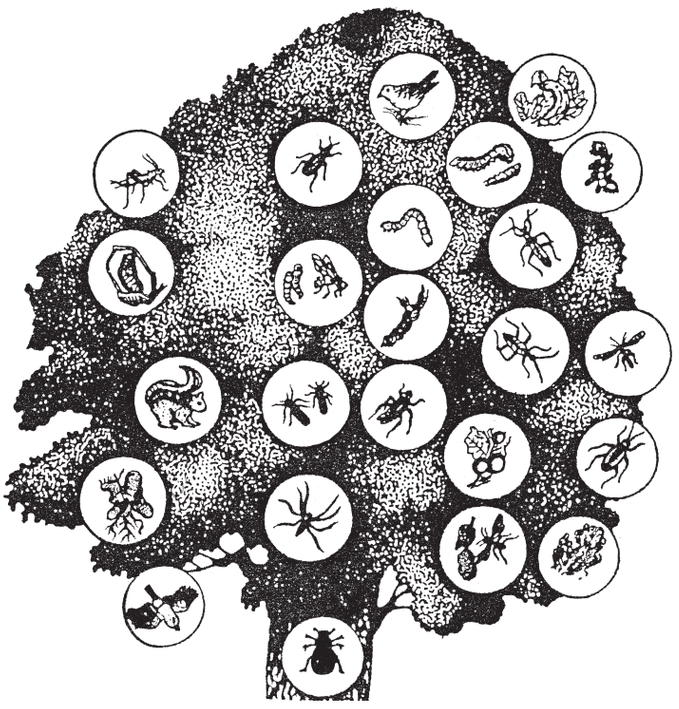
Evolution, Adaptation and Diversity

7

STRUCTURE



7.1

With a history dating back some 4.6 billion years the Earth has undergone many changes. A history of these changes is recorded in the layers or 'strata' of rock laid down over the millions of years, and by changes in the groups of fossils found in these rocks. This unit explores how life on earth has evolved and changed since then.

7.2

On completion of this unit, you should be able to

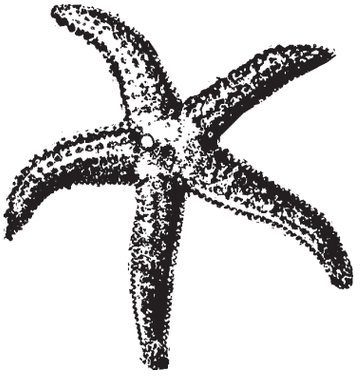
- Explain the evolution and extinction have occurred
- Define biological adaptations and exemplify these
- Describe biodiversity and its significance in maintaining the balance in nature

7.3 THE THEORY OF EVOLUTION

Millions of species of animals, plants, and microorganisms are alive today. Although different species might look dissimilar, the unity among organisms becomes apparent from an analysis of internal structures, the similarity of their chemical processes, and the evidence of common ancestry. Evidences such as these support the theory of evolution.

Before we look at the theory of evolution, let us understand the word 'evolution'. The dictionary meaning of evolution is "A gradual process in which something changes into a different and usually more complex or better form."

By the term 'organic evolution' we mean evolution of Lifeforms on the earth. The central thesis of the theory of evolution is that all present day organisms are related, and that they have descended with modifications from organisms that lived during the past. This theory was proposed in the publication titled 'On the Origin of Species through Natural Selection' (1859) by Charles Darwin. With the publication of this theory, most naturalists acknowledged that evolution provided a unifying theory that explained an otherwise collection of biological facts.



The theory of organic evolution has been supported by evidences such as embryology, comparative anatomy, geographic distribution of organisms and to a limited extent, fossil records.

The theory of organic evolution (proposed by Charles Darwin) states that natural selection (of species in nature) results in the survival of those organisms which are best adapted to their environment. This phenomenon is called the 'survival of the fittest'. Survival of the fittest is one of the mechanisms that accounts for evolution. This process, suggested by Darwin, is popularly known as the 'survival of the fittest'.

There are also other thoughts and theories suggested by different biologist which explain several other mechanisms in which evolution could have taken place.

However, the question how exactly evolution works, still does not have a single answer. New paleontological (fossil based) discoveries, as well as the development of theories on the close interaction between organisms and their environment, have profoundly changed the way in which scientists look at evolution. At the same time, rapid accumulation of molecular information and new techniques in developmental biology has revolutionized the different views on evolution of life.

