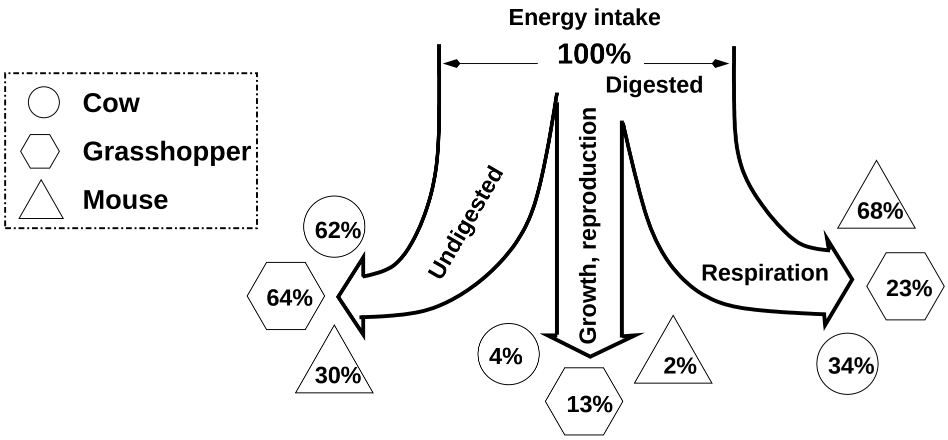
Food is a storehouse of energy. Animals and plants consume and store food. They break down the energy stored in their food whenever they need energy to perform tasks. The tasks may be moving, growing, breathing, reproducing, transporting materials from one place to another or just being still. Plants store food in their *body* as sugars and fats, just as animals do.

1. Figure 2.10 shows a daily energy balance of a laying hen weighing 2 kg. [3]How much energy does the hen consume in the form of food? In what ways is this used up by the hen? How much of this energy is released outside the hen's body? What fraction of the total energy is this released energy?

2. What percentage of the input energy is utilised for growth and reproduction together?

3. If the hen were starving, where would the energy for her activities come from? How will this modify her daily energy balance?

Figure 2.11: Energy flow for different kinds of animals.



4. Figure 2.11 shows patterns of energy flow for three different animals: grasshopper (hexagon), mouse (triangle), and cow (circle). [22] The total energy gained by the animal from all possible sources is considered to be 100%. The figure shows the distribution of this energy for the major needs of each animal. What are the common features in the figure for all three animals? What are the differences?

5. The mouse uses a greater fraction of its energy intake for respiration than do the others. Why do you think this must be so?

6. What happens to the energy used up in respiration, and the energy used in reproduction?

7. Explain the differences in the amount of energy thrown away as undigested food in the 3 cases. Would all the excreted energy get *wasted*? Is this used, perhaps, by another animal? Illustrate your argument through an example.

8. Draw an energy flow diagram (like in Figure 2.11) for the hen discussed above and for yourself as discussed in the last section.

9. Form groups of 3-5 members. Consider three animals, the first being a herbivore (which eats plants), the second eats the herbivore (carnivore), and the last is an adult human who eats the carnivore. Make imaginary (but realistic) flow diagrams of energy through these 3 organisms. How much of the total energy consumed by the herbivore will be available for the growth and reproduction of humans?

Explain to the class your picture, and the arguments for supporting your case.

10. Chickens eat worm meals, while humans eat the chicken. An African tribe relishes *mpane* worms. Who would consume less weight of food for the same amount of growth: the chicken-eating human or the worm-eating one? Justify.

Source: Centre for Science and Environment [12]

समता

क्या मानव, क्या खगकुल
कैसी यह समता ।
मिलती सर्वत्र है
निज संतति की ममता ॥

जीवन विविधा का भव्यरूप
कर देता मन को मंत्रमुग्ध ।
तृणपत्रोंकी रचित कुटी से
झांक रहा लघु विहग प्राण ।
निकलेंगे कब पंख मिलेगा
इस नन्ही दुनिया से त्राण ॥

कृष्ण कुमार मिश्र

2.4.2 The Wondrous Ways of Nature

Eons have passed, billions of years,
The once fuming globe is adorned
At present with teeming lives.

The Sun that sets and rises,
The moon that shrinks and grows,
Cycling of seasons – ■
Burning hot to showering rain
And shivering cold,■
From sweaters back to sweat again.

Plants sprout on all surfaces,
And grow, droop and decompose,
As tender saplings take their place.

Rivers that murmur and flood,
Enrich their beds, feed the hungry.
And quench thirst, refresh lives.

Volcanoes rumble and erupt,
Spewing molten lava,
And poison gas
Burning all, kindling life anew.
The eternal game goes on
With assets brand new.

Winds that blow, and shake
the boughs
Break the trees, and deposit seeds
Gently in their cradle to grow.

Earthquakes that rumble,
crack the land,
Swallow lives, gift a mountain,
Or a valley of flowers.

Each moment so new and thrilling,
Makes this game e'er challenging.
Some past is lost,
Some present feared,
While tempting hope beckons
Toward seductive future.

Unsure of a win or loss,
All run in the race of time;
Some on two legs, some on four,
Some on plenty, some on none,
Different strengths, diverse goals,
Follow radiating routes,
That often meet afresh,
Start and end are same for all.

Some lead the group,
Some lag behind,
Some jump the track
And join amid.
Life flows smooth and fine,
So long as nature
Is the law-maker,
Leader and the guide.

Think you can frame rules ?
And divert nature's flow ?
Heading for a crash ?
Pay heed, practise and learn,
From nature's laws and tricks.

Wish to frame rules and
command the rest?
Just ensure it doesn't crash on you.
What you need to learn and practise,
Are nature's own laws and tricks.

Chapter 3

Ecology

Have you ever wondered at all the variety of living beings around you? Some are so familiar you almost take them for granted. Others seem amazingly new and draw your attention. Humans have always been curious about the living world. They have made many efforts to understand and explain the variety. In this chapter, you will discover how intricately connected, and yet delicately co-ordinated, natural systems are.

1. You must have noticed grass grow in a variety of places: small patches of soil, wide stretches of land or even small crevices on pavements, between stones and rocks. What differences did you observe in their growth? It is common wisdom not to plant a big tree (say, peepal or jack-fruit) near a mango tree. What relation might this suggest?
2. Butterflies live only for a few days, during which time they lay hundreds of eggs. Yet, you rarely find hordes of butterflies around you, nor do you see the ground littered with their corpses. How would you explain this?
3. Are all types of land equally cultivable (used for growing crops)? If you were fool enough to clear a portion of a mountain forest, say in the Sahyadri ranges, for how many years could you grow crops

there? What difficulties might you have? Would it be different from the agricultural land in the plateau?

4. The last 3 activities have raised some questions about the living world around you. List at least 10 questions that you would like to ask about the world of living beings. Discuss in the class what you can do to find the answers to the questions you have asked.

You may not arrive at the answers to the questions you have raised through the study of school biology alone. The answers are best provided by a combination of different disciplines of study within the sciences.

Questions that concern types of living beings, the group each belongs to, its survival needs, its life cycle, and the effect of scarcity and abundance of resources are answered by biology. Chemists could enlighten you about the bio-chemical processes that sustain living beings. Laws of mathematics help you study populations of living beings, their proportion among others, their rates of breeding and death, and the relationship of all this to present population and prediction of future populations.

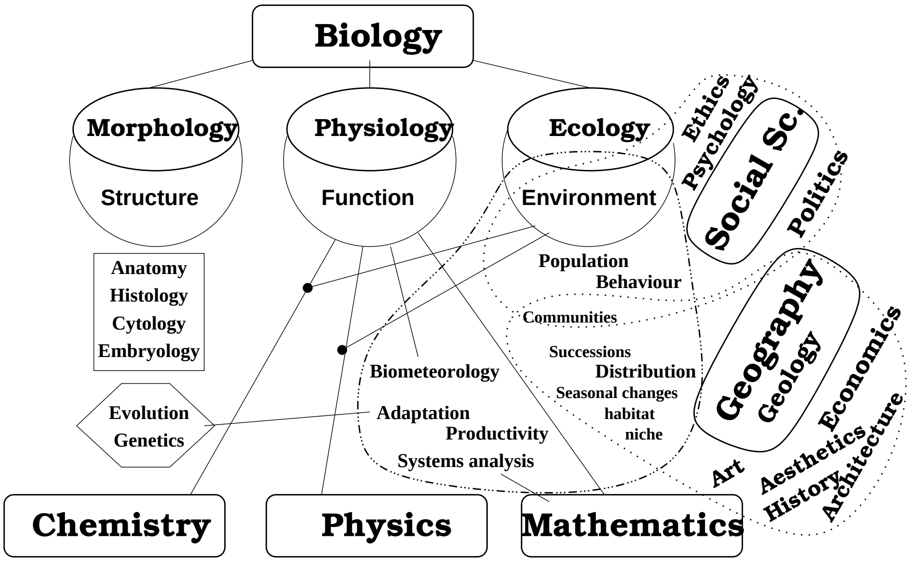
Physics provides justification of existing features of living beings in the context of physical laws. For instance, a physicist could argue based on the material properties of a cow why it cannot be as small as an ant or grow as big as an elephant while at the same time preserving all the functional features of a cow. It also explains the laws governing matter and energy use, and their interactions with the living world.

Your questions about living beings are very special. People who are deeply interested in questions about whole groups of living organisms and their environment (surroundings) are called **ecologists**. They find their answers through a study of a branch of biology called **ecology**. (Figure 3.1)

3.1 What is ecology?

Ecology is a study of the interactions between living organisms and their environment. The word *oikos* in Greek means 'house'. The term *ology*, a suffix for many subjects of specialisation in college, means 'a study of'. *Ecology*, a word coined by the biologist **Ernst Haeckel in 1866**, and derived from '*oikos*' and '*ology*', literally means the 'study of homes'. Thus, it stands for the study of the relationship between the organism and its

Figure 3.1: Ecology: a study aided by many disciplines.



home, or the environment, in which it lives. Besides the physical non-living surroundings, the environment includes other organisms as well.

Consider a fungus, the powdery "stuff" you see growing on over-ripe decaying fruits. It absorbs the chemicals in the fruits across its special membranes. The process of absorption involves several physical laws: laws governing movement of electrolytes across membranes, osmosis, etc. The conversion of these chemicals into food for the fungus, and the growth of the fungus depends again on another series of physical laws by which the food moves from cell to cell, chemical reactions and cell division.

Ecology not only builds upon all the basic sciences, but also enriches them because of its systems approach: treating whole groups of inter-related things together, rather than trying to understand them individually. This is indicated in Figure 3.1. You can get an idea about the complexity of this study if you imagine that living beings are the most complex organisations of molecules in the world, and Ecology is the study of the complex interconnections among these and their environment.

1. List all the words you know that begin with '*eco*' and note their meanings. Write a sentence or two using each word. How many different words did the whole class find?

2. For each word listed, name a profession that might be connected with it — either in its study or in using the term. Is it considered a scientific profession?
3. List all the words you know that end with '*ology*', and note its meaning. How many different '*ologies*' were listed by the whole class? Discuss the area of study that each of you plans to take up.
4. Are there branches that you have listed that were once common, but are not followed by anyone at the present time? Are there branches that are relatively new? How would you rate Ecology on this scale?

3.2 Living together

Physical and chemical laws govern the interactions between material particles. Life, in all its myriad variety, is essentially an organised collection of material particles. However, the organisation is so complex that it is nearly impossible to understand and predict the behaviour of even the simplest individual life form in terms of physical and chemical laws alone.

All living beings, necessarily interact with both the living and the non-living environment. These interactions may affect the organisms and their environment in harmful or beneficial ways. This forms one basis for classifying their relations.

3.2.1 Competition

Life in the natural world is filled with examples of competition for life-sustaining needs.

1. Have you noticed what happens when a dog wanders into a territory to which it does not 'belong'? Describe the possible reaction of the other dogs there.
2. Imagine a garden of exotic plants, or fields of grain or pulses. What would happen if the garden or fields were not weeded over a long period?

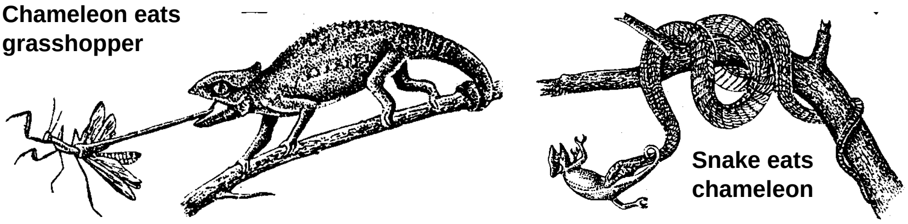
3. The dogs compete for use of territory, and the weeds for space to grow. The dogs, or the weeds and the exotic plants are said to be in **competition** with each other. In these cases two or more organisms share the same set of resources for their food or shelter. Hence they try to control the resources. In the first case of the dogs, the competition is among the members of one species. The weeds are in competition with another species, the grain or exotic plants. Form groups of 3 members. List 3 instances each of
   - competition among members of a species, and
   - competition between members of two or more species.
4. The word 'competition' is commonly used in various contexts, some examples of which are given below. In which of these contexts is the word used in the same meaning as in the (above) ecological contexts? Explain each case.
   (a) A class of 70 students, each trying to score a higher rank than the others. They are *competing* for the top rank.
   (b) Seven athletes running on 7 tracks, *competing* to come first.
   (c) Seven swimmers in a swimming race in a narrow single-lane pool. They are *competing* to come first. Explain the differences between the previous example and this one.
   (d) Several teams in the World Cup football match. They are *competing* for the trophy.
   (e) Politicians of different parties canvassing for votes in a particular locality. They are *competing* to be the elected representative.

3.2.2 Predator and prey

All living beings need to consume *food* in one form or another. Plants consume 'simple' molecules and minerals from the soil as food. Animals depend on plants and other animals for satisfying their food needs. Figure 3.2 is an example. [6]

1. Animals that feed on other animals are *hunters* or *predators*. The eaten animals are the *prey*. Animals which feed on plants are *gatherers* or *grazers*. This kind of relation or food dependence between

Figure 3.2: Predation.



two species is **predation**. In groups of 3 members, list 10 examples of such relationships among living beings. Your list must involve examples from both plant and animal kingdoms.

2. In all the examples given by you, what can you say about the habitat, or living space, of the prey and the predator? In each example, note how the predator benefits from the existence of the prey.

3. Does a prey have only one predator in its environment? Does a predator consume only one kind of prey (members of one species)? For each predator in your list, name other prey that live in the same environment. And for each prey list other predators.

4. An animal, or even a plant, may be a prey and a predator. In each example that you have listed, write a prey of the prey and a predator of the predator.

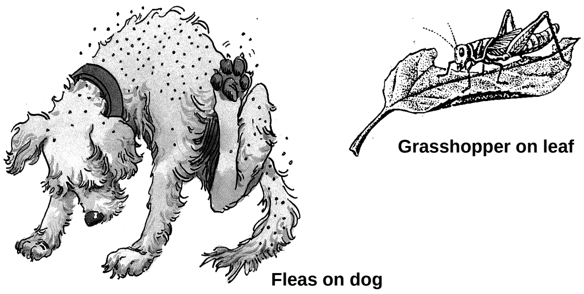
5. In the following examples, list all the relationships of *predation*.

   - A mosquito that bites you gets caught in a spider's net and is eaten; a lizard swallows the spider and the cat eats the lizard.
   - A beetle eats smaller insects and larvae, a sparrow eats the beetle, an owlet eats an unwell sparrow, and an eagle eats the owlet.

6. A large jungle was home to 10 herds of deer, with about 40 deer in each herd, and 4 tigers. The deer in that jungle had no other predator and the tigers largely depended on the deer to satisfy their hunger. In one year, poachers hunted down all the tigers for their skin. What could happen to the deer population?

7. Is the above situation realistic? Argue, in about one page, that the predator-prey relationship benefits both the species involved. (*Hint: This is not about benefits to individual members in the species. The consumed individual will not benefit!*)

Figure 3.3: Parasite and pest.



8. In what ways is the food relationship among animals different from that between animals and plants? For instance, how would you differentiate between these 2 relations: a rabbit and the carrot plants, and a wolf and the rabbit?

You have argued in the last section that the predator and prey benefit each other. Were you troubled by the example of the mosquito and humans? Surely, the mosquitoes do not benefit humans!

