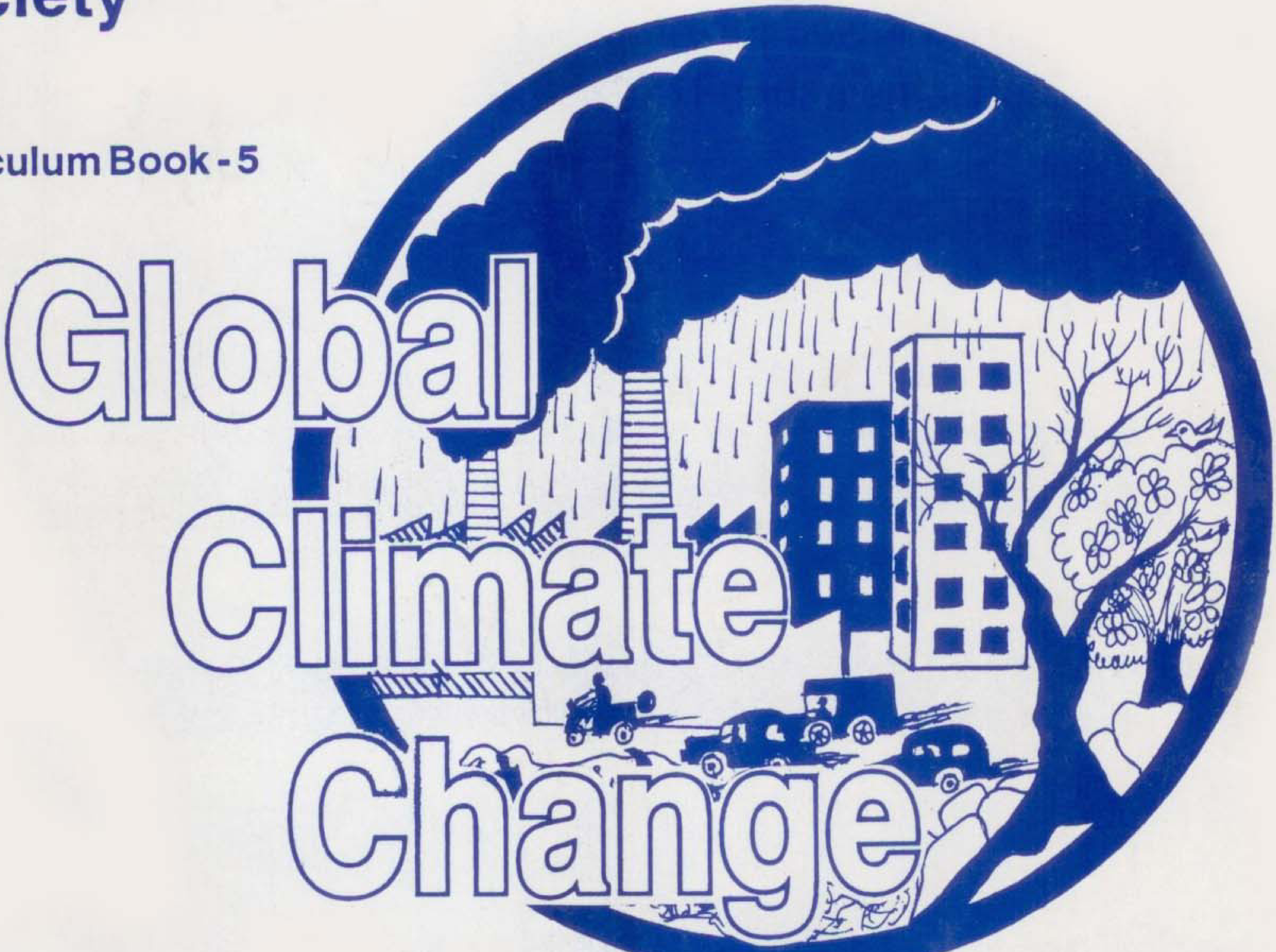
Activity Based Foundation course on Science, Technology and Society

Curriculum Book - 5



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Tata Institute of Fundamental Research

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Global Climate Change

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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.

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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.

Bringing out books of this kind involves a variety of tasks, like clarifying references, getting drafts printed, choosing appropriate illustrations, cover-page layout, photocopying, and so on. As in the earlier books, in referencing, wordprocessing, printing and illustrations, it is a pleasure to acknowledge Ms.Yogita Parab's help, which was often sought and willingly given. 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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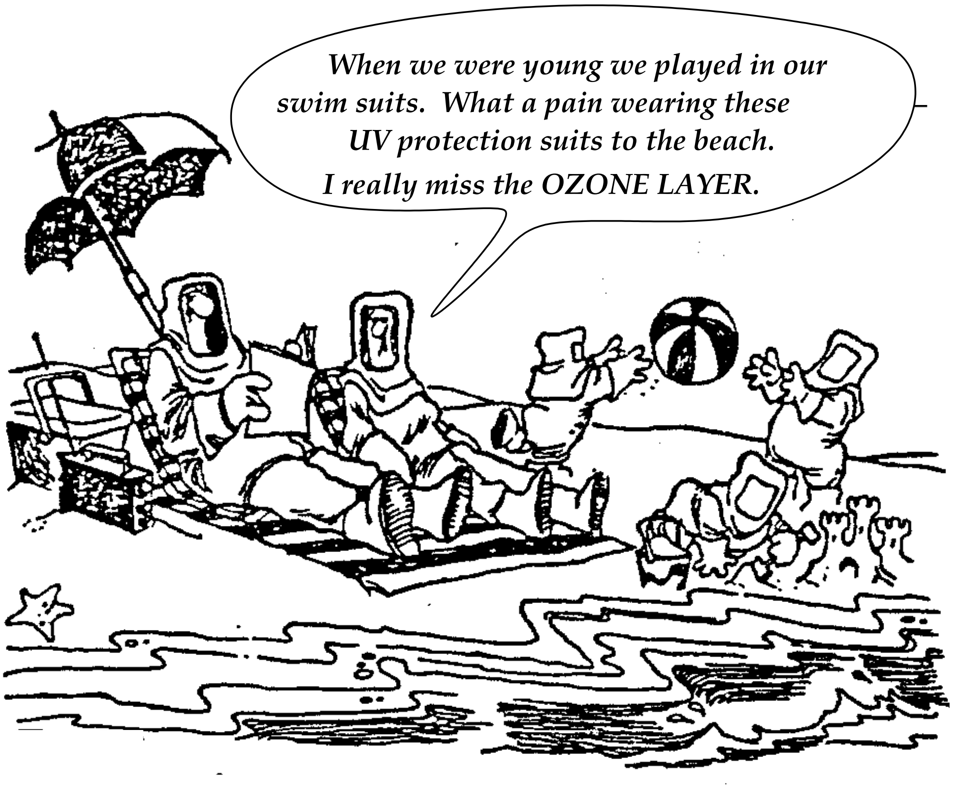
Adapted from G.Tyler Miller (1994) [18]



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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.

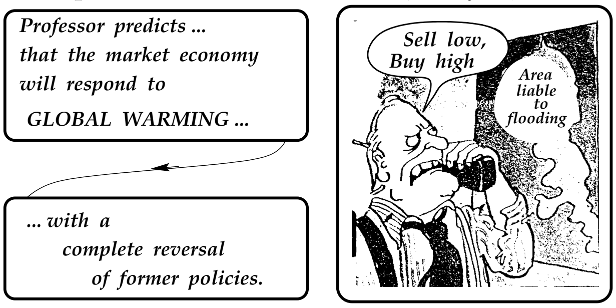
The important, but rather difficult, questions of evaluation have not been addressed here. In this curriculum, more than in any other, evaluation of any form is a measure not only of participant's comprehension, but also of the effectiveness of the leader. Test questionnaires have been provided in some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

1.4 This book

This book deals with three global concerns about the environment: global warming, stratospheric ozone depletion and environmental destruction by acid rain. These three issues are in no way unrelated. In fact, their resolution is possible only when they are addressed all together. However, each concern originated in a different context, and their impact varies with regions of the World. Hence, their solutions are bound to be perceived differently by various countries. This book devotes one chapter to each of the three concerns. It attempts to highlight the technical aspects of the causes of the problems, places them in the perspective of the individual, society and people's life-styles, and links them to national and global policies.

Completion of all the activities will take about 20 contact hours. Some activities, like experiments and surveys, can even be carried out by participants in their leisure time. Sections 2.1, 2.2, 2.6, 2.7, 2.8, 3.2, 3.3, 3.5, 4.2, 4.3, 4.6 will suffice for a shorter course of 10 contact hours.

Adapted from *New Scientist*, July 7, 1990.



Chapter 2

Global warming

Local actions in specific regions or countries in the post-industrial period have far-reaching consequences. This is in contrast to the pre-industrial world (that is the world before the industrial revolution). A policy change or development in one country or region today is likely to cause problems in places farther away. What is worse, the problems may surface many years, sometimes several decades, after the actions. This makes it very difficult for countries to predict, assess and control any damage caused by a particular action. Besides, finding any solution requires that all countries must

- respect the needs of other countries,
- be responsible for the well-being of future generations.

This is a good place to recollect the activities you have discussed in the chapter on "Survival of Humankind" in the book titled *The Population Problem*.

In this chapter you will discuss one out of the many problems that demand a global and future-based thinking: **the greenhouse effect and the resultant global warming**. As is typical of these problems, you need to make predictions using the present incomplete knowledge about the factors that contribute to the problem. You, the inheritors of tomorrows, must plan for a safe tomorrow for all. You have a stake in discussing how your behaviour and life-styles can determine your future.

Our Earth is very special in terms of maintaining the right temperature and composition of gases for life-forms to thrive. Some of us, animals and

Table 2.1: Wavelengths of electro-magnetic radiation with every day applications.

Common name	**Wavelength, metres**	**Application**
Gamma rays	less than 10^{-12}	
X-rays	10^{-12} to 10^{-10}	
Ultra-violet (UV)	10^{-10} to 3×10^{-7}	
Visible light	3 to 7×10^{-7}	
Infra-red	7×10^{-7} to 10^{-4}	
Microwaves	10^{-3} to 10^{-1}	
Radar	10^{-1} to 1	
Radio waves	more than 1	

plants, in the tropics find it rather comfortable, while others have learnt to adapt. You will discuss here crucial aspects of the energy balance on Earth that keeps us optimally warm.

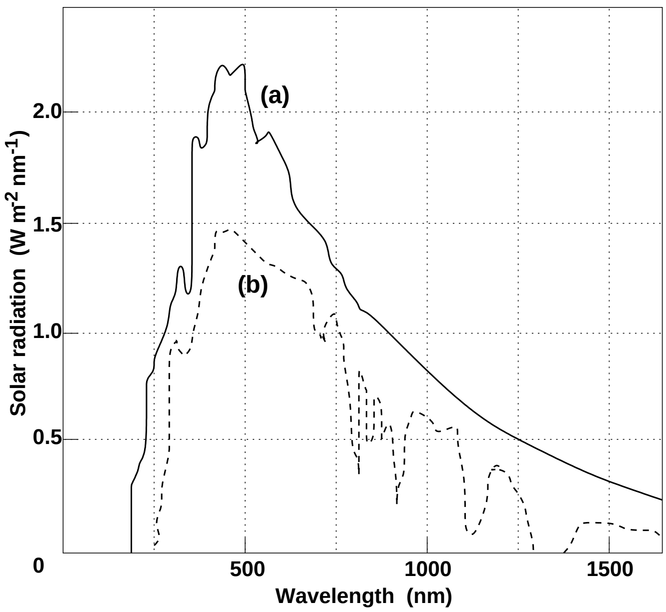
2.1 Sun warms the Earth

To understand the basis for the comfortable climate on Earth, it is important to know how sunlight interacts with the blanket of gases surrounding our planet.

1. How do you know when the sun is shining brightly? You can see it! Can you tell that it is sunny and bright or cloudy and dark if you could not see? Talk to a blind person in your area. Can the person 'feel' the sun in any way? Have you experienced any effect of staying too long in sunlight? Describe these effects.

2. We receive energy from the sun in the form of what scientists call the *electro-magnetic radiation*. In general these are mixtures of waves of many different wavelengths. The energy of these radiations depends on their wavelength. Radiation of longer wavelength have smaller energy. Table 2.1 gives an approximate range of wavelengths and their commonly used names. [28] In the last column of the table write one use (application) of each kind of radiation.

Figure 2.1: The distribution of solar energy at different wavelengths at (a) the top of the Earth's atmosphere and (b) at the surface of the Earth.



3. Some part of the solar radiation is visible light. Solar radiation also has waves other than visible light. Figure 2.1 shows how much energy is received by the Earth in the different wavelength ranges. [31]

   The y-axis of the graph is the energy (in *Watts*) reaching one square metre within a wavelength range of 1 nanometre. A nanometre (**nm**) is 10^{-9} metre. The scale on the x-axis shows the different wavelengths that make up solar radiation.

   The solid curve (a) gives the energy distribution in wavelengths as seen at the top of Earth's atmosphere. The dashed curve (b) is the distribution of solar radiation reaching the surface of Earth.

   From the graph, read off the minimum wavelength in nanometres at which Earth receives solar energy. At what wavelength does Earth receive the maximum energy per unit wavelength per square metre above its atmosphere? What is this maximum value of energy?

4. Notice that the dashed curve (b) never rises above the solid curve (a). Explain why this must be so. List all the differences between the energy distribution at the top of the atmosphere (curve (a)) and that at Earth's

surface (curve(b)).

5. Describe what happens in the wavelength range 700 to 1000 nm. What do you think this indicates?

6. List all that could happen to the solar radiation which falls on Earth's surface.

7. If all the solar energy falling on Earth were to be absorbed, day after day, what could happen to the temperature of the Earth?

8. What do you think prevents the temperature of the Earth from rising indefinitely?

   Most of the solar energy received by the Earth is in the form of ultra violet, visible and small amounts of infra red radiations. This distribution of energy corresponds to the sun's very high surface temperature of about 6000^o Celsius.

The Earth at a surface temperature of about $+15^o$ Celsius is certainly much cooler than the sun! Hence, the radiation, called **thermal radiation** from the surface of the Earth will be at energies much lower than that from the sun.

2.2 Earth's thermal radiation, heat balance

If the Earth absorbed some portion of the energy from the sun every day and did not radiate the heat away, Earth would get hotter with time. The sum of the energy absorbed by the Earth and the atmosphere must be balanced by thermal energy radiated away by the Earth.

Knowing that Earth radiates energy is not enough. You would also want to know how the distribution of energy of this radiation compares with solar radiation shown in Figure 2.1. The surface temperature of Earth is much lower than that of the sun. Hence, the thermal radiation from Earth should consist of waves of a much longer wavelength. In fact, thermal radiation from Earth is in the range of 2000 to 16,000 nanometres — 10 times longer wavelengths than the solar radiation. Microns (μ) is a convenient measure of wavelengths in this range, where $1\mu = 1000\ nm$.

Figure 2.2: Earth's thermal radiation as a function of wavelength, 2 to 16 μ.

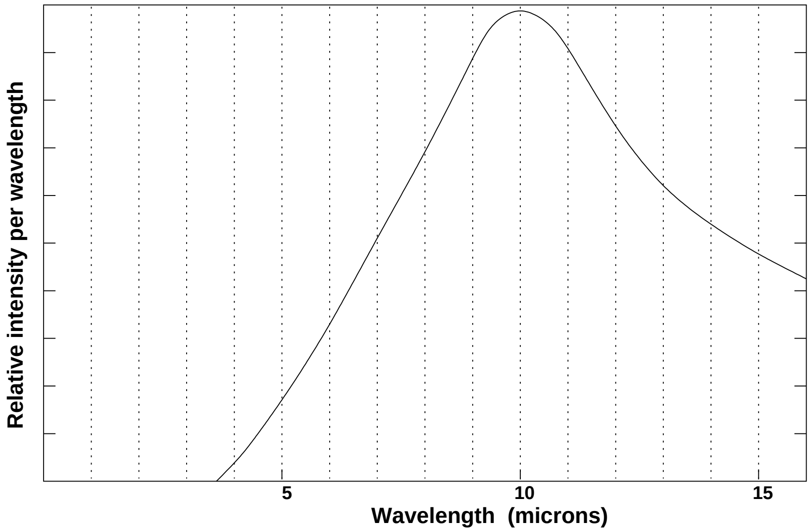


Figure 2.2 shows a graph of the intensity of thermal radiation from Earth's surface per wavelength plotted as a function of the wavelength of radiation. [31] The intensity is measured in some arbitrary units.

The range of wavelengths beyond 16 μ is not plotted because the energy contained in the radiation beyond this wavelength is too little to concern us.

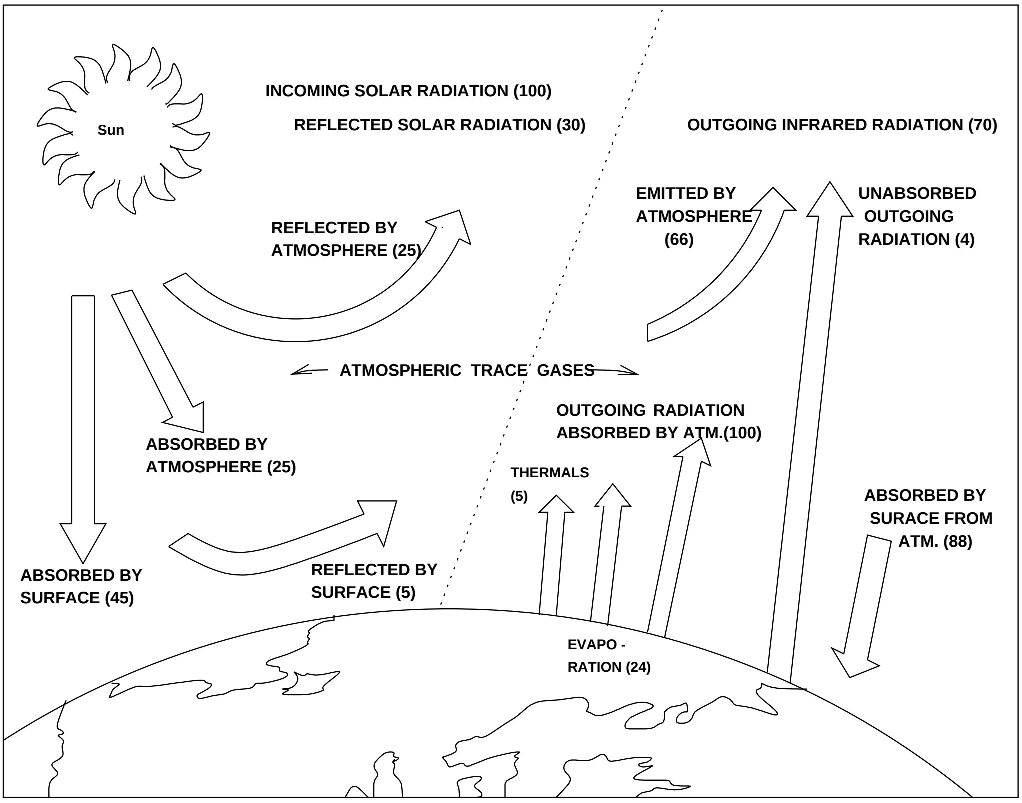
1. Describe the nature of the graph in Figure 2.2. Is this intensity distribution similar to the distribution of solar energy received by Earth (Figure 2.1)?

2. Try scaling the graph (making it smaller, perhaps) so that you can superpose one graph on the other to check for similarity. Do they have similar shapes? Would the radiation from most bodies have a similar shape?

   For those of you who want to know more about this interesting phenomenon in nature, the distribution of energy of thermal radiation from a body over different wavelengths follows a law. This law — **the black-body radiation law** — had caught the fancy of many great scientists in the past, and has evolved through their work.

3. What do you think might happen to the radiation emitted by the surface

Figure 2.3: A schematic showing the fate of solar radiation reaching the Earth. All numbers are in arbitrary units of energy.



of Earth? Would it escape into outer space? Explain.

4. Figure 2.3 depicts all that can happen to the solar radiation falling on the Earth. [22] All numbers are in arbitrary units of energy. There are 100 units of incoming solar radiation. What happens to all this incoming solar radiation? *Hint: Look at the left half of Figure 2.3.*

5. What is the total outgoing radiation? Where does the total outgoing infrared radiation come from?

6. How many units of radiation are absorbed by the Earth? Call this **A** units. In what forms and from where do these come?