7.4 EXTINCTION OF SPECIES

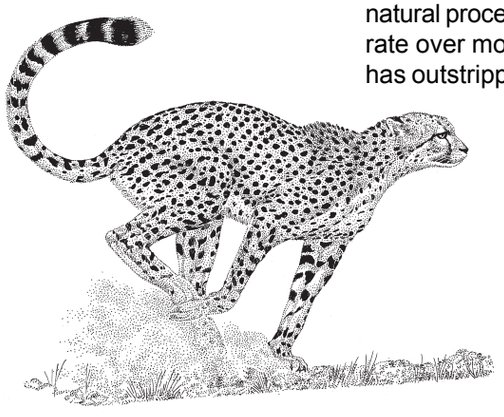
Just as the process of organic evolution is a natural process, the extinction of species is also a natural process. A species becomes extinct when its last representative dies. One of the most well known examples of extinction is, in fact, that of dinosaurs. More recent examples of extinction include the pink headed duck and dodo.

Most of the species (99.9 per cent) that have lived on the earth no longer exist. In nature, extinction of a species occurs when the environment changes and the adaptive characteristics of that species are insufficient to allow its survival. In nature, the causes of extinction can be either Biological (Predation, Competition, etc.) or Physical (Climate change, Sea-level change/habitat loss, asteroid/comet impact, etc).

Extinction can broadly be categorized as local extinction: One or more populations of a species disappears from part of its habitat, e.g. Cheetah is extinct from India, but is still found in Africa; Pseudo extinction/phylogenetic extinction: When one species evolves into another (evolutionary line continues) with no net loss of species; Terminal Extinction: When a species lineage becomes extinct in all habitats, leading to loss of a species, e.g. the dodo.

If extinction is a natural process, why you think many reports with titles such as ‘the vanishing diversity’ or ‘the lost species’, etc. make headlines.

While extinction of some species and evolution of new ones is a part of the natural process of evolution, these two processes occurred at a roughly equal rate over most of the history of life on earth. But now, the rate of extinction has outstripped the rate of ‘speciation’ (i.e. the evolution of new species).



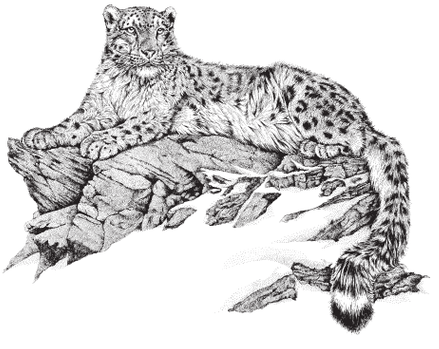
DID YOU KNOW?

Ecological significance of the process of extinction

Ecology helps us to understand the importance of mass extinctions in evolution. One of the important concepts is that of 'ecological niche' (more details in Unit 2). The environment is divided into millions of ecological niches, each of which represents a potential 'home' for life. Animals and plants will always try and take advantage of new opportunities, and so will always attempt to make a 'home' in an empty niche. In general, only one animal or plant can occupy a particular ecological niche - when two organisms try to occupy the same niche they will compete for the same resources, and one will always out-compete the other. However, when a niche becomes vacant - for example when the species which occupied it becomes extinct - there is a race to try and fill it. Mass extinctions open up a multitude of niches, and there is an evolutionary explosion as animals and plants adapt to fill the vacant 'homes'.

How Fast Are We Losing Them?

- During the last 200 million years, as part of the process of evolution, 100 to 1000 species became extinct every century. In recent centuries, human activities have accelerated the extinction of species. Today the extinction rate is 1,000 to 10,000 times higher than the natural rate before human intervention.
- More than 700 species of vertebrates, invertebrates and vascular plants have become extinct since AD 1600. Untold numbers probably have become extinct without ever being identified or described.
- Some of the habitats richest in biodiversity, such as tropical rainforests, are being destroyed because of human activities. The destruction of a habitat could lead to extinction of species that lived there and can live nowhere else.
- Over the last few decades India has cut down at least 50 per cent of its forests, polluted over 70 per cent of its water bodies, built or cultivated over much of its grasslands, and degraded many coastal areas. This has led to many species becoming threatened.
- At least 10 per cent of India's recorded wild flora (mainly flowering plants) and possibly a larger percentage of its wild fauna are threatened. Exactly how many are on the verge of extinction, no one knows.