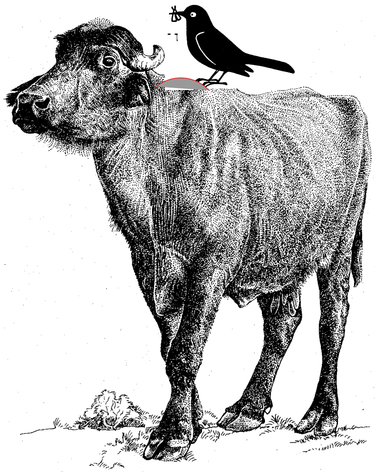
3.2.3 Pests and parasites

You will see that pests and parasites, like mosquitoes and the bacteria they carry, serve a purpose in nature.

1. Have you heard of someone who had worms in their intestines? You would want to get rid of caterpillars, fungi or viruses from plants. What is the relationship between the worms in your intestines and you, or the fungi, caterpillars and the plants?
2. How is this relationship different from predation? (*Hint: Consider the sizes of the species involved and their effects on each other.*)
3. The worms, fungi and viruses in the above relationships are all **parasites** or **pests**. The species, which they use for their survival, are the **hosts**. This relationship is called **parasitism**. List 3 other parasitic relationships among living beings (Figure 3.3).
4. In your list, explain how each organism gains or loses in the relationship. Should all parasites be totally exterminated (killed to extinc-

tion)? Debate this issue in the class, giving examples to prove your point.

3.2.4 Helping relations



The predator-prey relations result in long-term benefits for both the species. However, the individual prey is not benefited. It dies. On the other hand, there are relationships where none of the individual members lose, and at least one of them gains through the partnership. Such relationships are termed as **commensalism**.

1. Relations between pairs of species are given below. In each case, one of the species gains and the other, called the *host* is neither harmed nor benefited. Identify the host in each case, and explain the benefits for the species in each pair.

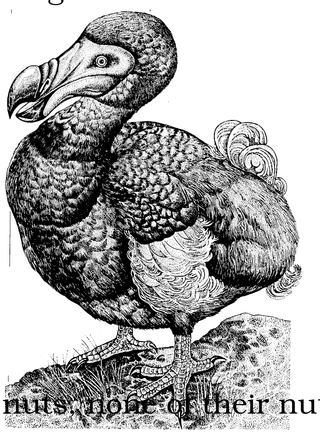
    - Crabs live in the burrows left behind by shrimp.
    - Snake lives in ant-hills and mole-burrows.
    - Barnacles attach and grow on the skin of whales.
    - The remora fish attach themselves on the back or body of sharks, or sea turtles. When the shark or sea turtle feeds, the remora fish consume the scraps of food floating by.

2. Describe the relationships given below, giving the advantages and disadvantages (if any) for individuals of the two species involved.
   - You and your pet dog.
   - The cow and the farmer.
   - Leguminous plants and the nitrogen fixing bacteria.
   - Bird riding a buffalo.
3. Which of the above relationships is essential for the survival of both the species? Such dependence is called **mutualism**. List five examples of mutualism.
4. What kind of relation do humans maintain with other living beings around them?
5. Do humans always gain from their interactions with other species? Are there instances where humans are 'used' for the well-being of another species?
6. Write about a page clarifying the difference between the benefits for an individual and the advantages for a species. Illustrate your points through examples.

3.3 Moral of the story

The two stories discussed in this section illustrate the interdependence of living beings. While the first one is a historical account [19], the second is an imaginary story. These stories, reveal the beautiful, intricately woven web of life.

Figure 3.4: The dodo.



3.3.1 Dodo and the nut

In 1973, a scientist (naturalist) discovered that all the trees of a particular kind in Mauritius were over 300 years old. About 13 in number, they were all dying. Though they bore fruits and nuts, none of their nuts were germinating. The scientist then happened to recall that about 300 years ago the last dodo was killed there. Figure 3.4 is an artist's impression of a dodo. [6] The scientist deduced that the nuts would not germinate unless they were first eaten by a dodo and had passed through its gut. Stones in the dodo's crop (a pouch in its gut) may have helped grind up the nuts, softening the seed-coat, so that the seedling could grow.

The dodos were extinct, and no other bird on Mauritius was able to crush the hard nuts of what the scientist called the *dodonut* tree. The scientist knew that *turkey*, a kind of bird found in the American continent had a crop (gut) similar to that of the dodo. When turkeys were brought from America, and they were fed the nuts from the dodonut tree, the seeds in the turkeys' droppings were seen to germinate. Thus, turkeys had to be introduced in Mauritius for the dodonut trees to be saved from extinction.

1. What does this story warn you about?
2. What adaptive advantage might the tree have in bearing nuts with hard seed-coats? You may do some 'research' on the climate, soil, flora and fauna of Mauritius to make up a realistic story about the possible advantages.
3. Many Indian trees have hard seeds. The Indian Laburnum *amaltas*, is one such tree. Find out the conditions under which it grows best and the time taken for its seeds to germinate. Do you know of any other tree with a hard seed-coat?
4. The dodo and the tree were 'made for each other' species; one was a plant and the other an animal. Do you know of any such plants and animals in India? List them and discuss the species in class.
5. Turkeys were introduced to Mauritius island. The island's flora and fauna had not evolved to deal with these birds. What new problems may the turkeys introduce into Mauritius?

3.3.2 Parkars' farm

Parkars are an agricultural family. They depend on seasonal rains for their annual needs, and work hard during the kharif crop season. They grow sufficient crops in the season for their annual food needs, and sell some in the market. They own many farm animals, like cows, bulls, buffaloes, dogs, cats and poultry. Discuss Parkars' farm and their lifestyles.

1. Parkar's youngest son *Pamya* had to sell the grains in the market. He wondered why they had to work so hard to grow extra grains which he had to sell. Discuss, in pairs, Pamya's question. One of you can be farmer Parkar, and the other, Pamya.
2. Parkar's teenage daughter *Gautami* does not like her chore of cleaning the cattle sheds, kennels and coops. She thinks it is a waste of effort to have animals in the farm. Do you agree with her? Persuade her about the advantages of owning animals on the farm.
3. *Motthi Aayee*, their grandmother, explains to the family that growing a combination of crops and vegetables and owning a variety of domestic animals is the most efficient way of using their land. List the important points that Motthi Aayee must have made.

3.4 Food relations

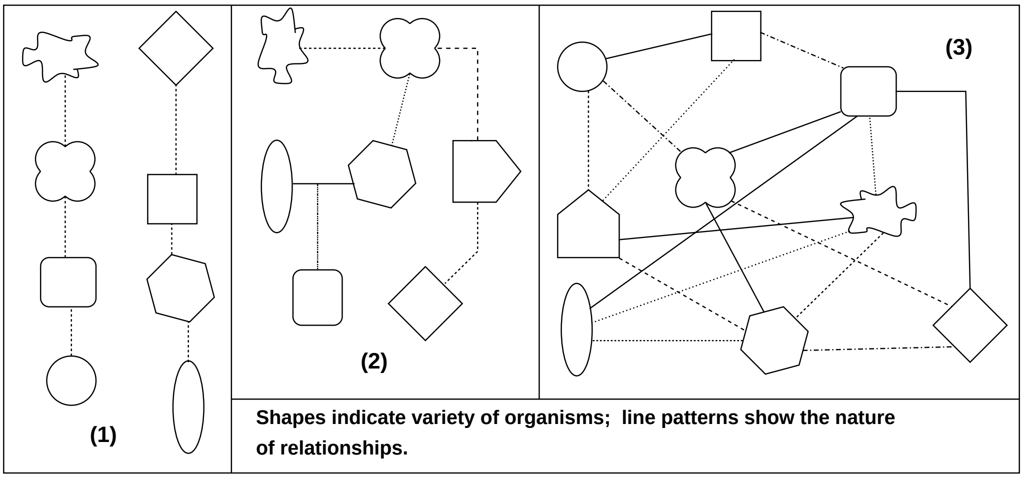
Of all relationships, those based on food needs are the most important, and account for the largest number of relationships in the living world. In Section 3.2.2 you had listed prey-predator relations starting with different organisms. This section is about the complex web of food relations. (see Figure 3.5)

3.4.1 Food web game

All the students in the class will participate in this activity. Five of you form the 'control team'. Play the game in a big room or on an open ground.

1. Discuss in class and choose some environment like terrestrial (land-based) or aquatic (water-based): a pond, lake, ocean, river valley, forest on a plateau, desert, urban area. List on a newspaper, with a sketch pen many names of organisms that belong to the area you have chosen. Select animals and plants of all kinds (as many as the number of participants). Each of you will pick an organism from the list, that you will represent throughout this game.

Figure 3.5: Chains: unlinked (1), linked (2) and webbed (3).



2. One member of the control team calls aloud the name of an organism. The member could say, "There is a *cricket* (name of organism) in this *garden* (environment)." Each member then decides whether she or he is related in any way to the announced organism. All those bearing any relationship to the organism will connect with it by a thread (grocer's packing thread or a jute rope will do).

   Each connected organism then identifies itself loudly. One might say "I am a *chameleon* and the *cricket* is my *food*." After each such identification, other related organisms, either already present in the connection or new ones, will connect themselves with the newly identified member. This will continue till all the students in the class have identified themselves.

3. While the game is being played, the control team documents and guides the events. At each step, the team notes the connected organisms on a newspaper and links them with lines. You can use the format given in Figure 3.5 for this purpose. For each stage of the game, use a different colour or a different kind of line (dash, dotted, etc.). Note how the connections develop.

4. Look for some necessary but missing links and complete them. Which organisms in the class were the most connected? Were all their relationships of the same kind or were they different (food, shelter, etc.)?

5. Which organisms were the least connected? List some possible reasons.

6. Now a control team member announces "*Cricket* (organism name) is extinct." The corresponding member then quits, leaving all the threads on the ground. All organisms drop those strands that are connected to the extinct organism. Those who have no strands left, also become extinct. If this situation does not occur, the organism that has the minimum number of threads becomes extinct. This is repeated until more than half the organisms are extinct.

   Note the number of organisms removed by the first extinction (first step), after the second round of extinction (second step), and so on.

7. Each of you should now do at least one of the following activities.

   - Write a page or two marvelling at the connectedness of all the organisms of the World.
   - Write and recite a poem on the web of life.
   - Write and narrate a story on the importance of understanding that all organisms are dependent on each other, directly or indirectly.
   - Script and stage a street-play on why we must refrain from indiscriminate killing of other organisms (including use of pesticides and other biocides). Suggest alternatives.
   - Script a skit on the dangers of introducing alien life-forms (like a new plant, animal or even importing manure) into a place.

All organisms have their own characteristics, needs and functions within the environment in which they live. Hence they occupy a particular location and share a set of resources. Sometimes groups within a species may differ in their characteristics. For example, food, shelter and other survival needs of Eskimos of the Arctic are very different from ours in India. Most species largely depend on the energy, nutrients and habitats available in the near vicinity. They form an interconnected system.

3.5 Ecosystems

Organisms are intimately dependent on each other and their physical environment. How far does an organism's physical environment stretch? Practical considerations would suggest that organisms depend maximally on the resources — including living and non-living ones — within limited areas.

All regions on Earth contain communities of plants and animals, which have a set of complex, interwoven relations among them and with the non-living components in the region. For some regions all these relations are contained within the region itself. They are comparatively less dependent on the components external to the region. Energy almost always comes from the Sun. Such *self-contained* collections of living and non-living components are termed as *ecological systems* or **ecosystems** for short.

You could, for the time, ignore the fact that energy is *imported* from the Sun. Ocean waves and climates are not only global, they also depend on the moon. Other than these influences, the whole Earth, together with its surrounding atmosphere has adequate resources to support all life on Earth. This is the **biosphere**.

This section is about ecosystems and how they operate. You will answer questions like, "How would I recognise an ecosystem?" or "Where might I find a particular ecosystem?"

1. Consider an oasis in a desert. For the date palms, the oasis is their *whole world*: the resources available there meet all their needs. In order to study date palms in their environment, you could focus on the oasis. Argue that an oasis in a desert is an ecosystem.

2. Camel is a desert animal. Can you study the camel and its environment by focussing on the oasis? What constitutes the physical environment of an organism?

3. Whether you choose the whole biosphere or just an oasis as an ecosystem, would depend on the species of animals and plants that you want to focus on. List the common characteristics of an oasis and the biosphere.

4. Argue that the biosphere is a sort of *super ecosystem* that contains many other ecosystems within it.

5. Climates, land composition, and altitude vary over the Earth. Each combination of these physical conditions has a typical collection of interdependent species living in it. The physical environment, together with the communities of organisms living in it forms a **biome**.

Figure 3.6: Biomes on Earth, their distribution by climate and latitude.

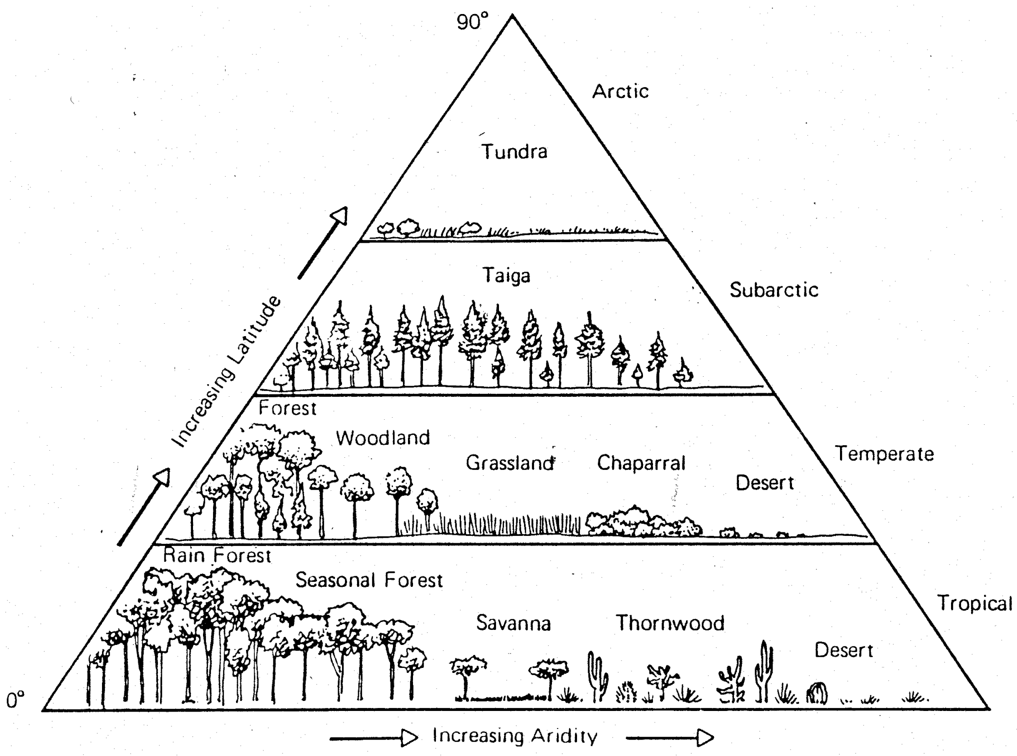


Figure 3.6 shows some familiar biomes. [20] List the prominent features of each of them.

6. Biomes often have names corresponding to the most abundant or important species living in them. These species are called the **dominant species**. Biomes may also be distinguished by their climates. Each biome is an ecosystem. It may consist of many subsystems, which are also complex ecosystems. The pictures in Figure 3.6 indicate only a few dominant species of living organisms. Guess some other possible organisms in the biome.

7. Can there be a biome in which the dominant species is an animal? Explain your answer in about a paragraph.

8. List the countries where you may find each of the biomes. (*Hint: Refer to your school geography.*)

9. Name the biomes that you will find in India. Mark the places, with different colours for different biomes, on a map of India.

Table 3.1: Is this an ecosystem?

