M.Sc. Final Year

Zoology, Paper - IV

WILDLIFE CONSERVATION AND ECOTOXICOLOGY

मध्यप्रदेश भोज (मुक्त) विश्वविद्यालय – भोपाल

MADHYA PRADESH BHOJ (OPEN) UNIVERSITY - BHOPAL

COURSE WRITERS

Dr. Neeti Pandey, Assistant Professor, Department of Zoology, SGTB Khalsa College, University of Delhi, Delhi
Units (1-2)
Dr. Sushil Kumar Upadhyay, D.Phil (Oxford of East), Asstt. Professor, Department of Biotechnology Maharishi Markandeshwar (Deemed to be University) Mullana, Ambala-133207 (Haryana), India
Units (3-4)

Published by Registrar, MP Bhoj (open) University, Bhopal in 2020

VIKAS® PUBLISHING HOUSE PVT. LTD.
E-28, Sector-8, Noida - 201301 (UP)
Phone: 0120-4078900 • Fax: 0120-4078999
Regd. Office: A-27, 2nd Floor, Mohan Co-operative Industrial Estate, New Delhi 1100 44
• Website: www.vikaspublishing.com • Email: helpline@vikaspublishing.com

SYLLABI-BOOK MAPPING TABLE

Wildlife Conservation and Ecotoxicology

	Syllabi	Mapping in Book
Unit I	**Wild Life Conservation-I** 1. Wild Life Management (a) Values of Wild Life - Positive and Negative. (b) Our Conservation Ethics. (c) Importance of Conservation. (d) Causes of Depletion. (e) World Conservation Strategies. 2. Habitat Analysis, Evaluation and Management of Wild Life : (a) Physical Parameters - Topography, Geology, Soil and Water. (b) Biological Parameters - Food, Cover, Forage, Browse and Cover Estimation. (c) Standard Evaluation Procedures - Remote Sensing and GIS. 3. Management of Habitats -. (a) Setting Back Succession. (b) Grazing Iogging. (c) Mechanical Treatment. (d) Advancing the Successional Process. (e) Cover Construction (f) Preservation of general genetic diversity.	**Unit-1:** Wild Life Conservation-I **(Pages 3-100)**
Unit II	**Wild Life Conservation-II** Wild Life Population, Wild Life Policy, Legislation and Practical Implementation: 1. Population Estimation (a) Population Density, Natality, Birth Rate, Mortality, Fertility Schedules and Sex ratio Computation (b) Faecal Analysis of Ungulates and Carnivores - Faecal Samples, Slide Preparation, Hair Identification, Pug Marks and Census Methods. 2. Natlonal Organization (a) Indian Board of Wild Life, (b) Bombay Natural History Society. (c) Voluntary Organization Involved in Wild life Conservation 3. Wild Life Legislation - Wild Protection Act - 1972, its Amendments and Implementation.	**Unit-2:** Wild Life Conservation-II **(Pages 101-174)**
Unit III	**Ecotoxicology-I** 1. Basic Concept of Toxicolgy (a) Toxicants and Toxicity. (b) Factors that Effect the Environmental Concentration of Toxicants. (c) Factors that Influence the Toxicity. (d) Effects and Response (e) Dose Response Relationship. 2. Toxicological Testing Methods : (a) General Test Design. (b) Acute Toxicity Test. (c) LD_{50}, Test, (d) Skin and Eye Test. (e) Toxicity Curves.	**Unit-3:** Ecotoxicolgy-I **(Pages 175-220)**
Unit IV	**Ecotoxicology-II** 1. Pathological Techniques in Toxicology and General Apptoaches. 2. Basic Techniques in Autopsy and Histological Practices. Methods Applicable to Specific Organ System - Skin, Subcutaneous Tissue, Pulmonary Systems, Digestive System, and Urinary Tract 3. Toxicants of Public Health Gazards : 1. Toxic Chemical 2. Pesticides 3. Automobile Emissions 4. Heavy Metals 5. Fertilizers 6. Food Additives. 7. Environmental Mutagenesis 8. Radio Active Toxicity.	**Unit-4:** Ecotoxicolgy-II **(Pages 221-283)**

CONTENTS

INTRODUCTION **1**

UNIT 1 WILD LIFE CONSERVATION-I **3-100**

1.0 Introduction
1.1 Objectives
1.2 Values of Wildlife- Positive and Negative Values
- 1.2.1 Positive Values of Wildlife
- 1.2.2 Negative Values of Wildlife
- 1.2.3 Wildlife Conservation
- 1.2.4 Importance of Conservation
- 1.2.5 Causes of Depletion
- 1.2.6 World Conservation Strategies

1.3 Habitat Analysis
- 1.3.1 Evaluation and Management of Wild Life
- 1.3.2 Physical Parameters
- 1.3.3 Biological Parameters
- 1.3.4 Standard Evaluation Procedures: Remote-Sensing and GIS

1.4 Management of Habitats
- 1.4.1 Setting Back Succession
- 1.4.2 Grazing
- 1.4.3 Mechanical Treatment
- 1.4.4 Advancing the Successional Process
- 1.4.5 Cover Construction
- 1.4.6 Preservation of General Genetic Diversity

1.5 Answers to 'Check Your Progress'
1.6 Summary
1.7 Key Terms
1.8 Self-Assessment Questions and Exercises
1.9 Further Reading

UNIT 2 WILD LIFE CONSERVATION-II **101-174**

2.0 Introduction
2.1 Objectives
2.2 Population Estimation
- 2.2.1 Population Density
- 2.2.2 Natality
- 2.2.3 Mortality
- 2.2.4 Sex-Ratio Computation
- 2.2.5 Fertility Schedules

2.3 Faecal Analysis of Ungulates and Carnivores
- 2.3.1 Faecal Samples from Carnivores
- 2.3.2 Fecal Samples from Ungulates
- 2.3.3 Hair Identification
- 2.3.4 Slide Preparation- Hair Samples
- 2.3.5 Pug-Marks
- 2.3.6 Wildlife Census

2.4 National Organization
2.4.1 BNHS (Bombay Natural History Society)
2.4.2 WII (Wildlife Institute of India)
2.4.3 IBWL (Indian Board for Wildlife)
2.4.4 WPSI (Wildlife Preservation Society of India)
2.4.5 WWF (Worldwide Fund for Nature)
2.4.6 IUCN (International Union for Conservation of Nature of Natural Resources)
2.4.7 CAMP (Conservation Assessment of Management Plan)
2.4.8 Constitutional Provisions for the Wildlife Act
2.5 Wildlife Protection Act, 1972
2.5.1 Drawbacks of the Wildlife (Protection) Act, 1972
2.6 Answers to 'Check Your Progress'
2.7 Summary
2.8 Key Terms
2.9 Self-Assessment Questions and Exercises
2.10 Further Reading

UNIT 3 ECOTOXICOLGY-I **175-220**

3.0 Introduction
3.1 Objectives
3.2 Basic Concepts of Toxicolgy
3.2.1 History of Toxicology
3.2.2 Prehistory of Toxicology
3.3 Toxicants and Toxicity
3.3.1 Xenobiotic
3.3.2 Toxicants
3.3.3 Toxicity
3.4 Absorption and Translocation of Toxicants
3.4.1 Absorption of Toxicants
3.4.2 Translocation and Distribution of Toxicants
3.4.3 Transport of Toxicants by Blood and Lymph
3.5 Elimination and Excretion of Toxicants
3.5.1 Elimination of Toxicants
3.5.2 Excretion of Toxicants
3.5.3 Biotransformation of Toxicants
3.6 Effects and Response
3.7 Dose and Response Relationship
3.8 LD_{50} and ED_{50}
3.8.1 NOEL and LOEL
3.9 Factors Influencing Toxicity-Response Relationships
3.9.1 Variation in Toxic Responses
3.10 Toxicological Testing Techniques
3.10.1 General Test Design
3.10.2 Acute Toxicity Test
3.10.3 LD_{50}/LC_{50} Test
3.10.4 Skin and Eye Test
3.10.5 Toxicity Curves
3.11 Answers to 'Check Your Progress'
3.12 Summary
3.13 Key Terms

3.14 Self-Assessment Questions and Exercises
3.15 Further Reading

UNIT 4 ECOTOXICOLGY-II **221-283**

4.0 Introduction
4.1 Objectives
4.2 General Approaches in Toxicolgy
  4.2.1 Genetic Toxicology and Biological Markers
  4.2.2 Genetic Toxicology
  4.2.3 Biological Marker in Toxicology
  4.2.4 Societal Issues and Safety in Toxicology
  4.2.5 Distribution of Toxicants in the Organisms
  4.2.6 Target Organ Toxicity and Critical Effects
4.3 Pathological Techniques in Toxicology
  4.3.1 Non-Animal Toxicity Tests
  4.3.2 Animal Toxicity Tests
  4.3.3 Neurotoxicity Testing
  4.3.4 Developmental or Embryo Toxicity Testing
  4.3.5 Genetic Toxicity Testing
  4.3.6 Target Organ Toxicity Testing
  4.3.7 In Vitro Ocular Irritation Testing
  4.3.8 Validation of Testing Methods
4.4 Autopsy and Histological Practices
  4.4.1 Types of Autopsy
  4.4.2 Procedure of Autopsy
  4.4.3 Histological Examination during Autopsy
  4.4.4 Reconstituting the Body during Autopsy
  4.4.5 Autopsy Report and Challenges
  4.4.6 Scopes and Benefits of Autopsies
4.5 Methods Applicable to Specific Organ System
  4.5.1 Skin Specific Technique
  4.5.2 Subcutaneous Tissue Specific Technique
  4.5.3 Pulmonary System Specific Technique
  4.5.4 Digestive System Specific Technique
  4.5.5 Urinogenital Tract Specific Technique
4.6 Toxicants of Public Health Hazards
  4.6.1 Heavy Metals
  4.6.2 Air Pollutants and Automobile Emissions
  4.6.3 Persistent Organic Pollutants
  4.6.4 Pesticides
  4.6.5 Plant and Animal Toxins
  4.6.6 Environmental Health Hazards
  4.6.7 Food Additives
  4.6.8 Radiation and Radioactive Materials
  4.6.9 Fertilizers
4.7 Answers to ‘Check Your Progress’
4.8 Summary
4.9 Key Terms
4.10 Self-Assessment Questions and Exercises
4.11 Further Reading

INTRODUCTION

NOTES

Wildlife plays an important role in balancing the environment. Wildlife provides a stability to different processes of the nature. The importance of wildlife can be categorized as ecological, economic and investigatory importance as well as conservation of biological diversities. Wildlife create jobs through outdoor recreation, sustain food and water supplies, and help us develop meaningful bonds with our natural world. Unfortunately, over the last century many of our wildlife species have seriously declined due to rapid and large-scale changes to their habitats and ecosystems.

Wildlife conservation refers to the practice of protecting wild species and their habitats in order to maintain healthy wildlife species or populations and to restore, protect or enhance natural ecosystems. Major threats to wildlife include habitat destruction, degradation, fragmentation, overexploitation, poaching, pollution and climate change. National and international organizations like the World Wildlife Fund, Conservation International, the Wildlife Conservation Society, and the United Nations work to support global animal and habitat conservation efforts on many different fronts. They work with the government to establish and protect public lands, like national parks and wildlife refuges. They help write legislation to protect various species. They work with law enforcement to prosecute wildlife crimes, like wildlife trafficking and illegal hunting (poaching).

Ecotoxicology is the study of the effects of toxic chemicals on biological organisms, especially at the population, community, ecosystem, and biosphere levels. Ecotoxicology is a multidisciplinary field, which integrates toxicology and ecology. Environmental toxicology, field of study in the environmental sciences that is concerned with the assessment of toxic substances in the environment. Although it is based on toxicology, environmental toxicology draws heavily on principles and techniques from other fields, including biochemistry, cell biology, developmental biology, and genetics. Its major areas are the assessment of toxic substances in the environment, the monitoring of environments for the presence of toxic substances, the effects of toxins on biotic and abiotic components of ecosystems, and the metabolism and biological and environmental fate of toxins.

This book is divided into four units that helps the students to understand the basic concepts of wildlife conservation, wildlife management, wildlife polices, wildlife legislation, and ecotoxicology. The book follows the Self-Instructional Mode or SIM format wherein each unit begins with an 'Introduction' to the topic followed by an outline of the 'Objectives'. The detailed content is then presented in a simple and structured manner interspersed with Answers to 'Check Your Progress' questions. A list of 'Key Terms', a 'Summary' and a set of 'Self-Assessment Questions and Exercises' is also provided at the end of each unit for effective recapitulation.

UNIT 1 WILD LIFE CONSERVATION-I

NOTES

Structure

1.0 Introduction
1.1 Objectives
1.2 Values of Wildlife- Positive and Negative Values
  1.2.1 Positive Values of Wildlife
  1.2.2 Negative Values of Wildlife
  1.2.3 Wildlife Conservation
  1.2.4 Importance of Conservation
  1.2.5 Causes of Depletion
  1.2.6 World Conservation Strategies
1.3 Habitat Analysis
  1.3.1 Evaluation and Management of Wild Life
  1.3.2 Physical Parameters
  1.3.3 Biological Parameters
  1.3.4 Standard Evaluation Procedures: Remote-Sensing and GIS
1.4 Management of Habitats
  1.4.1 Setting Back Succession
  1.4.2 Grazing
  1.4.3 Mechanical Treatment
  1.4.4 Advancing the Successional Process
  1.4.5 Cover Construction
  1.4.6 Preservation of General Genetic Diversity
1.5 Answers to 'Check Your Progress'
1.6 Summary
1.7 Key Terms
1.8 Self-Assessment Questions and Exercises
1.9 Further Reading

1.0 INTRODUCTION

Wildlife traditionally refers to undomesticated animal species, but has come to include all organisms that grow or live wild in an area without being introduced by humans. Wildlife can be found in all ecosystems. Deserts, forests, rainforests, plains, grasslands, and other areas, including the most developed urban areas, all have distinct forms of wildlife. While the term in popular culture usually refers to animals that are untouched by human factors, most scientists agree that much wildlife is affected by human activities. Wildlife conservation refers to the practice of protecting wild species and their habitats in order to maintain healthy wildlife species or populations and to restore, protect or enhance natural ecosystems. Major threats to wildlife include habitat destruction, degradation, fragmentation, overexploitation, poaching, pollution and climate change.

Habitat refers to the natural environment (constituting living & non-living entities on earth's surface) in which a particular species of organism lives. Food, shelter, water and mate are the basic requirement for the survival of the species

NOTES

and habitat refers to that places where the species can find them. A habitat is characterized by both physical and biological features. Physical factors include abiotic factors like soil, temperature, PH, light etc. whereas biological (biotic) factors include food and prey-predator relationship. Wildlife habitat assessment is the evaluation of the relative habitat conditions available to a focal group of wildlife. Assessments of wildlife habitat are predicated on the basic assumption that at some level wildlife is controlled by its habitat, because an organism's ability to survive depends in large part on the resources (e.g., food, water, and cover) available to it. These resources are provided by the habitat in which organisms live. Thus, habitat conditions are often used as a surrogate to make inferences about the presence, abundance, fitness, or productivity of wildlife populations, species, or communities.

Habitat restoration/management/manipulation is one of the most essential methodologies of wildlife management. Generally, habitat can be described as all of the food, water and cover resources, that wildlife requires to service. All these three resources must be present in sufficient or ample amount to maintain a healthy wildlife population. Habitat requirement may vary from species to species or some species can have the same habitat requirement.

In this unit you will study about positive and negative values of wildlife, our conservation ethics, importance of conservation, world conservation strategies, habit analysis, evaluation and management of wildlife, physical and biological parameters, standard evaluation procedure, management of habitat, setting back succession, grazing, mechanical treatment, advancing the successional process, cover construction, and preservation of general diversity.