7. How many units of radiation are emitted by the Earth? In what forms? Call this **B** units.

8. Is there a relation between the two numbers **A** and **B** that you have calculated above? What does this relation tell you?

9. Figure 2.3 shows that, of the total energy falling on our atmosphere, 45 units are absorbed by land and water. What could happen as a result of this absorption?

10. Does this absorption take place 24 hours of the day? What happens at night?

11. One of the important results of absorption of solar radiation is that Earth gets warm and radiates energy. This you have already discussed (Figure 2.2). All the absorbed radiation must get radiated away too. Recollect your result $A = B$ above. Suppose that all absorbed energy did not get radiated away. What could happen to Earth's surface temperature?

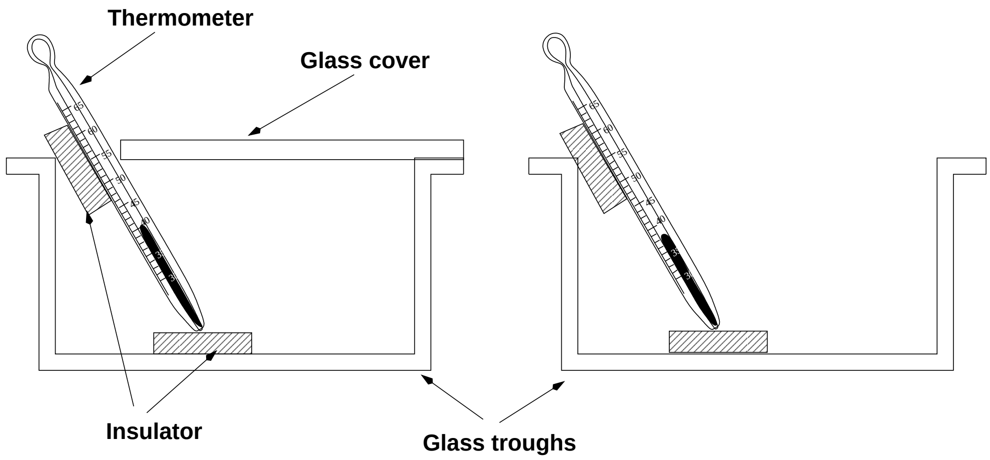
12. To understand what happens because of radiation from the Earth's surface, carry out the following activity.

    Take two identical boxes, say shoe boxes, along with their lids (covers). Paint one on the outside in silver colour, and the other in black. Alternatively, you could cover one with black paper and the other with white paper. Put these covered boxes out in the hot sun with a thermometer inserted in each box. Note the time. Measure the temperature in both the boxes after two hours. Which is warmer? Why?

The amount of energy in different wavelength ranges and the rate of radiation depend on the temperature of the body. There is a law — **the Stefan-Boltzmann law** — that governs the rate of emission of radiation from any hot body. If you were to measure the rate of emission from Earth, it would correspond to an average temperature of about -20^o Celsius (according to the law). This temperature is much lower, however, than $+15^o$ Celsius, the measured average temperature of the Earth's surface.

How then, does Earth manage to maintain her surface temperature at a comfortable $+15^o$ Celsius? This is achieved by the composition of our atmosphere contributing to what is called the **Greenhouse effect**.

Figure 2.4: Schematic arrangement to test the effect of glass cover on the temperature of air in a container exposed to sunlight.



2.2.1 Greenhouse effect

Take 2 identical wide-mouthed containers, anywhere between 1 and 5 litres in volume. If they are metallic, cover on the outside with newspaper. While glass troughs are the best option, other containers should give a smaller but noticeable effect. You will also need one glass plate about 3 to 5 mm thickness to cover the mouth of one of the containers. Measure the temperature of air in the 2 containers. Figure 2.4 gives the schematic arrangement of your containers in the sun.

Leave both the containers, one covered and the other open out in the hot sun for a few hours. You may leave the thermometers in the containers so they are in thermal equilibrium with the air inside. Ensure that the thermometer bulb does not come in contact with the container surface. You should try to measure the temperature of the air in the containers. It would be better to try this on a less windy day. Measure the temperatures in the 2 containers at the end of about 2 hours. Discuss your observations.

1. Do you find any difference in the temperature in the 2 containers? Did both get hotter to the same extent? Give possible reasons for your results.

2. Repeat the last activity, perhaps on the next day after putting some green leaves say 5 mango leaves in both the containers. Were your

results any different? Explain your results.

3. You have realised through your activities that putting a glass plate over the container increases the temperature inside. This is because the glass cover

    - admits solar radiation,
    - prevents all the heat waves from going out of the container by either reflecting them, or absorbing them and re-emitting a large portion back inwards, and
    - prevents convection currents from mixing the cooler air outside with the warm air inside.

    This is what happens in a greenhouse. Have you visited a greenhouse? It is a glass-covered enclosure that provides a warm moist atmosphere to grow plants. Where would you expect to find a greenhouse (specify locations and the needs)?

4. Earth is compared by scientists to a greenhouse. You know that the Earth does not actually have a glass cover over it. What acts like the glass cover?

5. Which of the processes in Figure 2.3 could contribute to the warming of the Earth (the greenhouse effect)? How many units of energy do they involve?

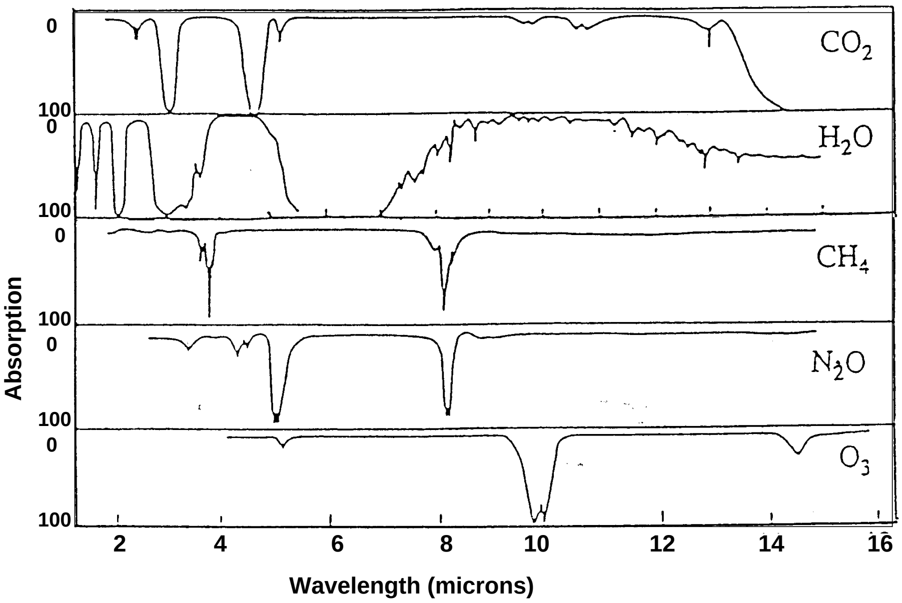
6. Referring to Figure 2.3, what would you say is the role of the atmosphere in keeping Earth warm? What would you have expected in the absence of the atmosphere?

7. Make a poster explaining the **greenhouse effect** in the Earth's atmosphere. You may make several pictures to explain the effect. Label all parts of the picture correctly and clearly and make your poster as colourful as possible.

2.3 Absorption by different gases

The atmosphere of the Earth absorbs much of Earth's thermal radiation, which is largely in the form of infra-red waves. The atmosphere re-emits

Figure 2.5: Absorption of radiation as a function of wavelength from 2 to 16 microns for CO_2, water vapour, methane, nitrous oxide and ozone.



this radiation, both upward and downward. The fraction emitted downward is absorbed by the Earth's surface, thereby providing an energy source to maintain the surface temperature above the equilibrium value (-20^o Celsius) that would have occurred without an atmosphere.

1. Write a paragraph on how changes in the atmosphere could affect the surface temperature of Earth. Remember that the average surface temperature of Earth has been around $+15^o$ Celsius for over 100,000 years.

2. Do you think all gases in the atmosphere would absorb radiation equally in all wavelengths?

3. Absorption of radiation in the range of 2 to 16 μ by some of the important absorbers in the atmosphere is shown in Figure 2.5. [31] Form groups of 3 to 4 members. Discuss among the group and write a paragraph describing the information contained in the five plots.

4. Study the topmost curve in Figure 2.5. It shows that CO_2 absorbs radiation at wavelengths less than 5 μ and beyond 13 μ. You could say that CO_2 *stops* the radiation emitted from the Earth at these wavelengths

Table 2.2: Absorption wavelengths of some gases.

Gases	**Wavelength range, microns**
Carbon dioxide (CO_2)	
Chlorofluoro carbons (CFCs)	8 to 12.5
Water vapour (H_2O)	
Methane (CH_4)	
Nitrous oxide (N_2O)	
Ozone (O_3)	

from escaping freely into space. You could represent this in Figure 2.2 as a horizontal line starting from 13 μ and extending to higher wavelengths. Absorption properties of the gases at wavelengths less than about 5 μ do not matter as there is not much radiation from Earth in that range.

Explain the information given in the other absorption curves in Figure 2.5. Write down in Table 2.2 the wavelength range in which different gases absorb most.

5. Absorptions by CO_2 and water vapour block the thermal radiation from Earth. Represent the blocks as horizontal lines in the appropriate ranges in Figure 2.2. Do this only for these 2 gases.

6. Assume an atmosphere where only oxygen, nitrogen, argon, CO_2 and water vapour are present. What are the wavelength ranges through which Earth's thermal radiation can pass through into space? (Assume that gases not included in the figure do not absorb in this range.) This is the **Earth's radiation window**.

7. In the assumed atmosphere, if the concentration of CO_2 were doubled, how would the 'window' change? In fact, would it change at all? Explain.

8. How do the remaining 3 gases in your table affect the thermal radiation from Earth? Draw corresponding lines showing their absorption. What can you say about Earth's radiation window now?

9. So many gases absorb the Earth's thermal radiation. Why then do we worry most about CO_2? Guess the answer. You will discuss this in a later section.

10. Would you expect the average annual solar radiation received by the atmosphere to vary with latitude (from the tropics to the poles)?

11. The radiation from the atmosphere to the space outside is uniform around the Earth. What can you say about the radiation of energy from the Earth to the atmosphere with respect to the latitude? Where will it be greater, at the tropics or the poles? Why?

12. The annual average solar radiation received at the equator is 4 times greater than that received at the poles. Together with the information given in the last two items there is a surplus of radiation from the surface to the atmosphere at the tropics and a deficit at the poles. What could this differential condition cause in terms of transport of energy near the surface? Make a guess. Discuss your guess in class.

You have realised through the discussions so far that,

- there are several gases besides carbon dioxide which decide Earth's temperature; and
- their absorption wavelengths decide the window through which radiation from the Earth escapes into space.

The concentrations and lifetimes of these gases are also important parameters which tell us how much, and for how long they will affect Earth's temperature. This is discussed later in Section 2.6. The radiation that escapes into space does not contribute to the warming effect. The absorbed radiation is re-emitted by the atmospheric gases keeping the Earth warm. Since the temperature of the Earth has remained relatively stable at $+15^o$ Celsius for over 100,000 years, you would think that the concentration of gases must have varied little over the period.

You can find evidence for this by comparing the measurements of CO_2 concentration in the atmosphere and the surface temperature of Earth over a long period of time. You will do this in Section 2.7.

You can imagine that the molecules of different gases in the atmosphere have not stayed there for millions of years. That means these molecules come from some place, and also go away after a while. They are in a flux. They move from one reservoir of molecules to another. And yet, the number of molecules has remained the same through a balance of fluxes.

Table 2.3: Match the carbon containing substances with their global locations.

Carbon containing substances	Major global locations
Elemental carbon, C	Atmosphere
Carbon dioxide, CO_2	Ocean water
Methane, CH_4	Aquatic life
Hydrogen carbonate ions, HCO_3^-	Land (soil)
Carbonate ions, $CO_3{}^{2-}$	Fossil fuels
Biomolecules	Land-based life
Hydrocarbons	

2.4 CO_2 reservoirs

This section and the next are about the reservoirs and fluxes of one of the most important and familiar gases: CO_2. The remaining gases will be dealt with in the succeeding sections. Form groups of 4 or 5 members, and engage in the activities below.

1. Name the chemical element that is the most common component in all the sources of energy you know, including those that keep you energetic through the day.

2. Saying that a lump of coal is source of energy is fine. What is the process that will release that energy to cook your food? What process helps you run around using the energy stored in the food that you assimilated?

3. Sources of energy are collectively known as *fuels*. Which gas is always produced whenever some of the commonly available fuels are burned? Is this true for the food burned in your body too?

4. Table 2.3 gives a short list of carbon containing substances in column **1** and the possible locations of these substances in the world in column **2**. Match the carbon containing substances to their locations (could be more than one) in which you might find them. These are called the **reservoirs of carbon**.

5. Take 3 used postcards or greeting cards, and stick a sheet of paper on them. Title one as ATMOSPHERE, another as LAND and the third as OCEANS.

Table 2.4: Amount of carbon in the reservoirs at the present time, in the pre-industrial (pre-1800) and pre-agriculture periods.

Reservoir	**Amount of C, gigatonnes (Gt)**		
	Present	**Pre-industrial**	**Pre-agriculture**
Ocean surface (dissolved)	1000	980	980
Ocean deep (dissolved)	38,000	38,000	38,000
Aquatic life	3	3	3
Atmosphere	750	580	580
Land (soil)	1500	1600	1800
Land-based life	550	700	1000
Fossil fuels	5000	5200	5200

6. Paste the cards on a large sheet of paper (say, a newspaper) in their appropriate locations with respect to each other. Divide each card further into the reservoirs contained in them (see Table 2.3).

7. Table 2.4 gives an estimate of the amount of carbon in gigatons in the different reservoirs. (UNEP report cited in [31]) The values are rough estimates. These are not the only reservoirs of carbon. A large reservoir of carbon, the Earth's crust contains about 90 million gigatons (9×10^{19} kg). This is of no concern to us, however, because it does not change appreciably with time. On the other hand, when you want to ensure conservation of carbon on Earth, you need to include this reservoir too.

   Has the sum total of carbon in all the given reservoirs (together) remained the same over the years? In what way has this total changed?

8. Which reservoirs have changed from pre-agricultural to the pre-industrial age? Which reservoirs have changed from pre-industrial age to the present time? Give possible explanations for these changes.

9. Which are the largest and smallest reservoirs of carbon in the given table? Are you a mini (small compared to atmosphere or oceans!) reservoir of carbon? Explain your answer.

10. In the cards that you have pasted on a sheet of paper, mark the present amount of carbon in each reservoir (as given in Table 2.4). Indicate

each reservoir by a different colour. You will use this picture in later activities. So preserve the sheet.

So far you have discovered that there are many reservoirs of carbon, besides the atmosphere. You are now ready to discuss the movement of carbon from one reservoir to another, that is, the fluxes of carbon.

2.5 Fluxes of carbon

What makes carbon move from one reservoir to another? There are several processes in nature, mostly reactions that involve carbon or carbon containing substances. These processes convert the carbon from one form to another. These forms could exist in different reservoirs, as you have seen in Table 2.3. You will discuss such processes and the quantity of fluxes that they involve on a global scale.

Other than water, the most abundant component of your body is the element carbon which is present in the form of many compounds. You were born with a certain quantity of carbon in your body.

1. You have *grown* up now. That has meant additional carbons in your body. Where did these carbons come from? Trace the origin of the carbon in your body to the reservoirs in the table. Do you also lose some carbons from your body? Where does this go?

2. In all the instances given below carbon moves from one location to another. Explain how this happens in each case.

    - You eat the tasty 'prawns' off the Kerala shore.
    - You cook your food on a gas oven.
    - You, your friends, plants and animals breathe.
    - Plants in your garden, in the fields and in the forests make their "food" and grow.
    - You throw away some leaves and food leftovers, which decay.
    - The rain dissolves some constituents of air as it falls to the ground.
    - Your friend leaves the soda containing bottle open for a while.

Table 2.5: Fluxes of carbon in gigatonnes of carbon per year.

Carbon Flux		Quantity
From Reservoir	**To Reservoir**	**gigatonnes**
Ocean	Atmosphere	90
Atmosphere	Ocean	92
Ocean surface	Deep ocean	39
Ocean deep	Ocean surface	37
Ocean surface	Ocean life	40
Ocean life	Ocean surface	40
Soil	Atmosphere	50
Land-based life	Soil	50
Land-based life	Atmosphere (natural)	50
Land-based life	Atmosphere (deforestation)	2
Atmosphere	Land-based life	100
Fossil fuels	Atmosphere	5

- Acidic rain (containing oxides of sulfur and nitrogen) dissolves slates, marbles and other carbonate rocks. (We will discuss this in a later chapter.)

3. List the reservoirs involved in all the cases. Draw arrows between the reservoirs to indicate the fluxes, including their direction. Give 5 more examples where carbon originally in one reservoir moves to another.

4. Estimates of the fluxes of carbon from one reservoir to another are given in Table 2.5. [31] Notice that the fluxes are not all equal. Alongside the arrows that you have drawn, note down (use a sketch pen) the value of the flux in each case.

5. What mass of carbon passes into the atmosphere each year? What mass of carbon is removed from the atmosphere each year? By how much does the mass of carbon in the atmosphere change in a year? Is this an increase or a decrease?

6. Which single process removes carbon from the atmosphere at the greatest rate?

7. Look at all the processes that put carbon into the atmosphere. Which reservoir puts carbon into the atmosphere but does not remove it from

the atmosphere? Explain the significance of this 'one-way-street' process in a couple of sentences.

Carbon reservoirs and the fluxes of carbon from one reservoir to another constitute the carbon cycle. Over many millennia these fluxes have been delicately balanced so that carbon does not accummulate in the atmosphere. However, the *one-way-street* process of burning fossil fuels threatens to upset this balance. This is causing the Earth to become warmer.

2.6 Other greenhouse gases

Besides CO_2 there are other gases that block the Earth's thermal radiation window, and hence contribute to keeping the Earth warm. Hence they are together known as greenhouse gases. Table 2.6 lists 4 of the greenhouse gases. [9] It also lists some of their characteristics that are relevant to the warming effect. These characteristics are:

- the present concentration of the gas in the atmosphere,
- its present rate of increase,
- its life time in the atmosphere (the average between its arrival in the atmosphere and its removal or dissociation),
- how effectively each molecule of the gas causes warming of the Earth as compared to a CO_2 molecule (relative greenhouse efficiency), and
- its present contribution to warming.

You will discuss in this section the relative importance of the different gases for global warming.

1. Which gas is the most abundant in the atmosphere, and which is the least abundant? Is the information about the present concentration alone sufficient to predict which gas will have a greater effect on global temperature? Would you rate CFCs as important contributors to the greenhouse effect?

Table 2.6: Major greenhouse gases and their characteristics.

Gas	Atm. Concn. ppm	Annual Increase %	Life time years	Relative Efficiency CO_2 =1	Current Contribn %
Carbon dioxide	351.3	0.4	2 - 4	1	57
CFCs	0.000225	5	75-111	15,000	25
Methane	1.675	1	11	25	12
Nitrous oxide	0.31	0.2	150	230	6

2. You are familiar with the range of wavelengths absorbed by different gases from the Earth's thermal radiation. Using the information about the quantity of Earth's thermal radiation shown in Figure 2.2 (the height of the curve at each wavelength), guess which gases are likely to have greater effect. What information would you need to understand the relative inportance of the different gases?

3. Consider a piece of ground glass and a dark-coloured glass (or sun glasses) of same thickness. Ensure that they do not have reflecting coatings on their surfaces. Look at the filament of a bulb through these glass pieces one at a time. Through which one do you see the filament brighter? Why?

4. For the same thickness, some materials transmit more light than others. Some absorb all the light and some are are reflecting surfaces. Study column 5 of Table 2.6 giving the relative efficiency of different greenhouse gases. Relate the idea of absorption of light by different materials (that you have just discussed) to the absorption of Earth's thermal radiation by different gases.

5. Compare the efficiency of absorption of the different gases. What does the value of unity for CO_2 mean in the table? Which is the stronger absorber; CFCs or CO_2? How many molecules of CO_2 will be required to do the warming work of one CFC molecule? On similar lines, argue the relative importance of the other greenhouse gases in warming the Earth.