S. No.	Place	Ecosystem? Y or N	Justify in brief
1.	lake		
2.	forest		
3.	garden		
4.	zoo		
5.	aquarium		
6.	tree		
7.	you		
8.	city		
9.	farm		
10.	sanctuary		
11.	garbage heap		
12.	satellite		
13.	cave		
14.	puddle		
15.	well		

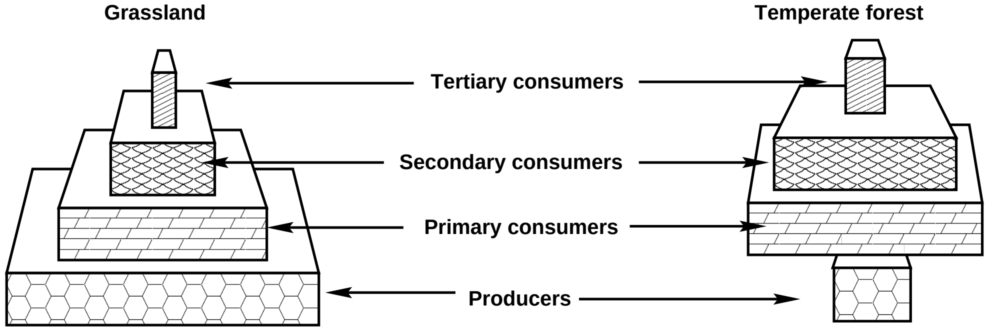
10. List the typical animals and plants that you might find in each biome in India. Write an essay (about two pages) about your visit to a place, describing its natural vegetation, and animal population. Be sure to include small herbs, insects, reptiles, birds and other details.

11. The biomes discussed above are natural ecosystems. Are there ecosystems that humans create and maintain? Name one, and explain why you would call it an ecosystem. Table 3.1 is a list of places familiar to you. State whether each is an ecosystem and why you would say so.

3.5.1 Energy and biomass stacks

Rain forests have the largest variety and populations of plants and animals, while deserts have the least. Variety and population of organisms is one more way to classify biomes. In this section you will compare biomes in terms of two parameters: (i) number of species at each trophic level and (ii) the dry weight or biomass at each trophic level, in the ecosystem.

Figure 3.7: Grassland (a) and Temperate forest (b) ecosystems: number of species at different trophic levels.



You could, for instance, list the number of different species in the ecosystem and then arrange them in the order of their food dependencies — the trophic levels. The organisms which depend least on others will be at the bottom of the stack; the organisms that only depend on these, will be above them, and so on. The organisms, which depend on all others for their food, will be right at the top. You could represent the organisms at each level by rectangular blocks of equal height, but different widths depending on their energy or food consumption.

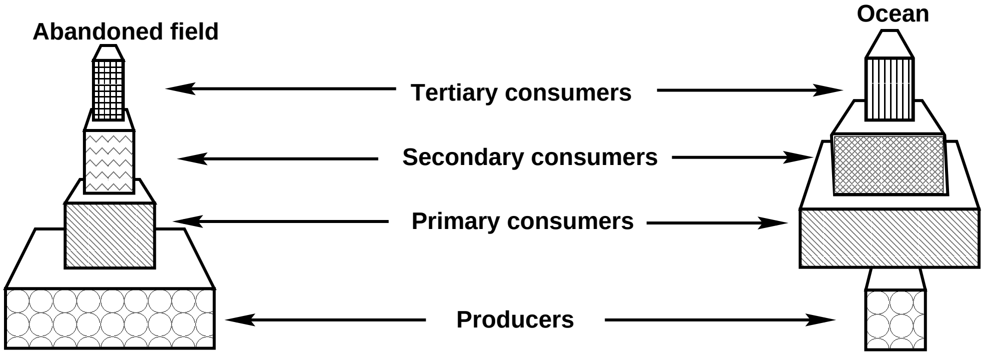
A stack made from these rectangular blocks placed in the order of their levels tells you a story about the ecosystem. You will discuss such stacks, representing energy flow or mass transfer within an ecosystem.

Grassland and temperate forests

Figure 3.7 shows stacks for grassland (a) and temperate forest (b). Each rectangular block represents the number of species in a trophic level. [16]

1. Name an organism at each trophic level in the two stacks.
2. In what ways are the two ecosystems in Figure 3.7 similar? What are the differences between them?
3. In India, where would you find the grassland ecosystem? Where would you find a temperate forest?
4. Imagine that you are walking through a grassland. Your friend has chosen to walk through a temperate forest. Who is likely to count

Figure 3.8: Abandoned field (a) and ocean ecosystems (b): biomass at different trophic levels.



more “producer” species in 10 steps? How would you predict this?

5. Which of the 2 stacks in Figure 3.7 is more stable? An insensitive person (a timber contractor?) has cut down equal areas of the two ecosystems. Which system will he upset to a greater degree? Explain. What can you say about the balance of the two systems?

6. Explain the fact that a smaller number of producers support a larger number of consumers in a temperate forest.

7. Imagine that you can weigh the producers and consumers in one square metre of your ecosystem. How would these weights stacked according to trophic levels look? Discuss the shapes of the 2 stacks.

An abandoned field and the ocean

In Figure 3.8 biomass rather than the number of species at each trophic level is used to make the stacks. [16] It shows stacks for an abandoned field (a) and an ocean (b). The size of each tier represents the dry weight per square meter of all the organisms at that consumption (trophic) level.

1. Give one example of a species at each level in the 2 stacks.

2. In what ways are the two systems in Figure 3.8 similar? What are the differences between them?

3. Explain the difference in the bases of the 2 ecosystems. The producers in the ocean ecosystems are microscopic green organisms called

phytoplanktons. Which part of the ocean would have them in greatest numbers? Why would you say so?

4. How are the producers in the ocean different from the producers in an abandoned field? Compare them in numbers, size and rate of reproduction and growth.

5. Explain how a smaller biomass of producers in an ocean is able to support a larger biomass of consumers. *Remember that whales and sharks weigh 20-40 tons.* Comment on the nature of the balance in the ocean ecosystem.

6. Estimate the number of producers and primary consumers you might find in one square kilometre of these ecosystems over one year. How would a stack based on your estimated numbers look? Why is the time important? Discuss this in class. Discuss the shape of each stack separately.

7. Write about a page comparing Figure 3.8 for an abandoned field and ocean ecosystem with the grassland and temperate forest ecosystems in Figure 3.7.

8. Biomes have a rich variety of species and complex webs (dependence) of life-forms. Many biomes, like rain forests or grasslands do not seem to change significantly over long periods of time. The Savannah existed for thousands of years. Argue whether they are changing at all, giving as many evidences as you can to prove your point. Discuss the evidences in class.

9. Ecosystems that have reached an apparently unchanging condition in terms of the variety and number of species are said to be **climax ecosystems**. The communities of species are said to be **climax species**. Ecologists believe that even the stability of climax ecosystems is a very delicate one. Do you agree? Write a page justifying your stand.

3.5.2 Productivity

Since the plants form the very foundation on which every ecosystem rests, just knowing the plants in an ecosystem — their variety, numbers, shapes, strengths and weaknesses — provides clues to the nature of the ecosystem. The role of plants as the producers of the ecosystem is determined by their **productivity**. Productivity is an important characteristic of an ecosystem.

1. What do plants produce? How do they produce it (the process and the materials they need)? List a few chemical substances produced by plants which you use as food or medicine.

2. The total amount of matter prepared by plants is called **gross productivity** (*GP*) of the plant. Plants themselves need some of this food. Explain how plants might use up some of the food they make.

3. Let *UP* be the amount of matter used by plants for their life processes over a certain period. The amount of matter available to the consumers over the same period is called the **net productivity** (*NP*) of the plants. The relation between *UP*, *GP* and *NP* is,

$$NP = GP - UP$$

   Which is greater, GP or NP? Will NP vary from day to night (diurnally) or with seasons? Explain.

4. All the plants in an ecosystem may not have the same productivity. Hence, you may define *average net productivity* (**ANP**) as an average *NP* for all plants in an ecosystem. As food fulfils the energy needs of life processes, productivity is expressed in units of energy, kilocalories per square meter per year (Kcal/m^2/year). Consider an ecosystem with an *ANP* of 560 Kcal/m^2/year. How many kilocalories can it provide over a decade to the animals living in $1\ km^2$ of area?

5. Respiration and burning of coal (combustion) are both processes that release energy. One kg of coal contains 30 megajoules of energy. One calorie of energy corresponds to 4.2 joules. Express the energy in the above ecosystem per decade per m^2 in terms of kg of coal.

6. Table 3.2 shows the average net (primary) productivity (ANP) in some of the major life zones and ecosystems on Earth. [16]

7. Why does the tropical rain forest differ from the temperate forest in productivity? (*Hint: Recollect the characteristics of each biome.*)

8. Savannah, a natural ecosystem, and human maintained agricultural lands, support different communities of organisms. Write a paragraph explaining how they may still have comparable productivity. Which of the other ecosystems have similar productivity?

Table 3.2: Estimated average net productivity (ANP) (Kcal/m^2/year) in some of the major ecosystems on Earth.

Type of ecosystem	**ANP**	**Type of ecosystem**	**ANP**
Tropical rain forests	9000	Lakes and streams	2200
Temperate forests	5700	Open ocean	1200
Savannah	3000	Tundra	700
Agricultural land	2900	Extreme desert	100
Temperate grasslands	2200		

9. Lakes, streams and open ocean are water ecosystems. Explain why they have different productivity. Compare and contrast the tundra (Antarctica, or Siberia) with extreme desert (Thar, Gobi or Sahara) in terms of their productivity.

10. Which ecosystems in the table are relatively more stable? Which one is more mature? Explain your answer in about a page.

All communities in the ecosystem adapt to a certain level of productivity in the ecosystem. The following sections are about some fascinating aspects of such adaptations.

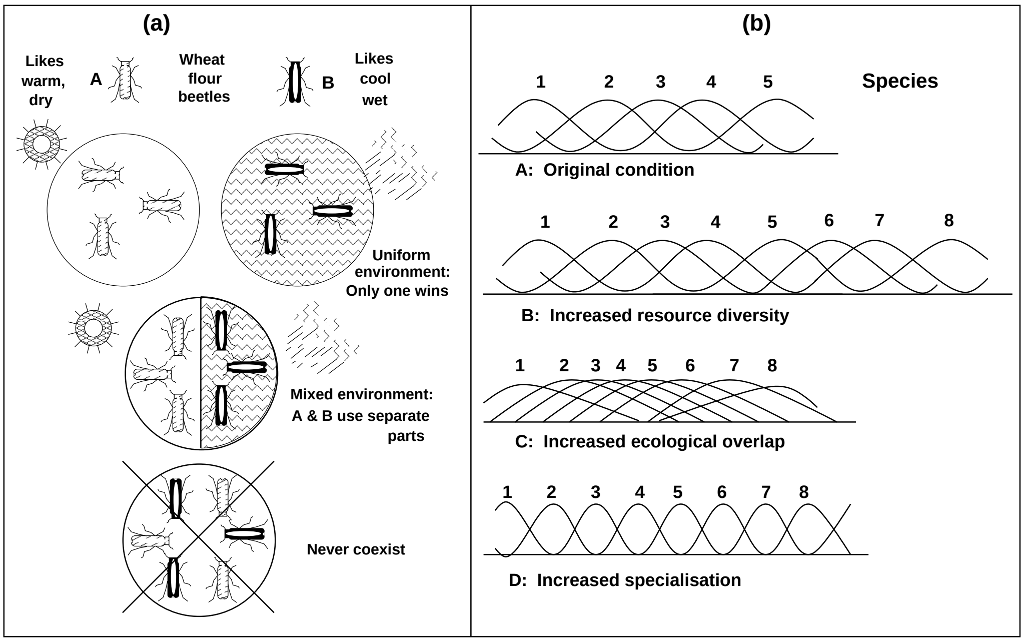
3.5.3 Ecological niche

One important relationship among the vast variety of life-forms in nature is competition. Does that mean that all organisms spend their whole lives fighting for survival with other organisms? Consider the following example.

There are over 17 pests living on the coconut palm. [10] Most of these spend some stages in their life cycle on the tree. Some even spend their whole life on it. The young *rhinoceros grub* lives in the soil near the tree while its *adults* live on the leaves. *Red palm weevil*, both the grub (young) and the adult, live on the stem, but at different heights. Thus all life forms living on the same coconut palm do not occupy the same location. They also have different functions and seasonal habits.

The combination of habitat (living space) of a species, its habits of eating, living and reproduction, considered in time and space, are together called the **ecological niche** of the organism. Ecologists have discovered an im-

Figure 3.9: Ideas about niche: (a) 2 species of flour beetles in wheat flour; (b) Resources, number of species and overlapping niches.



portant law regarding a niche: **two different species never occupy the same ecological niche.** In fact even different life forms, like the young beetle (grub) and its adult do not share a niche. [1]

1. List all the animals found in a home. Include insects, reptiles and mammals. Explain that they obey the rule about ecological niche.

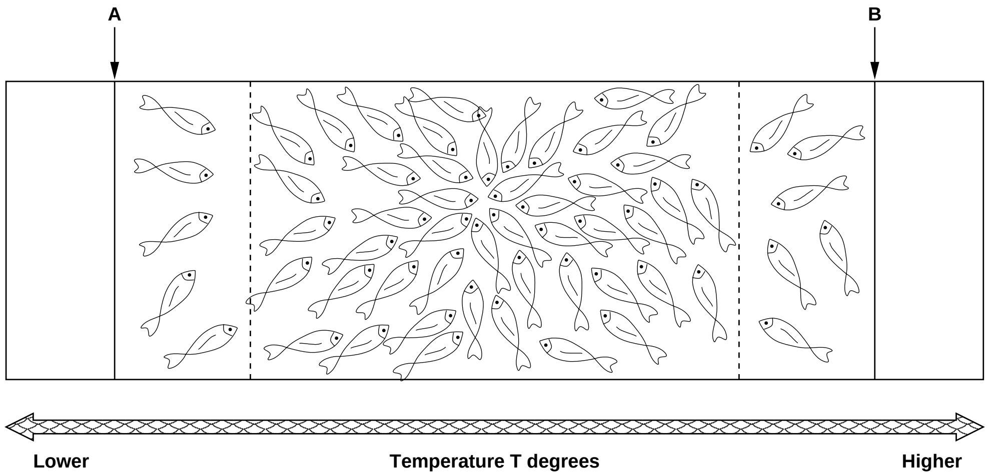
2. Part (a) of Figure 3.9 is a picture story about two species of *wheat flour beetle*. [1] They both love wheat flour. Explain the law about niches using the picture.

3. Part (b) of Figure 3.9 shows three possible scenarios when the number of species initially supported by an ecosystem (*A*) is increased. [18] What do the three situations shown in *B*, *C* and *D* mean? Describe them and discuss in class.

4. Which biome is likely to have more niches: a rain forest or an extreme desert?

5. Write a paragraph connecting adaptation, the variety of organisms

Figure 3.10: Temperature range for a fish population.



(diversity) and ecological niche. You will discuss diversity in Section 4.4.

6. Argue that the rule about unique niches is a result of adaptation of organisms to competition. Give examples to prove your point.

3.5.4 Tolerance

Every organism occupies a unique niche: a unique combination of habitat, food, feeding habit, breeding place and time, and functions. For instance, species living in the same habitat may prefer different locations depending on various factors like humidity, temperature, salinity, light, etc. The preferred range of values for each factor is called the **tolerance range** of the organism for that factor. The tolerance range may be different for different species, and may even change with the stage in an organism's life cycle. Figure 3.10 shows how a population of a fish species is distributed within a region of varying temperature. [16] Study the picture and discuss the issues raised below.

1. Draw a graph to show the temperature variation suggested in the picture. Then draw a graph representing the distribution of fish. Describe how the fish population has distributed itself with respect to the temperature of the region. Which temperature do the fish most prefer? Mark the lower and upper limits of tolerance.

2. Consider another kind of fish which prefer a different temperature range. Draw another graph showing how these new fish will be distributed.

3. Suppose 2 kinds of fish were found to be abundant in the same places. What can you say about their other habits? What relationship would they share?

4. In Figure 3.10 the fish seem to have a broad tolerance range in temperature. The fish would have some tolerance range for salinity too. Assume a salinity variation over the same location and draw it. How will the distribution of fish change as a result of these 2 factors? Draw a graph of the number of fish as a function of location to illustrate your idea. Compare your scenario with those of others in the class.

5. The difference in the distributions may be in the position of maximum tolerance or in the breadth (range) of tolerance. If the optimum tolerance range of salinity did not coincide with that of temperature, what might happen?