1.1 OBJECTIVES

After going through this unit, you will be able to:

- Explain the positive and negative values of wildlife
- Elaborate on our conservation ethics
- Understand the importance of conservation
- Comprehend world conservation strategies
- Define habit analysis
- Elaborate on physical and biological parameters
- Understand standard evaluation procedure
- Explain the setting back succession, grazing and mechanical treatment
- Define advancing the successional process
- Understand cover construction
- Elaborate on preservation of general diversity

1.2 VALUES OF WILDLIFE- POSITIVE AND NEGATIVE VALUES

NOTES

Wildlife traditionally refers to the animal species that are found growing or living wild in an area without being introduced by humans. However, wildlife come to include all organisms that grow or live wild in an area without being introduced by humans. Wildlife can be found in all ecosystems, Deserts, forests, rainforests, plains, grasslands, and other areas, including the most developed urban areas, all have distinct forms of wildlife. The five-kingdom classification was proposed by R.H. Whittaker in 1969. The five kingdoms were formed on the basis of features like cell structure, source of nutrition, mode of nutrition and body organisation. The five kingdoms were: Kingdom Monera, Kingdom Protista, Kingdom Fungi, Kingdom Plantae and Kingdom Animalia. The Kingdom Monera includes prokaryotic organism like bacteria which lacks a well-organized nucleus as well as membrane bound organelles; Kingdom Protista includes all unicellular and colonial eukaryotes like algae, diatoms and protozoans which are unicellular eukaryotic organisms having a well-organized nucleus, membrane bound organelles and exhibit both autotrophic and heterotrophic mode of nutrition; Kingdom Fungi includes mushrooms, Rhizopus, etc., which are multicellular eukaryotic saprophytic organism; Kingdom Plantae includes autotrophic, multicellular eukaryotic organisms whose cell walls are made up of cellulose and Kingdom Animalia include multicellular eukaryotic organisms lacking a cell wall. The Kingdom Animalia approximately comprises of 36 sub-divisions known as 'phyla'. Each phylum possesses specific structural and functional properties which separate it from other. The entire phylum starting from phylum Porifera to Phylum Chordata are clubbed together under kingdom Animalia. All members of Kingdom Animalia are multicellular, eukaryotic heterotrophic organisms. In total, there are around 9 to 10 million animal species that inhabit the earth system. However, only 800,000 species are identified to date. All the members are grouped together under 36 phyla.

Wildlife comprises of all wild living organisms such as animals, plants and microorganisms in their natural habitats. These wild organisms can neither be domesticated nor be cultivated. In other words, wildlife consists of non-domesticated members of class Pisces, Amphibians, Reptiles and mammals which are generally hunted for leisure or selfish commercial purpose. Wildlife is a renewable natural resource and forms the life support system on planet earth. We will be discussing below the positive and negative values of the wildlife.

1.2.1 Positive Values of Wildlife

The following are the positive values of the wildlife:

1. Ecological Value: Wildlife is a renewable natural resource and supports the life on planet earth. Ecology is the relationship between the living organism and the environment inhabited by them. As wildlife, is an essential part of the Mother Nature, they constitute the life-support system on it. Earth consist of both abiotic and biotic elements abiotic elements constitute water, minerals, gases (like oxygen, carbon-dioxide, Nitrogen, sulphur dioxide etc.) rock whereas biotic components constitute plants, animals, microorganism etc. Now, ecosystem is defined as the interaction between the biotic and abiotic components in any given area. These

NOTES

interactions are essential for maintaining the flow of energy that cycles from the abiotic environment and travels through living organisms via food-web. This energy flow is ultimately transferred back to the abiotic environment when living organisms die and the cycle starts all over again.

Energy flow is the flow of energy through living things within an ecosystem. All living organisms can be organized into producers and consumers, and those producers and consumers can further be organized into a food chain. The flow of energy in ecosystems is vitally important to the thriving of life on Earth. Nearly all of the energy in Earth's ecosystems originates within the Sun. Once this solar energy reaches Earth, it is distributed among ecosystems in an extremely complex manner. A simple way to analyse this distribution is through a food chain or food web. All organisms, dead or alive, have potential for energy transfer in an ecosystem. For example, a leaf is eaten by a caterpillar, which is eaten by a small bird, which is eaten by a hawk. If the leaf was left uneaten, it would fall to the ground and be decomposed by smaller organisms. Therefore little matter is actually wasted in ecosystems.

Abiotic factors in the environment

As discussed above, abiotic factors are the non-living components of the ecosystem. Abiotic factors include:

(a) Air– Consisting of gases like oxygen, carbon-dioxide, Nitrogen, Sulphur dioxide, etc.

(b) Water– Consist of ground water, surface water or water in the well, rivers, oceans, ponds, etc.

(c) Wind– Air that is moving across the surface of earth.

(d) Soil– Upper layer of earth that may be dug or ploughed and in which plants grow, i.e., in short the surface of the earth supporting plant and animal life.

(e) Light– Sunlight is essential for proper functioning of the living organisms on earth as well as for maintaining the optimal temperature on earth's surface, light is essential for the plants to carry out the process of photosynthesis. For example lack of proper light in the deeper ocean prevents photosynthesis meaning that the majority of the life in the ocean lies near the surface. Differences in daylight impact temperatures at the equator and the poles. Further, day-night rhythm of the light impact life patterns including reproduction for all living organisms.

(f) Salinity– Maintenance of ionic balance is essential for the survival of the organisms. Animals in the ocean are adapted to the salinity via salt renal gland to control the salt content of their bodies. Plants also have internal provisions to remove excess salt taken from the soil.

(g) Temperature– On the earth's surface a constant temperature is maintained by sunlight. Warm blooded animals like mammals have an internal mechanism to maintain a constant body temperature. Extreme temperature (either low or high) that go beyond an organism's tolerance will harm or kill the organism.

Animals that cannot regulate their internal body temperature according to that of the changing environment are known as cold blooded animals. Normally, they find it difficult to survive the extreme temperature conditions. For example fish and reptiles.

The influence and effect of temperature on living entities are in several ways. It has a role in morphology, cells, physiology, growth, behaviour, distribution of animals and plants, development and related aspects. Hence, the temperature is one of the limiting factors which can determine the presence of life on Earth.

Biotic Factors in the Environment

Biotic factor comprises of all the living parts of the ecosystem. Biotic factors include:

(a) Plants– Plants are autotrophs, i.e., they can produce their own food in the presence of sunlight by the process of photosynthesis. While performing the process of photosynthesis they also release oxygen in the environment and utilize carbon-dioxide present in it. Due to the ability to produce their own food, they are also known as producers. In ponds, lakes or oceans, many of the plants are grasses, algae or tiny phytoplankton floating on or near the surface. Chemosynthetic bacteria, also comes in the category of producers and form the basis of food-chain at deep ocean vents.

(b) Animals– Animals depends upon the plants for their basic need, i.e., food. Hence, they are called as consumers or Heterotrophs. Consumers are further categorized as primary consumers or herbivores that feeds directly upon the producers. For example, Deer, turtles, etc. Then, comes the secondary consumers that feeds upon herbivores and then tertiary consumers that feeds upon the secondary consumers. There may be more levels of consumers before a chain finally reaches its top predator. Secondary and tertiary consumers can also be categorized as: carnivores, i.e.,animals that eat only other animals and omnivores, i.e., consumers that can feed upon both plants and animals. For example, Tiger and lion strictly are carnivores as the feed upon other animals whereas human being are omnivores as they consume both plants, animals and their products.

(c) Fungi-They depends upon the bodies of their living hosts or depends upon remains of once living organisms. Fungi, also serves important role in the ecosystem as decomposers.

(d) Protists– They are microscopic organisms present in abundance in the ecosystem. Protists can be both plant like and animal like. Plant like protists serves as producers and manufacture food by the process of photosynthesis whereas animal like protists (paramecia, Amoeba) feeds upon bacteria and other small protists, so they form part of the food-chain. A third category of protists, i.e., fungus like protists often serve as decomposers in the ecosystem.

(e) Bacteria– Bacteria acts as decomposers in the ecosystem, i.e., they have the ability to break down remains of dead and decaying organisms for the release of nutrients in the ecosystem. They can also act as producers, for ex in deep-sea vents, chemosynthetic bacterial fills the role of producers in food chain. Further, bacteria also serve as food material for other organism like protists.

Interaction between Biotic and Abiotic factors

All the biotic and abiotic components of the ecosystem are closely interlinked with each other and thus there is a continuous flow of energy from abiotic to biotic components through different trophic levels arranged in the form of pyramid. For example, in a grassland ecosystem, grass acts as producers and is eaten up by

NOTES

grasshopper (First consumer). Grasshopper might get eaten by a rat which in turn is consumed by a snake. Finally, a snake is feasted upon by the hawk. Food chain represented as:

Grass→ Grasshopper→Rat→ Snake→ Hawk

Note: Grass acts as producers and synthesize their own food using abiotic components of the ecosystem whereas grasshopper, rat, snake and hawk acts as consumers at different trophic levels.

In a pond ecosystem, algae acts as producers. A mosquito larva feeds on algae and then a dragon fly larva feasts upon the young mosquito. The dragonfly larva serves as food material for a fish, which provides a tasty meal for raccoon.

Algae→mosquito larva→Dragon fly larva eats the young mosquito→Fish→Raccoon

In a marine ecosystem, phytoplankton provide food to tiny shrimp called krill which then is feasted upon by blue whale.

Depending upon the species, diversity and the manner in which they are organised, Ecosystems are of following types

1. **Permanent and Natural ecosystem**. These operate under natural conditions without any interference (even by human beings). These can be further classified in to-
   (i) Terrestrial ecosystem
   (ii) Aquatic ecosystem

   Terrestrial ecosystems operate on land hence Forest, Desert and grassland and Agro-ecosystems included in this type. While Aquatic ecosystem operates in water. It can be divided into-
   (a) Fresh water ecosystem
   (b) Marine ecosystem

   Freshwater ecosystems are usually named after the size and nature of the fresh water body such as pond, lake and river.Marine ecosystem is largest ecosystem on earth, which consists of several sub-divisions each having its physico-chemical and Biological characteristics. For example, in the deepest ocean producers are absent but in many other organisms survive which dependent for food on the dead organic matter coming from the upper layers of the ocean.
2. **Temporary and Natural ecosystems**: These are short lived but operate under natural conditions.
3. **Artificial or Anthropogenic ecosystems**: These are man-made like fishery tanks dams, croplands and space ecosystems also. Fish aquarium is also come under this head. These typologies are determined not only by the species composition but also by the physiognomic characteristics and soil and climatic conditions.

Thus, several units of ecosystem such as grassland ecosystem, marine ecosystem, and pond ecosystem are sustaining on the same principles comprising all the components of the ecosystem, though forming different communities. Thus, if any component of the ecosystem is disturbed, it will disturb the functioning of the ecosystem causing disastrous and calamitous situations for nature. Thus, life on planet earth depends upon the dynamism, structure and stability of the ecosystem.

2. Agricultural Value of Wildlife: Domesticated animals like cows, buffaloes help in ploughing or tiling of soil whereas other animals like insects, arthropods, annelids, reptiles etc. add to the fertility of the soil. However, the useful activities of wild animals is very vast. For example, Seasonal migration of wild animal, and birds helps in the development of vegetation through dispersal of seeds which they eat and defecate at different places. Most of the insects and birds perform the job of cross-pollination. Some wild animals and birds act as natural scavengers such as kite, jackal, crow, etc. Therefore, wildlife is essential for keeping the planet earth as a viable platform for healthy life and essential natural activities.

3. Scientific Value: Wildlife plays an important role in the advancement of life science in the field of medicine, physiology, ecology, anatomy, and embryology. A lot of scientific workers, researchers, institutes all over the world are engaged in conducting wildlife research activities with varied aims and objectives. Wild animals are used for carrying out drug testing before it is used for human trials. We learned about the presence of Rh factor in human blood via Rhesus monkey. Similarly, chimpanzee had helped us in conducting serological protein tests. Animal behaviour is one of the most interesting subjects for biologist as it helps in the in-depth analysis of psychology. Wild plants and animals are the source of most potent medicines. For example, Rhinoceros horn and musk pod of musk deer are great source of medicine. Tiger's fat is used for curing rheumatism, snake – venom is used for making anti-dote for snake bite. However, reckless killing and destruction of wild animals and plants for scientific purpose should be avoided. Further, scientific technologies should be adopted for preservation and propagation of wild flora and fauna.

4. Economic Value: Wildlife is huge source of income for individual, industries, nation etc. It can be used to earn money by trading wild plant products like medicine, food, timber, fibres etc. as well as wild animal products such as medicines, ivory, meat, lac, silk, etc. It provides raw materials to begin any industry or factory, etc. Thus, wildlife is considered one of the greatest factors for better development of world trade and increase in national income. Also, varied flora and fauna serves as a boost for tourism industry and hence is linked to the economic gain of the nation. Also, revenue generated from bio-reserves, zoos, national parks, safaris, sanctuaries add to the national income. Further, fishery industry adds to both the employment and income of the nation.

5. Cultural Value: Wild flora and fauna constitute an essential component of our national heritage. It is our moral duty to preserve and propagate them for the next generation. Wild animals serve as a source of inspiration for human race. For example birds must have inspired human beings to discover flying devices like planes, crafts, jet, etc. Further, lion and tiger are the symbols of bravery. Thus, we must preserve wild creatures as a source of inspiration to the coming generations.

6. Ethical: Human beings are considered as the supreme creation of God due to their ability to think logically and rationally. Thus, a look in ancient past, suggests that our philosophers, priests, books, sculptures have advised to protect, preserve and propagate the wild animals and plants. Hence, to respect and protect wildlife is part of our duty in life.

7. Entertainment Value: Performance of trained animals in circuses and presence of different wild creatures like birds, reptiles, mammals in national park, zoos, serves as source of entertainment for people. They also add to the knowledge and awareness

NOTES

of environment in children. Additionally, visiting such areas stimulates interest in wildlife creating emotion of love and sentiment of their preservation and propagation.

8. Aesthetic Value: People appreciates the aesthetic value of natural beauty or artistic appeal present in animal life. Giant Pandas, bald eagles and seals are familiar examples of wildlife with outstanding aesthetic value. As rightly said by our late Prime Minister Smt. Indira Gandhi 'A threat to any species of plant and animal life is threat to man himself. Wild species also offers recreational values, without which our life will be very dull and boring. Thus, mere beauty and colourfulness of these wild creatures, compels us to protects, preserve and propagate wild animals.

9. Game Value: Wildlife also offers recreational values in the form of sport hunting and bird watching. Our kings and emperors, used to hunt down wild animals for leisure, however reckless killing of the wild animals has led to the ban on such activities. However, fishing or bird-watching still serve as major fun or leisure activity.

Thus, positive values of wildlife can have direct benefits in the form of income, food, engagement as well as indirect such as ethical.

1.2.2 Negative Values of Wildlife

Apart from the positive values, a few negative values are associated with wildlife. The following are the negative values associated with wildlife:-

- Wild animals predate on domestic animals as well as on human beings.
- Responsible for destruction of properties (occasionally).
- They act as carrier of several life-threatening diseases.
- They are also responsible for destruction of crops in agricultural land like wild elephants destroys agricultural fields.
- Carnivores like Lion, tiger, etc., predates on domesticated cattle as well as human beings which leads to loss of life, property and human-life.
- Another threat is sometimes big carnivorous animals like Lion, Tiger, and Panther turns to Man-eater.
- However, all the above-mentioned negative values are primarily man-made arising due to habitat destruction of these wild animals for propagation of industrialization and urbanization.
- Increase in the population of wild animals accompanied by the increase in motor traffic have led to a strong increase in collisions on roads and motorways.

To conclude, wildlife has more positive values associated with it rather than the negative ones. Most importantly, negative values are often due to selfish-interest of human-beings.

1.2.3 Wildlife Conservation

Wildlife conservation refers to the protection, preservation and propagation of rare species of plants and animals in their natural habitats. While, wildlife management refers to the conservation of Wildlife along with the management of wildlife resources in such a way that they can meet the specific objective and requirements of human beings. Biological diversity of both plant and animal species is threatened by several anthropogenic activities such as hunting, habitat destruction, deforestation, pollution, mining activities, industrialization, urbanization, intensive

agricultural activities as well as a series of other commercial and economical to meet the ever-increasing needs of growing population. Though, each and every species of wildlife is essential, yet 'International Union for Conservation of Nature and Natural Resources' (IUCN) laid down the categories of rare plant and animal species for conservation purpose. IUCN maintains a 'Red Data Book' about the threatened species. The classification of threatened species is based on the following criteria and even a single criterion is enough to mark the species in this category:

(i) On the basis of past and present distribution of species.