6. List the sources of various greenhouse gases other than CO_2 (you have already discussed this gas). List the natural sources first, and then the

human activities that give rise to the gas. Against each human activity, write in brackets the approximate century or decade when the human activity first started or gained prominence.

7. From the information in Table 2.6 on the annual rate of increase of different gases, which of the gases is increasing at the fastest rate? Which increased by the maximum amount each year? Are these the same? Explain

8. Draw a pie chart to illustrate the present contribution of the different gases to global warming.

9. If the gases continued to increase at the present rate, which gas will double its present value first? In how many years? How long will the other gases take to double?

   Hint: Your calculation of time to double at a constant annual rate of increase is similar to a calculation of the years it would take your money in the bank to double at a compound interest paid annually. The time t *years for any quantity to grow to* x *times its original value (where,* $x > 1$*) at a constant annual increase of* $y\%$ *is given by*

$$t = \frac{100 \times 2.303 \times log(x)}{y}$$

   For $x = 2$*, that is doubling,* $t = 69/y$

10. When the amount of CFCs in the atmosphere doubles, how much will the other gases have increased? Make an estimate. You may use the above formula or infer from your calculations above. In all these calculations, it is assumed that all the gases continue to increase at the same annual rate as given in Table 2.6 for many decades or centuries. How good is this assumption? In what ways can this go wrong?

11. The World summit on global warming held in Kyoto, Japan (known as the Kyoto summit) in December 1997, resulted in a draft policy for reduction of greenhouse gases by various countries. It was signed by 169 countries. It has not been ratified by all the countries (approved by their governments) till March 1998.

According to the agreements reached at the summit the developed countries would decrease their CO_2 by 5 to 8% by 2010. So, you see, there is not going to be much decrease in greenhouse gases. However, as the developing countries industrialise further, CFCs may continue to increase. Consider the situation as above, where CFCs have doubled their present value. The other gases, as you have calculated will stay approximately the same. Calculate the new values of percentage contributions from all greenhouse gases at that time (when CFCs have doubled). Note that the sum of all percentage contributions must add to 100. Draw a pie chart to illustrate this situation.

At the present time, CO_2 appears to be the most worrisome global warming gas. The rate of increase of CFCs warns us that CFCs may catch up. In the next section you will discuss the evidences which prove that human activities cause global warming.

2.7 CO_2 variation in the atmosphere

Atmospheric carbon is present largely in the form of CO_2. Besides there are smaller quantities of methane, hydrocarbons and carbon monoxide. You have seen that CO_2 is a greenhouse gas, and that it is the most significant one at the present time. The evidence for this belief comes from some measurements and some estimates of atmospheric CO_2 content and the average temperature of the Earth's surface.

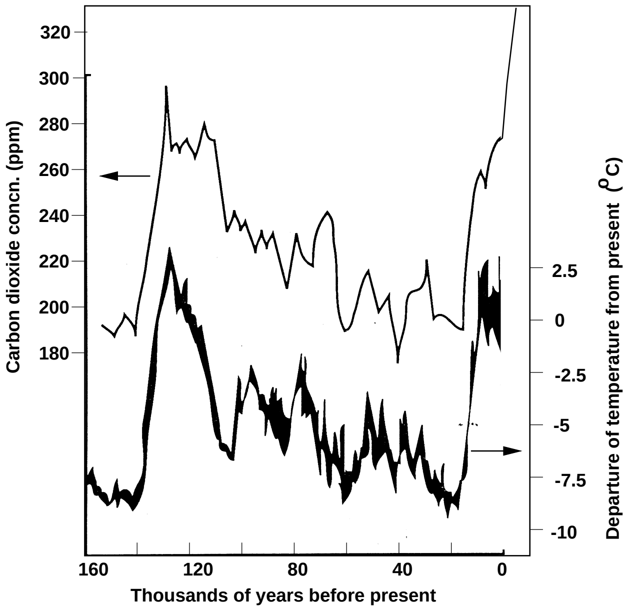
Figure 2.6 shows the variation of CO_2 in the Earth's atmosphere from 160,000 years ago to the present time. [31] [26] It also shows (right scale) the variation of Earth's average surface temperature (deduced from deuterium isotopic profiles) over the same period.

1. In Figure 2.6, how would you describe the relation between CO_2 variation and Earth's surface temperature?

2. Over which period in the figure has Earth's surface temperature remained relatively constant? What can you say about the CO_2 content in the atmosphere during that period?

3. What is the nature of the CO_2 variation in the recent past? If you were to predict its variation in the future, how would you extend the graph

Figure 2.6: Variation of CO_2 and Earth's surface temperature from 160,000 years ago to the present.



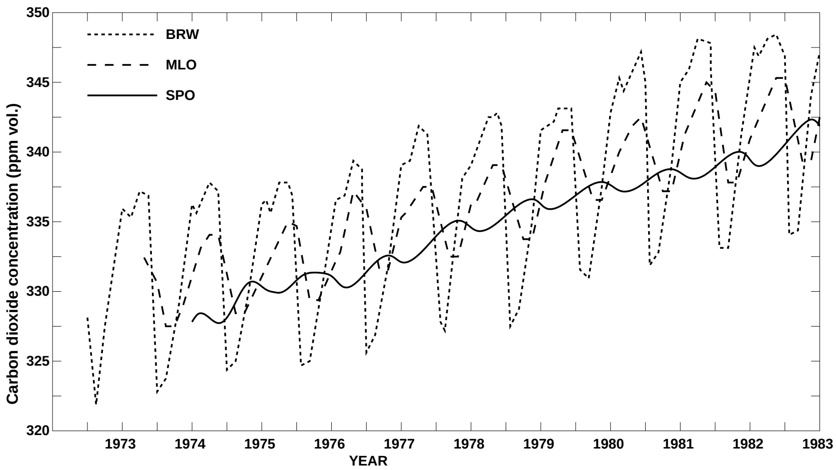
of CO_2 variation? Correspondingly, can you also extend the graph of temperature variation?

4. Figure 2.7 shows several plots. [31] Each plot shows how the CO_2 concentration varies in a different place are shown from 1973 to 1983. The concentration is given in *parts per million by volume* (ppm). For instance, in January 1973, the concentration of CO_2 in *BRW* was about 335 ppm. This means that a volume of 1000,000 litres (1 million litres) of air above that place would contain 335 litres of CO_2 at the same pressure. The places covered are Barrow in Alaska, Mauna Loa in Hawaii and the South Pole.

   Locate the places on a model globe or an atlas of the World. From an atlas showing the physical features of the regions find the difference between the 3 places in terms of vegetaion and climate.

5. CO_2 concentration shows an annual cyclic variation: one valley and a peak per year. What may have caused these oscillations? Make a guess. Discuss in the class. *Hint: Look for local sources of CO_2 emission. Why does its concentration increase?*

Figure 2.7: Variations in concentration of CO_2 in Barrow in Alaska (BRW), Mauna Loa in Hawaii (MLO) and the South Pole (SPO) from 1973 to 1983.



6. List the differences between the variation of CO_2 concentrations at different places. Write a paragraph explaining the differences in terms of the level of development, climate and the vegetation in each place.

Measurements of CO_2 concentrations over the last 20 to 30 years at many places prove beyond doubt that there this quantity is increasing. You have studied the interpretation of geological data on CO_2 concentration in the atmosphere and the temperature of the Earth deduced from deuterium isotopic data over periods as long as 160,000 years before the present time. These show a trend of global warming in recent years. How should humans respond to this?

2.8 CO_2 emission by different countries

You have seen so far that the temperature of the Earth is increasing. It is also clear that humans have contributed to this trend by

- burning large quantities of fossil fuels (CO_2 and N_2O),
- agricultural practices (CH_4 and N_2O), and

- introduction of new chemicals with little foresight about their possible consequences (CFCs).

The discussions in this section will be about who has contributed to the problems and how much.

1. Table 2.7 gives the average amount of CO_2 in tons (1000 kg) emitted annually per person in different countries of the World in 1991. [12] The data consists of emission from industrial sources and through changes in land use. Use a suitable abbreviation of 2 letters to indicate each country and note this in the table. On the world map provided in Appendix A, locate these countries. Draw the latitudes corresponding to the Tropic of Cancer and Tropic of Capricorn.

2. Which country in the list has the maximum annual per capita (per person) emission of CO_2 in 1991 from industrial sources?

3. In what ways can land use change give rise to CO_2 emissions? Write a couple of sentences explaining the connection between changes in land use and CO_2 emission. In which country do you find maximum per capita emission of CO_2 due to this source? Using your knowledge of school geography justify the values for CO_2 emission by the 2 different sources.

4. The data on per capita CO_2 emission through land use change is not available for many countries. Using your knowledge of the geographical location, developmental status, and past history of land use in these countries, argue that their contribution to CO_2 emission through land use change, if at all, is going to be too small to matter at present. *Hint: Presence of forests together with the need to utilise them for developmental purposes encourages countries to opt for land use change. Check whether any of these countries possess large forests and have a low developmental status.*

5. Approximate numbers for population of each country in 1990 are provided in the table. Calculate the total CO_2 emitted by each country and enter these values in the last column. Add per capita emissions from both the sources. Rank the countries according to their total CO_2 emissions.

Table 2.7: Annual per capita emission of CO_2 in some countries by industrial sources (**Industrial**) and land use change (**Land**) in 1991.

Country	**Per capita CO_2, tons**		**Popn.**	**Total CO_2**
	Industrial	**Land**	**millions**	**megatons**
Argentina	3.55	—	32	
Australia	15.13	—	17	
Brazil	1.43	6.46	150	
Canada	15.21	0.45	26.5	
China	2.20	—	1139	
Egypt	1.54	—	52	
France	6.56	—	56	
Germany	12.13	—	61	
India	0.81	0.025	853	
Indonesia	0.92	1.79	184	
Italy	6.96	—	57	
Iraq	27.86	—	18	
Japan	8.79	—	123	
Korea, Rep. of	6.05	—	43	
Mexico	3.92	0.56	89	
Pakistan	0.55	0.079	123	
Poland	8.06	—	38	
Saudi Arabia	13.96	—	14	
South Africa	7.18	—	35	
USSR (former)	12.31	—	281	
UAE	36.49	—	1.6	
UK	10	—	57	
USA	19.53	0.088	249	
Venezuela	6.16	8.5	20	
World	4.21	0.64	5292	

6. List the countries which annually emitted more CO_2 per person than 12 tons (about 3 times the world average of 4.21). Where are they located? What can you say about their development? Why do you think their emission is so high? List as many reasons as you can.

7. Tick all the countries whose per capita CO_2 emission from industrial sources is higher than the world average. Call these the **black** countries (because they emit more CO_2). Among these countries, which are the top three contributors to the total CO_2 emission of the world?

8. Suppose that these 3 **black** countries decide to reduce their per capita emission by half the value they had in 1991. Assume that all the other countries remained at the same emissions and populations as in 1989-1991. What will be the total change in CO_2 emission? What percent of the total world emission (in 1991) is this change? Is this desirable? Explain.

9. Mark all the countries whose per capita CO_2 emission from industrial sources is lower than the world average of 4.21. What can you say about their developmental status? Why do you think their per capita emission is low? List as many reasons as you can. Call these countries the **white** countries (less CO_2 emission). Are these countries more likely to reduce their emissions or increase them? Justify your answers.

10. Of all the **white** countries, which 3 contribute the most to CO_2 emission? Which countries would make the most difference if they decided to raise their standard of living and double their per capita CO_2 emission of 1991? Suppose, as in the above activity that all the other countries maintained their emissions and populations at the 1991 values. What will be the total change in CO_2 emission? What percent of the total world emission (in 1991) is this change? Is this offset by the reduction in CO_2 by the **black** countries that you have calculated above?

11. Discuss the stand that India should take on global warming. Write a draft suggestion for the next Global Summit on Climate Change, giving realistic guidelines on who should reduce CO_2 emissions and why.

The situations given here about the *white* and *black* countries are not very realistic, especially with respect to time scales in which either reduction or increase will happen. Moreover, populations, especially of the developing countries will continue to increase at least for a few decades more. Yet, the scenario depicted serves as a starting point for future estimates. What is more important is that you should now be equipped to defend your stand on the issue of global warming.

The concentration of CO_2 and hence the temperatures are not stable any longer. The CO_2 concentration in the atmosphere is on the increase. If, and when, a new balance is reached, the Earth's temperature would have changed to a new, and possibly increased value. That will lead to many changes on Earth. How many humans and other living species today are prepared for those changes? How many will be able to adapt? You should discuss this in class. You should also return to this discussion at the end of every chapter in this book. Ideas about *adaptation*, will be dealt with in the book on *Ecological Balances*.

Chapter 3

Ozone

Oxygen is the most familiar of all the gases that constitute the air around us. Over the years, all living beings have adapted to an atmosphere that contains nearly 20% oxygen. This familiar oxygen gas is made of two oxygen atoms bonded together. Scientists call this a *diatomic molecule*, meaning clumps of two (*di*) atoms. It need not always be diatomic, although this is the most stable form of oxygen near the Earth. As you go to higher altitudes, the amount of oxygen in the air decreases and the composition of the atmosphere changes. This chapter is about what is happening to a form of oxygen called **ozone** that forms a protective layer 25 kms above the Earth's surface.

Energetic radiation can break up the stable diatomic oxygen into 2 separate atoms. Single oxygens are reactive. They quickly combine with atoms of other elements, forming oxides. They may combine with another single oxygen to form a diatomic molecule. Less frequently, they may combine with a diatomic oxygen molecule.

1. Draw a picture to depict all the different possibilites when a diatomic oxygen molecule breaks up.

2. Thus, oxygen can exist in 3 different forms: as a single reactive atom for short times, as a stable diatomic molecule, and as a molecule of 3 oxygen atoms. Each of these forms is a gas at normal atmospheric pressure and room temperature. The 3-atom molecule is familiarly known as **ozone**. Ozone is a blue gas that is not very stable as a grouping of 3 is not a preferred arrangement for oxygen.

You have probably heard of ozone in different contexts. List whatever you know about it. Guess what it might possibly be useful for.

3. Ozone gas is a constituent of photochemical smog. This smog occurs almost all through the year in tropical cities choked with vehicular emissions. Ozone is a very reactive oxidising gas. It is an irritant to living cells and is known to cause health problems to all living organisms: plants and animals (see book *Resources: Land and Air*).

   This ozone formed from photochemical reactions of chemicals in vehicular exhausts hovers around the ground level causing all the harm. List what can be done to reduce this ground level ozone.

4. Ozone is also formed at higher altitudes when energetic solar radiation, (shown in Figure 2.1 in Chapter 2) break up the diatomic oxygen molecules. About 3-7% of the energy of solar radiation is in the form of Ultra Violet (UV) rays. Only a small fraction of this reaches the Earth. Table 3.1 gives the wavelength ranges for some UV radiation and the effects they may have on Earth and her life-forms. [5]

   (a) Which wavelength range of UV do oxygen molecules absorb the most? Which wavelengths do ozone molecules affect?

   (b) At what latitudes on Earth (like the Tropics, Temperate regions and Polar regions) would you expect the maximum amount of UV radiation to reach Earth's surface? Give some instances to show that living beings on Earth (humans and other life forms) have adapted to the different intensity of UV radiation in different regions.

3.1 Relations: oxygen, UV and life

Figure 3.1 shows the evolution of three things: life on Earth, oxygen and ozone in the atmosphere, and the UV radiation reaching Earth's surface. [22] Amount of oxygen at any time is given as a percentage of the present oxygen content in the atmosphere. That is, the present concentration corresponds to 100%. Half the present concentration of oxygen in the atmosphere would be 50%. Study the figure and discuss the issues below.

Table 3.1: UV radiation: wavelength ranges and effects on Earth.

UV Name	**Wavelength, nm**	**Effects**
UV extreme	< 200	• totally absorbed by N_2 and O_2
UV-C	200 - 280	• most energetic; • strongly absorbed by O_2; • negligible quantity reaches Earth
UV-B	280 - 320	• damages living cells; • most absorbed by O_3
UV-A	320 - 400	• least energetic; • can damage living cells; • transmitted to Earth

1. What can you say about the correlation between the evolution of life on Earth and changes in oxygen in the atmosphere?

2. Approximately how many years ago did life begin on Earth? Eukaryotes are organisms which have their genetic material protected within the nucleus. When did they begin to exist on Earth?

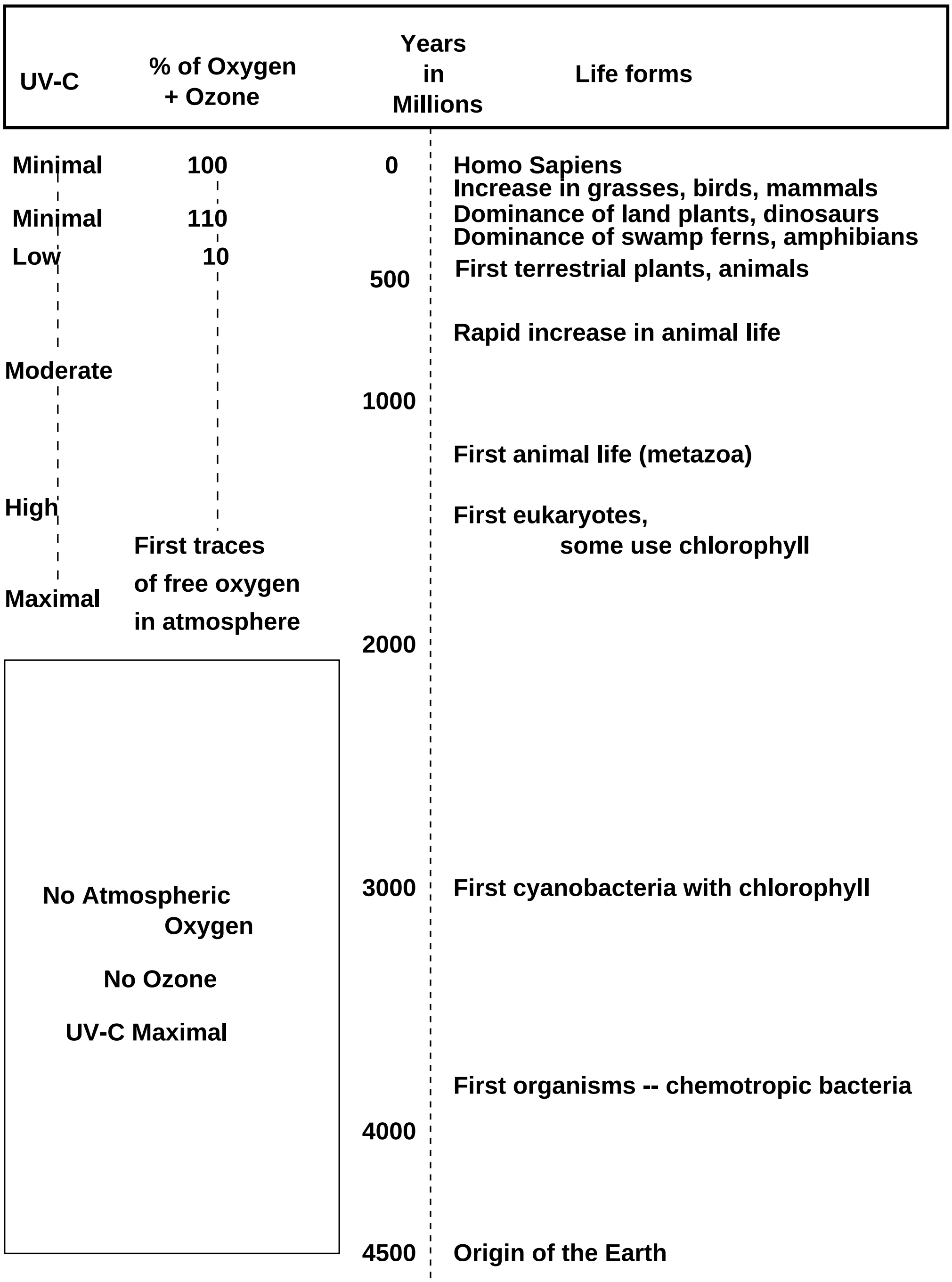
3. When did the first terrestrial plants and animals begin to populate Earth? How did this relate to the change in oxygen concentration in the atmosphere?