7.4.1

1. Define evolution. What is the central thesis of theory of evolution?

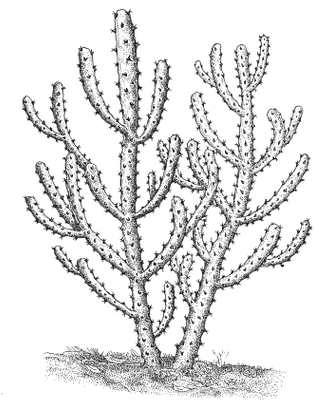
2. Is extinction a natural process? Is extinction of species a concern today?

3. State different kinds of extinction.

7.5 BIOLOGICAL ADAPTATIONS

Why is it that camels are not found in Jammu and Kashmir and that lions are not found in Tamilnadu? It is so because each organism is adapted to live in a certain kind of environment.

All organisms have the ability to adapt to the surrounding environment. Organisms exhibit responses to change (beyond the optimum range) in the environment. Such responses, exhibited by an organism to its environment, which are capable of being transmitted to the next generation, are called adaptations. Technically, a biological adaptation is defined as "an inheritable characteristic of an organism that increases its reproductive success". An adaptation is thus any alteration in the structure or function of an organism or any of its parts that results from natural selection (a part of the process of organic evolution) and by which the organism becomes better fitted to survive and multiply in its environment. Simply put, adaptations are behaviours/ characteristics that are favoured by natural selection.



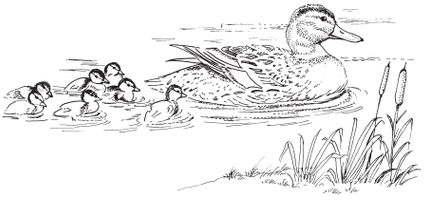
Adaptations help organisms to adjust to changes in their environment. All plants and animals are adapted to survive within the framework of non-living and living factors prevailing in their surrounding. For example, a cactus' ability to retain water is an adaptation to the dry, desert climate, i.e. its non-living environment, while its needles (commonly called thorns) discourage grazing and hence are an adaptation to the living or the biotic environment.

The ability of an organism to adapt is one of the key factors which decide the chances of its survival. We have already learnt that environmental conditions fluctuate from time to time. Some species can adapt much faster than others to such changes. Usually species with shorter life-cycles and higher genetic variety, like viruses, bacteria, pests, etc., adapt faster than others. Inability of a species to adapt to its changing environment could result in its disappearance, leading to its extinction.

Adaptations can be classified into three basic types: physiological, behavioral, and structural.

Physiological adaptations take place in the processes carried out in the body of the organism. For example, camels produce concentrated urine in order to conserve water.

Behavioural adaptations are adaptations with regard to behaviour, i.e. what an organism does. Examples of behavioural adaptations include mimicry, migration, and diurnal/nocturnal activity, etc. For example, during winters, many birds from the temperate countries fly down to sub-tropics and tropics (you may have heard about Siberian Crane coming to Bharatpur in winters). This is 'migration', a behavioural adaptation that helps these bird species avoid harsh winters in the temperate regions.



Structural adaptations are changes in the anatomy or body structure of an organism. Webbed feet of the duck is an example of structural adaptation that helps them in swimming and locomotion.

7.5.1

Fill in the blanks:

1. Any trait which makes an organism well-suited to its environment is called an _____.
2. The ability of most humans to break-down lactose (a type of sugar found in dairy products) is an example of a _____ (type of) adaptation.
3. Many apes build sleeping nests in trees. This makes them less vulnerable to predation at night time, and is an example of a _____ (type of) adaptation.
4. Herons use their long sharp bills to spear fish and amphibians. This is an example of a _____ (type of) adaptation

7.6 BIOLOGICAL DIVERSITY

Biological diversity or biodiversity refers to the range of Lifeforms on earth. These include millions of plants, animals and microorganisms, the genes they contain, and the intricate ecosystems of which they are a part. Biodiversity is usually described in terms of three levels:

Genetic biodiversity: It is the diversity of basic units of hereditary information (genes) within a species, which are passed down the generation. For example the different varieties of rice (basmati, deharaduni, jeerasir, etc.) belonging to the one single Oryza sp. Also different biological races of human beings are an example of genetic diversity. An important feature of the varieties or races is that individuals belonging to different varieties can breed with each other

ADAPTING TO THE ESERT

In the desert region, it is important for animals and plants to a) reduce water loss to a minimum, and b) tolerate high temperature ranges. Creatures have evolved many ways to do this. For example, scales on reptiles—a group of animals well adapted to the desert environment—help reduce water loss. Spiders, scorpions, millipedes and insects have body coverings which reduce the rate of evaporation. Producing concentrated urine helps desert reptiles reduce water loss from the body. Hare, a common desert animal, has large ears well supplied with an intricate web of blood vessels. This helps in dispersing the heat and keeping the animal cool.