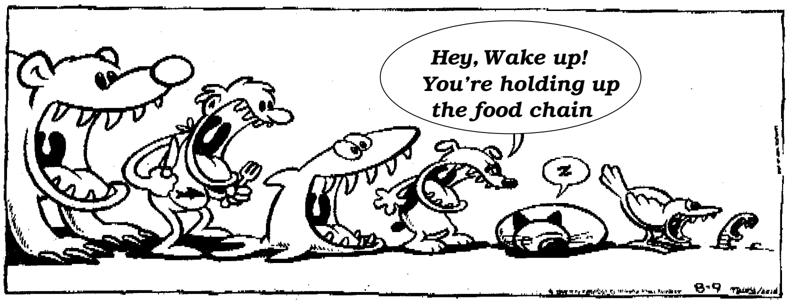
6. In a forest many factors vary with location: moisture, light, height above ground, or depth below ground. Describe the distribution of a few species within the same forest with some examples.

7. Observe the organisms that share your home, and your garden. List the living organisms you find, and their interdependence in your *home ecosystem*. Who prefer warm and dark places? Which ones stay near the light sources?

8. Are all the organisms listed above active at the same time of the year/day? Locate some birds that visit your garden in particular seasons. Does this indicate something about their tolerance for climatic conditions or food preferences? Relate this to the idea of niche.

As the human population increases on Earth, competitions among humans increase too. Humans adapt to this situation through differentiation of tolerance ranges: some prefer wheat, while others like rice; some like warm climates, and others prefer the cold. We need to respect differences in taste and functions, for they are essential for the survival of our highly populated species.

Source: Cartoon "Fluff" by Nina Paley, Business Standard, Aug.10, 1998.



Chapter 4

Population ecology

4.1 Life grows all around

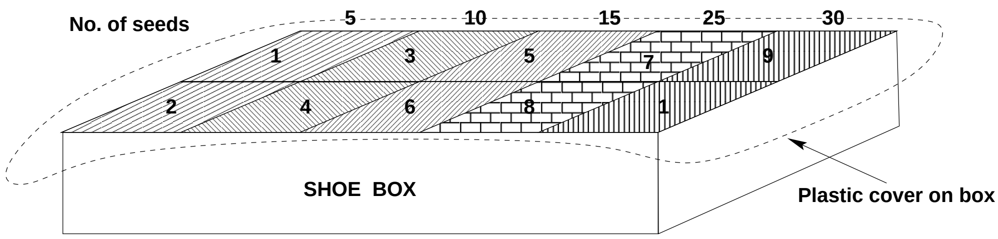
A parched land gets moist in the first shower, and Bermuda grass or *durva* sprouts, starting with one blade. A small root anchors itself in the soil. Under favourable conditions it grows and spreads rapidly. It dries up in the intense summer heat, but sprouts anew when conditions become favourable.

In the tropical forests on mountain slopes (cloud forests) *ferns* are abundant. In the cities farther away, they seem to sprout all by themselves. Wind blows away the dry fern leaves from the forest. The leaves have spores along their edge. The spores either germinate right away or stay dormant, depending on the climatic conditions. The activities below are about observing growth of life forms around you.

1. Land that was parched dry in the heat of the summer comes alive after the very first shower. Where does all this life suddenly spring from? What happens in the summer to these plants and animals which abound during the rains?

2. Write a paragraph describing your observations of growth of plants or animals in the environment around you. Include information about its birth, size and the number of individuals that it produced. Also include time and seasonal information.

Figure 4.1: Arrangement for growing seeds in a box.



3. Which plants or animals did you observe over the longest time? Which changed the most in size or numbers?
4. How do mushrooms originate and propagate?
5. List the differences in the growth and propagation of grasses and trees. Compare a paddy or wheat field with a mango grove or an orange orchard.

Durva and the *ferns* can survive through long periods of unfavourable conditions. This is true for many other living organisms too. The seasonal growth of insects, flies or mosquitoes and the green carpet that covers a barren land after the monsoon showers are evidences of this fact.

4.1.1 Growing seeds in a box

This activity will give you a chance to observe the growth of plants at close quarters. It will take about a fortnight, and you should note your detailed observations. You will discuss the observations and the issues raised by them later, in Section 4.2.

1. Take a shoe box, and divide it into 10 compartments using cardboard pieces as shown in Figure 4.1. Cover the cardboards (and also the inner sides of the box) with sheets of plastics. Fill each compartment with equal quantity of soil (a cup or spoon measure). Tag each compartment with a number.
2. In each compartment sow seeds of the same variety and quality. Prefer fast-growing seeds like fenugreek (*methi*) or coriander (*dhania*). Sow 5 seeds in compartments 1 and 2, followed by 10 (in 3 and 4), 15, 20, and 25 seeds. Note the tag number of each compartment

and the number of seeds in it. Draw up a table with 15 columns per compartment, to note your observations and remarks over the next fortnight.

3. Add equal amounts of water (bottle caps or spoons) to each compartment at the same time every day. Keep the set-up outside where it can get sunlight. To prevent the seeds from being eaten by birds, you could use a mesh over the box.

4. Observe the growth of saplings for about a fortnight. Note your observations for each compartment in the table every day. Your daily observations should include the total number of saplings in a compartment, their height, and the number of leaves. You could also comment on the comparative sizes of leaves. If saplings have not sprouted in all the compartments in a fortnight, wait for another week.

While you are waiting for the seeds to sprout, you could discuss the nature of growth of living organisms.

4.1.2 The nature of growth

The "thought" experiment discussed here will help you understand what happens when growth is not limited by any factor. Bacteria are microscopic organisms which reproduce by dividing. One bacterium divides into two, each of which further divides to result in four bacteria, and so on. Consider starting with a single bacterium in a bowl of rice. Assume that every bacterium divides once in every 20 minutes. Also assume that there is enough rice to satisfy the needs of all bacteria for the period of your experiment.

1. Calculate the number of bacteria at intervals of 20 minutes, for a period of 5 hours. Tabulate the number of bacteria after every 20 minutes interval.

2. Plot the data on a graph sheet with *time* on the x-axis and the *number of bacteria* on the y-axis. Describe the nature of the graph you have obtained.

3. Find the average slope of the following portions of the graph.

   (a) The plot from 20 to 80 minutes.
   (b) The plot from 140 to 200 minutes.
   (c) The plot from 240 to 300 minutes.

4. Compare the slopes. What information does the slope at any point tell you about the growth of bacteria? What does the pattern of variation in the slope mean?

5. Extend your plot, by guessing, to future time, say to another 300 minutes. Is the growth pattern in the first 300 minutes different from that in the next 300 minutes? Will the number of bacteria keep increasing for all times? Justify your answer.

6. What changes do you expect if the experiment were carried out in warmer weather? What will happen if the rice is steamed in a pressure cooker or kept in a refrigerator?

7. What will happen after the bowl of rice has been *consumed* by the bacteria?

In your "thought" experiment, the number of bacteria increased with time, but not at a constant rate. Their rate of growth also increased with time: a slow growth was followed by increasingly faster growth. Your plot of the growth curve must have resembled the letter **J**. This indicates **exponential** growth. Do you think human populations have grown this way? Human population growth has been addressed in the book titled *The Population Problem*.

Calculating growth

Recall the formulae you have used in calculating the growth of money in the bank at *simple* and *compound* interests. Let

- P be the starting (or principal) amount,
- R be the rate of interest, given as percent per interval (usually a year for money),
- N be the number of intervals (years),

- $P_{si}(N)$ be the final amount at the end of N intervals at simple interest, and $P_{ci}(N)$ the one calculated at compound interest.

The final amounts at simple and compound interest are given as,

$$P_{si}(N) = P + \left(\frac{P \times R \times N}{100}\right)$$

$$P_{ci}(N) = P \ \times \left(1 \ + \frac{R}{100}\right)^{N}$$

In the case of growth of population of bacteria discussed above, use $R = 100$, and confirm that it grows at *compound interest* rate. The bacteria grew under favourable conditions. The growth of bacteria population and of money at compound interest can both be described as exponential growth patterns.

The total increase of money in a bank at compound interest will depend on the rate of interest, and on how often it is calculated (whether annual or half-yearly). Similarly the rate of increase of population of an organism will depend on its reproductive properties.

4.1.3 Innate capacity for growth

Bacteria increase in number at an alarming rate, doubling every 20-30 minutes. Most animal populations do not increase that fast. The maximum number of offspring that members of a species can produce over their life span, averaged over all members of the species, is known as the **innate capacity for growth** for that species. The following activities are about innate capacity for growth and the factors that affect it.

1. Consider 3 different organisms, all with a life span of 50 years. Over the years, it was noticed that their populations increased at different rates. Guess the causes for the difference.

2. Elephants and humans have a comparable life span, say, 80 years. Human females can give birth to one child in one year, while cow elephants can give birth to one baby over 3 years. The number n of reproduction events that an organism undergoes per year is called

the **breeding frequency** of the organism. What are the breeding frequencies for humans and elephants? Find the average breeding frequencies of rats, chicken, cats, dogs, goats and cows.

3. Some animals reproduce almost through the year, while others breed seasonally. List some animals in each category.

4. Over a given period, a woman can produce (may not actually produce) more offspring than a cow elephant. Explain how differences in frequency of reproduction alone can change the rate of population growth.

5. Butterflies spawn hundreds of eggs while birds lay just a few eggs. The average number b of offspring that an organism produces in every reproduction event is called the **brood size** for that organism. Elephants and humans have a brood size, $b = 1$. Find the brood size of the organisms listed in item 2.

6. If an animal species has a breeding frequency n and brood size b, then the annual rate of increase of its population r is given by $r = n \times b$. Calculate the annual rate of population increase (r) for elephants, humans and the animals you have listed.

The total number of **breeding cycles** k completed by the organism in t years is given by $k = n \times t$.

The formula for calculating compound interest can be modified to give population growth in terms of the factors affecting innate capacity for growth. Thus, starting from a population size P_o, an organism having brood size b and breeding frequency n will increase to a population P_t after a period of t years given by,

$$P_t = P_o\left(1 + \frac{b}{100}\right)^{nt} \qquad or \qquad P_t = P_o\left(1 + \frac{b}{100}\right)^{k}$$

Another factor that changes the rate of population increase is **the age of female at first reproduction**. This is discussed in the next section.

4.1.4 Age at first reproduction

Consider people living in 2 different cultures: **Motapatnam** and **Chotagaon**. Assume that people everywhere have an average life span of about 80 years. (Is this possible?) People of *Motapatnam* and *Chotagaon* follow different customs of marriage, though they both want to maintain small families, and are monogamous.

- *Chotagaon* girls are trained to be housewives, marry early, and have their first child at the age of 15 years.
- The custom in *Motapatnam* requires their women to be educated, marry late and start a family only after the age of 25 years.
- In this imaginary story all women, whether in Chotagaon or Motapatnam, have only two offspring, one male and one female. In both places, the first born was a female, followed by a male after five years.

1. **Nayana** is a girl born in *Motapatnam*, and **Paro** is born in *Chotagaon* in the same year. The girls marry according to the custom prevalent in their respective localities and beget children. Trace the number of individuals in the families of **Nayana** and **Paro** over time.
2. Whose lineage — **Nayana's** or **Paro's** — has a larger number of individuals (population!) 80 years later (counted from the birth of the girls)? Assume matrilineal system, and ignore for now the children of the males in the family.
3. What do you conclude from the results obtained above? Discuss the issues raised by this hypothetical case in the class. What consequences will the differences in the custom have on population growth?
4. Consider the same situation as above, with one difference: the females have 4 offspring, rather than 2. As in the cases above, they were alternately female and male offspring at regular intervals of 5 years, with the female being the first born. Compare this situation with the previous one in terms of the relative sizes of the 2 families and the total number of individuals in each.
5. Table 4.1 shows the number of individuals in the families of **Nayana** and **Paro** at the end of 80 years in the 2 different situations (2 and 4

Table 4.1: Population after 80 years in the families of Paro and Nayana under two conditions.

Family	2 child	4 child
Nayana	8	16
Paro	12	47

children). Draw a bar graph illustrating the situations. How do the factors, (i) number of children born to each woman over her reproductive life span, and (ii) the age of the woman at first birth, affect population change?

6. How will this pattern (of population increase) change if

   - the women reproduced at shorter intervals (less than 5 years), or
   - the sequence of female and male offspring is changed?

In all the cases of population growth that you have discussed so far, you have assumed that resources needed for growth are not limited in any way. In reality, however, sooner or later all populations experience limits to their growth. The activities in the next section discuss the natural factors limiting population growth of organisms.

4.2 Limits to population growth

Analyse the observations of your seed growth experiment in Section 4.1.1 in terms of the number and size of plants over time, and the factors affecting these variations. You may discuss these through the questions raised below.

1. After how many days did the first sapling in your box germinate? In which compartment did it germinate first? Which of the compartments showed the fastest plant growth? How did you estimate that?

2. Compare the number of seeds germinating with the number of seeds sown in each compartment. How did they correlate?

3. In which compartments did the saplings grow higher, sprouting more leaves in a shorter time? Which compartments showed the slowest growth?

4. Which compartments showed similar growth, comparable both in terms of rate of growth and the number of saplings?

5. When did the saplings stop growing significantly? What happened after that?

Resources limit populations. On the other hand, the most obvious impact of population growth is an increased use of the resources. If the rate of use goes beyond the rate at which the resource is cycled, that resource is depleted. Resource depletion leads either to migration or death of the organisms depending on it. It may reduce the organism's reproductive capability. Besides, organisms living within disturbed surroundings are also more likely to fall prey to diseases.

Alternatively, other organisms having similar or overlapping needs and sharing the same resources, can also reduce the resources available to each (Figure 3.9 (b)). This is clearly seen when different types of plants are growing together. The plants having firm roots penetrating deep into the soil, show prominent growth. Trees shade small plants around them thereby slowing down their (small plants) growth.

Every organism is a part of some food web: either as a predator, a prey, or usually both. A population boom in a species at one place invites its predators, which may limit the population and its growth rate. The experiment below is an illustration of population changes within a "prey-predator" relationship.

Yeast-paramecium experiment

Yeast is a microscopic plant found in milk products or sugary food materials in warm places. *Paramecium* is a micro-organism which feeds on yeast. In an experiment, yeast was added to a dilute sucrose (a type of sugar) solution at 25^o C, and the mixture was gently agitated for 16 days. Samples of $10\ cm^3$ volume were withdrawn every day to count the number of organisms. On the 5^{th} day, a small number of paramecia were added. No more solution was added during the experiment, and temperature was

Table 4.2: Populations of yeasts (Y) and paramecium (P) in samples $10\ cm^3$ in volume.

Day	**No. of organisms**		**Day**	**No. of organisms**	
	Y	**P**		**Y**	**P**
1	20	–	9	222	72
2	84	–	10	218	138
3	224	–	11	120	162
4	264	–	12	84	96
5	266	30	13	180	54
6	224	150	14	178	90
7	114	168	15	120	144
8	154	76	16	60	120

maintained constant. [23] The results are shown in Table 4.2. Discuss the results and engage in the activities suggested below.

1. Plot two graphs: yeast and paramecium populations (on the y-axis) as a function of the number of days (on x-axis). Represent the different organisms distinctly. Write a paragraph about the nature of the graphs.

2. During which periods (days) does the yeast population increase ? What differences do you see in the rate of increase from day 2 to 3, 4 to 5, 7 to 8 and 8 to 9? Guess the possible causes for the differences.

3. If the paramecia were not introduced on the 5^{th} day, guess what might have happened to the yeast population? Would it have increased indefinitely?

4. Plot a graph to show the daily rate of change of yeast population change over time. How would the graph look if the paramecium were not added?

5. If paramecium were not added, how will the yeast population behave after the 5th day? Will it (i) increase continually, (ii) reach a steady value (around 266), or (iii) decrease after some days? Justify your choice.

6. Comment on the change in the paramecium population between the 5^{th} and 8^{th} days.

7. On the basis of the pattern of population growth for both the organisms over 16 days, predict the results for the next fortnight. Will both the populations die out after a while? What might cause such a pattern?

8. List some other pairs of animals which might follow similar patterns of population change. What relationship do they share?

You have just discussed the variation in populations of 2 dependent organisms. Later sections are about how organisms grow in their natural environments while they live within a web of prey and predators and limited resources.

4.2.1 Natural growth: S-curve

Ecosystems, as you have seen before, consist of a certain quantity and quality of resources needed for life forms to thrive. In the course of time, these resources are cycled, as organisms are born, use resources to grow, and die or decay. The population sizes of organisms and the number of communities determine the rate at which resources are consumed.