4. How much oxygen did the atmosphere have during "Dinosaur times"? What happened to the oxygen content in the atmosphere after the dinosaurs? Give possible reasons. Do you think the trend will continue into the future? What might be the oxygen concentration 200 million years from now?

5. The amount of UV reaching Earth's surface started decreasing about 2000 million years ago. Explain the possible causes for this. Argue that the oxygen content in the atmosphere may be related to this decrease.

6. Life originated on Earth in the presence of large amounts of UV radiation. According to one hypothesis, proteins were produced when a UV spark was passed through a flask containing methane, ammonia, hydrogen and water. Deduce from these two statements the possible role of UV radiation in the origin of life on Earth.

Figure 3.1: Evolution of the Biosphere and life systems.



7. Life first existed in water, over 3000 million years before land animals and plants came into existence. What advantage would life in the water have with regard to exposure to UV radiation?

8. Agricultural fields and cattle dung are known to give off large quantities of methane. This is transported to the upper atmosphere and is a reducing agent (uses up ozone and oxygen). In what ways could the growth of grasses and mammals have contributed to the change in oxygen and ozone concentrations?

9. In what way are the UV radiation and oxygen levels in the atmosphere correlated? Explain.

You have discussed how life, oxygen, its 3-atom molecule called ozone and the amount of UV radiation reaching the Earth have all varied together, influencing each other over the ages. Even at the present time, the quantity of ozone, the variety of life and the amount of UV reaching the Earth's surface are neither constant with time nor uniform over space. They vary with altitude above the Earth, at different latitudes on the Earth, and also with seasons. You will discuss these variations in the ensuing sections.

3.2 The ozone layer

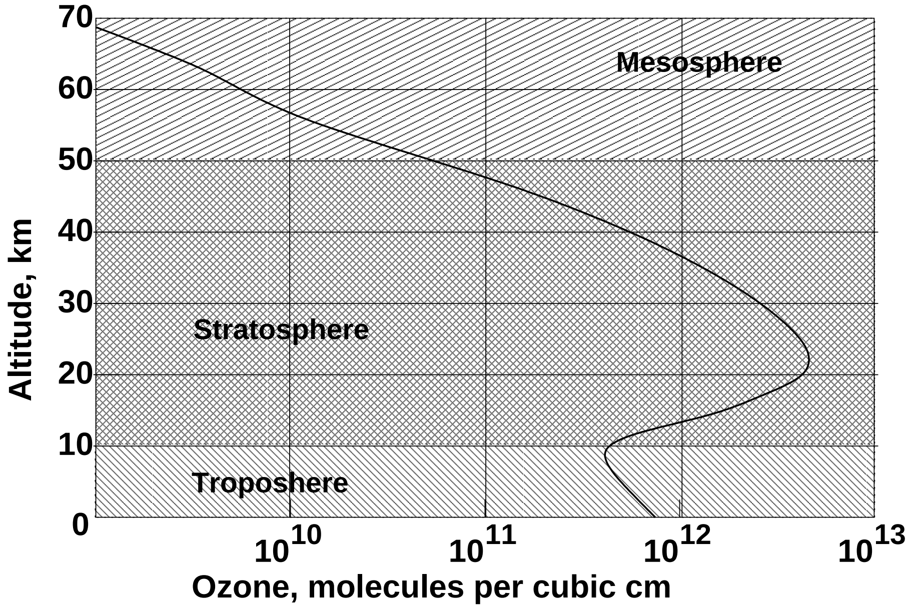
Figure 3.2 shows the variation in ozone concentration as you go above the Earth's surface. [5]

1. At what height would you find the maximum concentration of ozone? In which of the three layers shown in the graph would you find the maximum total quantity of ozone?

2. How does the concentration of ozone at the ground level compare with ozone at other altitudes?

3. Imagine a vertical column of air one square centimetre in cross section. Calculate (approximately) the average number of ozone molecules in a vertical column of air in the 3 regions of the atmosphere: Troposphere, Stratosphere and Mesosphere.

Figure 3.2: Variation of ozone concentration with altitude in the atmosphere.



4. Your calculations should have shown that most of the ozone in the atmosphere is concentrated in the Stratosphere. You have probably heard of this layer, the **ozone layer**. Write a few sentences on the ozone layer. Discuss your ideas in the class.

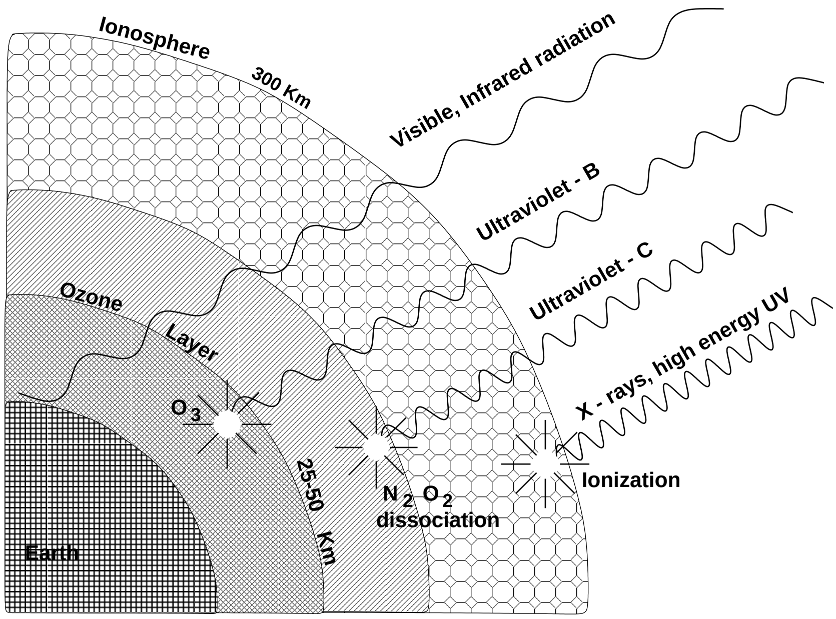
The ozone layer in the Stratosphere is concentrated around 25 kms above the Earth. The thickness of this layer is not uniform: it varies with latitudes and seasons. In the next few sections you will discuss the processes that may make the ozone layer thicker or thinner.

3.2.1 The ozone balance

Figure 3.3 shows a schematic representation of the processes responsible for the absorption of solar radiation in the Earth's atmosphere. [20] Study the figure and discuss the issues raised below.

1. What happens to the highly energetic radiation in the atmosphere?
2. What happens to the UV-C radiation in the upper Stratosphere (above

Figure 3.3: A schematic representation of the processes responsible for the absorption of solar radiation in the atmosphere.



60 kms)? With which molecules does it interact? How might this help in the formation of ozone?

3. What happens to the UV-B radiation lower in the Stratosphere? With which molecule does it interact? What might be the result? What effect might this have on the life forms on Earth? (*Hint: Refer Table 3.1*)

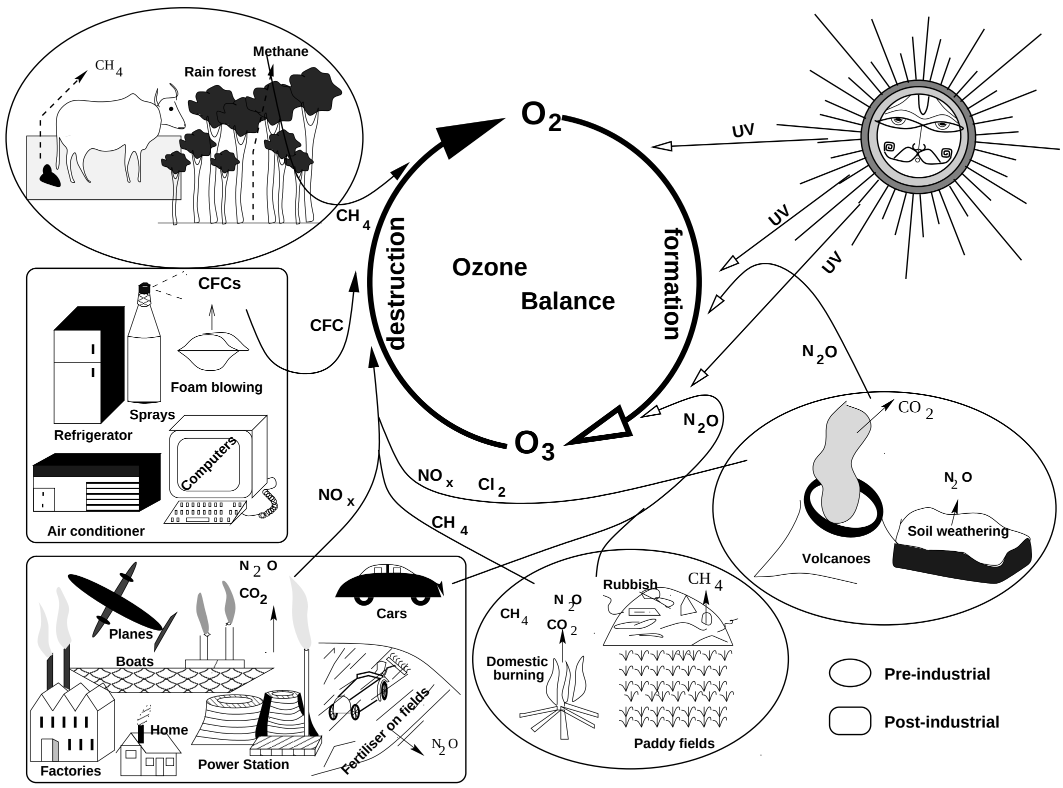
4. Argue (in a few sentences) that the 2 processes, one involving oxygen in the upper Stratosphere and the other involving ozone, protect Earth from UV radiation.

5. Natural processes on Earth, like decaying wood and animal dung also emit molecules like methane. Molecules like nitrogen oxide and methane speed up the splitting of ozone, resulting in formation of oxygen molecule.

   The concentration of ozone in the atmosphere has been fairly uniform for over 100,000 years, with some cyclic variations. Consider

   - the 2 processes involving sunlight, and
   - naturally occuring reactions with nitrogen oxides and methane.

Figure 3.4: A schematic of ozone balance.



Explain how an approximately steady concentration of oxygen and ozone may be maintained by a combination of the above processes. Do humans play any role at all in the ozone balance? Explain.

6. Figure 3.4 is a schematic of how a possible ozone balance may be maintained. Some of the processes require the presence of sunlight (UV radiation), while others do not. Identify the processes that occur in the absence of sunlight. Do they form ozone, break up the ozone, or do both? (NO_x refers to all oxides of nitrogen.)

   Discuss this with the whole class. Based on your discussion, would you expect the ozone layer in a particular place to be different in the night and day? Explain.

It is clear that nature has maintained an overall balance of ozone over a long period. This is a rather delicate balance, and the quantities of oxygen, radiation, and chemicals involved in this balance are not uniformly distributed over the Earth. Besides, you can imagine that varying winds and seasons would churn the constituents of the atmosphere. Yet, the ozone layer appears to have a definite structure, and it varies predictably with seasons.

3.3 Depleting ozone: the growing hole

You have seen in Section 3.1 that the ozone layer has grown as life on Earth has increased in number and variety. In the initial stages, UV radiation may have helped create the conditions for life to begin. However, UV is also harmful to living cells and hence to life. The increasing ozone layer protected the increasing life on Earth.

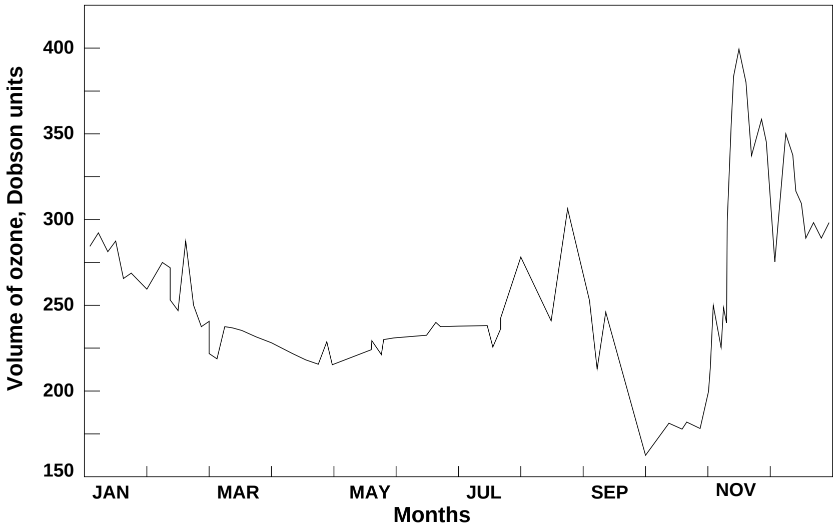
The abundance of ozone in the atmosphere is measured in **Dobson units** (DU), in honour of the pioneering atmospheric physicist Gordon Dobson. Consider a cylindrical column of ozone, of some base area A and of height H at a pressure P_1 and temperature T_1. Without altering the base area, of the column, compress the ozone column to the standard (at sea level) pressure and temperature. Its new height, say h expressed in millimetres gives the amount of ozone in the column in Dobson Units. Thus, 1 mm of this compressed column will correspond to 1 DU of ozone.

3.3.1 Ozone layer varies with time and place

The structure of the ozone layer is rather complex. Scientists have been struggling to find suitable climatic models that will predict the seasonal and spatial variations of the ozone layer and its Antarctic hole. Based on past measures and trends, it is possible to make some estimates of what might happen to the ozone layer with time.

The natural abundance of ozone in the ozone layer varies by nearly a factor of two with seasons and latitudes. You know that ozone is mainly produced by the action of sunlight. Hence, you may expect to find a greater abundance of ozone over the tropics, and less over the mid-latitudes and poles. However, the distribution of ozone is primarily governed by the air circulation over Earth. Due to the rotation of Earth and the temperature

Figure 3.5: A record of daily changes in ozone levels over the Antarctic in 1986.



variation across the latitudes, the lower atmospheric air fans out (goes up to the Stratosphere) towards the poles. There it descends and re-enters the Troposphere. The time taken for the poleward motion of the air is about 6 months. Ozone concentrations are seen to be the smallest at the tropics and the greatest at the poles. Thus the ozone layer is seen to be thicker in the temperate region and thinner nearer the equator. The hole in the layer in this abundant ozone region is another matter, discussed later.

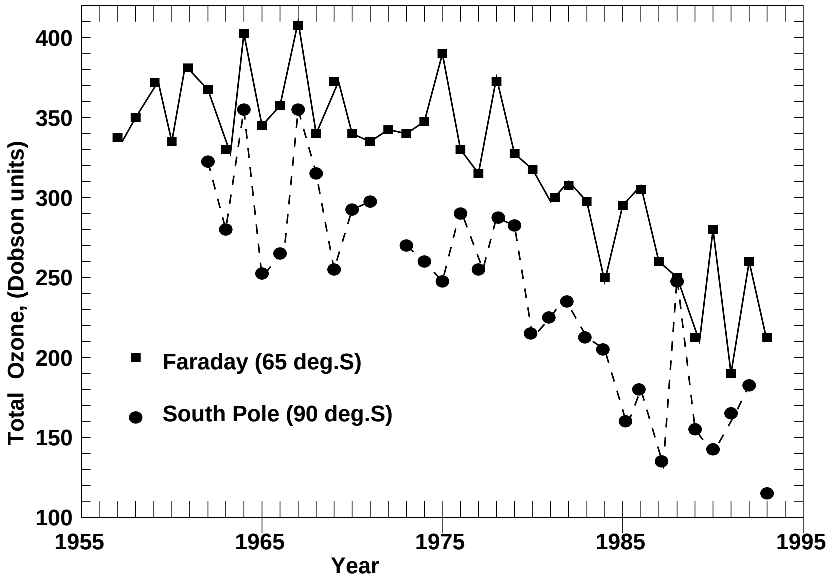
1. Figure 3.5 is a record of daily changes in ozone levels over the Antarctic in 1986. [6] In which months is the ozone minimum? In which months would you expect the hole to form over the Antarctic?

2. From Figure 3.5, what can you say about the approximate ozone balance over the whole year? Justify your answer.

3. Figure 3.6 shows the variation in mean concentration of a column of ozone, measured in Dobson units, in the month of October during the years 1957 to 1993. This is shown for 2 Antarctic monitoring stations at 65^o South (latitude) and 90^o South (the South Pole). [27]

   Some Antarctic research stations are given below. Using their latitudes (North or South of equator) and longitudes (East or West of Greenwich

Figure 3.6: Mean october concentration of a column of ozone at 2 Antarctic monitoring stations, 1957-93.



Meridian) locate these places on the Atlas in Appendix B.

(a) South Pole

(b) Faraday (UK) 65^o South, 65^o West

(c) Halley bay (UK) 76^o South, 25^o West

(d) Showa (Japan) 69^o South, 40^o East

(e) South Magnetic Pole 65^o South, 139^o East

4. Which of the 2 places in Figure 3.6 has a higher concentration of ozone? Has it been higher over all the years from 1957 to 1993? Explain why.

5. Note that each point on the graph represents the ozone concentration averaged over a whole year. Has this average concentration changed smoothly over the years? Would you say that it was periodic? That is, does it rise to a maximum (or fall to a minimum) at regular intervals? If yes, then estimate this interval.

6. Are the variations similar in both the places? Draw a smooth line joining all the peaks of the recordings at the South Pole. Draw a similar smooth line joining all the peaks of the recordings at the Faraday

research station. Are there any similarities between the 2 curves obtained?

7. The curves you have drawn will also exhibit 3 peaks and 2 valleys. Note the years in which the South Pole curve peaks. What is the interval in years between the first 2 peaks? What is it between the next 2 peaks?

   Repeat the above activity for the Faraday station recordings. Note down all the intervals.

8. Sunspots are phenomena occuring on the sun that are known to affect Earth. Sunspot activity peaks approximately every 11 years. Do you think there may be any relation between Sunspot activity and the concentration of ozone above the Antarctic region?

9. Calculate the percentage change in ozone levels from 1957 to 1993 over the South Pole. What would be the percentage change at the Faraday station?

You have just seen that there has been a decrease in ozone concentration above the Antarctic region over the past 30 - 40 years. In 1974, chemists Sherwood Rowland, Mario Molina and others warned of the dangers of ozone depletion. The results of the Total Ozone Mapping Spectrometer (TOMS) aboard the *Nimbus 7*, a NASA (USA's National Aeronautics and Space Administration) satellite in 1979 also indicated ozone depletion. It was thought that some human-made chemicals could accelerate the depletion. There was a demand that such chemicals needed to be phased out.

However, it alarmed the world only after a historic observation in 1985 by a British Antarctic Survey team. According to their report, over the previous decade, total springtime ozone levels above the Halley Bay station in Antarctica had fallen by at least 50%. Soon after, international conventions and treaties were intitiated to control and phase-out ozone depleting substances.

There are two issues that surface from these findings. You need to know how serious a problem this is. You must also find out what you can do about something happening in the Stratosphere, 25 kms over your head!

3.4 Ozone depletion: actions

The ozone layer is thinnest above the tropics. And yet, the tropical regions are thriving with a variety of life-forms. Humans and other species have evolved and adapted to live in a specific latitude under a certain thickness of the ozone layer.

The ozone layer at higher latitudes is normally thicker. However, it varies with seasons. There is a thinning of the ozone layer above the polar regions in spring (which follows winter). This 'hole' above the poles, especially above the South Pole (Antarctic region) has been getting bigger in recent years. Discuss the possible consequences of this through the following activities.

1. What do you think might happen if the ozone hole over the Antarctic kept increasing in size spring after spring?

2. The hole moves around the region during each year and also from year to year. This happens because of winds and climatic conditions. Which countries are most likely to get the hole above them?

3. What might happen if there were a thinning of the ozone layer, all over the World?

4. The temperate zone, has a thicker shield of ozone layer above it at the present time. Consider the following scenario 100 years from now. The temperate zone begins to receive some tropical-like UV radiation because of ozone depletion. Write a story related by a Russian grandmother in this setting to her grandchildren about her younger days.

5. In the grandmother's story above, the children may ask about the causes of the disastrous ozone depletion. What might the grandmother say?

3.4.1 Chlorine: the ozone eater

A class of chemicals containing chlorine atoms has been blamed for the recent increase in destruction of ozone in the Stratosphere. These chemicals have such appealing properties of inertness, long life and low vapour pressure, that they have been used in many applications for about half a century. The most

Table 3.2: Use and annual emissions of chemicals associated with Stratospheric ozone depletion in 1989.