Burrowing habit of several desert animals—gerbils, rats, mice, snakes—help them survive the desert heat. Desert life is more active after sunset. Nocturnal behaviour helps desert animals survive in the heat. Nocturnal creatures hide away in humid and cool places during the harsh daytime hours, thereby avoiding the heat. They become active during the night hours.

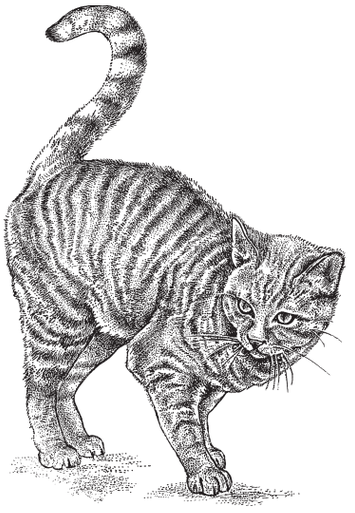
Camel, the ship of the desert, makes an excellent example of several kinds of adaptations. Camels' feet have resilient cushion-like soles for walking on sand. Camel's nostrils and eyelids also protect the animal in sandy conditions by filtering out the dust particles in the air. Their humps contain fat, which is used in case the food supply is short, but otherwise kept in reserve. Camels can remain active for weeks without drinking water, because they reduce water loss considerably by keeping their body temperature constantly at around 40^0C. Also the animal has very thin blood which remains in a functional fluid state even after the animal loses quarter of its body weight due to loss of water.

Several desert plants have leaves highly reduced in size—smaller surface area means less transpiration, thus reduced water loss. Grasses, which make one of the most dominant plant groups in the desert, show marvelous adaptations to their environment. They synchronize their life-cycle to the rains—they have a very brief reproductive stage with a very quick flowering process synchronized to the brief showers that the desert receives. Also, in case of lack of water, grass seeds can remain dormant for long periods of time and germinate only on the onset of favourable environmental conditions.

and produce viable offspring and hence they all belong to the same species (recall the definition of species, for details refer Unit 3).

Species biodiversity: As we have already discussed, each species is distinct from every other species. Some examples of such diversity include horses being distinct from donkeys and as are cats from dogs. This is the most commonly referred level of biodiversity.

Ecosystem biodiversity: Ecosystem diversity is the diversity of habitats (a place or site where an organism or a population of organisms naturally occurs), which include different Lifeforms within. Ecosystem diversity can refer to two phenomena—diversity of species within an ecosystem as well as the diversity of ecosystems on our planet.



7.6.1

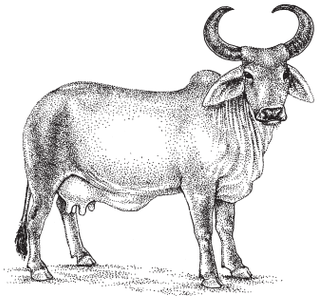
1. Give some examples of different types of adaptations.

2. State one example each of genetic biodiversity, species biodiversity and ecosystem biodiversity.

3. Define domesticated biodiversity

7.7 BALANCE IN NATURE

Homeostasis is a state of relative constancy vital to the survival of organisms. In nature, the state of Homeostasis is found at various levels. We know that our bodies have the regulatory mechanism to keep our body properties (temperature and function wise) in a balanced state; similarly ecosystems also possess many mechanisms that either resist change or help them recover from change, which helps to keep natural systems in a state of relative constancy. Numerous biotic and abiotic factors influence the growth of populations. Some stimulate growth; others deter growth. Ecosystem homeostasis is the result of the interaction of these factors. In ecosystems, changes in biotic and abiotic conditions lead to a cascade of effects, but the systems tend to return to normal over time. The ability to resist change is called resilience.