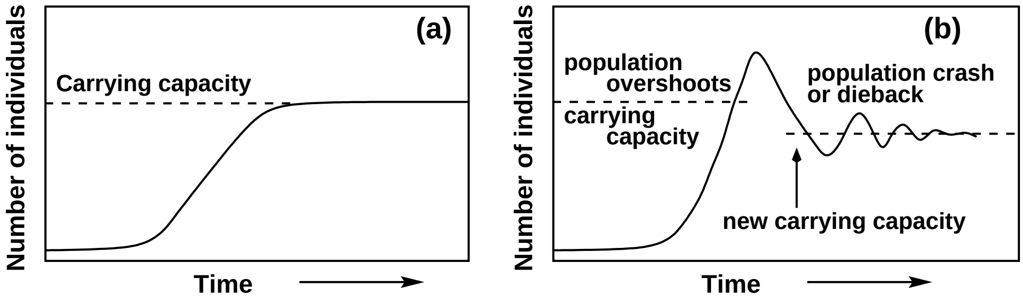
1. In a forest, the elephant herd is always smaller than a deer herd. Are their numbers related to the amount of food available in the forest? In what way?

2. The rate of increase in food and the rate of its consumption together determine the populations of organisms which depend on them. Besides food, what other resources might limit population growth?

3. There is a certain maximum population of an organism that an ecosystem can support together with communities of organisms that live there. This number can be supported for an indefinitely long period. This is called the **carrying capacity** of the ecosystem for that organism. The carrying capacity is a sort of upper limit of the population of the species in the ecosystem. The actual population of the species in an ecosystem is usually smaller than its carrying capacity. Give two examples to illustrate the different carrying capacities in the following cases:

   (a) the same organism in two different ecosystems.

Figure 4.2: The sigmoid curve of population change.



(b) different organisms in the same ecosystem.

4. In your discussion of the yeast and paramecium experiment, would the yeast have reached the same population on the 4^{th} or 5^{th} day if the quantity of sucrose solution were more? What might have happened if they had 2 kinds of predators instead of just the paramecium? What will happen to the paramecium population if all the yeast were removed from the sucrose solution on the 16th day?

   In each case, how will your J-shaped plot in Section 4.1.2 get modified? Draw the shape of the modified curve and indicate on it the carrying capacity of the ecosystem for the organism (yeast or paramecium).

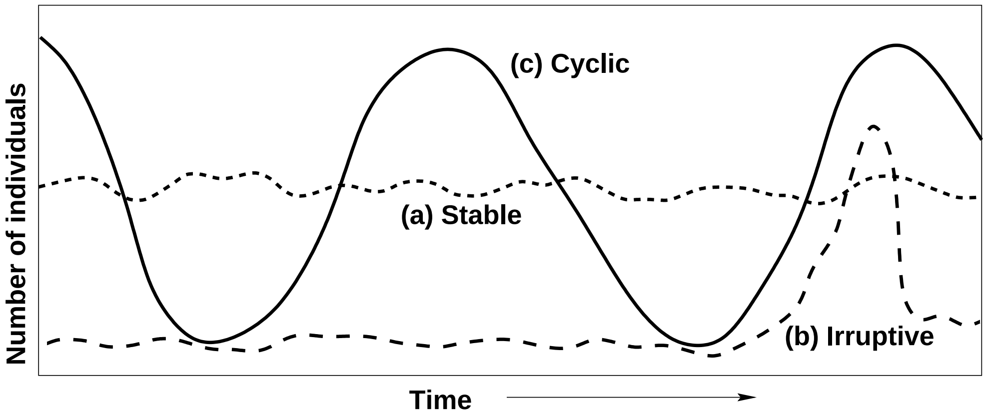
5. Your curve in the above activity, resembling an **S** is called the **sigmoid** curve. This is shown in Figure 4.2 (a). [16] Population size in the plot is the net (total) number of individuals living at a particular time.

   Explain the shape of the sigmoid curve in terms of the population size near the origin, in the intermediate period, and after long periods of time. Take as an example any animal or plant whose characteristics you know (the rate at which they multiply, their food and shelter needs, etc.) in any ecosystem of your choice (home, garden, pond).

6. Compare and contrast the J-shaped and sigmoid population growth curves.

7. Sometimes populations increase in a spurt (suddenly) beyond the carrying capacity of the ecosystem. However, they cannot be maintained at those levels. Part (b) of Figure 4.2 shows one such situation. What effect will such a spurt in population have on the resources in the system?

Figure 4.3: The sigmoid growth curve for real population changes.



8. If the rising population does not deplete the resources too fast, the system may recover. However, it will have a new carrying capacity. Will the carrying capacity be lower or higher than the earlier one? Justify your answer.

4.2.2 Variations in the general growth curve

The sigmoid curve is the most general pattern of population change over time. Populations may not always strictly follow this curve. How a population varies is determined by the causes of change: seasons, rapidity of reproduction, and other factors.

1. List the situations in which the population of an organism in an ecosystem overshoot its carrying capacity. Recollect the definition of carrying capacity.
2. Having overshot its carrying capacity, one way in which it may recover is given in plot (b) of Figure 4.2. The portion of the plot after time t_s is not flat. What may cause the ripples (small variations in numbers around a large mean value) in the population over time?
3. Plot (a) of Figure 4.3 shows a population that has ripples over a long time. [16] The ripples are small compared to the number of individuals of that species in the system. This is a **stable population**. What kind of changes might affect such a stable population? (*Hint: Consider a sudden increase in the available resources.*)

4. Draw a modified sigmoid curve to indicate what might happen after an explosion in a population that was stable up to a time. Discuss your plots. Relate your drawings to some real situations around you.

5. Plot (b) of Figure 4.3 shows one possible scenario after an explosion in the population. How does this compare with curve (b) of Figure 4.2?

6. Consider an animal whose population in an ecosystem varies widely in a cycle: almost zero population followed by a large population. This is shown in plot (c) of Figure 4.3. The maxima and minima in the cycle are fairly unchanged over time. Give a reason for such variations in the population.

Stability of the populations of organisms within an ecosystem measures the stability and maturity of the ecosystem. You will notice **cyclic** changes in the populations of organisms which have seasonal reproduction and death cycles. They usually have a large brood size, are very sensitive to changes in their surroundings, and are also capable of recovering. Through such changes organisms, and ecosystems that they belong to, evolve. Evolution is unavoidable given that nature is dynamic. In the next section you will discuss the direction in which an ecosystem is likely to evolve.

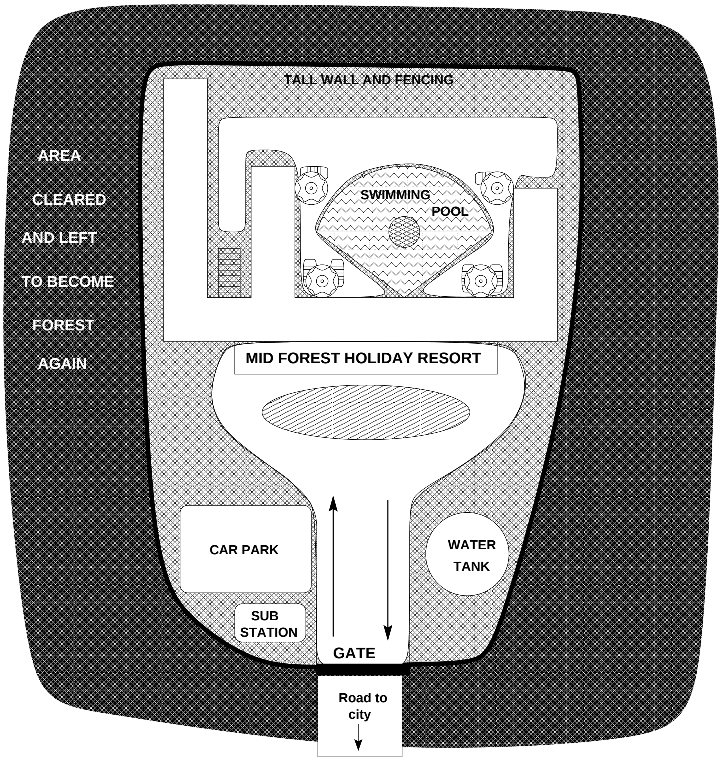
4.3 Evolving ecosystems

Observe the variety of landscapes around you: the gardens, barren land with poor grass cover, forest, streets of buildings, bush-land, lakes and ponds. These landscapes differ in many ways: soil richness and water retaining capacity are two important factors. They have different vegetation growing on them. Imagine that you have just bought a large plot of land. What will happen to the plot if you ignored it for a few years? This section is about how “barren” lands become rich ecosystems.

4.3.1 Changing landscapes

1. List some landscapes you have observed around you. Which of these will change in the next few years and in what ways? Consider the

Figure 4.4: A forest resort.



changes over a decade, a century, and a millennium (1000 years).

2. Imagine ruins of caves, temples, forts or palaces in the days when people used them. Compare the view at these places, then and now.

3. Dhondiba's family has been living off 50 acres of agricultural land for several generations. Dhondiba's educated children prefer office jobs in cities. Hence the family migrates to the city, fencing their farm for protection. After 50 years if a member of the family returns to the untended farm what will the land be like? Describe the different stages the land may have gone through during this time.

4. The Sahyadri Mountains in Maharashtra are endowed with rich soil, good rainfall and large forest areas. The state government decides to attract tourists to the forests. A large area in the midst of the forest is cleared for a tourist resort (Figure 4.4). The unused land remaining after building the resort and its amenities is allowed to recover by itself, untended. Describe what you might see on the land around

the resort after 1 year, 5, and 10 years, with respect to the number, type or size of plants and animals.

5. A dense vegetation cover on a majestic mountain is home to several rare species. The mountain is actually a volcano, which has been dormant for centuries. One day, the volcano erupts spewing lava and ash, burning all existing life. The nutrient-rich lava and ash settle on the lifeless slopes. Will the mountain slopes have life again? How will it begin? What life forms will come first?

4.3.2 Successions in ecosystems

You have discussed several examples of changing natural ecosystems. You have probably noticed that there was a sequence to the changes — in terms of the type of species and their number, and the population of each species. The sequential pattern of changes in the physical structure (soil, size) and species composition of an evolving ecosystem is called **succession**.

Recollect the case of life starting anew on the slopes of an erupted volcano. The very first organisms that inhabit the barren slopes are called the **pioneer species**. This section is about the sequence of stages in the evolution of ecosystems.

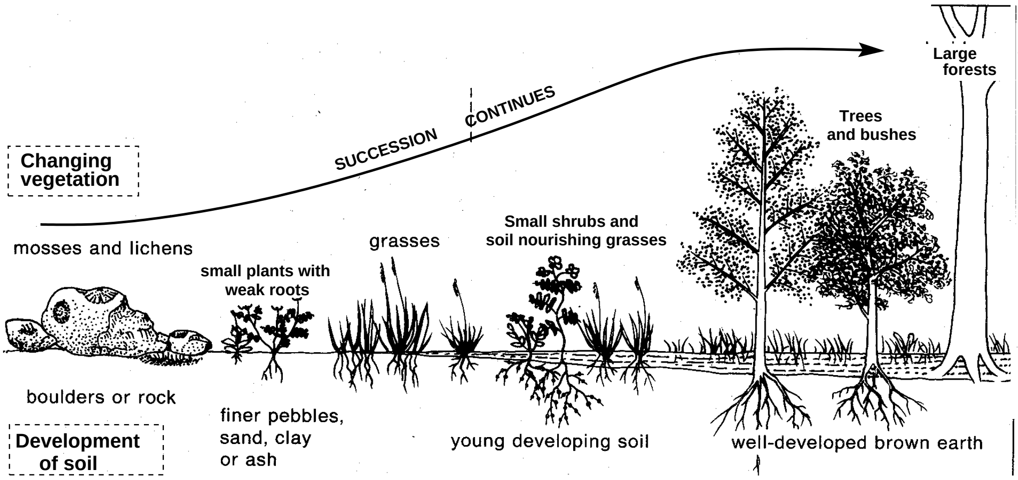
1. Give examples of pioneer species for a barren field and a pond. What special qualities should pioneer species have, so that they survive where there was no life before them, and attract new life too.

2. The first stage of life starting in a barren ecosystem — volcanic slopes or a newly formed lake — is called **primary succession**. A primary succession occurs only in areas which had no earlier trace of life. In the examples given in Section 4.3.1, pick those which were in the primary succession stage.

3. Would you find some form of life on a land which has been devastated by floods? How about earthquakes?

4. The sequence of stages following the pioneer species are all called **secondary successions**. A secondary succession starts with an existing pool of remnant life forms. These may be in the form of earlier

Figure 4.5: Steps in geological succession.



plants and animals, seeds, eggs or even roots. Identify the cases in Section 4.3.1 which involved secondary succession.

5. Figure 4.5 shows the successive steps through which a rocky land might become a wooded place. [5]

   (a) Is the first stage in the picture primary or secondary succession? Justify. Are there pioneer species? Which are they? List the sequence of species in different stages.
   (b) Describe the changes in the soil during the 3 major stages of succession: coloniser stage, early and late succession. Explain how the soil and the vegetation are linked to each other.
   (c) Does the moss growing on wet walls of old buildings indicate succession?

6. Will the number, type and population size of species keep changing for an indefinitely long time? Justify your answer. In what ways do rain forests and deserts change? If they are not disturbed by humans would you find large variations in the number of species and their populations over 10 or 20 years? In what ways would a garden, a park or a large puddle of water change?

7. In the early stages of succession, changes in the physical environment affect the types and populations of organisms living there. These in turn modify the physical environment. Will this "mutual

modification" go on forever? Do some ecosystems change more rapidly than others? Give an example of a rapidly changing system and another that does not seem to change much over many years.

8. Climax ecosystems have reached "comfortable" combination of species and their populations which are suitable for the geographical region and the climate. You have discussed them in Section 3.5.

   What can you say about the climax communities at different latitudes and altitudes on Earth? Given a latitude and altitude, can you predict the climax communities that are possible there?

9. List 3 climax ecosystems, at least two of which are found in India. Where would you find them?

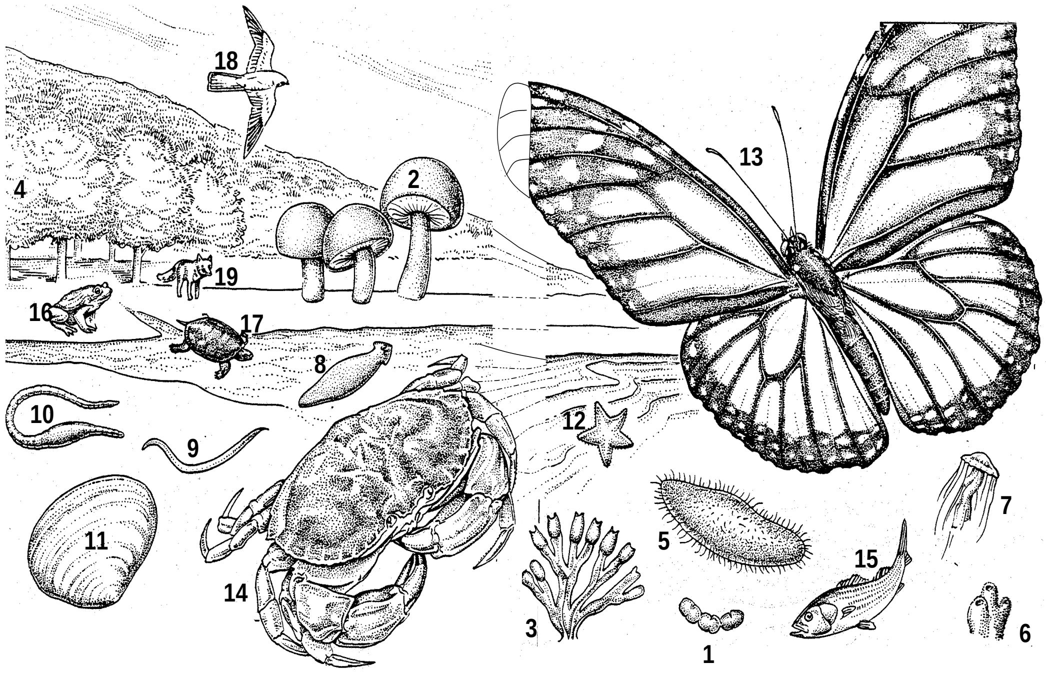
10. The nutrient cycles and energy flows are a part of every ecosystem. Compare and contrast the nutrient cycles in a climax stage ecosystem with an ecosystem that is in an intermediate stage of succession. Revisit your discussion about productivity of ecosystems in Section 3.5.2.