(ii) A sharp decline in the population over a period of time.

(iii) Species having biological or potential value.

Aims and Objectives of Wildlife Conservation

Following are the aims and objectives of wildlife conservation:-

- It helps in maintaining the ecological and economical process
- It aids in maintaining the life supporting system i.e. soil, air, water etc.
- Helps in the preservation of species diversity.
- To ensure a continuous supply of raw-materials to the industries.

Conservation Ethics

Conservation ethics refers to the ethics of natural resources utilization, allocation, exploitation and protection. The primary focus of conservation ethics is to safeguard the interest of natural world comprising of forests, fisheries, reptiles, amphibians, birds and mammals. Conservation ethics are guided by four R's namely Reduce, Reuse, Recycle and Rethink. Thus, conservation ethics basically lays emphasis on the sustainable development, judicious use of natural resources as well as moderation of destructive anthropogenic activities.

Environmental Ethics and Old Traditions

Our traditions teach us to live in harmony with nature and also to preserve and conserve the different elements of nature like forest, wildlife resources, water soil, etc. Our age-old traditions believe that we all (including human beings) are the creation of one God and hence we do not have any right to harm or destroy other elements of nature. Since Vedic time, the main principle of the social life is to live in utter harmony with nature. All our ancient sages, teachers, saints, thinkers have urged us to treat nature as 'God' and to have benevolent attitude towards all elements of nature. In our Vedas, trees, hills, animals mountains river all are worshipped as 'Gods' and it teaches us to:

1. To pay utmost respect to nature and also to preserve and conserve it
2. 'Ahinsa Parmo Dharma' or non-violence is the highest dharma and everyone should be non-violent towards trees, animals and other natural elements.
3. To maintain a clear and Green environment.
4. To show equal respect to both human and non-human lives.
5. Purity of thought and expression should be the way and life.
6. Different elements of nature like Sun, Wind, Fire, Earth, Forests were considered as 'Lord Surya', 'Vayu Devta' , 'Agni Devta', 'Prithvi Mata' and 'Vanya Devi' to mark their importance in human lives.

NOTES

7. Cutting of forest or trees is considered as sin and plants like Tulsi, Peepal were worshipped as God.
8. Our old manuscripts highlights the importance and medicinal properties of water.

Environmental Ethics and Constitution of India

The above teachings of peaceful existence with the nature got mentioned in the constitution in the form of following articles:

1. **Article 48A:** A state shall endeavour to protect and improve environment and to safeguard forest and wildlife of the country. This article was added to the Constitution by the 42nd Amendment in 1976.
2. **Article 51**A: It is the fundamental duty of every citizen of India to protect and improve natural environment including forest, lake, rivers and wildlife and to have compassion for living creatures.

Ethics refers to a branch of philosophy defining a set of cultural values which guide people's behaviour at individual, social, institutional, regional and global levels. Every religion teaches us to be in a cordial relation with the mother-nature for ensuring sustainable development. Ethics tells us what is right or wrong while dealing with the environment.

Thus, all in all, our conservation ethics teaches that humans should not consider themselves superior to other life forms and hence they should not kill other living beings, should not waste resources, and should aim at judicious use of natural resources which will ultimately pave the path to sustainable development.

1.2.4 Importance of Conservation

Conservation refers to the management of natural resource and their utilization in such a way that it can fulfil the needs of both present and future generation without disturbing the ecological balance.

1. Conservation of Forests

Conservation of forest refers to management of forests in such a way as to upkeep their maintenance and also to derive maximum benefits out of it. Note: Here, maximum benefits mean derive sustainable benefits in such a way that both present and future generations can be benefitted amply.

Before, studying the ways to conserve forest, let us first see the importance of forests.

(a) Economic– Forests provides us with timber, wood, fuel as well as other raw-materials which can be used by several industries such as paper industry, furniture, Construction Company and for domestic purposes also. Further, forest products such as Bamboo, rayon, paper, latex, essential oil, gums, resins, leaf, drugs, tasar, muga silk, horns, wax, honey, antler, ivory, etc., are obtained from forest and have high economic value.

(b) Ecological Value– Forest has huge ecological value as can be seen from following key points:

1. First provide shelter to large number of species
2. Forest fulfil the biological and ecological needs of several species

NOTES

3. Trees in the forest binds the soil particles tightly and thus prevents soil erosion.
4. Forest help in maintaining the cycles in nature such as water cycle, oxygen cycle, Carbon dioxide cycle, Nitrogen cycle, etc.
5. Forest help in maintaining the climatic conditions.
6. Forest help in controlling the air pollution, water pollution, soil pollution,. etc.
7. Forest have great aesthetic value and recreational value.
8. Forest provide great opportunity to researchers to carry out their research in open nature. They also have great educative value.

Now, we can say that forest have great importance on planet earth or we can say that they form the life supporting system on earth. Hence, let us look at the steps taken by the Indian government to conserve forest:

India is among the few countries which has a forest policy since 1894, and the forest policy was revised again in 1952 and 1988. The primary aim of the forest conservation policy is to ensure protection, conservation and development of forests. The following are the major aims and objectives of the forest conservation policy:-

1. Maintaining the environmental stability as well as ecological balance.
2. Preservation and conservation of natural heritage
3. Keeping in check the soil erosion
4. Checking expansion of sand dunes in desert areas of Rajasthan and along coastal tracts.
5. To increase the tree cover via afforestation and social forestry programmes.
6. To increase the productivity of forest such that it can meet the requirement of industries.
7. To look for substitution of forest products.
8. To reduce the ever increasing pressure on forests.

Integrated Forest Protection Scheme (IFPS) - Integrated Forest Protection Scheme was implemented during the 10^{th} five-year plan and is continued during 11^{th} plan. This plan was re-named as 'Intensification of Forest management' during the 11^{th} five-year plan. However, it added two more components to the existing programme. Thus, this programme aims at development of infrastructure, management of forest fire, conservation and restoration of vegetation and eco-system, conservation and protection of sacred grooves and joint forest management which lay emphasis on the development of partnership with forest people. Hence, the government of India allowed the people living in and around the forest to collect and trade minor forest product through a national level legislation named as the scheduled tribes and other traditional forest dwellers (Recognition of forest rights) Act, 2006. This act has helped the people staying in and around the forests to improve their economy.

Forest Conservation Act

Forest conservation Act was enacted in 1980 and it helps to check indiscriminate deforestation and diversion of forest land for construction work and industrial purpose. The act involves taking permission from central Government. Before the

allocation of land to non-forest purpose and even if the permission is granted it has to be followed by compensatory actions such as afforestation as well as some other mandatory conditions laid down in the act and National Forest policy, 1988.

NOTES

National Forest Commission

This commission was set up in 2003 and it submitted its first report in March, 2006. The following are the recommendations of the National Forest commission.

1. It laid strong emphasis on carrying out the scientific research to assess the forest cover in order to meet the aim and objectives of the commission.
2. Amendment of the Indian Forest act, 1927.
3. Implementation of Biological Diversity Act, 2002 and Environment protection Act.
4. In order to avoid potential man-animal conflict, it proposed re-scheduling of species under wildlife protection Act.
5. Forest conservation Act, 1980- should remain intact and un-touched with no further amendments.
6. Similarly, National Forest policy, 1988 should remain intact with no further amendments.

Conservation of Wildlife

With the increase in the number of threatened and endangered wild species, several Government and Non-government organisations have been set up to preserve and conserve the wildlife. The major aim and objectives of wildlife management in India are:

1. To prevent loss of habitat as animal's habitat provides it with food, shelter and cover to survive and reproduce.
2. To maintain endangered species in protected areas such as National Parks, Sanctuaries and Biosphere reserves.
3. Protecting the wild animals and their habitats via legislation.

A large number of wildlife acts have been implemented periodically to preserve and conserve wildlife. A large number of projects have also been started in the past to preserve and conserve wild animals. Below, we will be discussing a few such projects:

1. Project Tiger

- Launched in 1973 on the recommendation of IBWL (Indian Board of Wildlife)
- Project Tiger aimed at maintenance of tiger population in India so that they won't extinct in the future
- It also aimed at conservation of such areas (where tiger population is conserved) as a national heritage for the educative and recreation purpose of present and future generation.

2. Project Elephant

- Project elephant was launched in Feb, 1992.
- The main aim of the project elephant is to ensure sustainable population of wild elephants in their natural habitat

NOTES

- In India, wild elephants are mainly confined to Kerala, Tamil Nadu, Karnataka, Jharkhand, West-Bengal and Uttarakhand, etc.
- Illegal hunting and poaching for selfish interest have led to a sharp decline in the elephant's population.
- Moreover, inbreeding due to forced isolation also leads to subsequent negative effects.
- Keeping all this in view, project elephant was implemented in Assam, Jharkhand, Andhra Pradesh, Arunachal Pradesh, Kerala, Tamil Nadu, Uttarakhand, West Bengal, etc.
- Project elephant aimed at restoration of natural migratory routes and habitats of elephants.
- Scientific management of wild elephant's habitat to ensure their conservation
- To reduce the pressure of human activities on elephant's population.
- To avoid man-elephant conflict in crucial habitats
- To prevent illegal hunting, poaching and trading of wild elephant and their products like tusk etc.
- Strong emphasis to conduct educative and awareness-based programmes to educate general masses.
- To promote research on scientific management of habitats.
- To provide veterinary care to injured/sick animals

3. Protecting Vultures

- Vultures plays a crucial role in the environment; they are perceived as lowly scavengers but they act as nature's clean-up crew and thus helps to keep running the healthy ecosystem.
- However, in a report presented jointly by the 'Department of Animal husbandry, Dairying and Fisheries', it has been revealed that the population of vultures has been declining at an alarming rate.
- The reason behind this is the drug 'Diclofenac' (a popular pain killer) which is highly toxic to bird even at very low dosage.
- In May, 2006, government of India took preventive measures to prevent the further decline in the population of this key species
- This involves ban of the drug diclofenac in the veterinary sector.

4. Protecting Gharials

- Gharial (as fish eating Indian crocodile with a long snout) is a native to South-Asia.
- WWF strongly believes that it is now present only in India and Nepal.
- In 2008, it was reported that the population of gharials went down sharply and they turned up dead on the banks of Chambal River.
- It was later discovered that all of them were dying due to some liver disease
- Thus, Government took the initiative and set up protected areas along the Chambal to avoid the illegal hunting, poaching and trading of animal's skin for making high-grade leather.

- Further, the eggs of this rare- crocodile are raised in captivity to protect them from predators.

1.2.5 Causes of Depletion

NOTES

India is very rich in terms of biological diversity (both floral as well as due to its unique bio geographical location, diversified climatic conditions and enormous eco diversity and geo diversity. India is rich in floral as well as faunal diversity. The word 'Flora' comes from the Latin, *Flora* - the goddess of plants (*floris* means flower). Floral diversity refers to the diversity of naturally occurring indigenous or native plants. Out of 298,000 predicted plant species, a total of 215,644 species of plants have been catalogued on earth till-date. Further, out of 16,600 predicted plant species only 8,600 plant species have been recorded from ocean till date. India, being one of the tropical countries harbours 46,824 species including species of virus/bacteria and fungi. The floral diversity of India is concentrated in four phytogeographically unique regions namely Himalayas, Western Ghats, Northeast India and Andaman and Nicobar Islands. The Indian Flora accounts for approximately 11.4% of the total recorded plant species of the world.

Source of Information: ENVIS Resource Partner on Biodiversity/Hosted by Botanical Survey of India, Kolkata, West Bengal/Sponsored by Ministry of Environment, Forest and Climate Change, Government of India.

According to world biogeographic classification, India represents two of the chief realms (the Palaearctic as well as the Indi-Malayan) and three biomes namely Tropical Humid Forests, Tropical Dry/Deciduous Forests and Warm Deserts/ Semi-Deserts. The total land surface of India is approximately 2.4% of world's total land surface yet the fauna of India is so diverse that it accounts for over 7.50% of the animal's species found in the world. India reportedly has approximately, 92,000 faunal species so far has been reported from India so far.

Source of Information: ENVIS Centre on Faunal Diversity/Hosted by Zoological Survey of India, Kolkata/Sponsored by Ministry of Environment, Forests and Climate Change, Government of India Forests.

Based on the International Union for Conservation of Nature and Natural Resources (IUCN), we can classify species as follows:

- Extinct (EX)
- Extinct in the Wild (EW)
- Critically Endangered (CR)
- Endangered (EN)
- Vulnerable (VU)
- Near Threatened (NT)
- Least Concern (LC)
- Data Deficient (DD)
- Not Evaluated (NE)

Wildlife depletion refers to the loss of biodiversity. Anthropogenic activities like reckless hunting, selfish interest, illegal commercial exploitation, adventurous activities, etc., are responsible for extinction of wildlife. Further, other factors like pollution, urbanisation, etc., are equally responsible for depletion of wildlife. For instance: The world's fastest land mammal, the cheetah (*Acinonyx jubatus*), were

widely distributed throughout Asia and Africa prior to 20th century. However, Asian cheetah is nearly extinct due to severe decline in prey population of the animal as well as habitat destruction. The species was declared extinct in India long back in 1952. The following are the factors responsible for depletion of wildlife:

1. **Hunting–** Reckless hunting of wild animals for leisure, fun and fulfilling selfish motives have caused the extinction of wild animals in the list. With the advancement in fire-arms (as compared to traditional bow-arrow) hunting emerged as a popular sport leading to needless killing of wild animals.

   Disappearance of lot of medicinal plants or disappearance of 'Dodo' (a bird of Mauritius) or 'Cheetah' from India are attributed to illegal hunting and poaching activities.

2. **Destruction of Habitats**– Habitat destruction is the major threat to population of wild animals. There are several reasons for destroying the habitats of wild animals:
   (a) Requirement of land for ever-growing population as residential land, grazing ground or croplands.
   (b) Rapid deforestation due to increase in demand of trees and its by-products. For example, wood is required for constructing home, buildings, furniture as well as the starting material for several industries. Other forest products such as timbre, fibre, gum are also required for several other industrial purpose.
   (c) Over-grazing by ever increasing number of domesticated animals.
   (d) Conversion of forest into agricultural land
   (e) Damage of forest/grassland/agricultural land due to acid rain.
   (f) Pollution of water bodies killing aquatic plants as well as animals.
   (g) Rapid construction of dams/reservoirs in the name development leads to destruction of habitats of wildlife as well migration of certain fishes.
   (h) Increased mining activities.
   (i) Introduction of exotic species deliberately has affected many native species by undue competition for food, space, mate as well as transmission of diseases, parasites, etc. Also, exotic species might act as predator to native species.
   (j) Over-exploitation of resources is another serious threat
3. **Cleanliness**– Though, it is essential to maintain cleanliness of the environment but it is indirectly depleting some of the wild creatures. For example, vultures and kites feed on carcasses. Since, carcasses are burnt now, population of largest flying bird California condor has started declining.
4. **Migratory Routes**– Changes in settling areas and routes of migratory animals result in their perishing.
5. **Economic or Commercial Exploitation**– Wild animals and their products are illegally traded within and between the nations for selfish interest as well as for commercial exploitation. This leads to illegal hunting and poaching of animals which in turn threatened their existence.
6. **Introduction of Exotic Species**– Introduction of exotic species causes undue competition for space, food water, and mate between the native and

NOTES

exotic species. This often leads to ecological imbalance. For ex: Goats and rabbits introduced in pacific and Indian ocean islands have destroyed habitats of reptiles, birds and plants.