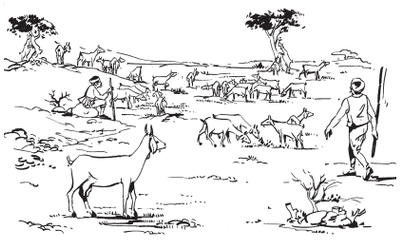


DID YOU KNOW?

When we think of biodiversity we tend to think only of wild plants and animals. But there is also considerable diversity among domesticated plants and animals. Domesticated biodiversity is the result of either the adaptation of crops and domestic animals to different climatic and geophysical condition or of the manipulation by humans of genetic diversity within species to produce new varieties of crops and new breeds of domestic animals. Since the invention of agriculture, people in different parts of the world developed different plant and animal varieties to meet certain needs and conditions. These included higher productivity, better taste, resistant to pest or disease, etc. Many such varieties of crops such as rice, wheat, etc. exist. There are also several breeds of cattle, poultry and other domesticates animals. The Kankrej cow, for example is adapted to survive in semi-arid conditions.

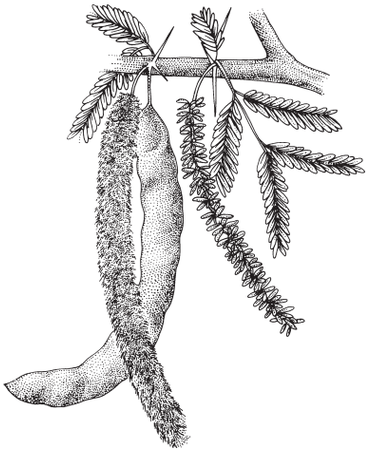
THE CONCERN

The ability of ecosystems to recover from small changes minimizes and sometimes negates the impacts of human actions. Thus it has led to a feeling among us, the humans that if ecosystems are selfmaintaining, then why not throw all wastes into nature and let nature take care of it? However, in many instances, though, human actions can overwhelm the recuperative capacity of natural systems. Stresses beyond the tolerance limits of these systems can be fatal for the biosphere and hence for us. For example Dal Lake situated in Srinagar, one of India's most well known lakes, is rapidly deteriorating. The lake attracts thousands of visitors every year. This pressure from the tourism industry adds nutrient-rich sewage to the lake which has resulted in eutrophication as a result of which, the lake is being rapidly colonized by a fern called Salvinia natans and algae. The lake is getting choked and will die if corrective measures are not taken. Here it is important to mention that wetlands also play a key role in groundwater recharge. Destroying a wetland can affect the groundwater status.



The other concern is that in the process of modifying ecosystems to suit our demands, we unknowingly simplify them. For instance, on the one hand we clear dense forests containing thousands of interrelated plant and animal species for a variety of human needs and requirements, like housing, setting up industries, etc. and on the other hand, try to balance it by afforestation programmes which create plantations of single or fewer species and not forests that are made up of numerous species in close interaction. Such simplified systems are highly vulnerable. With growing human population, too many of the world's complex, mature ecosystems have been made young and simple. Such alarming trends, if not attended to in time, can jeopardize the biosphere.

7.8 RECAPITULATION



- Organic Evolution (evolution of Lifeforms on earth) is an on-going process.
- Extinction of species is a natural process. Mass extinctions lead to creation of new ecological niches, which in turn help in creating more diversity of Lifeforms.
- Most organisms have the ability to adapt to their environment. In case of an extreme change in environmental conditions, sometimes the limited ability of a species to adapt become insufficient to allow it to survive, resulting in its extinction
- The biological world is rich with diversity. Life in some form can be found in nearly every conceivable environment on the planet earth. This diversity is in part the result of organisms adapting to exploit new environments.
- Due to increased human impacts on the environment, rate of extinction has overtaken the rate of evolution, disturbing the balance in nature. Further, human impact also has adversely affected the balance in nature.

7.9 CONCLUSION

Organic evolution accounts for a diversity of species developed through gradual processes over many generations. Species acquire many of their unique characteristics through biological adaptation, which involves the selection of naturally occurring variations in populations. Extinction of a species occurs when the environment changes and the adaptive characteristics of a species do not enable it to survive in competition with its neighbours. Fossils indicate that many organisms that lived long ago are now extinct. Extinction of a species is common. Mass extinctions help in creating newer niches, facilitating the process of evolution.Like evolution and extinction, all processes in nature operate in a state of balance. The homoeostatic property of nature helps the natural systems to regulate this balance.