Chemical	**Emissions 1000 tons**	**Atm. Life, yrs**	**Uses**	**Share of Depletion %**
CFC-12	454	139	Air-conditioners, refrigerators, aerosols, foams	45
CFC-11	262	76	Refrigerators, aerosols, foams	26
CFC-113	152	92	Solvents	12
CCl_4	73	67	Solvents	8
$C_2H_3Cl_3$	522	8	Solvents	5
Halon 1301	3	101	Fire extinguishers	4

important of these are called the **Chlorofluoro carbons** or **CFCs**. You have discussed in the last chapter (Table 2.6) that these chemicals are culprits in global warming too!

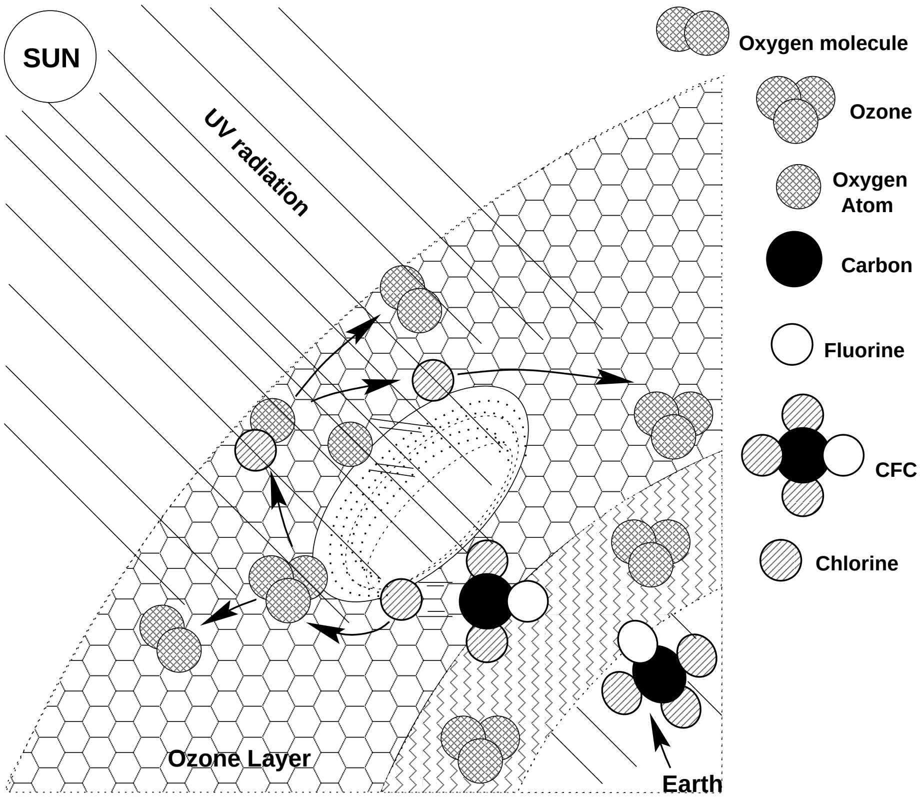
According to a popular model explaining ozone depletion, chlorine containing chemicals are released at ground level. Because of their inertness and long life they manage to rise to the Stratosphere when the atmosphere mixes vertically.

1. Table 3.2 gives the quantity used and total emssions of chemicals associated with Stratospheric ozone depletion in 1989 [5]. Give reasons to show that more depletion is likely to be caused by a CFC than by other chemicals, even though others are emitted in larger quantities. Use an example from the table to explain.

2. According to the model mentioned above the CFCs rise above the Stratosphere where they are bombarded by UV radiation (remember, there is very little UV below the ozone layer!). Under the bombardment, they dissociate to give off chlorine gas. This chlorine gas formed in the ozone layer is the real *ozone eater*. The mechanism by which this happens is schematically shown in Figure 3.7.

   Using Figure 3.7 explain what happens to chlorine after it has split an ozone molecule.

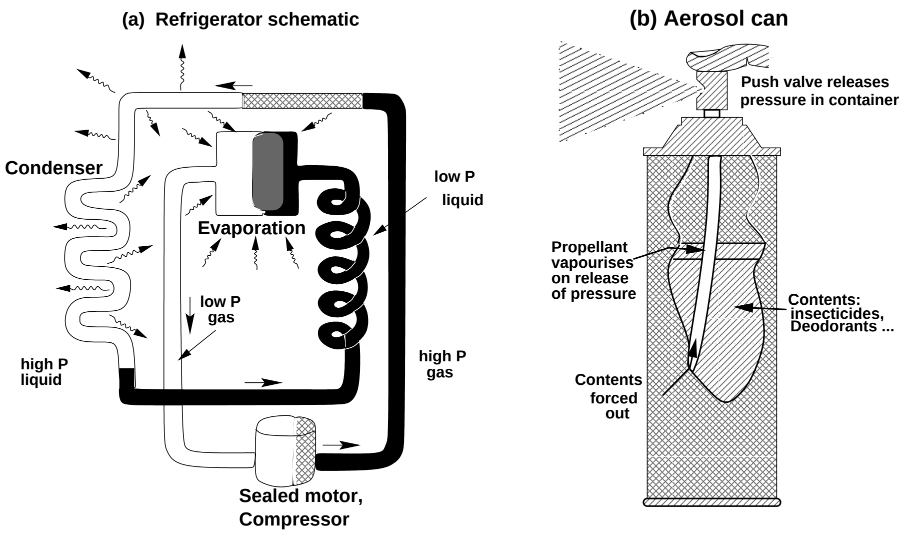
Figure 3.7: Role of chlorine in ozone depletion.



3. One chlorine molecule may dissociate 100,000 ozone molecules over about 2 years before it is carried away from the Stratosphere through chemical reactions or rain. Based on this, argue (in about a paragraph) that trace amounts of CFC can cause enough destruction to upset the delicate balance of ozone in the ozone layer.

4. Some people argue that scientists are unnecessarily alarmed about CFC emissions. Several thousand tonnes of chlorine have been emitted by volcanic activity and evaporation of sodium chloride from the oceans over many millennia. Chlorine gas is lighter than air, while CFCs are not. Hence, the effects of these *natural* sources should far exceed the effects of CFCs. List a set of arguments that could possibly falsify this claim. List any more evidences that you would like to collect before you can argue that CFCs are the real culprits in Stratospheric ozone depletion.

Figure 3.8: Schematic of (a) a refrigerator using CFC coolant and (b) an aerosol can.



5. Use the last column in Table 3.2 to make a pie chart depicting the share of the different CFCs in depleting ozone.

3.4.2 Coolers, refrigerators and spray cans

Refrigerators, air conditioners and spray cans of perfumes and pesticides have become a part of modern living. All developed countries use them in abundance. Developing countries, especially the ones with large populations, aspire for these goods. In fact storing and transporing food for the millions in countries like India would be impossible without the cold storage facilities. These needs will become more acute as more people migrate from rural to urban areas.

The schematic of a refrigerator in Figure 3.8 (a) shows that it consists of [15]

- a cooling fluid (gas or liquid),
- a compressor pump,
- a zig-zag tube called a condenser,

- a narrow constriction in the tube which serves as an evaporator, and
- valves to guide the flow of the fluid (refrigerant) in one direction.

The compressor circulates the cooling fluid (coolant). The low pressure side of the compressor is connected to an evaporator. The relatively hot "cooling" fluid liquifies as it flows from the high pressure end of the compressor through the condenser. In this process, it releases heat into the surrounding. The coolant, now a liquid at low pressure, is drawn through the evaporator because of the low pressure at the compressor. As this liquid vaporises in the evaporator region, it absorbs heat from its surrounding (latent heat), thus cooling the space. The gas is compressed to be circulated again.

1. Feel around a refrigerator and inside it. Where does it feel warm? Why? Which is the coolest portion inside the refrigerator?

2. What makes CFCs perfect candidates as refrigerants? Suppose that you, as a great scientist, have discovered a magic fluid for refrigeration. What would be the main properties of your magic fluid? Discuss all the ideas generated in the class.

3. Ahmed's family owns a refrigerator. Amala's family which lives in the same town does not own a refrigerator. Imagine the daily routines of the members of the 2 families. Make up your own story about the number of members, what they do and so on. In what ways might their routines differ? Make an imaginary comparison of these 2 families. Discuss the comparisons made by the whole class.

4. Razia owns a strawberry farm. Her farm yields large quantities of strawberries every season. She sells some in the local market. She packs off a major portion to the big city 500 kms away. Strawberries need to ripen on the plant and will perish soon after plucking. She finds that every year about 50% of the yield decays. List your suggestions for Razia to increase her benefit from her yield.

5. Many goods have to travel long distances from where they are produced till your home or till you use them. How many such goods might need to be kept cool? List as many as you can think of. In what ways do you think it might benefit our country to have more number of large sized coolers?

6. Organise a debate on the topic: **Refrigerator is essential for a productive life**.

7. Figure 3.8 (a) is a schematic of an aerosol can. Depending on its use, it may contain insecticide, fragrance or some liquid pain-killer, mixed with a liquid propellant which may be a CFC. The contents are packed under pressure. When you push the valve at the top, pressure is released from the can. Hence the propellant vaporises, and the contents are forced out with the vapours.

   Locate an aerosol can in a home, office, institution, or a shop. Find out how often it needs to be replenished (how soon the contents are used up).

8. Do you think all aerosol containers should mention what propellants and chemicals are used in them? Why do you think so? How will this help you?

3.5 Becoming sensitive to CFC use

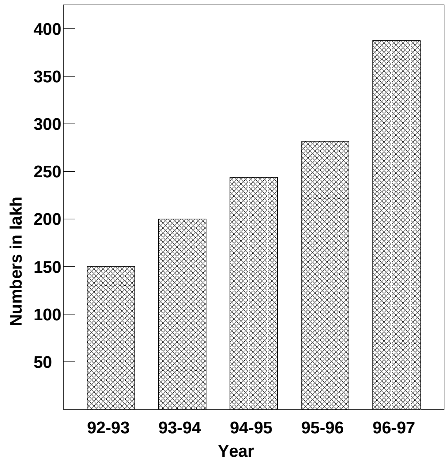
You know that many coolers and refrigerators in homes and in the market today contain CFCs as refrigerants (cooling fluids). All refrigerants have a finite life-time. Besides, in leaky systems, CFCs may leak to the atmosphere. Discuss the consequences of this through the following activities.

1. How can leaky CFC systems harm life on Earth? List all possible ways in which CFC emission into the atmosphere can be prevented. Come up with creative solutions.

2. Find the different kinds of airconditioning systems available in the market. You may have to visit more than one shop, and read through several advertisements for this. Find out how many of these devices use a refrigerant (or a coolant) other than CFC?

3. Figure 3.9 shows the production figures for room air-conditioners in India from the financial year 1992-93 to 1996-97 (*Source: "Business Line", The Hindu, December 28, 1997*). What is the ratio of the 1996-97 production to that in 1992-93?

Figure 3.9: Production of room air-conditioners in India, financial year 1992-93 to 1996-97.



4. What might the trends mean in terms of the amount of CFC released by India if we have no laws against selling or buying CFC based devices?

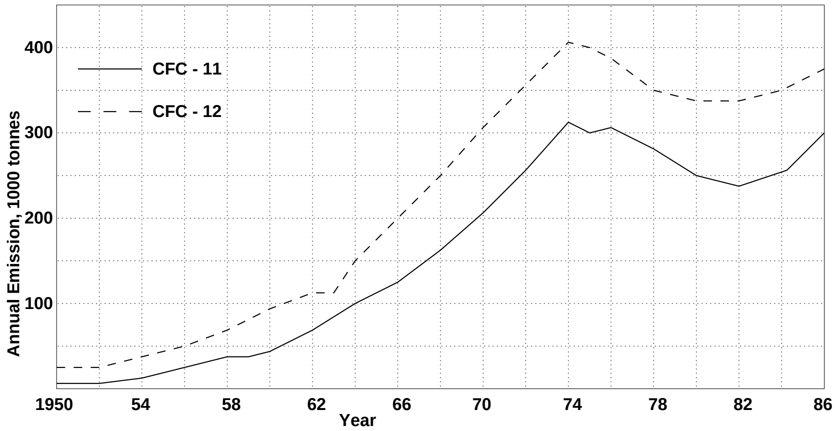
5. Consider the following real situation.

   In 1989, Newark, a county in New Jersey State of USA (rather like a district in India) decided to do something about its contribution to ozone depletion. It enacted an ordinance to do the following:

   - Prohibit the manufacture of any ozone depleting chemical.
   - Ban the retail sale of ozone depleting coolants for refrigeration and air-conditioning units.
   - Forbid the sale, purchase and use of food packaging materials made with any ozone depleting substance.
   - Prohibit the use of insulation containing any ozone depleting chemicals.
   - Impose a fine on the manufacturers for each violation of the above act.

   Do you think this was a sensitive gesture to prevent ozone depletion on the part of the administration in Newark? Discuss the situation in Newark county after the ordinance act was declared.

Figure 3.10: Annual emission of ozone depleting gases, 1950-86



6. If such a law were to passed in your district what do you think will be the reaction of people from different walks of life?

   Put up a mock play in which some many people of your district meet in the town hall to discuss the new ordinance act banning ozone depleting substances. Each of you could play the roles of local industrialists, housewives, working women, college students, skilled workers, office employees, farmers, environmental activists, scientists, teachers and many influential people of your town. Each of you should decide before the play begins who you are and what stand you are going to take on the ordinance.

3.5.1 Emission of ozone depleting substances

CFCs are added to the atmosphere as a result of human activities, like manufacturing and using refrigerators and air conditioners, aerosol cans, and foam products. Figure 3.10 shows the annual emission of 2 ozone depleting gases, CFC-11 and CFC-12 from 1950-86. [25] Study the graph and discuss the issues raised below.

1. Describe the overall trend in CFC emission from 1950 to 1974? What may have caused a decline in CFC emission around 1974? (*Hint: Refer to the discussion about Roland and Molina's warning at the end of Section 3.3.*) What possible reasons can you give for the increasing trend in CFC emissions in 1980's?

Table 3.3: Tabulation heads for noting cumulative emission of CFCs from 1950 to 1986.

Year	**Quantity of CFC-11 1000 tonnes**	**Quantity of CFC-12 1000 tonnes**
1950		
1952		
1954		
—-		
—-		
1982		
1984		
1986		

2. Assume that there were negligible emissions of CFCs before 1950. Justify this assumption. Calculate the total emission of CFC at the start of the years 1950, 1952, 1954, and so on, till 1984. Tabulate your values as indicated in Table 3.3. Note that for 1952, the total cumulative emission = *emission in* 1950 + *emission in* 1951 + *emission in* 1952. You will read off the values of annual emission for every successive year from the graph in Figure 3.10. Fill your table with values corresponding to CFC-11 and CFC-12.

3. Plot a graph of cumulative emission of CFC-11 and CFC-12 as a function of years. How does the trend look?

4. You have seen in Table 2.6 that each CFC molecule lives and devours (depletes) ozone in the Stratosphere for about 100 years. Write a paragraph describing your graphs, and the consequences of these trends for the future of the ozone layer.

5. The alarming trends in ozone depletion were first recognized as a global threat in 1985. The **Vienna Convention for the Protection of the Ozone Layer** was held on March 22, 1985. This was soon followed in 1987 by the **Montreal Protocol on Substances that Deplete the Ozone Layer**. The parties who have signed and ratified the Montreal Protocol held on September 16, 1987, and which came into force on January 1, 1989 are committed to follow the measures given in Figure 3.11. According to this, the developed countries had to cut the their CFC

emissions to 50% of the existing values by 1999, and freeze production of Halons at their 1986 levels of emissions.

The Montreal Protocol was ammended at the London Convention on June 29, 1990. This included the phase-out of a larger list of ozone depleting substances. Specifically,

- Production and use of CFCs, Halons, and carbon tetrachloride has to be phased-out by 2000 AD,
- Production and use of Methyl chloroform has to be phased-out by 2005 AD,
- Production of CFCs has to be reduced by 50% in 1995, by 85% in 1997 and by 100% in 2000 AD.

In the light of all this imagine the following future scenario for CFC emissions. **All countries freeze their emissions at 1986 levels. In 2000 AD all countries totally phase out CFCs**.

Extend your graph of cumulative emission from 1986 to 2000 AD to show future trends.

6. Describe the trends beyond 2000 AD. Extend from graph to 2050 AD. Since the approximate life of CFCs is 100 years, what might happen beyond 2050?

7. Figure 3.12 gives future concentrations of chlorine in the Stratosphere in units of parts per billion. [24] Three possible scenarios are shown.

   - Line 1: If only the 50% decrease in CFCs for developed countries as agreed in the Montreal Protocol were achieved.
   - Line 2: If a complete phaseout of CFCs and carbon tetrachloride (CCl_4) is achieved by 2000 AD and a phaseout of chloroform by 2025 AD as per the London Agreement.
   - Line 3: If the CFC substitutes, HCFCs, are also phased out.

   In what ways is this graph different from the graph of annual emissions of CFCs as a function of years shown in Figure 3.10? Compare the graph of cumulative emission of CFCs that you have drawn and extended to 2050 AD and beyond with the concentration of chlorine in the Stratosphere given in Figure 3.12. How are they related? [24]

Figure 3.11: The Montreal Protocol: salient features.

MONTREAL PROTOCOL: Measures Effective from January 1, 1989.

Control measures to reduce production and consumption of specific substances.

Control of trade with non-parties (to the Protocol)

Regularly scheduled assessment and review of control measures.

Reporting of data

Cooperation in research, development, public awareness and exchange of information.

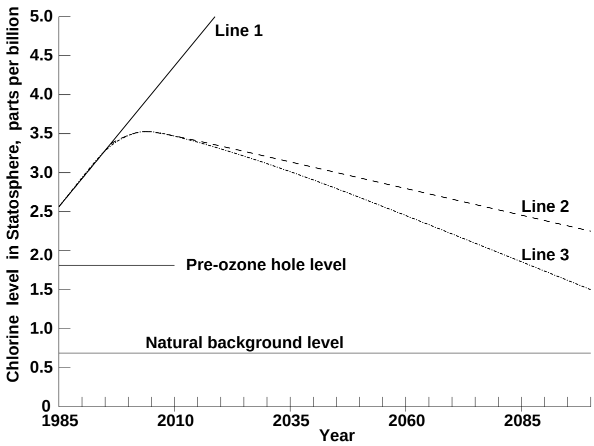
Establishment of financial mechanisms and transfer of technologies to assist developing countries

8. When you start to think about alternatives for ozone depleting gases, you need to remember 2 important characteristics of these gases:
   - Ozone depleting gases also cause global warming. List the gases you know that contribute to both the global problems.
   - An alternative to an ozone depleting gas must satisfy both ozone friendliness, and it must not increase the greenhouse effect. Would these conditions require development of one substance or many substances?

3.5.2 Problems and solutions

Why is the hole over the Antarctic so large and hence worrisome? The hole is caused by the formation of a vortex of atmospheric gases twirling around the polar regions in the winter. The Stratosphere in this region becomes isolated and cold. At these temperatures, well below -83^{o}C, Polar Stratospheric

Figure 3.12: Chlorine levels in the Stratosphere according to 3 scenarios.



Clouds (**PSC**) form. These mainly consist of nitric acid and ice particles. On the surface of the PSC, chemical reactions involving chlorine compounds form chemically active species (or *reservoirs*) of chlorine gas and HOCl gas.

In the polar spring, sunlight dissociates the chlorine from these reservoir gases. The liberated chlorine destroys the ozone. The ozone hole mechanism is thought to involve a combination of chlorine, put there largely by human activities, and the unique seasonal meteorology of the Antarctic.

1. Ozone depletion is often mentioned in 3 contexts:

   - There is an ozone hole over the Antarctica. This always existed. However, through satellites and sensitive measurement techniques that we have today, it is seen to be getting bigger with time and it is also moving. At the present time it is almost the size of USA. The ozone hole is often found to drift over the tip of South America and even as far north as Australia.
   - There is also a much smaller hole over the Arctic, which is also getting bigger.
   - There is an overall thinning of the ozone layer over the Earth.

   Spread out your World map, and list the countries or continents that will be most affected by each of these problems.