7. **Low Fecundity–** Low-fecundity among wild animals due to stress, limitation of resources, limitation of ample space, and absence of mate, excessive human interference, and ecological imbalance is also responsible for depletion of wild-life.
8. **Pollution–** Pollution of environment due to urbanization, industrialization, increasing traffic, etc., is also responsible for depletion of wild life.
9. **Urbanization and Industrialization**– For fulfilling the settlement requirement of ever-growing population as well as to provide ample employment opportunities there is rapid urbanization and Industrialization in rural as well as urban areas which in turn has resulted in over exploitation of natural resources as well as depletion of wildlife.
10. **Intensive Agricultural Activities**– There is rapid transformation of forest land to crop or agricultural land in order to fulfil the basic requirement of food of ever-growing population. Further, repeated use of same crop every year as well as use of excessive fertilizer and pesticides affects the soil productivity badly. All these activities lead to the conversion of forest land to waste-land.
11. **Insecticides and Pesticides**– All the insecticides and pesticides used for agricultural purpose gets washed away in the rivers, ponds, dams, lakes which ultimately pollute these aquatic ecosystems and hence leads to depletion of aquatic wildlife.
12. **Forest-Fires**– Natural as well as man-created forest fires destroys both vegetation as well as wildlife.
13. **Plant-Pest**– Pest like bacterial, fungi, viruses, insects etc. damages the plant and their products leading to depletion of natural flora.
14. **Excessive Mining Activities**– Use of unscientific methodologies for the extraction of minerals from the earth has also led to depletion of wildlife resources.
15. **Soil Erosion**– Removal of top layer of soil by wind is known as soil erosion. All this soil along with its pesticides, fertilizer, insecticides get washed away in the water bodies causing water pollution and hence depletion of aquatic population. Further, soil erosion loosens the anchorage of plants to earth's surface leading to depletion of natural flora which in turn affects the fauna also.
16. **Natural Calamities**– Natural forces such as earthquake, landslides, ice, snow, floods can adversely affect both flora and fauna of the ecosystem.
17. **Sewage Town Refuse**– Improper disposal or treatment of household as well as industrial waste can cause serious ecological imbalance.

1.2.6 World Conservation Strategies

World conservation strategy (1980) is the first international documentation on living resources conservation produced with inputs from government, non-governmental organizations and other conversationalist experts. The documentation

supports the idea of sustainable development, i.e., development should support the idea of conservation rather than hindering the process. The documentation was prepared by the' International Union for conservation of Nature and Natural Resources' (IUCN) with inputs from 'United Nations Environment Programme' (UNEP), 'The World Wildlife Fund' (WWF), 'The Food and Agriculture Organizations of The United Nations '(FAO) and 'The United Nations Educational, Scientific and Cultural Organizations' (UNESCO).

The Aim- World Conservation Strategy

The aim of the World Conservation Strategy is to help advance the achievement of sustainable development through the conservation of living resources.

The Strategy:

1. Explains the contribution of living resource conservation to human survival and to sustainable development;
2. Identifies the priority conservation issues and the main requirements for dealing with them;
3. Proposes effective ways for achieving the Strategy's aim.

The Strategy is intended to stimulate a more focussed approach to living resource conservation and to provide policy guidance on how this can be carried out. It concentrates on the main problems directly affecting the achievement of conservation's objectives, and on how to deal with them through conservation. In particular, the Strategy identifies the action needed both to improve conservation efficiency and to integrate conservation and development.

The Users - World Conservation Strategy

The Strategy is intended chiefly for three groups of users (none of which is wholly separate from the others):

1. Government policy makers and their advisers. Few governments have the financial and technical resources to address all of the problems of living resource conservation at once. Therefore, they need to know what needs to be done first. Accordingly, the Strategy both recommends ways of overcoming the main obstacles to conservation and provides guidance on what action is most important. The strategy is relevant to any level of government with significant responsibilities for planning and managing the use of living resources.
2. Conservationists and others directly concerned with living resources. For this group, the Strategy indicates those areas where conservation action is most urgently needed and where it is likely to yield the greatest and most lasting results. It also proposes ways in which conservation can participate more effectively in the development process, thereby increasing the likelihood of its being positively received by the development community and of helping to ensure that development is sustainable.
3. Development practitioners, including aid agencies, industry and commerce, and trade unions. For this group the Strategy demonstrates that conservation

NOTES

improves the prospects of sustainable development and proposes ways of integrating conservation into the development process. It also attempts to identify those areas where the interests of conservation and of development are most likely to coincide and therefore where a closer partnership between the two processes would be particularly advantageous to both.

Arrangement of the Text- World Conservation Strategy

The Strategy consists of 20 double page sections. The introduction (section 1), which defines key terms, is followed by three groups of sections. The first group (sections 2-7) describes the contribution of each of the objectives of conservation to human survival and wellbeing; outlines the main threats to them; and identifies the priority requirements for achieving the objectives. The second group (sections 8-14) sets out a strategy for action at the national and subnational levels. A framework for the strategy is outlined; then each of the main obstacles to conservation is described, together with recommendations for dealing with the obstacles. The third group (sections 15-20) is devoted to international action to stimulate and support national and subnational action. Section 20 includes a checklist of priority requirements, national actions and international actions.

Priority Issues- World Conservation Strategy

The priority issues discussed in the Strategy are (numbers in parentheses refer to sections): reduction in quality and quantity of agricultural land (2, 5, 16) and grazing land (4, 7, 16); soil erosion and the degradation of catchment areas and watersheds (2, 5, 11, 16, 19); desertification (2, 5, 16); loss of the support systems of fisheries (2, 5, 11, 18, 19); extinction of species, subspecies and varieties (3, 6, 15, 17); overexploitation of fish and other wildlife (4, 7, II, 18, 19); deforestation (4, 7, 16); climate alteration and air pollution (18); narrow sectorial approach to conservation (8, 9); failure to integrate conservation and development (9, 20); inadequate environmental planning and irrational resource allocation (I 0); inadequate or unenforced legislation (11); poor organization (11); Jack of trained personnel (12); lack of information (12); lack of support for conservation (13); lack of conservation-based rural development (14). Most of these problems are common in both developed and developing countries. Several, however, such as erosion, desertification, deforestation and lack of conservation-based rural development, are much more acute in developing countries than in developed ones.

Executive Summary- World Conservation Strategy

The World Conservation Strategy is intended to stimulate a more focussed approach to the management of living resources and to provide policy guidance on how this can be carried out by three main groups:

- Government policy makers and their advisers;
- Conservationists and others directly concerned with living resources;
- Development practitioners, including development agencies, industry and commerce, and trade unions.

NOTES

The aim of the World Conservation Strategy is to achieve the three main objectives of living resource conservation:

- To maintain essential ecological processes and life-support systems (such as soil regeneration and protection, the recycling of nutrients, and the cleansing of waters), on which human survival and development depend;
- To preserve genetic diversity (the range of genetic material found in the world's organisms), on which depend the functioning of many of the above processes and life-support systems, the breeding programmes necessary for the protection and improvement of cultivated plants, domesticated animals and microorganisms, as well as much scientific and medical advance, technical innovation, and the security of the many industries that use living resources;
- To ensure the sustainable utilization of species and ecosystems (notably fish and other wildlife, forests and grazing lands), which support millions of rural communities as well as major industries.

3. These objectives must be achieved as a matter of urgency because of the following reasons:

- The planet's capacity to support people is being irreversibly reduced in both developing and developed countries.
- Thousands of millions of tonnes of soil are lost every year as a result of deforestation and poor land management.
- At least 3,000 km2 of prime farmland disappear every year under buildings and roads in developed countries alone.
- Hundreds of millions of rural people in developing countries, including 500 million malnourished and 800 million destitute, are compelled to destroy the resources necessary to free them from starvation and poverty: in widening swaths around their villages the rural poor strip the land of trees and shrubs for fuel so that now many communities do not have enough wood to cook food or keep warm; the rural poor are also obliged to burn every year 400 million tonnes of dung and crop residues badly needed to regenerate soils;
- The energy, financial and other costs of providing goods and services are growing: throughout the world, but especially in developing countries, siltation cuts the lifetimes of reservoirs supplying water and hydroelectricity, often by as much as half; floods devastate settlements and crops (in India the annual cost of floods ranges from $I 40 million to $750 million);
- The resource base of major industries is shrinking: tropical forests are contracting so rapidly that by the end of this century the remaining area of unlogged productive forest will have been halved; the coastal support systems of many fisheries are being destroyed or polluted (in the USA the annual cost of the resulting losses is estimated at $86 million).

The main obstacles to achieving conservation are:

- The belief that living resource conservation is a limited sector, rather than a process that cuts across and must be considered by all sectors;

NOTES

- The consequent failure to integrate conservation with development;
- A development process that is often inflexible and needlessly destructive, due to inadequacies in environmental planning, a lack of rational use allocation and undue emphasis on narrow short term interests rather than broader longer term ones;
- The lack of a capacity to conserve, due to inadequate legislation and lack of enforcement; poor organization (notably government agencies with insufficient mandates and a lack of coordination); lack of trained personnel; and a lack of basic information on priorities, on the productive and regenerative capacities of living resources, and on the trade-offs between one management option and another;
- The lack of support for conservation, due to a lack of awareness (other than at the most superficial level) of the benefits of conservation and of the responsibility to conserve among those who use or have an impact on living resources, including in many cases governments;
- The failure to deliver conservation-based development where it is most needed, notably the rural areas of developing countries:

4. The World Conservation Strategy therefore:

(a) Defines living resource conservation and explains its objectives, its contribution to human survival and development and the main impediments to its achievement (sections 1-4);

(b) Determines the priority requirements for achieving each of the objectives (sections 5-7);

(c) proposes national and subnational strategies to meet the priority requirements, describing a framework and principles for those strategies (section 8);

(d) Recommends anticipatory environmental policies, a cross-sectorial conservation policy and a broader system of national accounting in order to integrate conservation with development at the policy making level (section 9);

(e) Proposes an integrated method of evaluating land and water resources, supplemented by environmental assessments, as a means of improving environmental planning; and outlines a procedure for the rational allocation of land and water uses (section 10);

(f) Recommends reviews of legislation concerning living resources; suggests general principles for organization within government; and in particular proposes ways of improving the organizational capacities for soil conservation and for the conservation of marine living resources (section 11);

(g) Suggests ways of increasing the number of trained personnel; and proposes more management-oriented research and research-oriented management, so that the most urgently needed basic information is generated more quickly (section 12);

(h) Recommends greater public participation in planning and decision-making concerning living resource use; and proposes environmental education programmes and campaigns to build support for conservation (section 13);

(i) Suggests ways of helping rural communities to conserve their living resources, as the essential basis of the development they need (section 14).

5. In addition, the Strategy recommends international action to promote, support and (where necessary) coordinate national action, emphasizing in particular the need for:

(a) Stronger more comprehensive international conservation law, and increased development assistance for living resource conservation (section 15);

(b) International programmes to promote the action necessary to conserve tropical forests and dry lands (section 16), to protect areas essential for the preservation of genetic resources (section 17), and to conserve the global "commons"-the open ocean, the atmosphere, and Antarctica (section 18);

(c) Regional strategies to advance the conservation of shared living resources particularly with respect to international river basins and seas (section 19).

6. The World Conservation Strategy ends by summarizing the main requirements for sustainable development, indicating conservation priorities for the Third Development Decade (section 20).

Source of Information: - World Conservation Strategy (iucn.org)

Check Your Progress

1. What do you understand by the term wild life?
2. What is the economic value of wild life?
3. Define wildlife management.
4. What are Conservation ethics?
5. Give the classification of species based on the International Union for Conservation of Nature and Natural Resources (IUCN).

1.3 HABITAT ANALYSIS

In ecology, Habitat refers to the natural environment (constituting living and non-living entities on earth's surface) in which a particular species of organism lives. Food, shelter, water and mate are the basic requirement for the survival of the species and habitat refers to that places where the species can find them. A habitat is characterized by both physical and biological features. Physical factors include abiotic factors like soil, temperature, PH, light etc. whereas biological (biotic) factors include food and prey-predator relationship. A habitat is not just a geographical location but it could be anything like a rock, interior of stem, rotten log, and a clump of moss or even host's body for the parasitic organism. The following list will describe the types of habitats observed:

NOTES

1. **Terrestrial Habitat**– It includes grasslands, forests, deserts, wetlands etc. Within these broad habitats, we have specific habitats with varied temperature, soil quality, altitude, vegetation etc. Many of these habitat's grade into each other and each one has its own typical communities of plants and animals.
2. **Fresh-Water Habitats**– It includes reservoirs of fresh-water like ponds, lakes, well, rivers, streams etc. A few organisms are found across most of these habitats, majority have some more specific requirements. Water velocity, oxygen saturation and temperature determine the type of flora and fauna occupying the habitat. Aquatic flora can be seen floating, submerged, semi-submerged or grow in permanently or temporarily saturated soils besides bodies of water. Marginal plants play an important role by providing habitat for both invertebrates and vertebrates whereas submerged plants play an essential role in the oxygenation of water, reducing pollution as well as absorbing nutrients.
3. **Marine Habitats**– Marine Habitats includes sea, estuaries, intertidal zones, sea bed, reefs, brackish water, bags etc. Further variations include brackish lagoons, sand banks, mudflats, rock pools, etc., all supporting their own unique fauna and flora. Seabed also known as the benthic zone of the sea provides habitat for both static organisms (organisms which are anchored to the substratum) as well as for organism crawling or burrowing into the surface. A few aquatic creatures float on the surface of water whereas other prefer to swim at varied depths.
4. **Microhabitat-** Every broad habitat constitutes numerous small-scale microhabitats having their own physical parameters, i.e., humidity, light exposure, temperature, soil conditions etc. Thus, in short microhabitat refers to the physical and biological factors present in the immediate vicinity of a living organism, i.e., either plant or animal or we can also say that microhabitat is a habitat within a habitat that possesses unique properties where new variations of life can exist and thrive due to the unique conditions that microhabitat offers. For example, a decomposing log in a forest supports a distinct population of decomposers, plants and invertebrates, but the forest houses the log itself. For a parasitic organism, its habitat is the particular site (whether inside or outside) of the host's body. The life cycle of some parasites includes different life stages occupying different parts of the host body.
5. **Extreme Habitat**- Majority of the living organism on earth's surface opt to thrive under moderate physical conditions of light, temperature, soil, etc. However, there are some organisms which sustains in extreme environmental conditions that are mostly unfavourable for other complex life forms. Generally, microbes like bacteria, archaea, protist thrive well under such extreme conditions. For example, scientists have recorded bacteria living in Lake Whillans, half a mile below the ice of Antarctica in the absence of sunlight, depends upon the dead and decaying organic matter from glacier melt water or minerals underlying rock. Some bacteria have been reported from Mariana Trench, the deepest place in the ocean and on earth. There

are few microbes which are thriving well in places devoid of oxygen and are dependent upon chemical reactions other than photosynthesis.

6. **Monotypic Habitat**- Generally, a habitat is a polytypic means different species thrives well within the same habitat. However, some monotypic habitats also exist on planet earth. A monotypic habitat is defined as a habitat in which a single species of animal or plant is the only species of its type to be found in a specific habitat and forms a monoculture. However, monotypic habitats are generally considered impoverished when compared to polytypic habitats, though it is not necessarily the case most of the times. For example, monocultures of plant hydrilla, supports a rich fauna and invertebrates as a more varied habitat. In some cases, invasive species, i.e., non-native species that spreads from the point of introduction and becomes abundant) create mono-culture, thus preventing the other species from thriving well there. Such dominant colonization of a particular species may occur due to several reasons like – nutrient monopolization or lack of natural controls such as climatic conditions or pest/predators that would help to keep the balance maintained between native and non-native species in the respective habitats. Such monotypic habitat can be observed in both zoological as well as botanical context. For example, non-native fresh-water zebra mussel colonizes areas of the great lakes in a zoological monotypic habitat. Also, yellow star thistle is a botanical monotypic habitat covering nearly 61,000 km^2 in California only.