7.10

1. Define evolution. Do you think survival of the fittest is the mechanism that helps in evolution?
2. It is said that humans are highly evolved species on this planet. If nature has a control on evolution and that only the fittest survives, has nature erred in selecting humans as an evolved species? Give your opinion.
3. Extinction is important for evolution. Elaborate.
4. Biodiversity plays a key role in maintaining the balance in nature. Device an interactive teaching idea on this concept, try it with your students and share your idea and feedback with us.

7.11

Quadrat Exercise

The greatest diversity of species exists in mature ecosystems. Ironically today human activities disturb these ecosystems the most. Some of the highly diverse ecosystems include rain forests, other tropical forest types, as well as the oceans that support a diversity of plants and animals. However, most of these systems have been modified by humans to suit our demands—to process environmental resources the way we want and to produce the output that would fulfill human needs and demands. Such activities have severely impaired the productivity and sustainability of these systems, because the process of modifying ecosystems to suit human demands simplifies them.

The following plotting activity could help students understand that some ecosystems are highly diverse while some are not.

Group size: 20-25

Duration: About half a school day

Requirements: Long iron nails and meter scales and strings (or quadrats), pen and paper.

Objective: To enable students to understand that species diversity is different in different ecosystems; and to help them build their skills of monitoring biodiversity.

Procedure: Make groups of 4-5 students each. Take students outdoors to at least three significantly different green locations—may be a roadside plantation site, a garden, a woodland, etc.

In each of the areas, ask the groups to randomly select at least three different sites. Give the following instructions:

1. For each of the three selected sites make a quadrat (size would depend on the plant diversity—higher diversity, smaller quadrat) by marking the four corners using the nails and the string to draw the perimeter.
2. In each quadrat, record observations in the form of how many plant species are present in the quadrat. Inform the students that it is not necessary to know the scientific names of the plants. For identification they may give their own names—plants with purple flowers may be named as ‘P’, plants with serrated leaf margins as ‘S’, tall herbs as ‘T’ and so on.
3. For each of the three quadrats, calculate the average species diversity by dividing the number of species found by the area of the quadrat. Thus for each area, at least three such readings will be available. From these three, derive an average species diversity figure for that area.

   Repeat steps 1 to 3 for each of the three green sites. Once back to the classroom, ask each group to plot a graph comparing the species diversity of the three areas.

Discussion

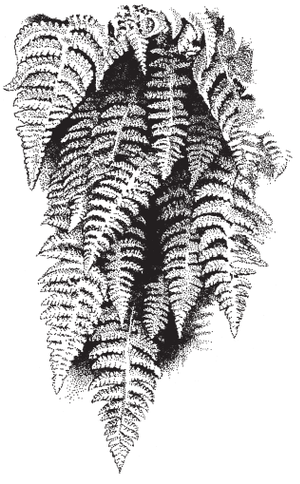
Ask the students what is the species diversity in each case? Is it different for the three selected areas? What could be the reasons for these differences? Categorize them into natural and human-made.

Discuss possible human impacts on the biodiversity of a region.

7.11.1 QUADRAT EXERSISE: THE FEEDBACK

(credit points: 5)

1. What kinds of plot areas did your students select (such as roadside, a riverbank, a children park, etc.)
2. Were the students very concerned about knowing names of the various plant species? Did you know names of some plants? How did you tackle this particular concern of theirs?
3. What were some of the key conclusions that students came out with , based on the data collected and observations made?



ANSWERS TO 'CHECK YOUR PROGRESS'

1.4.1

Multiple choice

1. b 2. d

True or False

3. True 4. False

1.5.1

Fill in the blanks

1. up and down

2. tropo *and* strato

3. Stratospheric ozone

4. Carbon di oxide and oxygen

1.6.1

Chose the odd item:

1. a. Rock. The remaining three are the zones of lithosphere.

2. d. Lakes. The remaining are all manifestations of tectonic movements.

3. c. Hydrogen. The remaining are all atmospheric gases.

4. a. Sunlight. The remaining are forces that shape features of a landscape.