2. Table 3.4 shows the annual production of CFCs in 1991 by some countries of the World [12]. The units are 1000 tonnes per year. List the 6 countries with the largest production of CFCs in 1991. What is the quantity of CFCs produced in the World in 1991?

3. What is the share of each country or region listed in the table to the total contribution of CFCs by the World in 1991? Calculate the percentage production by each country relative to the World.

4. Draw a pie chart based on the percentage contribution of each country. Do you find that the production of some countries is difficult to indicate in the chart?

   One way of making things clearer would be to mark as "minute" all the regions and countries except that are not

   - other than the top 6 countries,
   - the countries under *others*

   You will now have 8 regions, namely, the top 6 countries, *others* and the "minute". Draw a pie chart depicting only these 8 regions.

5. India's share is not separately shown in the pie chart so far. You could show this by drawing a separate pie chart for the countries in the "minute" group

   Remember the shares of all contributors in a pie chart must always add up to 100%. Now imaginatively depict the two pie charts together to illustrate the share of all countries or regions listed in Table 3.4.

6. The Table 3.4 also gives the population of the regions (except for the entry *other*). Calculate the per capita production of CFCs in 1991 in each country or region. Which are the top 3 countries?

7. Assume that the production of each country or region approximately reflects the use of CFCs in those countries. How do you, an Indian, rank in CFC use?

8. In what ways would you like to change the scenario with respect to the use of refrigerator in India and in the rest of the World?

Table 3.4: Production of CFCs in 1991 in some countries.

Country/ Region	**CFC, 1991 1000 tonnes**	**% Share of World**	**Popn., Millions**	**Per capita, kg**
Japan	90		123.5	
USA	64		250	
Germany	23		80	
UK	17		57.4	
Italy	17		57.6	
France	17		56.7	
Rest of Europe	47		200	
Australia, NZ	6		20.5	
Canada	8		26.6	
China	8		1153	
India	3		846	
S.America(*)	8		223.3	
Others(**)	88		—	—
World	400		5290	

Note: (*) S.America includes Argentina, Brazil, Columbia and Venezuela; (**) Others include all countries not listed in the table or included in any region.

9. According to the Montreal Protocol, there is a multilateral global fund to assist some of the less developed signatories to the Protocol to reduce emission of ozone depleting substances. Who should invest maximum into this fund? Who should the benefit most?

Chapter 4

Acid rain

The phenomenon of acid rain seems to have been noticed as early as the beginning of the Industrial Revolution. Robert Angus Smith first documented this in 1852 in England. [14] More than century had passed before acid rain began to be documented and seen as a threat to the well being of planet Earth.

4.1 Pitter-patter rain drops

All children love playing in the rain. As you have grown older, many of you have probably lost the charm of getting wet in the rain. Yet, thoughts about the rain are pleasant by far: the cloudy green days, the smell of wet soil, fragrant flowers, the lush greenery, the song of the birds and the magic of the rainbow. You will relive the rainy season in this section and imagine some scenarios of the present and the future.

Monsoons and the magic it weaves around us is a thing of pictures and poetry. You will create both in this section.

1. Collect as many poems connected with rain as you can.

2. Read every poem brought in the class. Discuss the ideas presented in the poem and the images that it conjures up.

3. Form groups of 3 to 5 members. Each group should make a poster on rain. It could include any idea connected with rain: the processes, the

phenomena, the living and the material world. It could have pictures drawn or pasted, short verses and phrases, and colour.

4. Hang up your posters around the classroom. Study each poster and note the following points.

    (a) How many posters represented rain as a cycle of evaporation and condensation of water?

    (b) In each poster, count the number of instances of plants, like grasses, fields and forests. Were plants shown most often as individual plants (a single tree or vine) or in clusters (field, forest)?

    (c) How many posters had references to animal life forms other than humans? Which figured most often: insects, reptiles, birds, small animals, larger animals, or fish? How many referred to humans?

    (d) The air looks clear after the first rains. Did any group refer to the cleansing action of rain?

    (e) You could not have thought of rain without at the same time thinking of puddles and ponds. Count the number of ponds, puddles, streams and rivers in the posters. Did any one include the ocean in the poster? In what way was it referred: as a source of rain clouds or as a destination of the rivers?

    (f) How many had pictures of mountains with water falls?

    (g) Were there references to ceremonies and festivals?

    (h) How many poems poured forth on the rain?

4.2 Rain drops are sour!

You have intensely discussed how rain, is a phenomenon that supports life, and that rain is a cleansing agent. Rain also 'washes' down some of gases in the atmosphere. Some gases that are present in the atmosphere may combine with rain and form compounds. Carbon dioxide (CO_2) combining with water would form carbonic acid. Acids are sour. In fact, acid means sour. Chlorine from the oceans and oxides of nitrogen in the air would also make rain sour or acidic. You will discuss here some everyday examples of sour and acidic things. You will also learn to classify and compare such substances.

1. List some sour or acidic substances that you use every day. Include the substances you consume, solids or liquids you wash with, etc. **Caution: do not taste any substance that is not part of food. Make a guess.**

2. Lemons, sweet and sour limes, oranges, raw mangoes, tomatoes and tamarind, vinegar, curd (yoghurt), are all used as food items. All these are sour. Order them according to their "sourness". All fruits belonging to the lime family contain a compound called *citric acid*. This is the main reason for their being sour. Find out what makes tamarind, raw mangoes, grapes and curds sour.

3. When a copper coin or utensil turns green, what do you think happens? Get one such object. Rub a cut lemon or tamarind fruit on the object. What happens?

4. What might happen if it rained lemon juice in a certain area? Describe the scenes. Draw a picture of a land where it rains lemon juice.

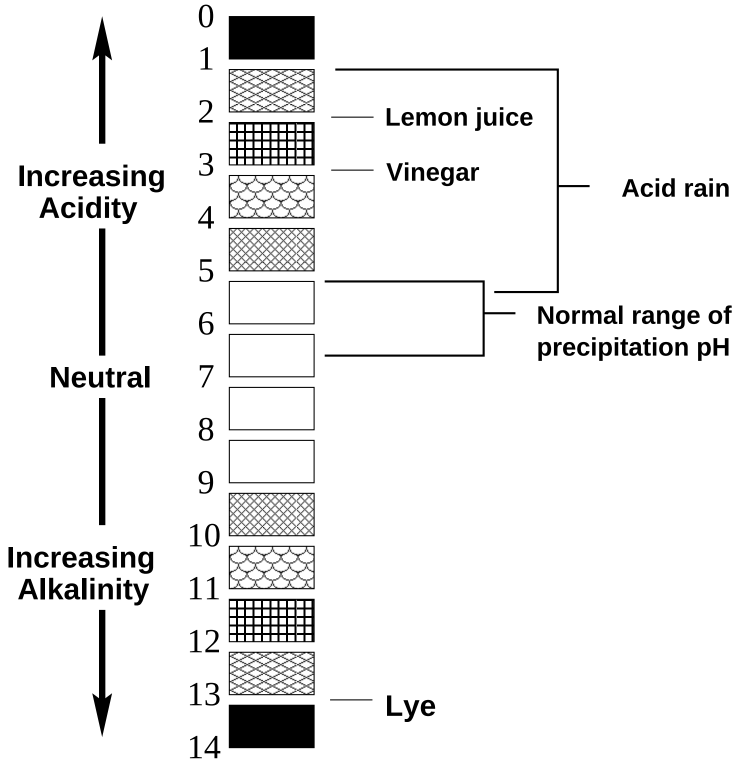
4.2.1 Scales of acidity

Normal rain is certainly not as sour as lemon juice. You might say that rain is less *acidic* than lemon juice. However, all acidic substances have a common property: the ability to corrode metals. You saw in the activity in the last section that green (oxidised) copper became shiny on being rubbed by lemon or tamarind. When these acids corrode metals, hydrogen gas is released. This implies that these acids must contain hydrogen. Compounds having hydrogen, when dissolved in water, may release hydrogen ions.

The acidity of a substance may be understood in terms of the amount of hydrogen ions in its solution in water. Consider water itself. Some of the water molecules in a container of water are normally dissociated into hydrogen ions (H^+) and hydroxyl ions (OH^-). In any sample of pure water you would find that

- one in every 10^7 water molecules dissociates into (H^+) and (OH^-), and
- the number of H^+ is equal to the number of OH^-.

Figure 4.1: The pH scale.



Hence, in pure water you would find one H^+ for every 10^7 water molecules. In other words, there are 10^{-7} hydrogen ions per water molecule, or hydrogen ion concentration 10^{-7}. **Acidity is measured as the negative logarithm of the hydrogen ion concentration**. Logarithm of 10^{-7}, to the base 10, is -7. Hence water is rated 7 on the scale of acidity. This value is called its **pH** value. The pH scale runs from 1 to 14. Substances with pH less than 7 are more acidic than water. Those having pH greater than 7 are known as *basic* substances. The logarithmic scale implies that lemon juice with a pH of 2 is 10 times more acidic than vinegar with a pH of 3.

Figure 4.1 shows the pH scale with the positions of 2 common liquids on it. [19] The pH is easily measured using a strip of special paper that changes colour on dipping in a solution. A *key* interprets the colour change in terms of pH values. The strips are useful only in a limited range of acidity. Activities given below will clarify the scales of acidity.

Table 4.1: Some familiar substances and their pH values.

Substance	**pH value**	**Rank**
Battery acid	1	
Ammonia	12	
Baking soda	8.2	
Tomato juice	4.3	
Tamarind juice	2 to 3	
Fresh curd	4	
One day old curd	3 to 4	
Cola (carbonated drink)	2.8	
Cow's/ Buffalo's milk	6.6	
Milk of Magnesia	10.4	
Grape juice	4	
Bristol Cigarette contents in water	6 to 7	
after 24 hours	7 to 8	
after 58 hours	9	

1. Table 4.1 gives the pH values of some liquids you know. Mark the position of these liquids on the pH scale in Figure 4.1. State whether each liquid is acidic or not. Rank the acidic liquids in the table from the most acidic to the least acidic.

2. Pour some familiar acidic liquids (lemon, tamarind juice, ...) on the following:

   - Piece of iron, like a nail or steel washer,
   - Piece of copper, a strip or wire,
   - Piece of aluminium, a wire or a bolt,
   - Small tile of marble,
   - Chalk piece,
   - Small black coloured "cuddappah" tile,
   - A piece of cloth with a coloured stain on it.

   What do you observe in each case while the acid is on the material? Wash the material in running water and describe whether the surface has changed in any way. Explain what you observe.

Table 4.2: pH of rain in some locations in India.

Location	**pH**
Udhyogamandal, Cochin	4.3
Calcutta	5.80
Chembur-Trombay	4.45
Hyderabad	5.73
Chennai	5.85
Thane-Belapur	5.20

4.2.2 Rain gets more acidic

The different constituents of air exist in more or less equal proportions at all places on Earth. Surely, if oxygen were to decrease in proportion, we would find it difficult to breathe. All the same, air does seem fresher in unspoilt rural areas than in urban road intersections. In the earlier chapters you have discussed some consequences of these variations in atmospheric constituents. Global warming and depletion of the ozone layer are two phenomena caused by this. In this section you will discuss how rain gets more acidic.

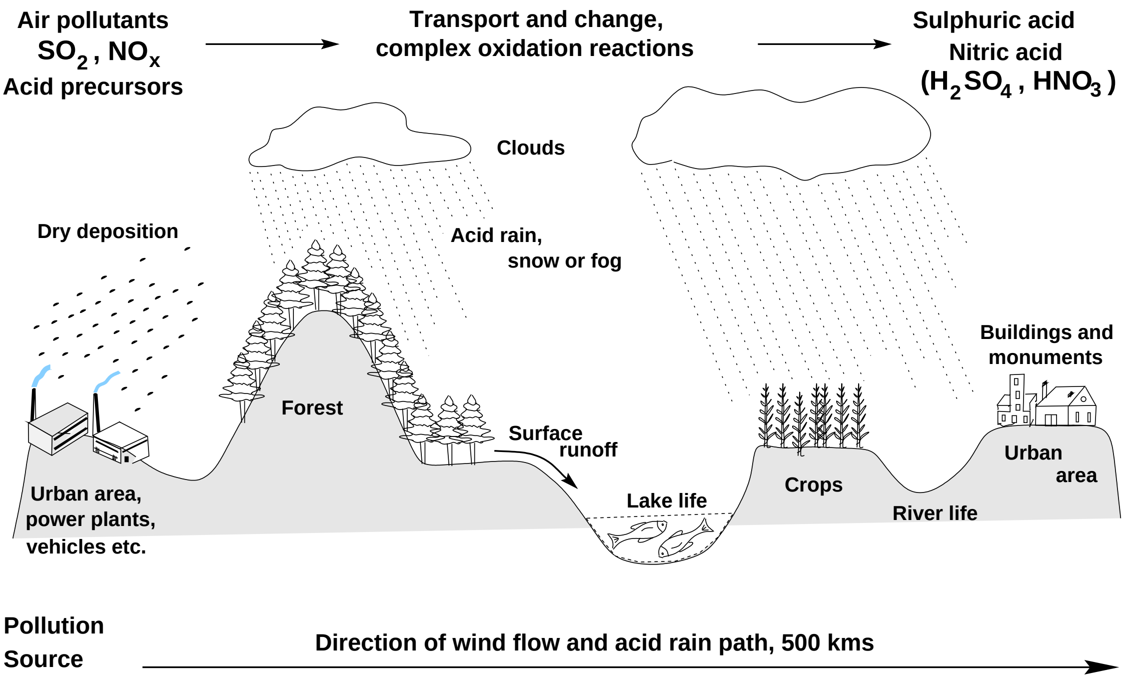
1. Using the services of a Chemistry department (in a college) nearest to you, monitor the acidity of the rain in your locality. You could form groups of 3 or 4 members. Each group could select different areas to monitor. Describe the differences. Explain their origin. You will discuss more about such differences in a later section.

2. Normal rain, even in a "clean" area is acidic. It has a pH of about 5.6. When its pH decreases below this value, the rain is considered to be acidic. Table 4.2 gives the pH of rain in some locations in India. [23] Which of these locations receive acid rain? Locate the spots on a map of India and guess the possible reasons for the acidity of rain in these locations.

3. Figure 4.2 shows a possible scenario of acid rain over a region. [5] Write a paragraph on the spatial separation between the causes of acid rain and its ill effects. How far apart can they be? What will it depend on?

4. Imagine a crowded city **Gas-Chembur** which has many industries. It also has a thermal power plant to power them. On its roads are

Figure 4.2: Acid rain: origins and effects.



many trucks, cars, autorikshaws and buses, which spew oxides of carbon, sulphur and nitrogen. Several villages surround the city for about 50 kilometres. The villages to the West engage in rice cultivation, while the villages to the East have soil and climate suitable for growing flowers and fruits. *Gas-Chembur* has monsoons from June to September. The winds in the first half of the year in *Gas-Chembur* blow from West to East, and reverse direction in the next half of the year. Who will face maximum difficulties due to the activities of *Gas-Chembur*, the rice growers or the fruit growers? Draw a picture to explain your answer.

5. The average wind velocity in *Gas-Chembur* from January to June is 5 kms/hour, while the wind blows at a much higher average speed of 10 kms/hour in the later half of the year. The gases stay in the atmosphere for about 5 days. How far would the effect of *Gas-Chembur*'s activities be felt? What would be the difference if the gases stayed in the atmosphere for 10 days?

6. In the 1960s and 70s, it was advocated that tall chimneys or smokestacks would reduce problems due to the polluting emissions from industries. Argue that this is wrong. Explain the differences between the pollution patterns with short and tall chimneys (smoke-stacks).

7. Describe 2 factual cases (that actually happened) of air pollution leading to loss of either life, livelihood, or heritage monument. Select one Indian case and another about Europe (loss of forests, fishing, etc.) or USA (lakes and soil).

You have seen that there is a connection between location of sources and acid rain. Acid rain problems depend on the climatic patterns in a region, especially wind direction and velocity and precipitations (rain or snow). You will look at this in a little more detail in the next section.

4.3 Causes of acid rain

If the concentrations of gases like CO_2, nitrogen oxides (NO_x) and sulphur dioxide (SO_2) are increased in the atmosphere, more of these would get washed down with the rain. That may make the rain more acidic. Thus the increasing acidity of rain appears to be related to industrialisation. However, the origins of acid rain could be as far away as 500 to 1000 kms from the affected locations. Study Figure 4.2 in greater detail, and discuss all the possible causes for increasing acidity of rain.

1. List the human activities that produce CO_2, NO_x and SO_2. Circle the major acidic gas emitted in each activity.

2. Which is the nearest power station to your home? Where is it located? Are there other power stations in your State? If your native State is different from where you live, list the power stations in that State. Collect the lists of all members of the class.

3. Of all the power stations listed, how many are coal powered? Locate them on a map of India.

4. Of the 3 most important gases causing acid rain, which would you find most near a thermal power station that uses coal as fuel? Some varieties of coal contain more sulphur than others. For instance bituminous coal is a high sulphur hard coal, while lignite and anthracite are low-sulphur coals. Which would you prefer to use in a thermal power plant? Why?

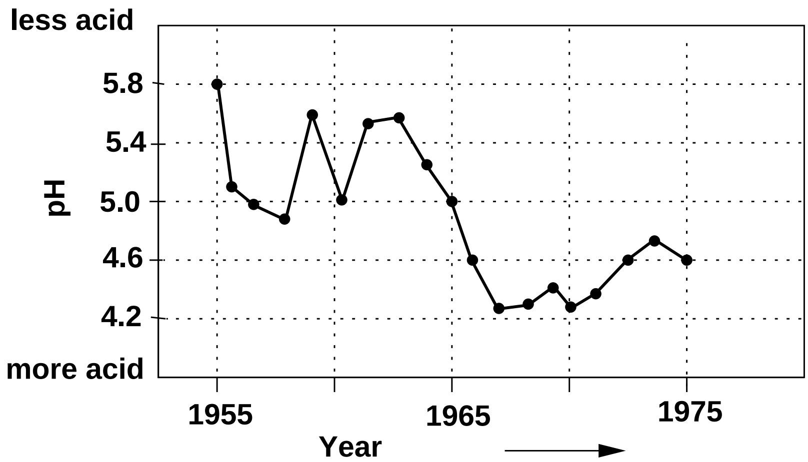
5. More than half of India's commercial energy is produced by coal powered thermal plants. [29] India's coal is generally poor in quality, containing impurities that are left behind as ash, which has acidic substances and sulphur oxide, after the coal is burned. While some part of the ash is washed and disposed as effluents, a significant fraction is emitted into the atmosphere. What remedy would you suggest for the possible acid rain problem that can arise from the sulphur content of Indian coal?

6. In a town called **Motorgunj**, the roads are choked with different vehicles at all times. Which gases from Motorgunj could cause acid rain?

7. How would you rate garbage burning as a possible source of acid rain in Indian metros? (Refer to the table on exhaust from diesel in the book titled *Resources: Land & Air*.)

8. Figure 4.3 shows the variation of pH of rain during the period 1955-75 in Oslo. [5] What trend do you notice in the acidity of rain in Oslo? Draw a trend line.

Figure 4.3: Variation of pH of rain in Oslo from 1955 to 1975.



9. Suppose that the measurements were available only for the years from 1958 to 1963, what would you have concluded? Over what periods must you collect data before you can talk about trends?

10. What can you say about trends in the sources of acidic (polluting) gases from the trends in acidity of rain? Would the increasing acidity in Oslo be related to happenings in other parts of Europe?

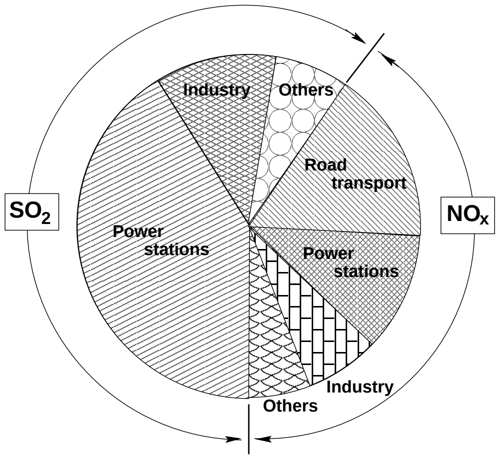
    Write a letter to the local meteorological office requesting information on the pH value of rain in different localities in your town.