Habitat Analysis

Habitat analysis aims at discovering what certain wildlife species need from the environment. Habitat Analysis address a series of planning needs using a variety of assessment tools. Habitat analysis aims at not only discovering what the wildlife needs from the environment but also what the environment receives from the species they host. This helps to create a symbiotic environment among trees, wildlife, birds, fisheries, aquatic systems, soils, water, indigenous traditions and norms as well as livelihoods. Habitat analysis aims at assessing following in a particular environment/area

- Assessment of Endangered Species residing in the environment
- Analysis of the Wetlands
- Hydrologic Analysis
- Analysis of the Watershed as well as other natural Resource Management Plans
- Analysis of the Vegetation present in the concerned area
- Forest Management Planning
- Timber Volume Mapping
- Wildlife and Fisheries Habitat Analysis as well as Reporting

Habitat analysis is carried out by wildlife managers from time to time. A variety of tools and techniques are used to analyse, investigate, discover, and understand

NOTES

how different systems are related to each other. Following are the tools and techniques of habitat analysis:

- Thorough assessment of the concerned area (field assessment). This involves a lot of field work due to which huge data is collected.
- Sampling of the concerned area by using technique like quadrate method, PCQ method, etc.
- Integrated planning committee collaboration
- Geospatial analysis- Geospatial analysis refers to the gathering, display, and manipulation of images, GPS, satellite photography as well as historical data, described clearly in terms of geographic coordinates or indirectly, in terms of a street address, postal code, or forest stand identifier as they are applied to geographic models.
- Econometrics- Econometrics refers to the use of statistical methods using quantitative data to develop theories or test existing hypotheses.

1.3.1 Evaluation and Management of Wild Life

Broadly wildlife includes flora and fauna in its natural habitat. According to IBWL, i.e., Indian Board for wildlife, 'Wildlife is the whole native and uncultivated fauna and flora of a particular country' (IBWL, 1970). Further, according to wildlife (Protection) Act, 1972 'Wildlife includes any animal, bees, butterflies, crustacean, fish and moths; and aquatic or land vegetation which form part of any habitat. Thus, wildlife includes fishes, amphibians, reptiles, birds, mammals, butterflies, their eggs, larva in their own natural habitat. Wildlife consist of an uncultivated, non-domesticated, non-tamed species. Wildlife is a renewable natural resource and with proper management and care it can be renewed under natural circumstances. According to ecology wildlife management is an ecological science, which deals with the relation of an organism to its environment including other living things that co-inhabit the same basic resources of soil, water, vegetation and atmosphere. According to Indian forests records 'Wildlife Management is a branch of conservation which handles wildlife as a renewable natural resource. Concerned primarily with production, it also undertakes control measures that will preserve a species or hold its population in bounds. Wildlife forms an integral part of the land and hence wildlife management involves a type of land-use.

- **History of Wildlife Management**

Wild life is essential to maintain the ecological balance of Mother Nature. As seen in previous sections also, wild flora and fauna helps in maintaining food chain and food web in the ecosystem. However, unchecked commercial exploitation, selfish interests, rapid industrialization, over-population, illegal hunting, poaching, smuggling, lack of education and awareness among people are some of the primary reasons behind the rapid depletion of wildlife and its resources. Due to all these activities, we are observing the disturbed ecosystem as well as life support system. Due to reckless hunting of wild animals and birds, several species have been brought to endangered/threatened category and other are on the verge of extinction. To protect wildlife, several measures have been adopted in history from time to time. First forest conservator was appointed in the year 1806 at madras presidency. In Bombay, an eminent botanist was appointed

as forest conservator in 1847. Administrative structure of forest department was framed in the year 1855. In 1864, Sir Brandis was chosen as the first forest Inspector General. Wild Birds Protection Act came into force in the year 1887. Wild Birds and Animals (protection) Act, was passed in 1912 to prevent their reckless hunting. Wild Birds and Animals (Protection) Act, 1912 was amended in the year 1935 and came to known as Wild Birds and Animals (Protection) Act, 1935. However, all these laws did not give much importance to the conservation and propagation of wild animals throughout the country. Wildlife and its products are the sole responsibility of forest officers under Indian forest Act, 1927. To prevent the depletion of wildlife, British rulers implemented several acts from time to time like Rhino Protection Act, Arms Act, Elephant protection Act. BNHS (Bombay Natural History Society) formulated Bombay Wild Animals and Wild Birds Protection Act, 1951. An advisory board named as Central Board for wildlife was set up in 1952. This board was later renamed as Indian Board for Wildlife (IBWL). There was an urgent need to prevent rapid decline of India's wildlife population. It required legal protection from illegal activities like poaching, smuggling, etc. For example, it was reported by Edward Pritchard Gee (A naturalist), that at the turn of the 20th century, India was home to close approximately 40000 tigers. However, a census in 1972 showed this number radically reduced to about 1827. Such drastic decline in wild flora and fauna can lead to severe ecological imbalance, which in long term affects several aspects of climate and ecosystem. The Wild Birds and Animals Protection Act, 1935 had become completely outdated. The outdated laws had the provision for punishments, which were not proportionate with the severity of the offence as well as financial benefits that occurred from illegal activities such as poaching and trading in wildlife produce. Wildlife protection Act was formulated in the year 1972. This covers all the aspects of wildlife conservation like conservation, propagation, protection, trading, scientific management and administration. Act aimed at opening natural parks of sanctuaries to preserve the wild flora and fauna. It acts as a deterrent to illegal hunting, poaching and smuggling activities. The Act provides for the formation of wildlife advisory boards, wildlife wardens, specifies their powers and duties, etc. It helped India to become a party to the 'Convention on International Trade in Endangered Species of Wild Fauna and Flora' (CITES).

- **Types of Wildlife Management**

Two general type of wildlife management are:

(a) **Manipulative Management**: This type of management involves regulating the number of wild animals by harvesting or by altering food supply, density of predators and habitat.

(b) **Custodial Management**: This is a protective or preventive kind of management which involves minimal external influence on the population as well as their habitat. This type of management involves setting up of national parks and sanctuaries where ecological conditions are protected and threatened species are conserved by law.

Elements of Wildlife Management

Effective management of wildlife requires the coordination between wildlife managers and general masses. The following points describe the elements of management of wildlife:

NOTES

1. **Public Awareness**– The first and foremost thing in the wildlife management is public awareness. Steps should be taken to make people aware regarding the socio-ecological importance of wildlife. Public awareness should be spread through magazines, newspapers, Journal, shows, talks, media, films, television, radio to make people aware about the concepts and importance of wildlife management.
2. **Public Education**– Education is as important as awareness for the preservation of wildlife and natural resources. Subjects related to wildlife management and importance of wildlife should be taught from very beginning, i.e., in schools as well as colleges to sensitize the students at an early age. This will give nation well-educated and trained specialists on environmental forest issues. Moreover, nation can also use these trained environmentalists in public training as well as to interact with people and solve their queries to make them more responsible towards their wildlife management duties.
3. **Proper Coordination**– Well coordination between the common public and government at different levels, i.e., local, state, national and international is necessary for the proper planning, management, protection, preservation, conservation and propagation of wildlife.
4. **Nature interpretation centres**: This involves organizing exhibitions and educational camps in nearby regions of protected areas such as zoological gardens, parks and wildlife sanctuaries. Such exhibition camps are organized by wildlife managers and concerned forest authorities. Such camps and exhibitions carried by trained and educated staff will motivate people to learn about the concepts of wildlife management.

- **Forms of Wildlife Management**

The following are the types of wildlife management

1. **Restoration and Management of Habitat**: Habitat is the place for animal where it can feed, drink, mate and feel secure. Thus, preservation, conservation and protection of wildlife requires proper restoration and management of wildlife. Different species of wildlife animals can benefit when an entire ecosystem is preserved or improved to meet the basic needs of endangered or threatened species or a group of species.
2. **Harvest**: Wildlife managers aims to maintain or reduce populations so animal's conflicts less with human activities. For example one solution to ever increasing population of monkeys in urban areas is to capture and release them in wild areas.
3. **Management of Endangered Species:** Threatened or endangered species requires extensive management. There should be proper identification of such critical habitats so that their proper management can be planned effectively. It is essential to recognize and manage such critical habitats as researchers believe that endangered species or wildlife species moving towards the endangered zone have restrictive habitats and depend upon specialized food.
4. **Re-introduction of Species**: This involves re-introduction of a lost species in a suitable habitat. The wildlife species can be re-introduced from some

other area or location under the re-introduction program. However, a proper study should be conducted regarding the ecological and biological needs of the species before re-introduction.

5. **Preservation and Conservation**: Conservation and preservation of wildlife includes a balance between the wildlife and human populations. However, this also involves the special care and treatment to endangered and threatened species. This also ensures a balance between the consumptive and non-consumptive activities (Hunting, fishing, etc., comes under the consumptive activities whereas bird-watching, photography, hiking comes under the non-consumptive activities). A habitat can be restored either by effective human interference or by leaving the area as such. For example, re-introduction of a species requires effective management and planning by wildlife managers, however, sometime, a particular habitat or forest area can be conserved by allowing it to mature on its own without any human intervention (such as, tree plantation, harvesting, grazing, etc.).

- **Aims of wildlife Management**

Following are the aims and objectives of wildlife management

1. Preservation of different species of flora and fauna especially the endangered, threatened or vulnerable species.
2. Maintaining and managing the population of different species of flora and fauna. National parts and sanctuaries are established on this objective.
3. Conservation of biodiversity which is essential so that genetic resources remains protected.
4. Management of annual wildlife productivity in a sustained manner
5. Habitat Management is the prime objective of wildlife management. Survival of wildlife is not possible without managing the habitat of wildlife.
6. To enhance the quality and richness of wildlife so that they get healthy, happy and prosperous life.

- **Need of Wildlife Management**

Wildlife is rapidly deteriorating and hence there is an urgent need of protecting, preserving and propagating wildlife population. Following are the main reasons causing depletion in wildlife population

1. Illegal hunting and pouching of wild animals.
2. Rapid industrialization and urbanization are responsible for habitat destruction
3. Transformation of forest into crop lands.
4. Illegal trading of wild flora, fauna and their products for monetary gains
5. Terrestrial and aquatic pollution due to release of industrial by-products, polluted gas, insecticides are also responsible for depletion of wildlife.
6. Forest fire is another primary cause of depletion of wildlife.
7. Over-grazing by increasing domesticated animals is also responsible for wildlife depletion.

NOTES

• Planning of Wildlife Management

Wildlife management includes three aspects namely wildlife (flora and fauna), its habitat and its stakeholders (people related to wildlife management). The management of wildlife is possible only by establishing the relations among all three components. For wildlife management, scientist or workers or institutes or researchers should have detailed knowledge about the structure, dynamics and relations of these components.

The planning of wildlife management may be classified into following steps.

1. **Wildlife Census**– This step determines the population status of wild animals in their habitats. Different methods are employed to determine the population status of wild animals before adopting any methodology for carrying out wildlife management.
2. **Assessment of Productivity**– Biological status of the species such as, natality, morality, birth rate, death rate, carrying capacity, predator- prey relationship should be thoroughly studied to assess the productivity of the species concerned before implying any management methodology.
3. **Identifying the Limiting Factor**– It is essential to identify the factor which is hampering the growth of the concerned species before adopting any wildlife management planning. The limiting factor could be food, water, shelter or some other invasive species which might be affecting the propagation of wildlife.
4. **Treatment**– This step includes applying appropriate remedial measure to do away with the limiting factor before opting for management of the concerned species.

Problems in Wildlife Management

Wildlife Managers faces several challenges in the direction of wildlife management. Some of the challenge faced are as follows:

1. **Fund Requirement**– Huge funds are required for taking concrete steps in the direction of wildlife management.
2. **Vast Habitats**– Wildlife habitats includes diverse regions such as reservoirs, aquatic bodies, rivers, agricultural lands and it is not restricted only to the forest. Hence, it becomes difficult to maintain or manage such vast habitats.
3. **Increasing Human-Population**– To fulfil the food, shelter, cloth, employment needs of the ever- growing population, it becomes impossible to stop encroachment of forest land.
4. **Unchecked Commercial Exploitation**– Illegal trade of wild animals and their products promotes hunting, poaching, killing of wild animals and hence adversely affects the management planning.
5. **Lack of Awareness among Masses**– Generally, people look for the short term gains that can be achieved by killing or trading wild animals. However, they fail to see the bigger picture or massive role wildlife plays on planet earth. They are vital for maintaining ecological balance on mother earth. They form the life supporting system on earth and have huge ecological and

scientific value. As rightly quoted by our late Prime Minister Smt. Indira Gandhi "A Threat to Any Species of Plant and Animal Life is a Threat to Man Himself".

Thus, steps should be taken in the direction of maintaining or having a sustainable wildlife management program. Wildlife has huge financial value, but it is also important to remember that it has considerable socio-cultural and religious importance. Hence, wildlife managers should aim for management program that are both ecologically, socially and financially viable. In the past, total ban on the marketing of game animals have forced communities to poaching. The implication is that it is not generally possible to manage natural resources and fauna without the active participation of local communities in decision making. Resource conservation programme have become hugely successful in countries where integrated communities programmes have been implemented.

1.3.2 Physical Parameters

Physical parameters of the habitat include topography of the habitat, soil quality and texture, availability of water, etc. Let us discuss the physical factors one by one:

1. Topography

Topography is defined as the form of the landscape – its shape, steepness and slope aspect, i.e., the direction at which a slope is oriented. The importance of topography can be seen from the fact that even a small variation in topography can lead to variation in the amount of moisture, temperature, sunlight, wind received by the habitat. All these little differences ultimately leads to drastic changes which can alter the type of natural flora and thereafter fauna prevailing in the habitat. In other words, we can say that, these little differences create microclimate which then become important deciding factor as to where various natural communities can be found. For instance, a windy hilltop, with very high rate of transpiration and evaporation will be having a drier microclimate as compared to a well sheltered area. Hence, hilly tops tends to have trees that can withstand dry and windy conditions as compared to sheltered area which provide favourable conditions to plants that prefers moist but less windy environment.

For example, in the northern hemisphere, sun's rays will directly hit the south facing slopes, thus plants adapted to drier, warmer conditions will be present on the south facing slopes, while plants adapted to shady, moist or cooler temperatures will be present on the north-facing slopes.

Slope shape also determine the type of flora seen in a habitat. For instance, a concave slope acts like a bowl, and hence it can accumulate both moisture as well as soil. On the contrary, a convex slope is simply the opposite of concave slope, i.e., a bowl turned upside-down. Hence, it cannot retain much of the moisture as well as soil. Rain water runs off quickly from convex slope taking away the nutrient rich upper layer of soil leaving the soil infertile and dry. Further, it has been observed that convex slope are located at higher elevation and hence are exposed to more sun, light, wind when compared to concave slopes that are located at lower elevations hence closer to the water table allowing the groundwater containing dissolved minerals to seep through it.

NOTES

Thus, convex slope due to their shape and location tends to have infertile, shallows or dry soil that create unfavourable soil conditions for plants whereas concave slopes or surfaces owing to their shape and location tend to have fertile, moist, deep soil favouring the growth of different plant species.

Thus, from above instances, we conclude that latitude, longitudes, landforms and elevations are the four main topographical features which affects the type of vegetation present in habitat.

[Note– Latitude refers to the north-south positions with respect to equator whereas longitude refers to the east-west position with respect to the prime meridian. Landforms refers to the physical features present on earth like rivers, mountains, plains, lakes, hills, plateaus etc. and elevation refers to the height of any landform from the main sea level.] All these topographical features unveils the related information about the landforms.

Importance of Topography

1. As seen in the above examples, topography determines the flow of water and soil conservation in an area.
2. The gathered information about the landforms helps the scientist to devise steps for preventing soil erosion.
3. The collected information helps the weather forecasters to determine the weather conditions.
4. Armed forces can also plan their strategies on the basics of collected information.
5. Helps civil engineers, in designing, planning and construction of new projects strategies to gather information related to landforms.

A topographical survey locates all surface features of an area and depicts all natural surfaces and elevations. It is like a 3D-Map giving idea about location, size, height, elevation of the area. The information collected by topographical survey are required by local government bodies to determine the existing topographical features and elevations of a site. There are two methods to collect information related to topography.

Direct Survey: It utilizes equipment like levels, clinometer, theodolities.