2.3.1

Fill in the blanks

1. 'Life at home'

2. Environment

3. Laws of ecology

2.4.1

1. Match the following

1 to c

2 to a

3 to e

4 to b

5 to d

2. Correct sequence of events in the story titled "Cats Parachuted' is as follows:

d ABC Health Services sent DDT to Gyanpur

e Mosquitoes were wiped out

l Lizards ate mosquitoes and stored DDT

b Lizards slowed down

i Cats caught lizards

k Lizards disappeared

h Cats died

c Caterpillar numbers went up

f Caterpillars ate grass roofs

a Rats increased

j Rats spread the plague

g Cats were parachuted in

2.5.1

State true or false

a) False b) True

c) False d) False

3.3.1

Fill in the blanks

a) Ecological community b) Dominant

c) Ecological succession

3.4.1

State true or false

1. False 2. True

3. True 4. False

4.3.1

1. An ecosystem is a community of organisms involved in a dynamic network of biological, chemical and physical interactions between themselves and with the nonliving components. The ecosystem differs from an ecological community in having both abiotic (non-living) as well as biotic (living) components. An ecological community is made up of living beings only.
2. Biotic components of an ecosystem include plants (autotrophs), herbivores, carnivores, etc.); the abiotic components include air, water, land and the various properties and qualities of these (turbidity of water, salinity of soil, humidity in the air, etc.)

3. Autotrophs are self feeders. They can make the organic nutrients they need, using simple inorganic compounds in their environment. Heterotrophs (also called consumers) cannot make their own required nutrients/food. They directly or indirectly depend on food provided by autotrophs (also called producers).

5.3.1

Fill in the blanks:

1. Energy flow and nutrient cycling

2. Nutrient

3. Micronutrient and macronutrient

6.3.1

1. The two laws of thermodynamics are: Energy can neither be created nor destroyed; No energy process is 100 per cent efficient

2. The second law of thermodynamics, 'no energy process is 10 per cent efficient, implies that in any of the energy transformation, there is always a loss (energy wastage, in the form of energy that cannot be captured and transformed by that process). It is thus said that energy always gets transformed from a high grade form to a lower one.

6.5.1

1. Decomposers are the connecting link between nutrient cycles and energy flow in an ecosystem. They break down complex organic molecules (energy loaded nutrients) into their simpler forms, the forms in which they exist in the nutrient pool. Also the decomposers function at a very low level of energy in the food chain, thus utilizing low grade organic energy that other organisms would not be able to use.

2. The chain of eating and being eaten in nature is called food chain. A common example of food chain is a garden lizard eating an insect and in turn being eaten by cats or birds.

3. The two major types of food chains are the grazing food chains and the detritus food chain. Yes they are linked, for example an end or a byproduct of a grazing food chain can be the beginning of a detritus food chain.

7.4.1

1. 'Organic evolution' is the evolution of Lifeforms on the earth. The central thesis of the theory of evolution is that all present day organisms are related, and that they have descended with modifications from organisms that lived during the past.

2. Extinction is a natural process. Yes, extinction is a concern today because the pace of extinction has accelerated dramatically (due to human activities) and is affecting the balance in nature.

3. Extinction can broadly be categorized as local extinction, pseudo extinction and terminal extinction.

When *one or more populations of a species disappear from part of its habitat, then the species is said to be locally extinct. e.g. Cheetah is extinct from India, but is still found in Africa;*

When one species evolves into another (evolutionary line continues) with no net loss of species, it is referred to as pseudo extinction or phylogenetic extinction (mammoth into elephants);

When a species lineage becomes extinct in all habitats, leading to loss of a species, it is referred to as terminal extinction (e.g. the dodo).

7.5.1

Fill in the blanks:

1. Adaptation

2. Physiological adaptation

3. Behavioural adaptation

4. Structural adaptations

7.6.1

1. The Migratory behaviour exhibited by some birds is an example of behavioural adaptation. The modified leaf in cactus spp. is an example of structural adaptation.

2. The various kinds of rice like basmati, jeerasir, etc. are examples of genetic diversity. Different kinds of species found on the earth, say the variety of species within the cat family tigers, lions, leopards, cheetah, etc. are examples of species diversity. Similarly the variety of ecosystems—types of forests, different lakes, seas and oceans, etc.—are all example of ecosystem diversity.

3. Domesticated biodiversity is the diversity found among domesticated plants and animals. It is the result of either the adaptation of crops and domestic animals to different climatic and geophysical condition or of the manipulation by humans of genetic diversity within species to produce new varieties of crops and new breeds of domestic anima