11. Which is likely to be richer in the variety of species, the climax ecosystem or the one undergoing succession? Assume that they are both in the same geographical and climatic region and discuss your stand.

You can guess the combination of species that may occur in the climax communities in a specific geographical region. The species would depend, of course, on the latitude, altitude, soil and climatic conditions of the region. The actual combination of species that you will observe there in any intermediate stage of succession will also depend on the history of the region — the species that existed there earlier — and on the surrounding regions. You may not be able to predict how the existing species will adapt to newer conditions. It is nearly impossible to predict the new species that may emerge in any region (future climates are hard to predict). Emergence of new species in an ecosystem is called **speciation**. Speciation and adaptation together account for all the variety of life forms on Earth.

For instance, two ecosystems starting with a similar combination of species may follow different sequences of succession. This could lead to similar category of climax systems (tropical forests or Savannah) with different compositions of species. Savannah of Africa, India and South America

Figure 4.6: Species diversity on Earth.



are all different kinds of grasslands. Thus the climax category may be somewhat predictable, but the stages of succession leading to it are not.

4.4 Diversity

This section is about the rich variety of life on Earth. **Species diversity** of an ecosystem refers to the number of different species living in it. Some ecosystems, as you have seen, have a greater diversity than others.

1. Consider the case of two species of butterflies which have evolved from the same original stock (species) on a grassland. The members of the original species were separated at some time by a river flowing through the region. The butterflies on the two sides of the river evolved differently with time, as the soil wetness and vegetation was different on the 2 sides. The river dries up with time.

   In the above story, the situation that caused diversity started with a river separating the initial population of butterflies, followed by climate change and increased wetness on one side. Write a story illustrating the development of species diversity. Compare the stories given by the whole class.

2. Figure 4.6 is a sort of **species-scape** (like landscape!) of the whole Earth. [25] Each major group of organisms is represented by one organism from that group. Name each organism. What are the most striking features of this picture?

   Rank the organisms in the picture, by their number, in the order of their size: number 13 with the largest size would be ranked 1. Does the picture show the organisms in the same proportion as their actual sizes? What information does the size indicate?

3. Table 4.3 lists the names of the major categories of organisms shown in Figure 4.6, along with the number of species within each category. [25] Does your ranking according to size of species relate in any way to the number of species in each category?

4. Draw a pie chart indicating the proportion of species within each category. Include drawings or pictures of suitable examples in your chart. You may even make a collage of organisms in each category within a pie chart drawn on poster-sized paper.

4.4.1 Genetic diversity

Hapus grown in Ratnagiri district and *Banganpalli* of Andhra Pradesh are both famous tasty mangoes. These mango trees differ in size and taste of the fruit, size of seeds, shape of leaves, quality of wood, and the pests they attract. They are said to be **genetically diverse**.

1. List examples of fruits or flowering trees, crops or animals of the same species which are genetically diverse.

2. What advantage does genetic diversity within a species have for the survival of that species? How is genetic diversity useful to us? List the two separately.

3. Areas with high genetic diversity of crop varieties are shaded on a World map in Figure 4.7. [14] Using an atlas, name the countries,

Table 4.3: Species diversity within the major categories of organisms.

No.	Category name	Examples	No.of species
1.	Monera	bacteria	4,800
2.	Fungi	mushroom, bread mold	69,000
3.	Algae	phytoplankton	26,900
4.	Higher plants	all plants, trees	248,400
5.	Protozoa	paramecium	30,800
6.	Porifera	sponges	5,000
7.	Cnidaria, Ctenophora	corals, jellyfish	9,000
8.	Platyhelminthes	flatworms	12,200
9.	Nematoda	roundworms	12,000
10.	Annelida	earthworms	12,000
11.	Mollusca	snails, shellfish	50,000
12.	Echinodermata	starfish	6,100
13.	Insecta	butterfly, ant, beetle	751,000
14.	Noninsectan Arthropods	spiders, crabs	123,400
15.	Fishes	small marine animals	18,800
16.	Amphibians	frog	4,200
17.	Reptiles	tortoise, snake	6,300
18	Birds	dove	9,000
19.	Mammals	fox	4,000

which have high genetic diversity of crop varieties. Find their latitude and altitude, and state whether they are coastal areas.

4. At what latitudes are the largest regions of genetic diversity? What are the biomes in those areas?

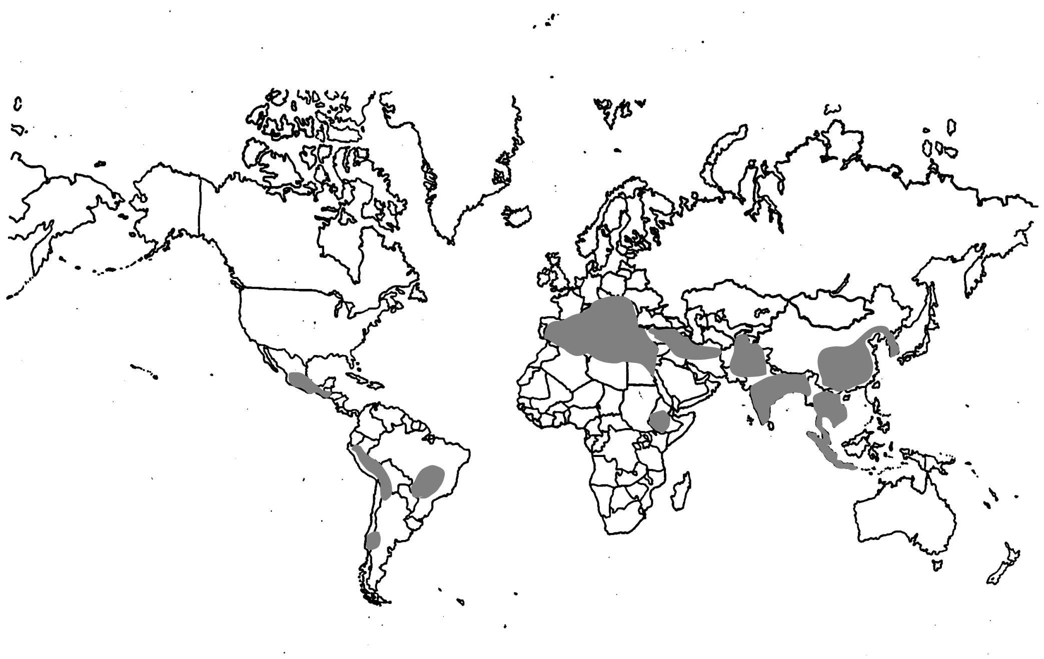
5. The Swallowtail butterfly occurs all over the World. Table 4.4 shows the number of sub-species of the butterfly in strips of 10^o at various latitudes. [24]

   (a) Plot the number of species (on y-axis) as a function of latitude

Table 4.4: Diversity from the equator to the pole.

	North							South			
Latitude	70	60	50	40	30	20	10	10	20	30	40
No. of species	14	31	74	136	131	167	240	261	161	92	23

Figure 4.7: Regions with high genetic diversity.



(on x-axis). How does the number of species in the butterfly family change with latitude? At what latitudes are the maximum and minimum values?

(b) Compare the distribution of the butterfly in the two hemispheres. At what latitude does the number of species differ significantly for the two hemispheres? Verify whether this is related to the physical variations in land mass.

(c) Altitude is not a parameter in the figure. Will altitude play any role in the distribution?

6. Based on the Figure 4.7 and Table 4.4, write a page on the distribution of diversity over the Earth? Include some examples of places and species.

4.4.2 Rising biological diversity

Many people worry that biological diversity is decreasing because of the unwise actions of human beings. Before you discuss this in the next chapter, you need to know how biological diversity has varied over geological time. First, it will be useful to recollect how organisms are categorised.

Families, genera and species

You and I are members of a species called the *Homo sapiens*, written in short as *H. sapiens*. Our identification name has 2 parts: *Homo*, which refers to the genus (plural - genera), and *sapiens*, which is the species name. Although there are no other living species under the genus *Homo*, *Homo erectus*, who lived over 400,000 years ago belonged to this genus. The genus *Homo* is one among many human-like genera under the family *Hominidea* (hominids). Hominidae belong to a superfamily called *Hominoidea* (hominoids), which includes the family of great apes. Our family tree is schematically represented in Figure 4.8.

All organisms, big and small, animals and plants, carry around in every cell of their body, all the information about their constitution, characteristics and replication. This is coded in the DNA. Organisms in the same category have similarities in their genetic coding too.

Figure 4.8: The human family tree.

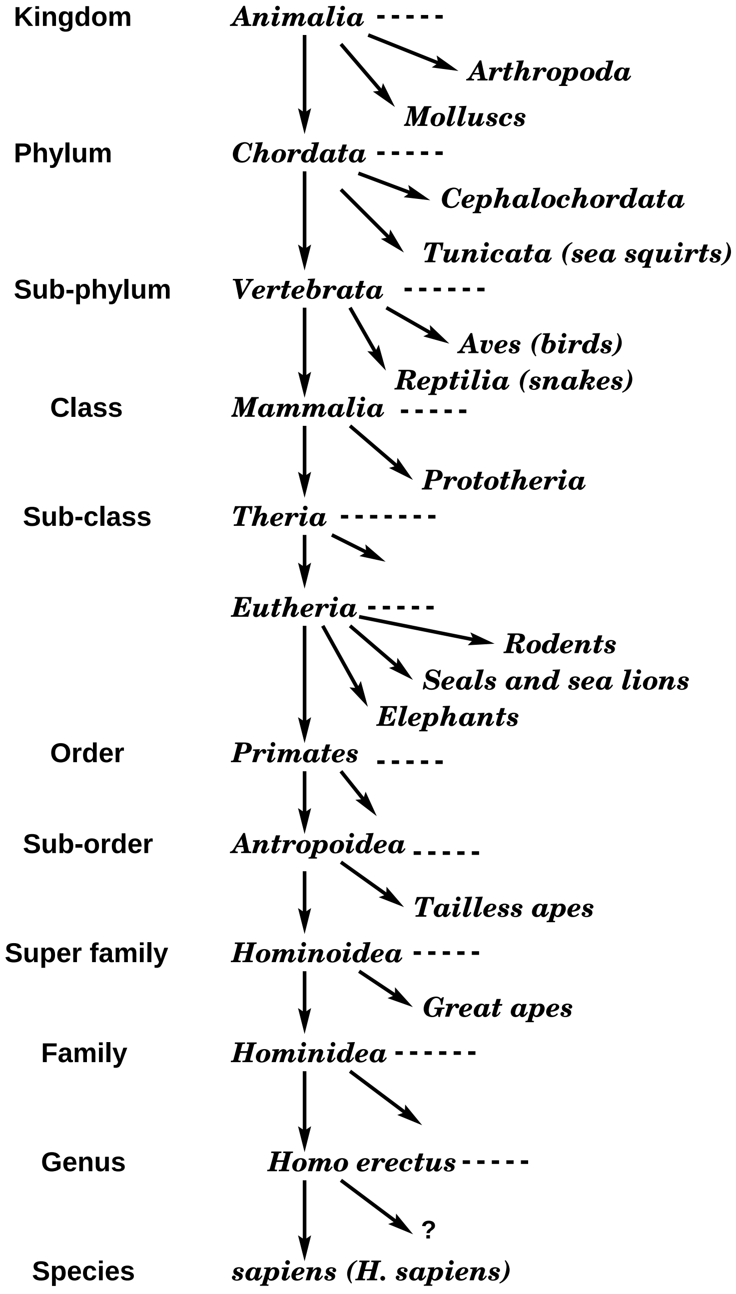
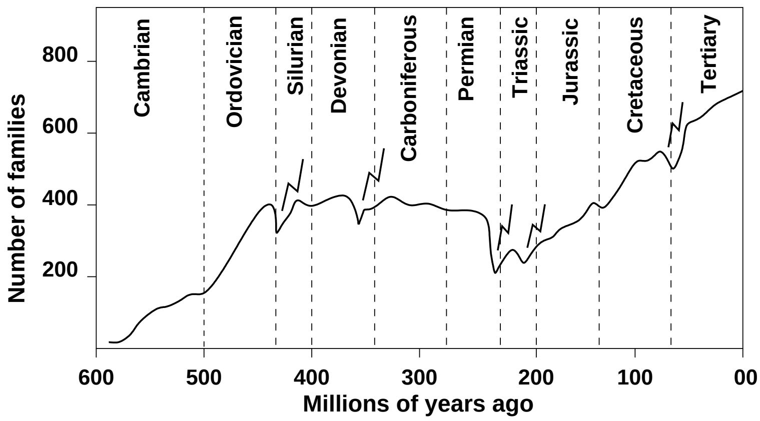


Figure 4.9: Increasing biological diversity over millions of years.



Ecologists worry about the extinction of species and the resulting loss of evolved genetic information. It is well known, however that few extinctions have occurred at the level of the phylum or above in the hierarchy of classification. This implies that genetic evolutions, at least up to a certain level, have been preserved through geological time. Many small modifications have, however, been lost through the extinction of species. Species are getting extinct almost all the time, while extinction of genera, and family are rarer.

4.4.3 Diversity: variation over millions of years

Figure 4.9 shows the number of families of marine organisms from 600 million years ago to the present time. [25] Remember that each family has many genera, and each genus has many species.

1. Which geological period saw the fastest increase in the families of marine organisms? Do you think there must have been a similar increase in land organisms, both plants and animals? Find out.
2. Assume that the figure reflects the evolution of all organisms. Describe the variations in the number of families of organisms during different periods in geological history.
3. What do the variations in the plot near the lightning symbols correspond to? How many such variations have been there over the last 600 million years?

4. What is the average number of families that decreased in a catastrophe (lightning symbol)? Guess how many species, on the average, may have become extinct in a catastrophe.

5. When a few species of organisms or some genera become extinct, how will the surviving organisms be affected?

6. Giving examples, show that –

   (a) a family may be preserved over geological times even after all the genera that evolved from it are extinct.

   (b) a phylum may be preserved despite the extinction of many families of organisms that belong to the phylum.

7. Evolution biologists tell us that *H. erectus* evolved into 2 subspecies: *H. sapiens sapiens* and *H. sapiens neanderthalensis*. Of these only *H. sapiens sapiens* is alive today. *H. sapiens neanderthalensis* became extinct. What happened to *H. erectus*? Describe, in a page, how extinction of a species differs from its evolution. Refer to the preservation of genetic information and characteristics.

8. One of the major causes of mass extinction of families of organisms was supposed to be the collision of an asteroid with Earth. Such a collision would have caused massive tidal waves around the world, started fires everywhere and raised enough dust in the air to block out the sun. This would have cooled the Earth for many years, and led to the destruction of many families. [1]

   Do you think this would have affected all species — plants and animals — equally? Dinosaurs and other large animals are thought to have died in this catastrophe. Would this have opened up several niches to be filled by mammals at that time? What would that mean in terms of the evolution of mammals?

9. Write a story set in the late Cretaceous period describing a mass extinction. Imagine that some families survived the disaster while many families of organisms became extinct. You could write it as an autobiography of an animal or plant living at that time. You may also find more imaginative ways of telling the story.

10. In the evolution of biodiversity, smaller size has meant more species. Within particular groups of animals, such as insects, the smallest organisms are able to exploit more niches and thus pack more species into existing communities.

In the rain forests of Papua-New-Guinea, a large weevil carries a garden of lichens (white powdery stuff you see on moist tree trunks) on its back. This supports several species of mites and small wingless insects called springtails. The large weevil is a walking micro-ecosystem. [25] Based on this fact, argue that when a species is extinct, a whole ecosystem may become extinct.

11. Originating 400 million years ago, insects reached their present level of diversity in about 100 million years. They have dominated land and water around the world since then. They have also survived mass extinction many times. There are almost a million known species among them (see Table 4.3), and also half as many that are unknown. Together they weigh more than all of humanity living today!