- It also includes digital imaging system with other system such as satellite images and aerial photography.
- It gathers information related to the measurement of elevations.

Indirect Survey– It utilizes radar, images captured from the plane and sonar.

- It also involves raw survey data and remote sensing data.
- Sonar mapping helps to map the ocean floor.

2. Geology

In a broader sense, geology refers to the study of earth – its interior and exterior surfaces, the rocks and other materials that are around us, as well as the processes that over a period of time have resulted in the formation of those materials, the

NOTES

water present underground as well as flowing over the surface and all the changes that have occurred over the geological time or the changes we expect to happen in future. Geology is very strongly linked to biodiversity in a way that the nature of the substrate which is determined by the nature of the rock, is a key factor in determining the distribution of habitats and species. Sediments, rocks and soils form the land on which all the biotic component of the ecosystem survives. Geomorphological processes shapes our coasts, rivers, mountains and also plays an important role in maintaining the ecosystem and dynamic habitats on which bio-diversity depends. Geo-diversity and biodiversity interacts with each other to shape ecosystem which greatly affect ecosystem responses to climate change.

How Geo-Diversity Affects Biodiversity:

The composition of the substrate plays an important role in determining the biodiversity. For instance, limestone pavement communities and serpentine health rely on the underlying rock types, i.e., primarily the chemical composition of rock. There are other factors which affect biodiversity such as: slope, altitude, latitude, hydrology, climate etc. We have already discussed some of the factors in the previous section and others we will discuss in the later sections.

How Geo-diversity Shapes Landscapes

Landscapes are shaped by the geological processes. Over geological timescales, the additive effects of weathering and erosion wear away softer rock to form valleys. The rocks which do not undergo wear and tear remains as higher altitude terrain. Further, geo-morphological processes helps in shaping the landscape.

1. Coastal processes are essential to the well-being of coastal bio-diversity.
2. Fluvial processes have also created diverse river habitats.

How Geo-diversity affects Species Distribution

Geological map as well as soil map helps to determine the location of a particular species with specific conditions or requirements. This includes the factors like chemical tolerance, substrate PH and drainage requirements.

Ecosystem Change and Geo-diversity

Geomorphological processes determine the response of ecosystem to climate change as well as sea-level rise. Geomorphological processes determine the dynamism of the habitats. Certain habitats become more and more dynamic with the change in rate and nature of geomorphological processes. More variety in such geomorphological processes make it convenient for some species, to adapt to climate change, however certain species as well as habitats are not able to keep pace with the rapidity of changes in geomorphological processes. For instance, frequent flooding, will cause greater soil erosion which will ultimately affect the rate of sediment movement finally affecting the quality of freshwater habitats.

3. Soil of the Habitat

Soil which is formed by the weathering of rocks is the most essential medium for the survival and growth of both plants as well as animals. Soil constitute air, water,

NOTES

minerals as well as both living and dead plant and animal matter. All these components of the soil can be categorised in two categories:

(a) All the living or once living beings in soil such as insects or plants are placed in the first category as biotic factors.

(b) All non-living things such as mineral, water air are placed in the second category as abiotic factors. Thus, all the biotic and abiotic factors together constitute soil's composition.

Soil affects both floral and faunal bio-diversity. Major minerals like potassium, phosphorous, nitrogen gas as well as less common minerals like sulphur, magnesium and calcium present in soil supports the plant growth. Hence, mineral rich soil supports more floral bio-diversity than poorly aerated and acidic soils. Further, animals also require soil for their development. For instance, snails which always remains protected in their shell requires calcium rich soil for the formation of its shell.

Thus, from the above paragraph we can clearly figure out that the floral and faunal diversity varies with the variety of soil. Hence, a healthy good quality of soil promotes vegetation which in-turn attracts herbivores followed by carnivores, maintaining dynamic and viable ecosystem. However, poor quality of soil affects the vegetation hence deteriorating the ecosystem.

4. Water of the Habitat

Water covers almost 70% of the earth's surface. 97% of the water (of the total water available on earth) is present in the oceans and approximately 3% is present as freshwater. Nearly, 70% of the fresh-water is trapped as glaciers and ice caps whereas 20% of as underground water whereas the remaining water is found in streams, lakes and rivers. Water is essential for the survival of all living beings i.e. plants and animals.

Water-Cycle

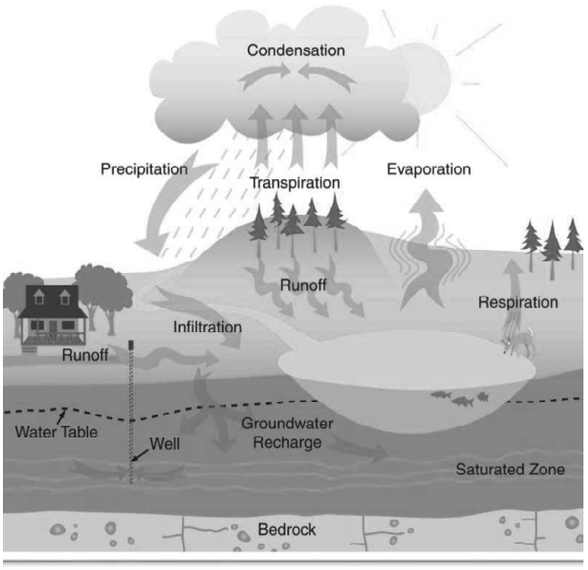


Fig.1.1 *Biological Water Cycle*

NOTES

Figure 1.1 illustrates the biological water cycle. It tells us how water reaches to all living things, i.e., plants, animals as well as human beings. Also, water cycle helps in the movement of nutrients, pathogens and sediment in and out of the aquatic ecosystem.

As, all plants and animals require water for their survival, they adapt accordingly:-

(a) Adaptations in Plants

Terrestrial plants acquire ground water via their roots for performing basic life processes whereas aquatic plants know as hydrophytes possesses specialised parenchyma referred to as aerenchyma which is filled with air (present in leaves and stems of plants) and enables the plants to float. Below, we have summarized the different types of hydrophytes:

- **Submerged Water Plants** - Submerged water plants are not rooted in the substrate and floating beneath the surface, i.e., they are completely submerged in water.
- **Emergent water plants** - Emergent water plants are rooted in the substrate, however their leaves and flowers extends into the air. They are present near the shoreline.
- **Floating-Leaved Water Plants** - Floating-leaved water plants are rooted in the substrate but with floating leaves. Their roots can easily suck nutrients.
- **Amphibious Plants-** Some parts of the plant body grow in water while some others above the surface of water or even on the land.

(b) Adaptations in Animals

Animals living in the water are called as aquatic animals. Aquatic animals can be both fresh-water as well as marine-water habitants. For ex invertebrates like star fish, octopus, prawns and vertebrates like fish, whale, seals etc. are aquatic animals. Aquatic animals present on the surface of water are called as pelagic animals whereas those residing in deep waters are referred to as benthic organism. Aquatic animals exhibit various type of adaptations known as aquatic adaptations. Below, we will be discussing the adaptations seen in the common aquatic animal, i.e., fish.

1. Presence of streamlined body so that it can swim easily with negligible resistance.
2. Presence of different fins which aids in locomotion. For example, pelvic, pectoral and dorsal fins helps in movement whereas caudal fins helps in changing the directions.
3. Presence of gills for exchanging gases with the surrounding water.
4. Presence of lateral line sense organs that helps in determining the changing pressure, temperature of the outside environment.
5. Presence of a swim bladder which helps the animal to swim over the surface of water. It can also be used as a sense organ or a sound producing organ.
6. Presence of protective scales over the body.
7. Presence of glands like mucous glands whose secretion i.e. mucus prevents the diffusion of water through the skin. Temperature or heat generates an

NOTES

energy known as thermal energy. It penetrates into each and every region of biosphere and affects the key physiological processes of living beings such as movement, growth, metabolism, reproduction, death, behaviour etc. Sun is the major surface of earth's thermal energy. It keeps on varying from place to place as well as from time to time. For instance, equators are warm when compared to Polar Regions. Similarly, deserts record a maximum temperature of 85°C whereas lowest temperature is recorded from Siberia is around –70°C. However, temperature does not remain constant, it keeps on fluctuating like temperature is low during night time whereas it is higher at day time. Thus, variation in temperature is known as diurnal variation. Further, temperature is low in aquatic habitats whereas it is high in terrestrial habitats. In aquatic habitats, such as ponds and lakes, there occurs a decrease in temperature from surface to bottom of the aquatic habitat. The arrangement of varied layers on the basis of temperature is referred to as thermal stratification. Thermal stratification in aquatic bodies varies in summer as well as winter.

(a) Summer stratification– During summer, the aquatic body is divided into following layers:-

- Epilimnion or upper layer– This is the warmer upper layer with temperature fluctuating along with the temperature of the atmosphere.
- Hypolimnion or lower layer– This is the bottom layer with a temperature between 5-7°C.
- Metalimnion or Thermocline or Middle layer– This is referred to as transition zone with a variation in temperature from 21°C at the top to around 7°C at the bottom.

(b) Winter stratification– During winters, aquatic body is divided into an upper ice layer and a lower water layer with a temperature of around 4°C.

Biological Effects of Temperature

Following are the biological effects of temperature:

1. **Poikilothermic and Homoeothermic Animals:** Poikilothermic or ectotherms or cold-blooded animals are those animals in which the body temperature varies along with the environmental temperature. For example, amphibians and reptiles together referred to as herpeto-fauna are cold-blooded animals which means they lack an internal thermostat.

   Homeotherms or Endotherms or warm-blood animals are the animals in which the body temperature remains constant and is independent of outside environmental temperature. For example, birds and mammals maintains its body temperature by metabolic activities.

   According to their state, animals undergo several behavioural adaptations. For instance, hibernation and migration are behavioural adaptations for animals to survive winter months when the food is scanty.

NOTES

Hibernation refers to the period when animals asleep or rest during the entire winter. Animal hibernates or sleep for longer duration during winters and look for a warm place to sleep. This helps in preventing any internal body damage due to low temperatures. Hibernation happens both in cold or warm-blooded animals. Further, another phenomenon known as 'aestivation' or summer sleep happens in cold-blooded animals. This happens for a very short duration with animals looking for a moist, cool and shady place to sleep. This basically helps the animal to prevent loss of excessive water as well as damage owing to very high temperatures. Further, animals also exhibit migration, i.e., movement from one place to another primarily for food, shelter etc. especially during the cold environment when the resources are scanty.

2. **Temperature also affects the growth and development of the animals**. For example, low temperature prevents metamorphosis in salamanders and makes them neotenous.
3. **Temperature also affects the morphological characters such as size, relative proportion of body parts of animals.** Following rules will describe how temperature influences morphological features of animals:
   (a) **Bergman's rule**– This rule states that mammals in warmer areas are smaller when compared to mammals in colder areas, i.e., mammals in colder areas are larger in size than in warmer climates.
   (b) **Allen's rule**– This rule states that extremities of the mammals like ears, tail, snout, legs are shorter in colder regions than in warmer regions.
   (c) **Gloger's rule**– This rule states that animals in the topic region are pigmented and darker than animals in the colder parts.
4. **Temperature also affects the distribution of animals**. Endotherms are not affected by the external environmental conditions whereas ectotherms are more abundantly present in the temperate and tropical regions whereas their abundance declines towards the poles.

How plants are affected by temperature:

In nature, we have observed that some seeds germinate easily in summer whereas other require cold temperature to germinate. Further, in desert regions, plants like cactus exhibit several adaptations like leaves are modified to form spines which reduces transpiration, waxy skin to seal moisture, extensive spread out root system for allowing the plants to absorb water immediately after rains as well as cactus keeps their stomata closed tightly during the day to further reduce transpiration.

How animals are affected by temperature:

We have already discussed, how animals are affected in the previous section. Let us discuss this in more depth with the help of an example. In hot deserts, temperature is very high. Animals exhibits different kinds of adaptations to survive majorly to conserve water and food. Camel is one of the animal to survive comfortably in deserts due to the adaptations like it can store fat in its hump which can be used as an energy reservoir during unfavourable

NOTES

situations, they have long legs to keep heat away from the main body, padded feet to walk on hot sand, they can drink and store plenty of water which can be used later on, they do have thick skin coat which insulates them from excessive heat and hence prevents loss of water. Further, oval R.B.C's of the camel facilitates their movement in dehydrated state.

5. **Light – Effect of light on Plants**: Light is the most essential physical parameter without which existence of life on earth is impossible. Sun is the most important source of light on earth. Plant utilizes sun's energy to perform photosynthesis, a process by which plants synthesize organic compounds from inorganic substance. The energy from the sun comprises of short, high-energy radiations to long, low energy radiations. Sunlight is composed of gamma rays, cosmic rays, Ultraviolet rays (UV rays), X rays, infrared rays, radio waves, visible light, etc. Out of all these rays, UV rays, infrared rays and visible light are biologically significant. The wavelength of UV rays varies from 100 nm-390 nm. UV rays are of three types namely: - UV-A, UV-B and UV-C. Out of all these, only UV-A reaches the earth surface. Both, UV-B and UV-C are responsible for causing harmful skin diseases and thus are absorbed by the ozone layer in the atmosphere. Plants perform photosynthesis by using visible portion of the sunlight with a wavelength varying between 340nm-700nm. This part of the electromagnetic spectrum is referred to as the photo synthetically active radiation or PAR. Factors such as quality of light, intensity of light and the length of the light period (day length) play an important part in an ecosystem. Physiology and behaviour of the plants are affected by the lengths of the daylight and accordingly the plants are classified as:-

   (a) Short-day Plants– Flowering in such plants requires longer night compared to nights with critical lengths.

   (b) Long-day Plants– Flowering in such plants requires shorter nights compared to nights with critical length.

   (c) Day-neutral Plants– These plants are not affected by the duration of night.

Stratification in Aquatic System on The Basis of Light

Aquatic ecosystems are divided into different zones, based on the penetration of light:

(a) Littoral Zone

- The **Littoral Zone** is known as the shore area of the aquatic body
- The littoral zone consists of the area from the dry land sloping to the open water
- It allows easy penetration of light.
- Littoral zone can be very narrow or wide.
- Oligotrophic aquatic system has very narrow littoral zones whereas eutrophic aquatic system has wide littoral zones.

NOTES

- The littoral zone obtains a lot of nutrients from runoff water as well as from non-point source pollution favoring the growth of large number of algae and other rooted aquatic plant species
- A few other familiar inhabitants of the littoral zone are crawfish, snails, insects, cattails, reeds, zooplankton and small fish.

(b) Limnetic Zone

- The Limnetic Zone is known as the open water area of the aquatic system
- The upper layer of the limnetic zone near the surface of the water is known as Euphotic Zone or Epilimnion (warm water region).
- Epilimnion receives ample sunlight.
- Euphotic zone or epilimnion ends where the sunlight fails to penetrate the water.
- Algae and other aquatic plants thrive well in the euphotic zone along with the littoral zone.
- This zone is dominated by planktons
- This zone also gets rich oxygen supply due to contact with the air.

(c) Profundal Zone

- Profundal Zone or hypolimnion (cold water region) is present below the euphotic zone
- The sunlight does not penetrate in this zone
- Heterotrophs are predominantly present in this zone
- The size of this zone depends on the age of the aquatic system and water clarity
- The oxygen supply is not very rich here.

(d) Benthic Zone

- Benthic Zone is the bottom of the aquatic system
- It consists of organic sediments and soil.
- The benthic zone is also referred to as the aquatic system's digestive system.
- Decomposers are predominantly present in this zone.
- This is the zone where bacteria decompose organic matter obtained from dead algae, aquatic plants as well as animals and their waste.
- The rate of decomposition depends upon the organic matter in the aquatic system as well as the type of bacteria carrying out the process of decomposition.
- Decomposition can take place either aerobically (in the presence of oxygen) or anaerobically (without oxygen).
- The size of benthic zone increases with the age of the aquatic body.