11. Such detailed measurements about pH variation are not easily available for Indian metros. Do you think there is a need to monitor the pH of rain? Justify.

12. You have discussed coal powered thermal power plants, vehicular emissions and garbage burning as possible sources of acid rain. How would you rate industries in this regard? Note that consumption of coal by steel and cement industries rate the highest after the power plants. What role do wood-stoves play in causing acid rain?

13. Which gas contributes most to acid rain would depend on where the emissions originate (sources) in a locality and may vary from one locality to another. One example of the contribution of various sources is given in Figure 4.4 for a particular location. [3] The 2 main gases,

Figure 4.4: Contribution of different gases and their sources to acid rain in a certain locality.



namely NO_x (it is in fact many gases clubbed together!) and SO_2, are shown. The proportion emitted by each kind of source (like industry, road transport, etc.) are also separately indicated. Which is the biggest polluting source in the locality shown? Convert the pie chart into a table of percentages from each source.

14. Draw a similar pie chart for your town. Explain in what ways it would be different.

15. Cloud moisture has been measured in Germany to be very acidic with a pH as low as 3.5, even more acidic than acid rain. [24] Argue why that may be so? *Hint: The atmosphere may also contain some particles of carbonates which could neutralise acidic rain.*

4.4 Acid rain across national boundaries

Effects of air pollution as acid rain can be potentially felt over distances of 500 to 1000 kms. Hence, in countries with a large expanse, like the USA, Canada, Brazil, China, Russia and India, acid rain is often a regional problem. Sources of gaseous pollutants in one part of the country affect other parts. In many instances, two or more countries need to cooperate in finding a solution.

Table 4.3: Countries affected or likely to be affected by acid rain (1994).

Countries with		
High pollution	**Present problem**	**Sensitive areas**
W., C.USA	N. E., E. USA	E., W., C. Canada
Peru, Ecuador	N. Columbia	S. Columbia
W.Brazil, N., W.Bolivia	N.W. Venezuela	Brazil, Venezuela
Spain, Great Britain	Great Britain	Guyana, French Guyana
Austria, Germany	Norway	Surinam, Guinea
France, Poland	S. Sweden	Sierra Leone, Liberia
N. Italy	S. Finland	Ivory Coast, N.Morocco
Czechoslovakia (past)	Austria	Cameroon, Gabon
Yugoslavia	Germany	Congo, Angola
Hungary, Romania	France	Namibia, Zambia
Bulgaria, Albania	Poland	Mozambique, Tanzania
Lithuania, Latvia	E. Nigeria	Zaire, C.African Rep.
C., W.Russia	N. Cameroon	Uganda, Madagascar
S.Africa, N., E.Nigeria	E. China	S. India, Sri Lanka
N. W. Saudi Arabia		S. Myanmar
Iraq, N.Syria		Thailand, Laos
Uzbekistan		Cambodia, S.Vietnam
C.India, E., C.China		Indonesian Is.
S. Japan		Australia (N.Queensland)

Table 4.3 gives a list of countries affected at present or likely to be affected in the future by acid rain. [18] This data is most likely a picture in the early 1990s and is adapted from a contour map. The problems are classified into 3 groups:

- Regions which have high emissions which could lead to acid rain.
- Regions that are affected by acid rain in early 1990s.
- Sensitive sites: regions which are most likely to be affected by acid rain.

1. Form groups of 3 to 5 members. Mark countries listed in the table on the World map provided in Appendix A. Use a different colour for the countries in the different categories.

2. Study the countries that are the source of air pollutants. Besides themselves which other countries are they likely to affect?

3. The general direction of surface winds on Earth depend on the latitudes. The winds for the relevant regions of World are given as:

   - The Westerlies (winds blowing from the west): between the latitudes of 60^o and 30^o North.
   - The Northeast Trade Winds: between the latitudes of 30^o North and the equator.
   - The Southeast Trade Winds: between the equator and 30^o South latitudes.

   On the basis of these winds, explain which countries will be affected by the countries with high emissions. Do the countries you have listed in the last activity figure in the list of countries affected by acid rain at the present time? *Local wind patterns in an area may be different from the global pattern, depending on nearby oceans, large water bodies and mountains.*

4. Compare the list of sensitive areas most likely to be affected by acid rain in the future with those countries that are already affected (columns 1 and 2 in Table 4.3). What strikes you about the economies of the 2 lists of countries in general? Do you find exceptions?

5. Consider the case of a country which is a source of air pollutants but does not suffer from the effects of acid rain. It has a thick layer of soil capable of *buffering* (neutralising) the acid. However, the air pollution affects the neighbouring country that has thin sensitive soil. How is this problem to be solved?

6. You have realised by now that acid rain does not respect state or national boundaries. Within one country, it may be tackled by framing laws. How can this problem be addressed when it is across countries?

7. What hurdles do you foresee in solving such problems? Consider the hypothetical situation of Bangladesh's industries affecting the forests in India's Northeastern States. Suggest steps that India and Bangladesh should take. Should any other global body be involved in this process?

Is there a need for a global body to be created to deal with such issues? What might happen if the problem concerned Pakistan and India?

Several affected countries have recognized the problem of air pollution leading to acid rain. They came together to discuss the issues. You too have discussed this issue based on the limited data available to you and assuming some future scenarios. You will compare your suggestions with those of global conventions and treaties in the last section of this chapter.

4.5 Effects

Acid rain is constituted in large part by sulphuric, nitric and carbonic acids besides some other organic acids. In this section you will see how these acids affect land, water and life. You will be discussing the effects of air pollution on land, water and life.

4.5.1 Effect on plants and soils

Figure 4.5 shows the possible effects of air pollutants on soil and trees. [18] Study the figure and discuss the effects one step after another.

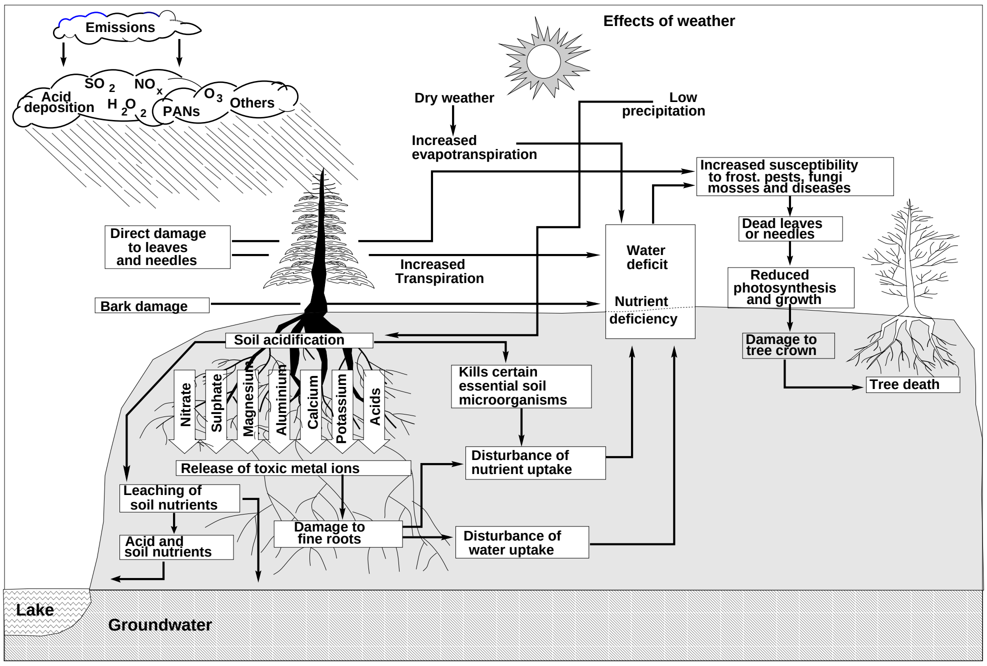
1. The figure shows acid rain falling on a pine tree. Which parts of the tree come in contact with it first? How are they affected by the rain? Where in India would you find a pine forest?

2. Figure 4.6 shows the cross-section of a leaf which has been affected by precipitation of acidic substances. Describe how the damage will affect the functions of the leaf.

3. Magnesium, for instance is an imortant constituent of chlorophyll. Plants absorb such minerals from the soil. What other minerals do plants draw from the soil? List as many as you can. At least for a couple of them, state how plants use them.

4. You have studied some interactions of acids with other materials like metals, cloth, etc. in Section 4.2.1. What do you think will happen to the constituents of the soil when acids mix with the soil? (*Leaching* means dissolving in water and getting washed away.)

Figure 4.5: Effects of air pollutants on soil and trees.



5. Does the soil contain anything other than minerals and nutrients? Name at least 2 uses of micro-organisms to plants. What effects may acid rain have on micro-organisms, the soil properties, and hence the plant? How would all these factors affect the plant root?

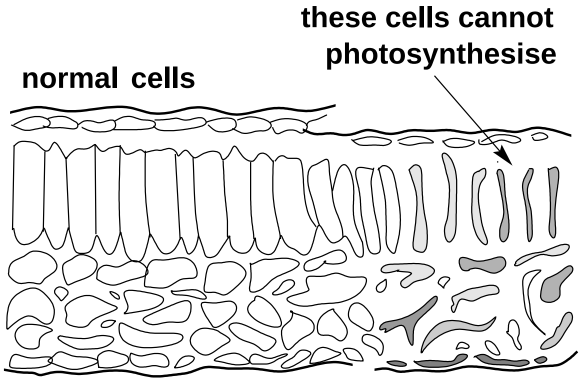
6. In dry weather, what could happen to a tree already affected by acid rain?

7. Would acid rain harm forests other than pine forests? Explain in what ways the effects would be similar. In what ways would they be different?

8. Clouds can be even more acidic than the rain. How might this affect trees on mountain tops?

9. Some soil conditions reduce the extent of damage due to acid rain. For instance, carbonates of calcium (lime stone) and magnesium, and silicates neutralise the acid. In India, where might acid rain have the maximum impact on the soil and vegetation? How will it affect our economy?

Figure 4.6: Schematic of leaf damage due to acid rain.



10. Split the class into 2 to 3 groups. Each group should put up a street play depicting the death of a pine forest due to acid rain.

    Acid rain falling on the soil will wash soil nutrient and flow into a water body. This will increase the acidity of the water. Discuss this and its effects on life in the water in the next section.

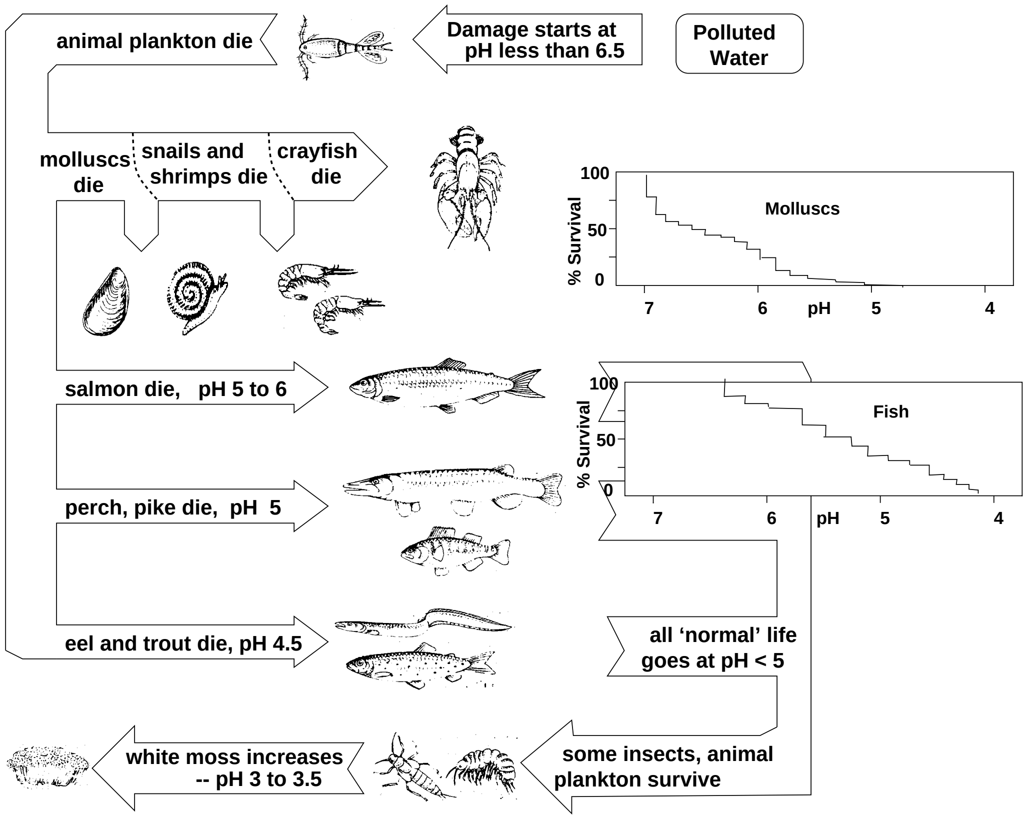
4.5.2 Effects on water and aquatic life

Most living organisms are adapted to their environment. This includes conditions like temperature, moisture and so on. All animals have a tolerance limit for such environmental conditions. When the conditions are within these limits they can survive, and beyond these limits the organisms may perish. For instance, when temperature becomes too low (say below 0^o C) or when it gets too hot (say above 45^o C) humans feel uncomfortable and may even die.

Fish are sensitive to the pH level of water which is the environment to which they are adapted. Fresh water has a pH close to neutral. You can imagine that organisms in this water would feel uncomfortable with decreasing pH. Figure 4.7 shows the effect of increasing acidity of a lake or river on the survival of the organisms in it. Study the figure and discuss the issues raised here. [2] [24]

1. Fish live in the water, breathe, find their food there, grow and lay eggs. Eggs hatch and young fish are born and go through the same cycle. Any disruption in this cycle will endanger the fish population. How can

Figure 4.7: Effect of increasing acidity on the survival of freshwater organisms.



changing the acidity of the water disturb this cycle? (For instance, how would it affect eggs themselves, hatching of eggs, etc.)

2. Table 4.4 summarizes the effect of the pH of a lake on its life forms. [8] Would all the different fish in a lake be affected at the same time? Would they be affected to the same extent? Use this discussion to argue that the organisms in a lake give a clue to the acidity of a lake.

3. Acid rain falling on slopes dissolves metals like aluminium in the soil as it flows down into the lakes. Some of these metals are very toxic to organisms. Aluminium, for instance, irritates fish gills, forms mucus, and suffocates the fish. List how dissolved impurities will change as the acidity of the water increases. How would this affect life in the fresh water?

Table 4.4: Effect of pH level of the lake on its life-forms.

pH Level	Effects
< 6	• Basic forms of food die off, eg. Mayflies and stoneflies are important food sources for fish. They can't survive at this pH level.
< 5.5	• Fish cannot reproduce. • Young have difficulty staying alive. • More deformed adult fish due to lack of nutrients. • Fish die of suffocation.
< 5.0	• Fish population die off.
< 4.0	• Very different lifeforms, if any, from before.

4. How will you know that an aquatic system (a water body) is getting degraded? One indication is the death of organisms as shown in Figure 4.7. Among the organisms shown in the figure, which are the "fittest" with respect to acidity?

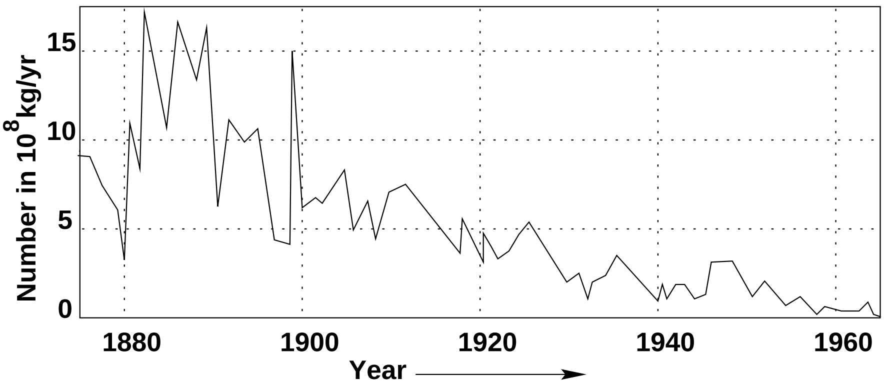
5. If you saw a very clear lake with only some insects, animal planktons and white moss growing at the bottom, what would you suspect? Explain.

6. An indication that a lake is getting degraded is a decreasing catch of fish over a period. Figure 4.8 is a plot of salmon catch in the Tovdalselva river of Southern Norway from 1880 to 1970. [5] The acidity of the river was also recorded and found to increase during the same period (not given here). Use this plot to argue how acid rain may affect economies dependent on fishing.

7. Here is a story told by an old fisherman *Mammud Kaka* who has been fishing at lake *Aamla* for three decades.

> When I was younger, and loved to be at the nets all day, I have seen many kinds of fish here in *Aamla*. Our children would carry small nets and bring in small molluscs (freshwater shellfish) and snails, while we adults would net a lot of salmon, and trout. Aamla fed us well.
>
> But things are not the same anymore, you know. About 2 decades ago, most of my friends went to the town 50 kms away. They work in the many factories there. About 10

Figure 4.8: Salmon catch from Tovdalselva river in Norway, 1880-1970.



years ago, there were very few molluscs in the lake and the fish catch had reduced to half the number. And tiny sick fish these were. Now, there is hardly any fish at all. Our children have gone to the factories too. Our grandchildren who live with us have never seen any snails or molluscs in *Aamla*. *Aamla* will not feed me or my small family anymore. We are dependent on the money from the town.

What do you think happened to lake *Aamla*? Give a possible scenario that developed over the years. Using Figure 4.7 what can you say about the acidity of the lake (pH value) 30 years ago, 10 years ago and at the present time? What does the story suggest as the cause of the problem?

4.5.3 Effects on animals, you and me

Mammud Kaka's life was affected by acid rain, which destroyed the fish of *Aamla* lake. Decreasing aquatic food is one of the ways in which acid rain can affect animals and humans. There are many other ways in which acid rain could affect you and me, and all the animals around us.

1. In section 4.2, you imagined what would happen if it rained lemon juice. How might rain as acidic as lemon juice affect your skin or other parts of your body?

2. Acid rain is also accompanied by dry deposition of oxides of sulphur and nitrogen which attach to tiny particles in the air. In what ways

could this make you uncomfortable or ill? *Hint: You could breathe these particulates, oxides could combine with water to form acids, etc.*

3. Acidic water dissolves several metals including aluminium and lead. What harm would drinking untreated acid water containing such salts cause?

4. This acidified water containing toxic metals are absorbed in fruits, vegetables and in the tissues of animals, which may not be affected. How would this affect humans and other animals? The effect is magnified in carnivorous animals over time. Explain how this happens in a paragraph. This is called **Bio-magnification**.

5. Consider the following 2 cases.

   - Mercury that accumulate in the organs and tissues of all animals has been linked with brain damage in children as well as nerve disorders, brain damage and death.
   - Aluminium, present in the organs of animals has been associated with kidney problems, and until recently, was suspected to cause Alzheimer's disease.

   How might biomagnification play a part in the above cases?

6. The aluminium in acid water displaces calcium in the bodies of birds with aluminium. This reduces the thickness of egg shells. How would this affect the bird population? What effects could that have on other aquatic and terrestrial (land) animals?

7. In what ways would the terrestrial animals who live in the vicinity of a lake, stream, river or sea be affected by the increasing acidity of the water?

The SO_2 and NO_2 emmisions, which are precursers for acid rain, give rise to respiratory problems such as asthma, dry coughs, headaches, eye, nose and throat irritations. When these gases come in contact with humans as dry deposition with particulates, as wet deposition in combination with moisture in the air, or directly as acid rain, they can cause enormous harm. Humans are unique among living organisms, in that they live in elaborately built houses, are proud of their evolving and varied architecture and are continually inventing new materials and creating artefacts. How acid rain would affect these structures of human creation is the topic of the next section.

4.5.4 Effects on materials and architecture

In Section 4.2.1, you had observed the effects of pouring acids on several materials around you including building materials like marble. You will now think about the effects acid rain can have on structures of all kinds.

1. Describe the materials that make up your home. What is its exterior made of? What materials are used in bringing water to your house? What is the material used in carrying waste water away from your house? What is the vehicle you travel in made of?