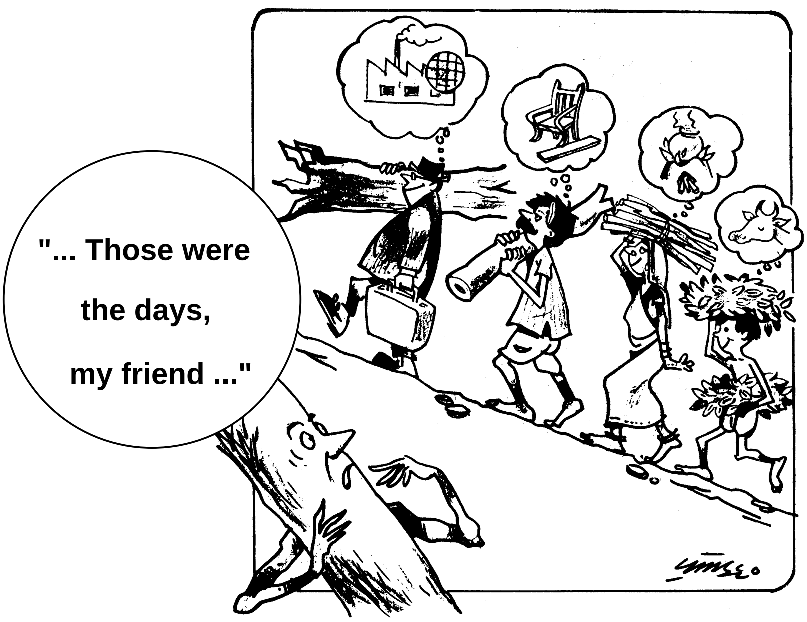
    Edward O.Wilson says, "The human race is a newcomer dwelling among the six-legged masses. Less than 2 million years old, it has a tenuous (weak) grip on the planet. Insects can thrive without us, but we and most other land organisms would perish without them." [25]

    Compose a poem or write an essay expressing your thoughts about the dependence of humans on all the other species of organisms on Earth: all kinds of plants (from algae to flowering plants), animals (from sponges to elephants and whales), fungi (mushrooms, molds, etc), protists (amoeba, paramecium), and monera (bacteria).

12. Nature has, over almost a billion years, recovered from many calamities, to increasing numbers of species and families that you see around you. What, then, is worrying many people today? Why do many among us lament the loss of diversity and destruction of nature?

The next chapter is about the role of humans in nature, as the most evolved, and complex of all organisms. Humans, of all living beings that have existed so far on Earth, are the only ones who can *read* nature's book, reconstruct natural history, and communicate it to future generations. You have the potential to **design** your future. How good is your future plan? Will you allow your race to go the way of the dinosaurs? Most biologists agree that, on the average, a species exists for 1 to 10 million years. Where do *you* stand?

Adapted from Monographs of Indian Institute of Ecology & Environment. [11, 12]



Chapter 5

Signatures of decay

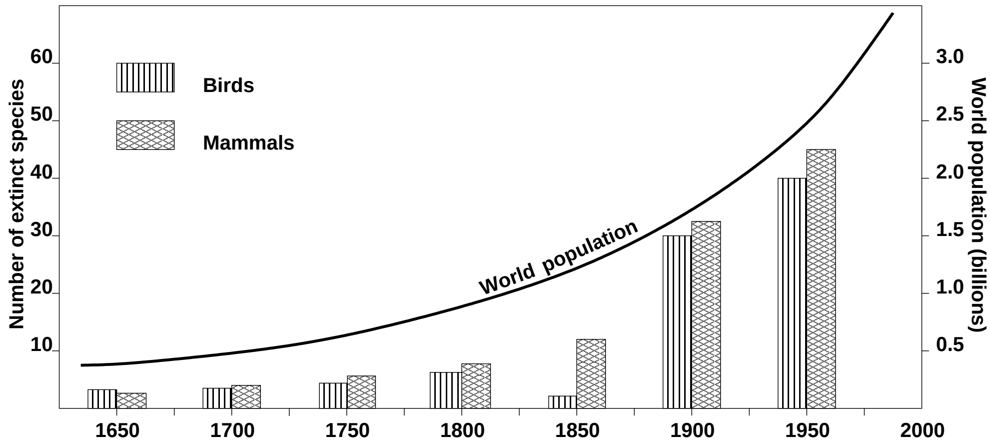
Nature signals her grand changes: dark clouds that fill the sky before a storm, the birds that chirp and flutter around uneasily before an earthquake, the cuckoo that heralds the onset of rains. Do you observe these signals? If you do, then you must have heard the fish that tell you that the lake is dying of acidity, and you must have seen the leaves shrivel in the foul air.

Many plants and animals can sense even small perturbations in their surroundings. In response, they change their behaviour in the short term, or even their pattern of life. Observing plants and animals, and knowing their normal life will alert you about impending disasters.

One sign of environmental decay is the changing pattern of diversity. You have discussed through Figure 4.9 that diversity has been increasing over millions of years. In this chapter you will discuss the possibilities that a catastrophe may be round the corner, and the reasons for believing so. Figure 5.1 shows the growth of human population and the number of species of birds and mammals which have become extinct during 1650 - 1950. [1]

1. Based on the graph, describe the growth of human population during 1650-1950. Include ideas of rate of growth, doubling time, etc. How has the number of extinct species of birds and mammals changed over the same period? Draw a line graph showing changes in the number of species of birds and mammals.

Figure 5.1: Growing human population and extinctions.



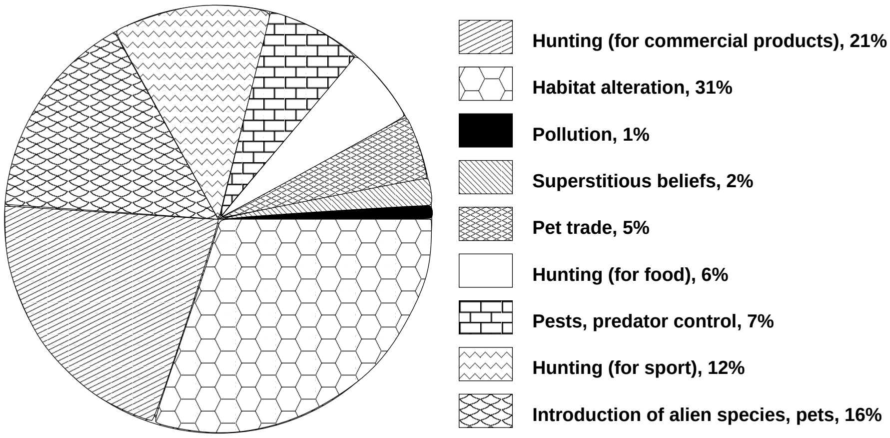
2. Is the extinction of birds and mammals related to the growth of human population? Explain.
3. What can you say about the number of extinct species of birds before 1850's and after? Repeat the comparison for mammals.
4. Before 1850's numbers of extinct bird and mammal species were comparable. What would you say about the 1850's? What does the data show about later periods? What would have happened in the 1800's to change the extinction rate of species?

5.1 Causes of extinction

An accelerated extinction of species is one sign that more problems will follow. However, such extinction have occurred several times in geological history, as you have seen in Section 4.4.3. The causes are possibly different this time.

1. List all the factors that are likely to cause extinction of species. Rank the causes of extinction given by the whole class, according to how often they have been mentioned.
2. The pie chart in Figure 5.2 shows human activities that contribute to extinction. [7] Rank these activities according to their contribution and compare it with your ranking in the last activity.

Figure 5.2: Causes of extinction of species: a pie chart.



3. List the ways in which your life-style (what you eat, buy, use, throw) could contribute to each of the causes in the pie-chart.

4. From newspapers and magazines, find articles that relate to one or more causes in the pie chart. Which species were affected? Make a collage of all your articles and organise a poster exhibition.

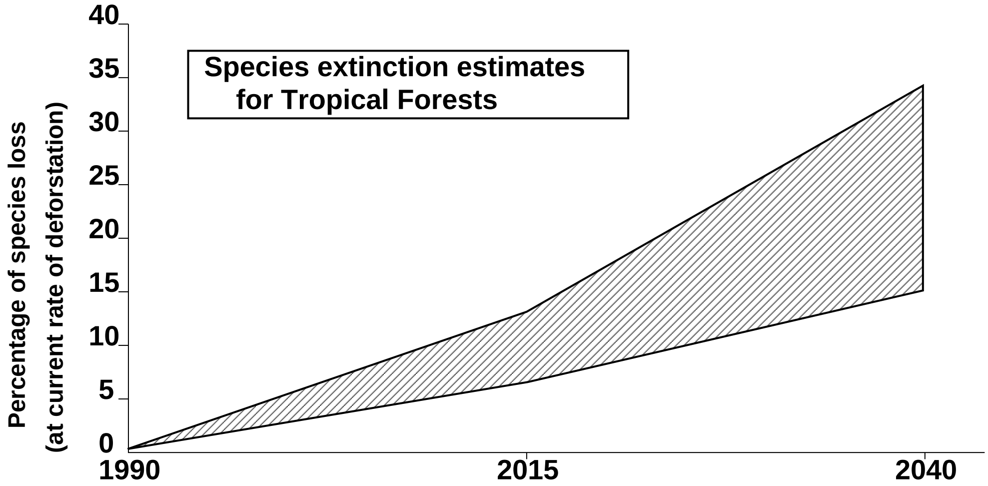
5. What is the total contribution of hunting to species extinction, if you include hunting for all purposes? To what extent is this avoidable?

6. Hunting is a major cause of extinction of animal species. Would this also lead to extinction of plant species? Explain your views with examples.

7. Read the book by Rachel Carson titled, *Silent Spring*. [4] The book intensified the environmental movement in the USA. Write a summary of the book. What do you think is the most important point made by the book? Is it still valid?

8. Tropical forests are some of the most mature ecosystems in the World, home to a large variety of life forms. Figure 5.3 indicates the proportion of species that will be lost over the next 50 years, assuming the current rate of deforestation. [26] The calculation begins from 1990 (0% in 1990), ignoring earlier losses. The shaded region shows the uncertainty in the prediction. Which causes given in the pie chart in Figure 5.2 are included under deforestation? How will the graph change if earlier losses are taken into account?

Figure 5.3: Estimated species loss due to deforestation, 1990-2040.



9. Do you think it is possible to change the shape of the graph, say after 2015? Justify your stand. List some strategies that can be adopted for bringing about the change. Write a page about the future scenario of extinction and its consequences to humans.

Thanks to the advent of technology that liberated humans from the limitations of seasons, and provided much leisure and luxury, humans can hunt through the year. These and other human actions alter the environment of animals and plants faster than they can adapt to them. Plants and animals perish, and with them the diversity, the basis of our survival.

5.2 Selective hunting, selective conservation

Pleas of, “Save the panda and the whales, conserve wildlife ...” are muffled by shouts of, “Kill that roach, eliminate the rats, shut out the mosquitoes ...” Should you conserve some animals and eliminate others? This chapter is about the consequences of such actions on the environment, and on humans.

1. You would like to eliminate organisms like some bacteria, all viruses and those animals you consider as pests today. What strategies will

you adopt? Will any single strategy work for all pests? Will each strategy have different effects depending on the pest?

2. You have discussed genetic diversity within a species. Some insects may be resistant to a pesticide because they are genetically different. For instance, the sun affects some people less than others. In the light of this, guess how a pest population might respond if you used a pesticide against it over a long period.

3. Imagine that you have successfully eliminated all pests from your house and garden. What immediate effect might this have on the cycles of nutrients and energy flow in this environment (house and garden)? What changes will you expect in the other organisms and non-living resources?

4. On the basis of the above activities, discuss the proposition: **Our attempt to eliminate pests chemically is a boomerang now headed towards us.**

5. What is the difference between a pasture (grazing land) and a wheat field? Recollect that both have grasses. Farmers, like Parkars and Dhondibas, need both.

6. Think of a grass, not a wheat plant, that grows among the pasture as well as in the wheat field. Where is it unwelcome? Why?

7. Write the story of the discovery of food grains by humans. Discuss the role (in nature) of plants that you call "weeds". Do you know of some weeds that have been cultivated by people for some use? (*Hint: Read about the case of 'Lantana' plants in West Bengal.*)

8. Weeds are plants which you think are in the wrong place, competing for the resources that you would like your pet plants (cultivated ones!) to use. Farmers spend a lot of money and effort eliminating weeds. A Japanese farmer, Masanobu Fukuoka, found that he could get yields comparable to other farmers without spending any effort in weeding. Do you think it is worth following such a procedure? Read his book, *The One-Straw Revolution* [13] and write a page summarising your opinion about the method. List its usefulness and disadvantages.

9. After discussing the role of weeds in nature, how do you think you should deal with what you now call pests? List instances where you

initially thought of an animal (insect, bacteria, reptile, amphibian, mammal) as pest which you later realised was useful to humans. Do you think the pests of today may turn out to be the future saviours of the human race? Describe possible scenarios to prove your point.

10. *Pest* is a term used for all animals which are harmful to humans. Do you think that the "useful to humans" criterion should be used to either preserve or eliminate animals on Earth? Debate this issue in class.

11. *Mani*, a farmer in Kerala, has been breeding rice plants to get varieties which are resistant to the diseases in that region and also have relatively high yields. *Mani's* neighbour, *Ponnan*, starts cultivating a new variety of rice imported from Japan which has a higher yield. What is likely to happen to the paddy yields in the region?

12. Argue that any plant may have qualities that may make it resistant to some future disease of unknown origin. What does this imply for agriculture? On the basis of this argument, which varieties of plants should humans preserve?

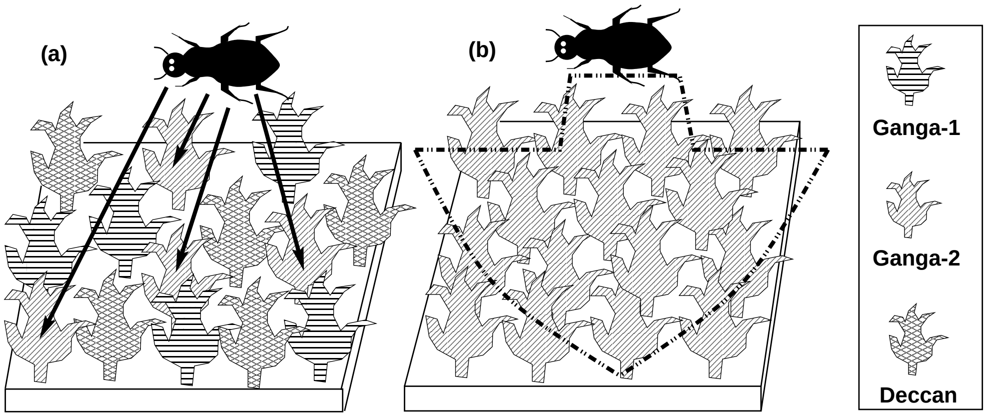
It is clear that samples of all existing plants and animals must be preserved. Any of them may be useful for cross breeding to get new, "more adapted" species. This is one of the strongest arguments for preserving biodiversity.

In what ways should plants and animals be conserved? One method is to keep them under controlled conditions in greenhouses and zoos. The other is to preserve them along with their natural habitats (ecosystems). In the next section you will discuss the consequences — to us, to the plants and animals — of tampering with natural habitats and creating artificial ones.

5.2.1 Dangerous uniformity: monoculture

Farmers Ajit and Naseer grow maize (corn) on their plots (a) and (b), shown schematically in Figure 5.4. Ajit grows 3 varieties of maize: Ganga-1, Ganga-2 and Deccan. Ganga-2 has higher yield and is easy to grow year after year, but is not as resistant to all pests as the others. On the other hand, hybrids like Ganga-1 and Deccan yield less, but are resistant to

Figure 5.4: Maize plots of Ajit (a) and Naseer (b).



several weeds and pests. Naseer cultivates only Ganga-2 on his plot (b). A new pest, *flea beetle*, which selectively attacks Ganga-2, is accidentally introduced in the area. Discuss the scenarios that can result.

1. Which plants in the two plots will be attacked by the *flea beetle*? Assume that the pest is resistant to the pest control methods normally used by the farmers. Which farmer will suffer greater losses?
2. Naseer's variety of maize has given him a yield advantage all these years. He is said to be following a pattern of **monoculture**. List the advantages and disadvantages Ajit has in growing three varieties on his plot.
3. Would you call the Tropical Seasonal Forests of Assam, or the Rain Forests of Sahyadri ranges as monoculture? Explain. Would strawberry gardens be monoculture? List as many examples of monoculture as you can. Discuss your lists.
4. Contrast the natural growth over 3 years, of plants in an untended plot of fertile land, with the growth in an agricultural field. Which would need more water, energy and nutrient inputs to maintain it?
5. Discuss the effect of monoculture of plants on the animals in the region.
6. Would a large variety of species be always desirable? Justify your answer. Under what conditions would you opt for monoculture rather than a natural ecosystem with its variety? What precautions must

you take if monoculture were the only choice under the given circumstances?