NOTES

Biological Effects of Light on Organisms

1. **Pigmentation**– Sun loving creatures are more pigmented than those staying in caves, bottom of aquatic system etc. where there is no sunlight.
2. **Metabolism**– Light increases the metabolic activity
3. **Colour Change**– Due to varied distribution of melanophores, some animals like chameleon are able to change colour.
4. **Morphological Characters**– Animal that occupies dim habitats (where there is no light) have larger eyes as compared to animals that stays in well-lit habitats.
5. **Reproduction**– There are animals whose sexual activity varies according to the length of the days. For ex:- birds are more sexually active when the days are longer as compared to goats, sheep and deer which are sexually active when the days are shorter.
6. **Diurnal Migration**– Migration of animals to upper surface of aquatic ecosystem during morning and their return to lower layers during evening is known as diurnal migration.
7. **Circadian Rhythm**- The Daily rhythm of both plants and animals is in synchrony with the rotation of earth.

Check Your Progress

6. What is a habitat?
7. Write the definition of micro habitat?
8. What is a monotypic habitat?
9. Write the types of wildlife management?
10. Define Econometrics.
11. What are the aspects of wildlife management?
12. How is geology linked with biodiversity?
13. State Bergman's rule.

1.3.3 Biological Parameters

The biotic factors or biological parameters involved in habitat analysis and wildlife management are:

1. Food

Food, water and shelter are the basic requirements of any animal. Food is essential for any living being as oxidation of food provide energy to the animal for walking, breeding, hunting, mating as well as other basic and physiological functions performed in day-to-day life.

Plants are referred to as producer as they synthesize their own food (organic matter) by fixing inorganic matter (like CO2, water) in the presence of sunlight. Animals are consumers in the ecosystem and they can be either herbivores,

carnivores or omnivores. Herbivores feeds only on plants, carnivores feeds only on other animals whereas omnivores feeds both on plants and animals.

Further, these consumers are categorized as primary, secondary or tertiary consumers depending upon their place in the hierarchy or trophic level. The choice of food varies between different species and depends upon a lot of factors like immediate environment, habitat of the animal, type of vegetation/food plant present in the habitat (for herbivore species), type of other animal species present in the home range of the animal species (for carnivorous animals), taste of the animal (a particular food kind may be edible for one consumer species but not for the other) and also the nutritive value of the food. Now, animal consume different type of food depending upon their food choice of different levels, i.e., primary, secondary or tertiary and also depending upon the seasonal variations. Accordingly, the food can be classified as:

(i) **Choice of Food**– A food is referred to as choice food if it is the most preferred food of the animal. The animal enjoys eating this tasteful food, for example juicy concentrated herbage.

(ii) **Staple Food**– As humans also have a staple diet (made up of cereals like rice, wheat, maize, etc.) wild animals also do have a staple food which is essential for its survival as this food is available to the animal for long duration, for example grass for zebra.

(iii) **Stuffing Food**– As the name suggest, (stuffing literally means to fulfil) animal consume this type of food only to fill its stomach in the absence of nutritive food, staple or preferred food. Such food is generally deprived of essential nutrients required by the animal, for example corncobs, feathers say catton seed hulls..

(iv) **Emergency Food**– In between the staple food which is highly nutritive and stuffing food which is non-nutritive, animal consume another food known as emergency food. This is neither tasty nor highly nutritive but yet somewhat more nutritive than stuffing food and helps the animal to survive. However, such food cannot sustain the animal for long duration as it is not highly nutritive, for example algae and wood.

(v) **Varied or Miscellaneous Food**– Sometimes in adverse environmental factors animal start consuming food which is not into the range of food described above. Such unusual food taken by the animal out of their habit is known as miscellaneous food. Animal generally consume such food only during pinch period i.e. the period where seasonal food is not abundantly present and forces the animal to look for different variety of food outside its food range.

Hence, food is required by the animal for its survival and propagation. Hence, improvement in the production of food is the most common and favoured technique to manipulate the habitat of wild animals while planning wildlife management. The following methods are adopted to improve the food quality and quantity.

- **Plantation of Edible Fruit Plants**– Herbivores 'preferred' or 'choice' food are fruit and seeds of several plants. Special efforts should be taken to prevent the cutting down of such fruit trees as well as plantation drive should be conducted from time to time to propagate such plant species.

NOTES

- **Production of Browsing and Grazing food**– Different animal species have different choice food. Grazing animals (herbivores like cows, goat, etc.) prefer to move over its habitat and graze on a variety of grasses, shrubs, herbs, small trees etc. However, all these are not beneficial or of interest or of high nutritive value to the animal. Thus, efforts should be taken to remove, weeds (unwanted plants), or less nutritive food and replace them with highly nutritive foods for the animal.
- **Creation of Pasture Land**– Pasture land refers to the area which is used for browsing and grazing activities. There are the areas used for grazing by herbivores such as horse, cattle, sheep etc. The vegetation of the pasture land majorly consists of grasses with an interspersion of legumes and other forbs. Legumes are the plants whose seeds or fruit are known as pulse. (For example chickens, soybean, lentils, peas, etc.) And forbs refers to the herbaceous flowering plants. Pastures are different from meadows which are ungrazed area or used for grazing only after being mown to hay for animal folder. For effective improvement in the quantity and quality food, existing pastures lands should be improvised and efforts must be made to improve the pasture lands which have undergone severe damage due to over-grazing or some other environment factors. Management of the pasture lands includes important factors such as soil type, temperature conditions, rainfall received by the area etc. Also, a complete ban on browsing and grazing activities should be imposed till the proper growth and propagation of the desirable vegetation in the damaged pasture lands.
- **Controlled Burning and Grazing Activities for Improvement in Food Quality**– In order to allow the proper growth and propagation of the desirable vegetation both controlled grazing and burning practices should be followed on periodic basis. Controlled grazing helps in proper development of vegetation as well as germination of seeds and thus prevents the huge damage to pasture lands. Controlled burning practice should be followed in area having hard and unpalatable bushes and vegetation. Herbivores loves to feed on the soft and delicate grass which is palatable as well as do have high nutritive values. Controlled burning removes the old and hard plant and vegetation and replace them with new nutritive soft vegetation. However, adequate measures should be adopted to prevent the spread of fire in the entire area as well as care should be taken to avoid burning of small wild animals and desirable plant species.

  These are some of the practices which needs to be followed to improve both the quantity and quality of the food. However, under adverse climatic conditions, artificial mode of feeding should be adopted to protect the wild animals. However, such artificial feeding should be avoided in general, because this makes the animal weak, lazy and also animal tends to forget its basic wild characters. For example, food searching and hunting skills are best developed in animals protected in their natural setting with minimal human interference when compared to animals kept in zoo (where animals are fed artificially throughout their lives).

2. Cover

Shelter refers to the area which fulfil biological needs of the animal as well as provide protection and safe breeding place. Shelter is generally divided as cover and space.

NOTES

(a) Cover– Cover refers to the area which provides safety, shade and protection to the animal under unfavourable environmental conditions. Covers can be classified based on the purpose it is serving: -

(i) **Escape Cover**– As the name suggests, escape cover refers to the area where animal can hide to protect itself from predators and hunters. The shape and size of the escape cover varies with the size of the animal.

(ii) **Breeding Cover**– It refers to the area where animal can feel comfortable and safe to mate, reproduce, lay eggs or nursing the young ones. As mentioned in the above case, shape and size of the breeding cover varies with the shape and size of the animal as well as physical and biological requirements of the animal.

(iii) **Shelter Cover**– Shelter cover refers to the area which safeguards the animal from unfavourable weather conditions. The shape, size, kind of vegetation in the shelter covers varies in accordance with the animal.

(iv) **Resting Cover**– It refers to the area where animal can rest to overcome stress, tiredness or to rejuvenate after consuming food. There can be a variety of resting cover comprising of trees, vegetation, and bush depending upon the comfort of the animal.

(b) Space– Space refers to the multi-dimensional entity having both horizontal and vertical components. Horizontal component includes both home range and territory of the animal. Home range is referred to the space which is not defended exclusively by the animal. Animal can roam freely in the area and is sharing the area with member of the same or sometime different species. Whereas, territory is a limited space exclusively defended by the animal and do not overlap. Vertical components of the space refer to the bushes, branches, vegetation and trees of the space. The choice among them depends upon the requirement of the animal, some animal like to dwell on ground, other love bushes and vegetation whereas birds like crow, etc. love to sit on trees and monkeys love to move from one branch to other.

3. Forage

Forage refers to the plant material taken as food by grazing livestock (cows, horses, sheep, goats, llamas), and wildlife (deer, elk, moose, rabbits). Similarly, forage crop refers to annual or biennial crops which are grown to be utilized for grazing or harvesting as a whole crop. Some of the common forages are grasses, herbaceous legumes, tree legumes, silage and crop-residue.

NOTES

Wildlife managers chooses forage based on following categories.

(a) Persistence– Annuals are chosen as forage material over other as they offer the advantage of rapid growth as well as excellent quality of forage.

(b) Forage quality– Wildlife Managers looks into the nutritional quality of forage before growing it depending upon the target species.

(c) Forage act as insect attractant– Some of the forage picked by wildlife managers acts as insect attractant, i.e., it attracts a lot of insects to the habitat. Several avian species are benefitted by the presence of insects in the habitat.

(d) Availability of forage– It involves choosing forage material that can provide ample nutritional food-stuff to animals for a longer duration of time and that too in sufficient quantity.

(e) To prevent migration of animals– This helps to keep the desired animal species localized to a particular habitat and prevent their migration from one habitat to another habitat.

(f) Cover– Forage provides excellent cover to several animals like game birds, rabbits, etc. Thus, selection of forage material by wildlife managers depends on the above-mentioned criteria ensuring effective management of both wildlife and its habitat.

There are several types of forages. Some of the most important forages are listed in the table below.

Vegetation Terms	Definitions
Forage	Edible parts of plants, other than separated grain, that can provide feed for grazing animals, or that can be harvested for feeding. Includes browse, herbage, and mast.
Browse	Leaf and twig growth of shrubs, woody vines, trees, cacti, and other non-herbaceous vegetation available for animal consumption.
Herbage	The biomass of herbaceous plants, other than separated grain, generally above ground but including edible roots and tubers.
Forb	Any herbaceous broadleaf plant that is not a grass and is not grass-like.
Legume	Members of the plant family Fabaceae.
Grass	Members of the plant family Poaceae.
Grass-like	Vegetation that is similar to grass in appearance and is usually a member of the plant family Cyperaceae (sedges) or Juncaceae (rushes).
Pasturage	Not a recommended term. The recommended definition of pasture refers to a specific kind of grazing management unit, not that which is consumed, which is forage. Thus, pasturage is not a useful term.
Mast	Fruits and seeds of shrubs, woody vines, trees, cacti, and other non-herbaceous vegetation available for animal consumption.
Forage crop	A crop of cultivated plants or plant parts, other than separated grain, produced to be grazed or harvested for use as feed for animals.
Aftermath	Forage grown following a harvest.
Residue	Forage remaining on the land as a consequence of harvest.

NOTES

Silage	Forage preserved in a succulent condition by partial anaerobic, acid fermentation.
Hay	Grass or other plants, such as clover or alfalfa, cut and dried for fodder.
Haylage	Product resulting from ensiling forage with around 45% moisture, in the absence of oxygen.
Fodder	Coarse grasses such as corn and sorghum harvested with the seed and leaves green or alive, then cured and fed in their entirety as forage.
Green chop	Fresh cut forages.

Source of Information Allen, 1991

4. Browse

The plant material eaten is referred to as browse and is naturally taken directly from the plant, however, owners of livestock like goats and deer may cut twigs or branches for feeding to their stock. Animals held in captivity may be fed browse as a replacement for their wild food sources. If the total population of the browsers goes too high, all of the browse that they can reach may be consumed. The level below which a few or no leaves are present is referred to as the browse line. If the problem of over-browsing continues for a long period of time, the natural capability of the ecosystem's trees to reproduce may be reduced, as young plants cannot sustain long enough to grow too tall for browsers to reach. Browsing refers to a type of herbivory in which an herbivore feeds on leaves, soft shoots, or fruits of high-growing, generally woody plants such as shrubs. A few preferred browse of the animals are as follows:

Oak, maple, maple, box elder, poison ivy, eastern, aspen, aspen, quaking, blueberry, willow, chokeberry, birch, sweet, tamarack, buckthorn, walnut, black, pawpaw, ash, black, oak, white, oak, northern red, sumac, staghorn, viburnum, maple leaf, dogwood, alternate-leaf, sweet bay, hackberry, common, hackberry, honeysuckle, Japanese, pear etc.

Source of Information: 75 Best Browse for Wildlife – Wild foods 4 Wildlife

5. Cover- Estimation

Vegetative cover gives significant indication about the ecological process occurring in a habitat (site) as well as it provides valuable management indicator for monitoring the cover. Let us discuss, one by one, how vegetative cover can serve as ecological and management indicator:

(a) Ecological Indicator– Vegetative cover is basically an ecological indicator giving an idea about the type of species dominating the habitat. The area occupied by a particular species is directly related to the control that species has over the natural resources i.e. soil, water, solar radiation, nutrient reserves etc. of that particular habitat. Cover represents the total amount of nutrients, soil, water that a plant can harvest and utilize to create biomass which ultimately gives an idea related to the ecological dominance of the plant. Hence, it can be concluded that cover closely reflects biomass and can be estimated with much ease when compared to biomass. Plants reflecting a higher cover at a particular habitat exhibits a greater influence on successional

NOTES

phenomenon such as immigration as well as establishment of new plants. Cover which is expressed as % of area is a utility method in charactering ecosystems across life forms. It allows species of different vegetation like trees, shrubs, forbs, grasses etc. to be estimated and evaluated on a comparable basis. Cover is further helpful in evaluating hydrological processes. For instance, ground cover influences the process of infiltration as well as soil erosion.

(b) Management Indicator– Apart from ecological indicator, cover also serves as a valuable management indicator for monitoring the cover. It offers a variety of interpretation of direct concern to rangeland management including trends in range condition, values of wildlife habitat, availability of forage as well as erosion potential. For instance:-

- Ground cover indicates about how well a particular habitat is guarded or protected against soil erosion.
- Vertical or canopy cover gives an idea about hiding or thermal cover of the wildlife.
- Basal cover helps in monitoring rangeland trend, specifically trends in herbaceous plants like forbs and grasses. A change in basal cover over a period of time indicates real time changes in the big plant species occupying the habitat. Basal cover is assessed over a period of time as it is not highly influenced by:
    1. Seasonal patterns such as springs or falls
    2. Annual precipitation pattern.
    3. Recent grazing history
- Cover variables relates to availability of forage for livestock (domesticated animals) or wildlife habitat.

In the next section, we will discuss in details the methods used for estimating cover:

1. Quadrate Method

First method is quadrate method which is used for ground cover estimation. In quadrat sampling, a series of quadrats of fixed area and shape i.e. a rectangular, circular or square shaped quadrat with fixed shape and area is placed in a habitat of interest and all the species coming under that quadrat region are identified and recorded. A photograph of the species under the quadrat region can be taken for future analysis. Quadrate method is best fitted for easily accessible habitat. However, the sampling should be carried out at random to avoid biasness.

The following data can be recorded for each quadrate:

(a) Cover– It involves estimating percentage of quadrate that is covered by each organism type. It is one of the most common measure of plant abundance.

NOTES

(b) Population Density– It refers to the total number of individuals per unit area/volume. The methodology involves counting the number of individuals within the quadrate.

$$\textbf{Population Density } \frac{Ni}{Q}$$

Where, Ni is total number of individuals of a particular species calculated in all the quadrats and Q is total number of quadrants taken into consideration.