2. Rain as acidic as vinegar (pH 2.4) was recorded during storms in New England, USA. During one particularly acid summer storm, rain falling on a lime-green automobile leached away the yellow in the green paint, leaving blue raindrop-shaped spots on the car. [8]

   From instances like this, discuss how acid rain can affect the materials you use every day. Against each material you have listed above, note down the effect that acid rain could possibly have on it.

3. In Section 4.2.1 you found that acid acts on limestone and marble to result in a crumbling substance. This crumbling substance (formed with sulphuric acid) is called gypsum, which is like *Plaster of Paris.* Use this information to explain how statues and monuments will be affected by acid rain.

4. In 1967, the bridge over the Ohio river collapsed killing 46 people. Cause was traced to corrosion by acid rain. Can you recollect any instances in your town or (elsehwere in India) of such a collapse of a bridge or any structure which killed people? Would you trace it to the effects of acid rain? Explain.

5. **Shilpanagari** is a city known for its heritage buildings, monuments and statues. Tourism, which depends on these structures, is big business in this city. In fact, a good fraction of the revenue for the upkeep of the city is derived from tourists. At the same time, the city also has

several industries, where many people in the city are employed. These industries are highly polluting ones and were set up before there were stringent laws preventing pollution in the vicinity of monuments.

Shilpanagari faces a dilemma. If the people demand the closure of industries is many will lose their jobs. If industries are allowed to continue as they are, the city will lose revenues from tourism. Discuss your suggestions for this city.

6. List the cities and towns of India that face dilemmas like *Shilpanagari* above. Name at least one monument of each city or town and at least one industry that might damage it. From the whole class, pick one city whose problems are most urgent.

   Draft a letter to the Mayor of that city or town about the importance of taking urgent action, and giving your suggestions for such actions. Ensure that the actions do not lead to more problems. You could publish this as an open letter to the Mayor in your local newspaper.

4.6 Reducing the effects of acid rain

One of your first responses to reducing the effects of acid rain would be to say, "cut down the sources". You would be right. However, this may not be the only option. Besides, this would not solve the problems that have been already created.

You would also have to consider the fact that acid rain does not cause the same level of problems in all places. For instance, water flowing over igneous rock (granite) or metamorphic rock (gneiss) cannot dissolve the minerals in them. Hence lakes into which these waters flow are *soft*. Such lakes are very sensitive to acid rain, for it does not contain the minerals needed to neutralise the acidity.

On the other hand, sedimentary rocks (calcium carbonates, for example) are more easily dissolved by water. The lakes fed by these waters have *hard* water. These lakes resist becoming acidic because the carbonate minerals neutralise the acidity. Use these facts to discuss the possible ways of solving the acid rain problem in the local and regional context.

1. In the USA, the major producers of acidic emissions, namely, Indiana

and Ohio States are least affected by the problems of acid rain. Give all possible reasons that may explain this situation.

2. Suggest ways in which acidified lakes may be regenerated.

3. Soon after the harvest of rice in paddy fields, farmers in Kerala add lime or wood ash to the soil. What purpose do you think this serves? Discuss with a farmer for more details (or someone you know who is familiar with farming).

4. An important method to solve the acid deposition problem is to prevent it at the source. The three main sources of acid deposition are:

   - Coal in electricity, where sulphur in the coal is emitted as sulphur dioxide.
   - Base metal smelting, involving nitric and sulphuric acids.
   - Fuel combustion in vehicles, which give rise to larger quantities of nitrogen oxides.

   For each source suggest at least one strategy to reduce the gases which lead to acid rain. How many strategies were suggested? Discuss them

4.6.1 Global measures and actions

In this section you will discuss some regional steps that have been taken to reduce both SO_2 and NO_x emissions. Table 4.5 lists Conventions and Protocols on Long-Range Transboundary Air Pollution, **LRTAP**. The Convention and Protocols are regional in scope and are coordinated by the United Nations Economic Commission for Europe through its Environment and Human Settlement Division. [4]

The Protocols brought together several countries in Europe and North America. They discussed the possible steps that they could take to reduce the problem of air pollution. Countries that came together in these platforms included those that produced air pollutants and suffered its consequences, and which merely suffered.

1. All the countries which were party to the Conventions and Protocols had one geographic characteristic: they lay to the North of the latitude

Table 4.5: Chronology of Conventions and Protocols on Long-Range Transboundary Air Pollution (LRTAP)

Name of Conv/Prot	**Year Held**	**Year Effective**	**Signitories**	**Objectives**
Convention on LRTAP, Geneva	Nov.1979	Mar.1983	36 parties	• protect humans, environment against air pollution, • limit, gradually reduce, prevent air pollution including LRTAP
Protocol to Convention on LRTAP, Geneva	Sep.1984	Jan.1988	34 parties	• for financing cooperative programmes in LRTAP in Europe, • to share cost of monitoring programmes, • measurement of air and precipitation quality, • modelling of atmospheric dispersion.
Sulphur Protocol, Helsinki	Jul.1985	Sep.1987	20 parties	• reduce annual emission of Sulphur by at least 30% from 1980 level at the latest by 1993.
NOx Protocol, Sofia	Oct.1988	Feb.1991	21 parties	• take effective measures to control/ reduce NOx or their transboundary fluxes, latest by Dec 1994. • do not exceed their national annual emissions of such substances for 1987.

40^o North. USA was not a party to the Sulphur Protocol. Using this fact and the objectives given in the table, write a page commenting on the Conventions and Protocols. Guess why it must have been limited in scope, why it involved just the northern countries, and so on.

2. The implementation of Protocols showed these results in 1993:

   - Several countries (over 75%) submitted national reports on the emissions of SO_2 and NO_x.
   - Taken as a whole the parties to the Sulphur Protocol reduced emission from their 1980 level by 35% by 1991.
   - In Europe overall emissions of NO_x were stabilised by 1990 at their 1987 level or even less.

   Based on these results, would you say that the Protocols were successful in curbing the acid rain problem? Explain. What additional data would you need?

3. Table 4.6 gives the amount of SO_2 and NO_x emitted by some of the industrial countries over the period 1980 to 1989. [12] The units are thousands of metric tonnes (= $1000kg$) per year. The countries given in the table are either participants of the Convention on LRTAP mentioned above, or they are members of the Organisation for Economic Cooperation and Development (OECD). Turkey, Albania, Iceland, Luxembourg and Romania have been omitted from the list. Their emissions were low and were not actual data. Study the table and carry out the activities given below.

   (a) List the countries that decreased their SO_2 emission by 20% or more from their 1980 levels by 1989. (Remember that they had to decrease by 30% by 1993.) This is your "SO_2 List".

   (b) List the countries that either

   - maintained their NO_2 emission in 1989 to within 5% of their values in 1985, or
   - decreased their emissions from the 1985 values by 5% or more.

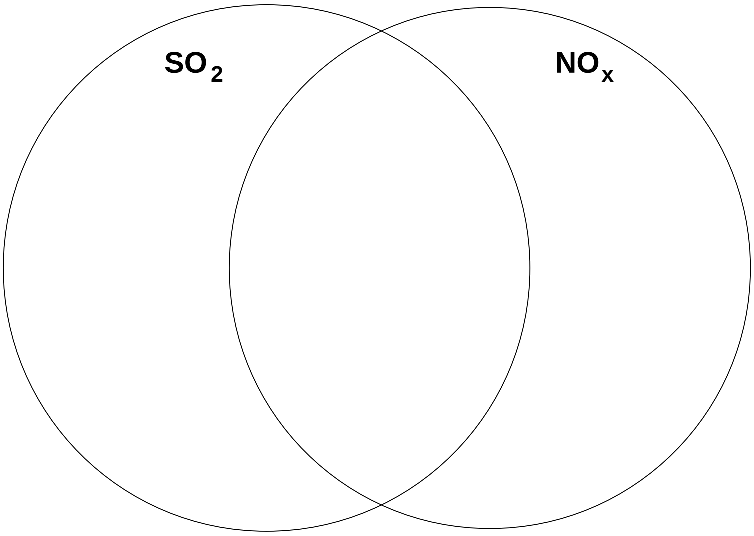
   This is your "NO_x List".

Table 4.6: SO_2 and NO_x emitted by some of the industrial countries in 1980, 1985 and 1989.

Country	Emissions, 000 metric tons per year					
	SO_2			NO_x		
	1980	**1985**	**1989**	**1980**	**1985**	**1989**
Canada	4,643	3,704	x	1959	1959	1943
USA	23,400	21,100	20,700	20,400	19,800	19,800
Japan	1,263	x	x	1,400	x	x
Austria	346	158	124	232	219	211
Belgium	828	452	414	317	281	297
Bulgaria	1,034	1,140	1,030	x	150	150
Czechoslovakia	3,100	3,150	2,800	x	1,127	950
Denmark	450	340	242	241	263	267
Finland	584	372	318	264	240	255
France	3,510	1,846	1,520	1,834	2,400	1,688
Germany (FR)	3,200	2,400	1,500	2,980	2,950	3,000
Germany (DR)	5,000	5000	5210	x	955	708
Greece	400	360	360	x	150	150
Hungary	1,634	1,420	1,218	x	300	259
Ireland	220	138	148	71	68	77
Italy	3,800	2,504	2,410	1,585	1,595	1,700
Netherlands	464	276	290	558	544	565
Norway	142	98	74	192	203	220
Poland	4,100	4,300	3,910	x	1,500	1,480
Portugal	266	204	204	166	96	96
Spain	3,250	3,250	3,250	951	950	950
Sweden	502	270	220	394	301	301
Switzerland	126	96	74	196	214	194
UK	4,848	3,676	3,552	2,442	2,278	2,513
Yugoslavia	1,176	1,500	1,650	350	190	190
USSR (Europe)	12,800	11,100	9,318	x	2,930	4,190

Note: FR – Federal Republic; DR – Democratic Republic

Figure 4.9: Venn diagram: countries and their actions on Sulphur and NO_x Protocols.



(c) Figure 4.9 shows 2 intersecting circles, forming 3 regions. In the region marked SO_2 mark those countries which are in your SO_2 list, but not in your NO_x list. Similarly in the region marked NO_x mark those countries which are in your NO_x list, but not in your SO_2 list. In the central region, mark those countries that are in both the lists. What you have obtained is called a **Venn Diagram**.

(d) Which countries show a decrease in SO_2 as well as a stability in their NO_x emissions? How many are they?

(e) Using the pie chart in Section 4.3 suggest possible reasons for some countries not reducing their SO_2 or NO_x emission. Discuss the cases of Japan and USSR separately.

(f) India, is not a party to the Convention or Protocols on LRTAP. Nor are China and most other countries in Asia. The total estimated emission of SO_2 in India in 1987 was about 10,000 metric tonnes, while for NO_x in the same period was about 130,000 metric tonnes. Do you think India needs to worry about the regional impact of its emissions? Justify.

4. Almost all of India's emissions arise from its towns and cities. You

also know the possible sources for these emissions. These are already causing health problems in local areas. The health problems due to polluted air is not solely India's problem. Many other countries in Asia face such problems either due to pollution from industries, power production or burning and logging of forests. Discuss some examples reported in newspaper in the recent times.

5. In the above context, form groups of 5 members and discuss which one of the following options India should choose.

   - Start a national mission on clean air, and frame suitable policies to get measurable results as early as possible,
   - Canvass for a Convention on regional co-operation on clean air (on the lines of Convention and Protocols in the European region)
   - Opt for both at the same time.

   Choose one of the above lines of actions and write 2 pages justifying your choice. List the steps you would suggest.

6. Discuss the writings in the whole class. Draft a policy report titled **Clean Air Mission of India**. Send it to a local newspaper.

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Adapted from G.Tyler Miller [18]

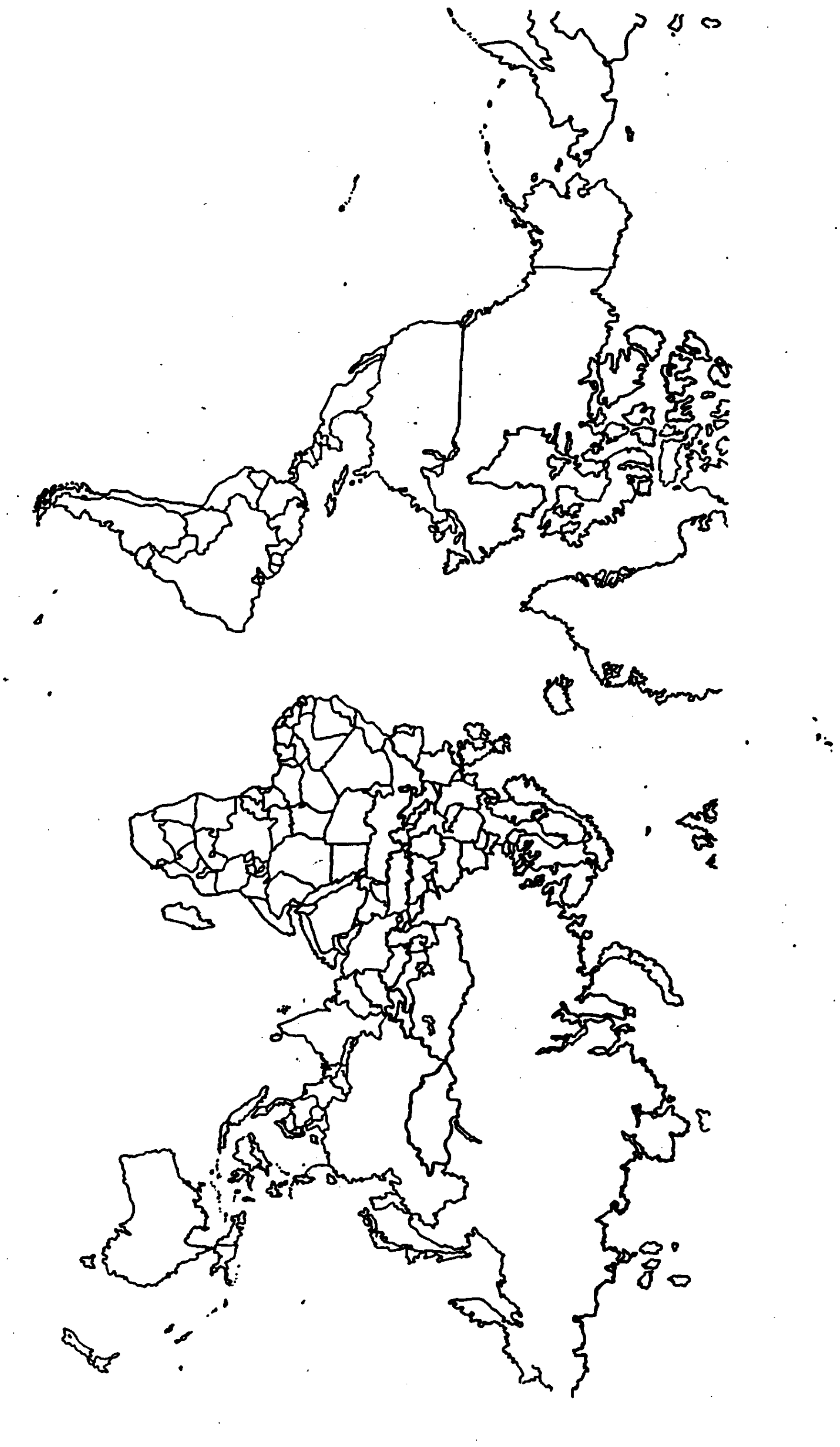
Appendix A

Political map of the World

You may make as many copies of the map given overleaf as you need for the activities in this book.

Adapted from *New Scientist*, 11 August 1990.

Figure A.1: Political map of the World.



Appendix B

Map of the Antarctic region

A map of the Antarctic region with names of monitoring bases is given overleaf. It also shows some reference latitudes, longitudes and the Greenwich Meridian. You may use this map for the activites in Chapter 3.

Adapted from Stephen Croall and William Rankin (1981), *Ecology for Beginners*, Pantheon Books, NY.

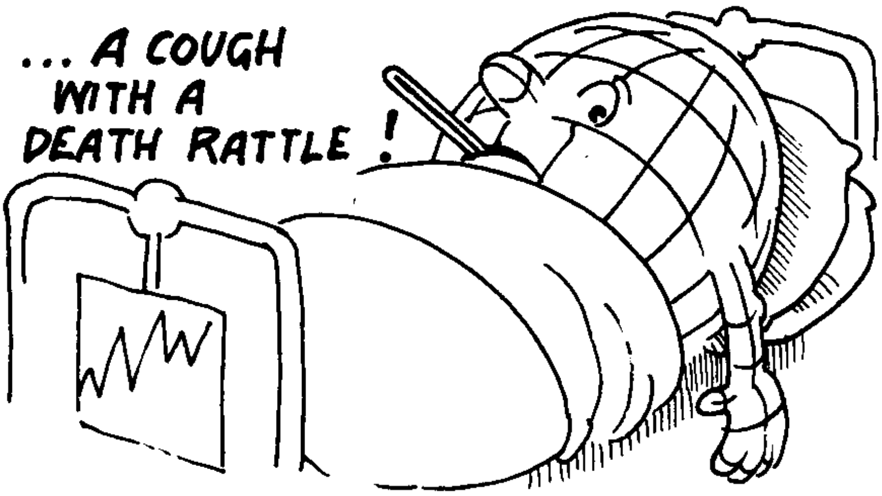
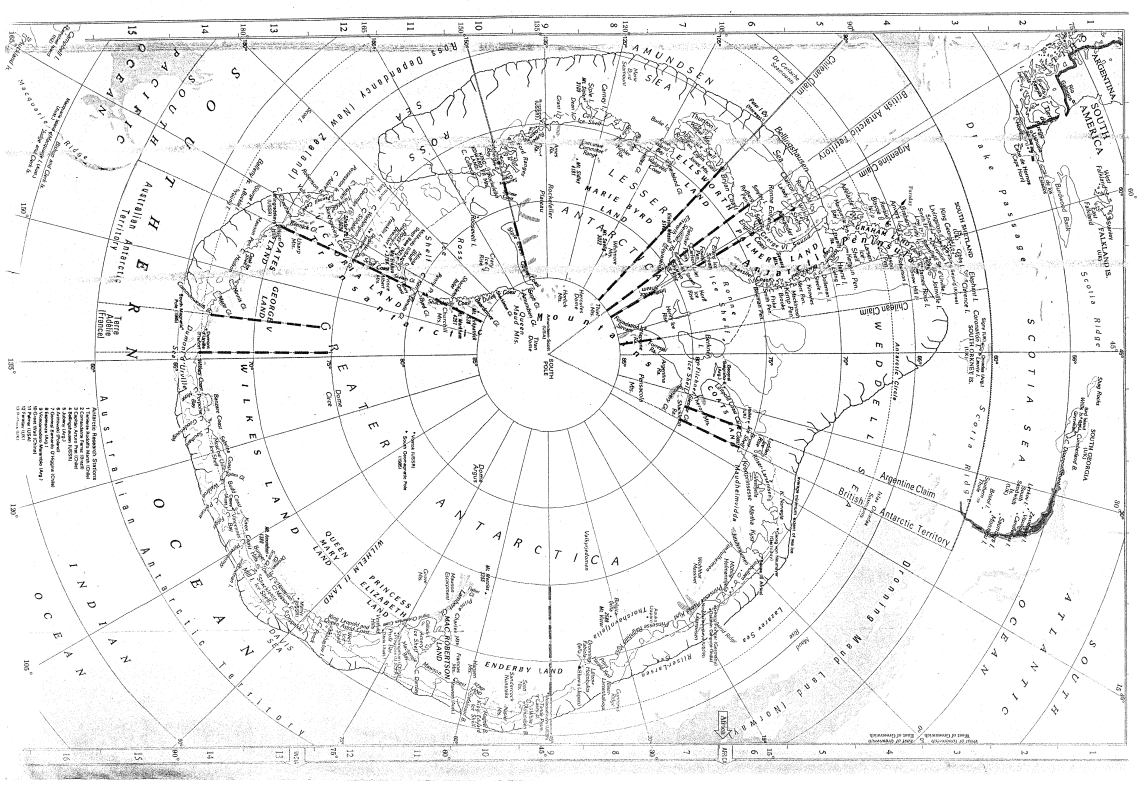


Figure B.1: Map of the Antarctic region.



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