7. **Investeak International** is a commercial venture which owns large tracts of teak plantations. It has acquired, or leased, land belonging to small farmers and community plots by paying the local owners. The local people are happy at their new-found prosperity. Farmers who had once owned land now have money, and many find work in the plantations. *Investeak International* invites investors to own portions of the plantations, but not the land. The plantations are developed using investors' money. The investors — mostly the urban rich and non-resident Indians (NRI) — believe, thanks to the advertisements, that their money will go into greening the country, and that they can contribute to saving the environment and get richer too.

   After a period of 20 years, the teak trees are selectively cut down (logged) for timber, while new trees are planted in their place. Owing to this practice no tree in the plantation will ever grow to be more than 20-30 years old.

   Conduct a debate in the class for and against the activities of the Investeak International. One group can be the company spokespersons and the local people who think they gained from the venture. The other group could represent many environmentalists and academics.

8. You have discussed the effect of plant monoculture on animals, their habitat and variety. Is monoculture of animals possible? How? List examples and discuss them in class.

9. There is a term *battery chickens*, meaning poultry farming of a single variety of fowl in cramped spaces, each fowl living in a cell about 1 foot cube. What benefits and disadvantages could this have for the farmer, fowl and the consumer of the fowl? Discuss the consequences of growing different animals in this manner: cows and buffaloes for milk, and sheep for wool.

10. There is genetic diversity among humans: from the Australian aborigine to the Arctic Eskimo; from the indigenous people of Andaman to the Kashmiri. **Cloning** of mammals is a possibility today. Dolly has made this technique rather famous. What might happen if cloning were combined with monoculture?

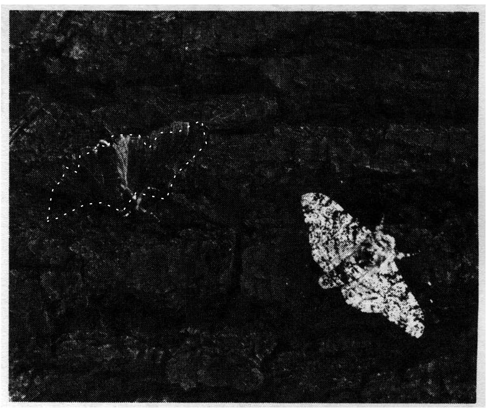
11. Write a story-line (a page or two) of a thriller novel based on the idea of cloning of humanity by the fanatic ruler of a powerful country.

Humans have often tampered with nature and created environments of their own liking. However, not even human-made environments are out of the reach of natural laws. Humans are often ignorant of these laws, or choose to ignore them for gains that are short-term, local or for a small community of people. The following section is about how natural laws working on such ill-conceived projects have brought unforeseen troubles for people.

5.3 Stories from the past and present

The grey and peppered moths of England

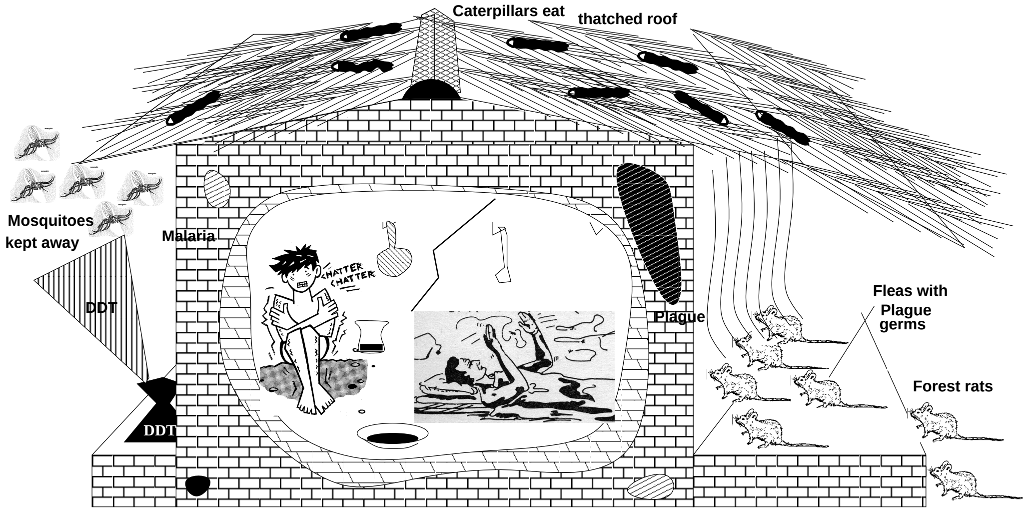
Figure 5.5: Spot the moths.



Collecting moths was a favourite hobby in 19th century England. Collectors would most often find the grey peppered variety while the black moths were rarely found. These two moths were genetic variants of the same species. The peppered moth flew and fed at night. During the day it rested on its preferred tree trunks which were covered with lichen. Towards the end of the 19th century the industrial revolution had changed the scene for moth-collectors, especially near the industrial cities. They started to find more black moths than grey ones. Far from the industries, the ratios stayed the same as before: many more peppered moths. [20]

1. Argue that the peppered moths were adapted for survival in the environment of pre-industrial England.
2. Mimicry and camouflage are two of the most common adaptation traits of animals and plants. What role did camouflage play in this story? Consider both the varieties of moths.

Figure 5.6: DDT in Borneo.



3. How did the industrial revolution affect the moth populations?
4. Write about a similar ecological story — real or imaginary — set in your town or city.

The pesticide boomerang 1: Borneo story

You will discuss two pesticide events. The first is a real-life drama set around the middle of the 19^{th} century in Borneo, an Indonesian island. It is about blind troubleshooting by humans who did not foresee the long-term effects of their actions. [20]

The World Health Organisation (WHO) wanted to eradicate malaria from Borneo. The whole region was heavily sprayed with DDT to kill mosquitoes, which are the vectors that spread malaria. Larger insects and cockroaches too consumed some of the DDT. They did not die immediately and were eaten by lizards. DDT is a poison known to damage the nervous system of small animals. Hence, the lizards with slow reflexes were preyed upon by the cats.

Soon, caterpillars in great numbers began to eat away the thatched roofs (made of leaves). Cats were dying from DDT poisoning. Rats, carrying fleas, came down from the neighbouring forests, and ravaged the houses. The fleas are vectors for plague (carry the bacteria). The people in Borneo were now left with houses without roofs and a new and more dangerous threat in the form of plague (Figure 5.6).

The pesticide boomerang 2: Warangal disaster

Pest attacks destroyed thousands of metric tonnes of cotton crops in 1997, in Warangal district of Andhra Pradesh. Read the series of related events described below, and discuss the issues about pesticide use raised at the end. [21]

Dam and a shift to cotton Since the Nagarjuna Sagar dam project took effect in the 1970's, the area under cotton cultivation and the yield increased considerably in Warangal district. Farmers from many villages were attracted to the profits of cotton cultivation. By mid-1990, 70% of the cotton crops were in rain-fed areas, not irrigated ones.

Changing crop patterns The Indian cotton is genetically diverse and grows under divergent climatic conditions. However, most varieties have low yield. Many hybrids of the 4 main varieties are cultivated in different parts of the country throughout the year.

The new varieties of high yield cotton, which have been recently replacing the Indian ones, are more vulnerable to diseases and pests. They also require greater quantities of fertilizers. The yield and profits do not compare favourably with input costs of fertilizers, pesticides and labour.

Pests attack By the 1990's, pests were attacking not only the cotton crops but anything grown in the area. For a couple of years from 1996 the area received insufficient rains for cotton cultivation when needed. It was excessive during the harvesting seasons when it was least required. The rain-fed areas suffered most by renewed pest attacks. Some pests destroyed whole plants while others damaged the fruits. All known pests had attacked the crops: something that had not been noticed, at least, for many decades.

Pesticide overuse Some poor farmers tried burning baskets full of insects. However, even one female insect which escaped could lay thousands of eggs. In a hurry to rid the pests and minimise the losses, the farmers in the affected areas in Warangal sprayed their crops with 200,000 kilolitres of pesticides. This amounted to 33.6% of the pesticides used in the whole country that year.

Suicides Many farmers had borrowed from moneylenders and loan sharks to finance the buying of fertilizers and pesticides in the previous years. They had to borrow even more in 1997-98 for new seeds, since their previous year's crops had failed. Thus, deep in debt, their lands and sometimes even families sold off, many committed suicide.

Ignorance The 13,000 retailers of pesticides in the district are completely unaware that the pests have become resistant to most of the pesticides used in that area. Nobody has made specific efforts to ensure that the farmers know about the possible evils caused by pesticides.

Contaminated cotton In one study by an association of International Textile Mills, Indian cotton was found to be one of the most contaminated in the World, and fetched low prices.

1. In the light of the 2 stories, examine all your everyday instances of pesticide use. What consequences do you expect from such use?
2. If you were part of the WHO team, how would you have tackled
   - Borneo's malaria problem, and
   - the consequences of spraying DDT in Borneo?
3. If pesticides, combined with ignorance can cause such a havoc as in Warangal's ecosystem, other ways must be found. List all possible ways in which damage due to plant pests can be controlled.
4. Integrated Pest Management (1945) methods have been suggested since 1945. It includes suitable cultural, mechanical, biological and chemical practices. Based on your understanding of ecology so far, and the disasters you have now read about, list the facts that any farmer should know about pest management. What problems will you face in implementing these techniques? (*Hint: These take time to show results.*)
5. Make a poster (or a collage) showing that pesticides must be used carefully, and indicating that there are other ways of controlling pests. Organise an elocution in your institution on **"Know the laws of nature and abide by them," is the slogan for survival of the human race**.

The above stories point to the urgent need for all of us to understand the web of life thoroughly before wilfully disturbing the life of any organism.

Troubled waters 1: The Aswan dam

This story happened on the river Nile, which flows from its headwaters in Ethiopia and Uganda, into the Mediterranean Sea, after quenching the thirst of Sudan and Egypt along its way. [7]

Once upon a time, the Nile carried with it millions of metric tons of silt every year, enriching Egyptian farmlands along its banks. Besides, some of the silt reaching the sea nourished one variety of phytoplanktons which formed the food for many fishes. This picture changed in the 1960's when humans, with their technological skills, interrupted the flow of the river.

Figure 5.7: Birth of a dam. [11, 12]

Egypt built the Aswan dam on the Nile. They hoped that it would provide electricity for Cairo and irrigation water for the lower Nile basin. The benefits and the possible ecological damages were discussed. The officials involved in the decision convinced the people that the benefits outweighed the adverse effects. Soon after the dam was completed and Lake Nassar — the reservoir formed by the dam — began to fill up, a series of problems struck the area.

The farmlands, fertile so far, now needed fertilizers. The fish catch near East Mediterranean reduced to 30% of its original value in a few years. Historical monuments near lake Nassar had to be dismantled and reconstructed away from the rising water levels in the lake. The river flow, now without the silt, eroded the sandy bottoms, the banks of the river and built structures, like bridges.

The incidences of *schistosomiasis*, a debilitating and sometimes fatal parasitic disease, increased in the regions near the dam. The disease was found to be transmitted by the snails which flourished in the constant water supply provided by the lake and the irrigation channels. Thus, the dam project which had significant economic benefits, also caused the Egyptians enormous environmental and health losses. These incurred costs.

Troubled waters 2: Canal in the desert

Indira Gandhi Canal Project, begun in the 1970's, had the grand goal of solving the water scarcity problem in the driest part of Rajasthan. Given below is a brief account of what has happened over the years. [15]

Land degradation The irrigation facility brought some of the grassland, which was originally used as pasture, under agriculture. Some of the agricultural lands became flooded and water-logged due to unlimited use of water for irrigation. This happened especially where the soil was non-porous and impermeable. The excess water dissolved more the salts making the land saline and less fertile. These were turning into marshy deserts, where the weeds grew and supported insects and pests. Problems of land degradation and increased diseases caused villages to be deserted.

Ecosystem degradation New flora and fauna that can thrive under the new conditions are now replacing the older ones. The amazing variety of species of plants and animals well adapted to the dry, hot environment of the Thar desert is rapidly decreasing. One of the dying species is the *sewan* grass. It is highly energy efficient, produces substantial biomass with little water, and is the most nutritious food for cattles. 24% of the pasture-land is already lost and 44% is in highly degraded state.

Cultivation of wheat, rice and other cash crops new to the area, and the changed soil structure, have encouraged growth of weeds and invited new types of pests. Preventive measures against these are yet unknown in the region. Desert rodent species are replaced by field rodents which cause heavy losses to the standing crops as well as stored grains. Plague is an obvious threat in the future. Vectors of diseases like malaria (mosquitoes) and leishmaniasis (sand flies) breed faster in the water logged areas.

1. Industry and agriculture contribute equally (about 30%) to India's Gross Domestic Product (GDP). Many dams are already built and many more are proposed, in order to satisfy the country's electricity and irrigation needs. In recent times, the dams on the Narbada river have raised several environmental issues in India. Figure 5.7 shows how people are bewildered spectators to the problems created by dam development.

   Comment on the possible environmental and health problems that may be caused by such developments. Suggest an alternate way to satisfy the needs of the people.

2. Organise a debate on the topic: **Electricity and irrigation are more important for India than being concerned about environmental and health problems caused by present development methods.**

3. Analyse the Indira Gandhi Canal project and its fall-out. Read articles related to it. State what lessons it has for present and future irrigation projects in terms of the following issues.

   (a) Environmental impact of a project.

   (b) Social impact of a project.

   (c) Fragility of ecosystems.

   Collectively, draw up a checklist of questions that you would ask a planner about any irrigation project.

4. Describe a present area of development which can have environmental, health and economic backlash (problems at a later time).

You have engaged in the activities suggested in this book, and discussed several issues raised here. What role do you think ecological principles must play in deciding developmental strategies and planning? You, the inheritors of our common future, cannot afford to be ignorant of nature's laws concerning life on Earth. You also need to be sufficiently inspired to ensure the survival of human beings, one of the most evolved of all species. May nature be your guide in your intellectual and humane quest for a better life for yourself and all of humanity.

Some eco-thoughts ...

In 1854, the Red Indian Chief Seattle said to the Great White Chief (President of USA) ...

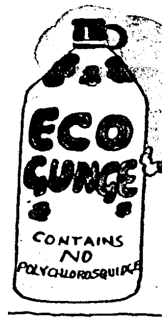
"... Every part of this earth is sacred to my people.
Every pine needle, every sandy shore,
every mist in the dark woods, every clearing,
and every humming insect is holy
in the memory and experience of my people.
The sap which courses through the trees
carries the memories of the red man. ...

... We are part of the earth, and it is part of us.
The perfumed flowers are our sisters; the deer,
the horse, the great eagle, these are our brothers.
The rocky crests, the juices in the meadows,
the body heat of the pony, and human -
all belong to the same family. ...

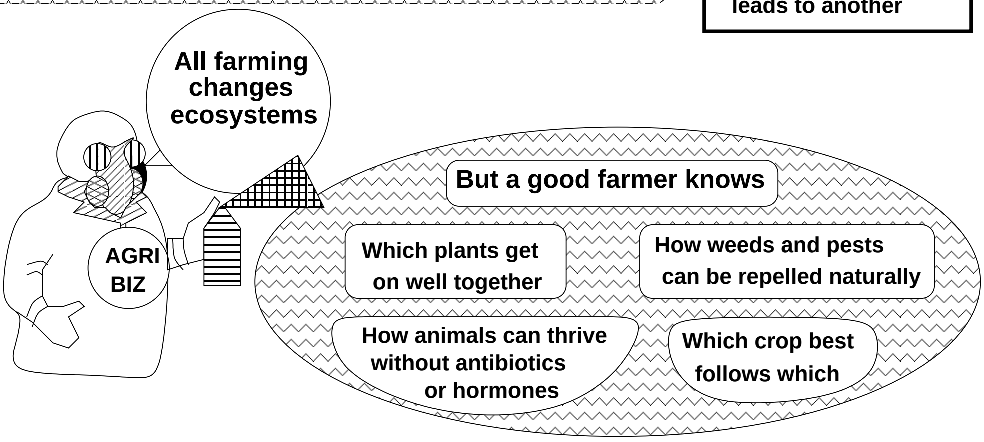
... All things are connected...
Humans did not weave the web of life,
they are merely a strand in it.
Whatever they do to the web,
they do to themselves..."

The great thing about applied science is ...

... one successful project ...



leads to another



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