(c) Species Density– This involves counting the total number of species within the quadrat. The formula used for calculating species density is:

$$\textbf{Species density} = \frac{\textbf{Total number of individuals of species}}{\textbf{Number of quadrat studied}}$$

(d) Abundance– It refers to the total number of individuals in a species divided by the number of quadrates per unit in which they occur. It can be calculated by the formula:-

$$\textbf{Abundance} = \frac{\textbf{Total number of individuals of the species}}{\textbf{Number of quadrate per unit in which they occur}}$$

(e) Species frequency– Species frequency can be calculated as:-

$$\textbf{\% frequency} = \frac{\textbf{Number of quadrate units in which species occurred}}{\textbf{Total number of quadrate studied}} \times \textbf{100}$$

(f) Species diversity– It is referred to as species richness and relative abundance of different species in a community and it can be calculated by using diversity index which is also known as mathematical measure of species diversity in a community. One such index is Shannon-Weiner Diversity Index (H) that accounts for species richness as well as abundance. It can be calculated by the formulae:

$$\bar{H} = -\Sigma(P_i)(\log P_i) \text{ where } P_i = \frac{N_i}{N}$$

N_i = Total number of individuals of the particular species in all the quadrate

N = Total number of individuals of all the species in all the quadrates.

= Shannon – weiner diversity index

Thus, P_i = proportion of individuals belonging to I^{th} species in dataset of interest.

NOTES

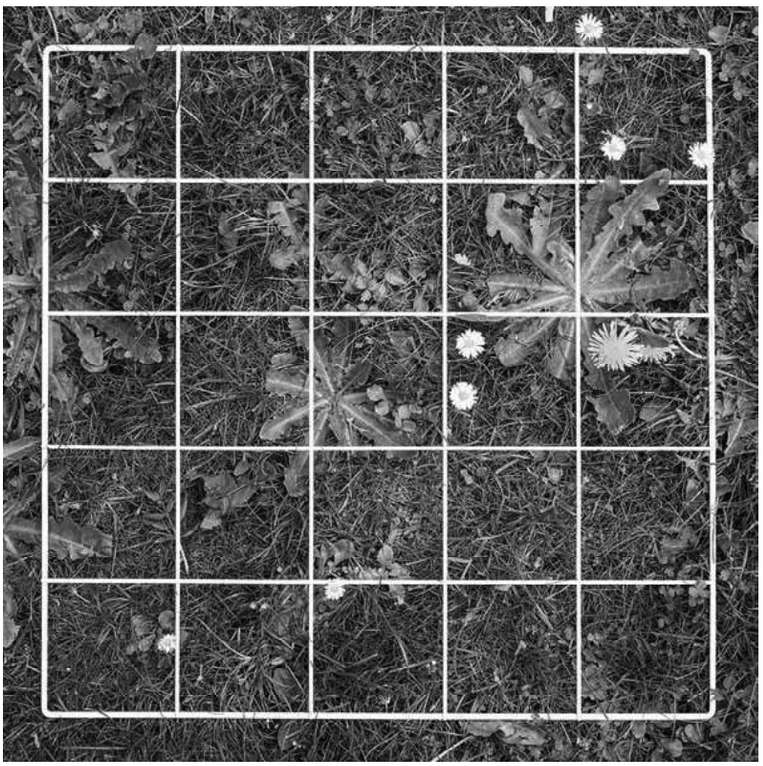


Fig. 1.2 *Square Quadrate*

Figure 1.2 is depicting a square quadrate used for assessment in a field.

2. PCQM (Point Centred Quarter Method)

Second method is PCQM, i.e., point centred quarter method. This method was developed by Cottam and Curtis in 1950 as a plotless technique to estimate density.

Plotless method are generally fast, economical, cost-efficient and are preferred when plot based sampling is difficult or costly. The basic assumption behind the PCQM method is that the key species follow a random spatial pattern and is sensitive to bias when plant exhibits a more contagious arrangement. However, using PCQM requires more computational inputs, as well as field work. Now, let us discuss the principle of PCQM:

In the PCQM method, first of all a point is identified in the desired habitat and then the area surrounding the point is divided into four quarters. Next, in each quarter, the nearest tree with a diameter – at – breadth height (dbh) of 40 cm is identified and known as 'Large Tree Sample'. Further, the nearest tree with a dbh of 2.5 cm but less than < 40 cm is identified and known as 'Small Tree' sample. Dbh is referred as the diameter (in cm) of a tree measured at 4½ feet above the existing grade. Once a 'Large Tree Sample' and 'Small Tree Sample' is identified in each quadrant, it helps the researcher to compare overstory to the understory. Overstory refers to the trees in a forest whose crowns constitute the highest layer of vegetation in a habitat forming the canopy whereas understory refers to vegetation growing beneath the forest canopy with penetrating it to any extent.

Average density for both large and small trees can be calculated as:-

$$\text{Average density} = \frac{10,000\ \text{m}^2}{(\text{Average mean distance inmetres})^2}$$

NOTES

This, will give an idea about total number of small and large trees in the habitat.

Advantages of Assessing Cover

1. Helps in the measurement of different life forms such as forbs, shrubs, moss and trees.
2. It is strongly associated with plant biomass and ecosystem processes.
3. It is also helpful in measuring mosses or lichens at the ground surface as well as plants.

Disadvantages of Assessing Cover

1. Measurement of cover varies depending on climatic conditions.
2. Except basal cover, measurement of all cover is disturbed by grazing and browsing activities.
3. Sometimes, it is difficult to estimate the measurement of cover with accuracy.

1.3.4 Standard Evaluation Procedures: Remote-Sensing and GIS

With the advancement in technology, two fields have rapidly gained popularity, i.e., remote sensing and GIS. A lot of research organizations are spending huge money in these fields due to following reasons.

1. Keen interest of scientists, students and other research bodies in studying and understanding the events happening in the geographic space of area of interest.
2. Availability of huge amount of data collected by sophisticated space technology system
3. Easy interpretation of the collected data due to availability of cheap and affordable hi-tech computer hardware and software systems.

Remote sensing and GIS, both technologies work hand in hand. As we will read in the subsequent sections that the primary function of the remote sensing is to gather voluminous data about the area or object of interest whereas GIS is competent enough to analyze this data within no time. The development of one technology without the other will be useless as manual interpretation of the huge data gathered by 'Remote sensing' is next to impossible without the development of GIS. Similarly, advanced GIS technology will be wasteful if there is no substantial data to work on.

1. Remote Sensing

The term 'Remote Sensing' literally means collecting information about an area, system, space, phenomenon or object from a distance, i.e., without coming in

direct contact with the body of interest. Although, in scientific terms 'Remote Sensing' means obtaining data about earth's land and water surfaces by using reflected or emitted electromagnetic energy.

NOTES

Latest definition of Remote Sensing as suggested by James B. Compell (1996), Remote Sensing is the practice of deriving information about the earth's land and water surfaces using images acquired from an overhead perspective, using electromagnetic radiation in one or more regions of the electromagnetic spectrum, reflected or emitted from earth's surface.

History of Remote Sensing

History of remote sensing can be studied in six phase:

(1) Stage I

- This phase lasted till 1920
- Initial photographs of the earth were taken from the elevated platforms present on the surface of earth only.
- Initial photographs of the earth were taken from the elevated platforms present on the surface of earth only.
- In 1958, free balloons were used for photography by French Gaspard Felix Tournachon (known as Nadar)
- In 1909, first aerial photograph was taken from an aero plane, piloted by Wilbur write over centocelli, Italy.
- Aerial photography in that time was used for two purpose namely spying and mapping.
- World War I provided further boost to aerial photography.

2. Stage II

- This phase lasted from 1920 – 1945
- Aerial photography improved due to improvised aero planes, cameras, films, etc.
- Researchers began to interpret these photographs to derive information.
- Photo Interpretation techniques were much developed during World War II for military intelligence purpose.

3. Stage III

- This phase lasted from 1945-1950.
- Much importance was given to the teaching of learning due to its previous use in military of intelligence.
- Several course, were started by reported universities that the world.

4. Stage IV

- This phase lasted from 1950 – 1960.
- Development of much advanced instrumentation for rapid analysis and interpretation.

- This led to considerable development of advancement in the field of Geology, Geophysics, Geography, archaeology and agriculture.

5. Stage V

NOTES

- This phase lasted from 1960 – 1985.
- Artificial satellites were launched in the space during this phase for getting information on earth's surface.
- Satellites carrying improved cameras of sensors were launched one after the other in this phase.
- ERIS-1 (Earth resource technology satellite) was launched in 1972, followed by ERTS-2 in 1975.
- Names of ERTS-1, 2 have been changed to LANDSAT – 1, 2 respectively.

6 Stage VI

- This phase started from 1985 onwards.
- Huge development of sensors was observed in this phase.
- These sensors can use infrared or microwave spectrum.
- Improvised platforms were also observed in this phase on which sensors can be mounted.

Components of Remote Sensing

1. Platforms

Platforms are like base on which the sensors can be mounted to acquire view or information regarding earth's surface. One of the simplest platforms we see in a day-to-day life is a 'Tripod'. Major types of platforms are:

A. Ground Borne

- They are stationary platforms fixed on earth's surface.
- Capable of collecting information about the area of interest at different angles.
- For ex: - Tripod, Vans

B. Air Borne Platforms

- As the name suggests, they are placed within the earth's atmosphere.
- Inexpensive mode of platforms, no power is required.
- Comes in different shapes and sizes
- Air borne platforms are of following types:

(i) **Free Balloons**

- Can almost touch the top of the atmosphere
- Thousands of kg of scientific payloads can be lifted by free balloons.
- However, the speed and trajectory of free balloons depends upon the direction of wind.

NOTES

- Hence, it becomes difficult to guess whether the free balloons will pass over the object of interest or not.
- For example, TIFR (Tata Institute of Fundamental research) has set up a balloon facility in Hyderabad.

(ii) Tethered Balloons

- Connected to earth's surface via high strength wires and thus keeps the balloons at a fixed paint for a long period of time. This feature allows to acquire specific data about the area of interest for a long period of time

(iii) Powered Balloons

- As the name suggests, it required some sort of power or acceleration to reach or maintain specific height over the area of interest to acquire data.

(iv) Air-Craft

- Used for obtaining aerial images.
- They cover a large area of interest.
- For example, DAKOTA, AVRO, CESSNA and CANBERRA are frequently used in India for carrying out remote sensing operations.
- They can carry much more scientific payloads and can easily access very remote areas.
- The only disadvantage with the Air-crafts having altitude and range it can work upon.

C. Space Borne Platform

- These platforms are present in space and move in their respective orbit around the earth to collect data.
- They are capable of acquiring huge data.
- For example, Moon is one of the natural satellites.
- **Geo-stationary or Earth synchronous satellite** – revolves around the earth in the direction of earth's rotation.
- For example, INSAT, METSAT are some of the Geo-stationary satellites.
- **Sun-synchronous satellites** maintain the same relationship with sun i.e. it is an orbit arranged so that it processes through one complete revolution each year.
- For example, LANDSAT, SPOT, IRS are some of the examples of sun-synchronous satellites.

2. Remote Sensors

As the name suggests, they are the instruments, which can detect objects on earth's surface via measuring the EMR (Electro Magnetic Radiation) emitted by them. These remote sensors are mounted on platform as discussed above.

NOTES

There are different types of remote sensors as discussed below.

(A) Active Sensors: As the name suggests, active sensors use their own energy to illuminate the earth's surface or the object of interest and a part of this energy is reflected back to the sensor. Thus, an active sensor has two components – 'transmitter' which emits energy and 'receiver' which receives the reflected energy. One of the highest advantages of using active sensors is that it is an all-weather sensor and thus is not affected by environmental conditions.

(B) Passive Sensors: As the word 'passive' suggests, passive sensors utilize Sun's energy to illuminate the area of interest. Thus, passive sensor serves to collect the reflected light. The biggest advantage of the passive sensor is that it is inexpensive, simple to use technically and does not have special power requirement. However, one of the highest disadvantages of passive sensor is that it depends upon the environmental conditions.

(C) Framing System Sensor: In this type, light collected by the lens is focused on the photosensitive target. 2D or Two-dimensional images are formed at a single instant.

(D) Scanning System Sensor: A large number of detectors are used which moves across the area of interest in a series of parallel lines to gather data.

(E) Thermal Sensors: Photometers, thermometers and spectrometers are used to detect temperature changes.

(F) Multispectral Imaging System: This system use a series of cameras and sensors to detect various bands of EMR (electromagnetic radiation)

Methodology of Remote Sensing

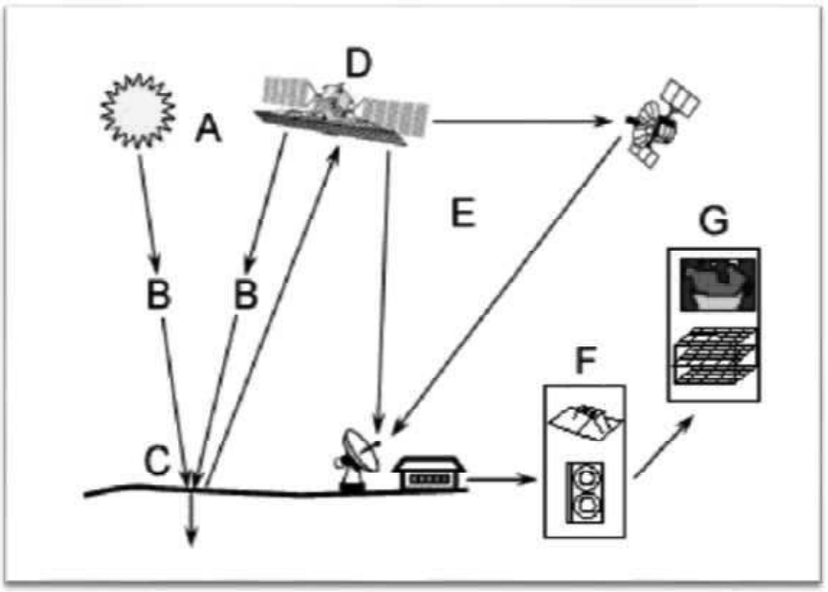


Fig 1.3 *Process/Methodology of 'Remote Sensing'*

NOTES

Figure 1.3 is depicting the process/methodology of 'Remote Sensing'

A- Source of Illumination (Sun)

B- Transfer of Energy from the source (Sun- Passive sensor) to Earth's surface. Energy can also be transferred from sensor mounted on platform (D component in figure) in case of active sensor as shown in the figure.

C- Interaction of the radiations with the object/area of interest/Earth's surface

D- Receiving/Detecting energy by the sensor mounted on a platform

E- Transmission, Reception and Processing of the input data

F- Interpretation and Analysis of the data at ground station

G- Using/Applying the data

- **Remote Sensing Data Products**

Two types of remote sensing data products are:

1. **Digital Data Products**– It gives information in the form of quantitative values collected from all objects within the area of interest. A digital data product is also known as digital image. A digital image consists of numbers which are stored in magnetic tape. A photographic image can be formed from the digital data product.
2. **Pictorial Data Products**– It collects information from the object of interest in the form of images or photographs. Aerial photographs captured by aircraft and satellite image captured by satellites are the forms of pictorial data products.

- **Interpretation of the Data**

Digital data is in the form of numbers and hence it is interpreted mathematically using computer software and is known as digital interpretation. Digital interpretation of the data requires complicated computer software but the end product is good.

Aerial photographs and satellite images are pictures and hence they are interpreted visually and the process is known as visual interpretation.

Visual interpretation is easy, straightforward method to analyse data. However, unaided human eye cannot visualize all the colour tones etc. Further, combining data from various sources manually is a tedious task.

However, image requires two other processes namely 'image correction' to correct the errors in digital image and 'image enhancement' to improve the quality of the image.

3. GIS (Geographical Information System)

GIS refers to a computerised system or mechanism that can store and interpret the vast geographical data collected by the remote sensing process.

Components for GIS

GIS requires two components namely:

1. Computer System: A good computer system with several software to store and interpret the digital and visual data easily. A computer system used for GIS operation must have:

(a) a high processor

(b) sufficient memory

(c) High resolution graphics

(d) Data input and output devices

Some of the software packages used for GIS operation are:-

ARC view, ARC Info, Map Info, etc.

2. Data for GIS: All these hi-end computer and software are waste without data. The data can be in the form of digital data products or photographs (aerial or satellite images) as described above. All the data can be classified as:-

(a) Spatial Data

Spatial data gives the idea about the object. All the spatial data is simplified before entering into the system. Spatial data is entered as – point, lines or areas. Points denotes small one-dimensional objects such as tube well, electric pole. Lines denotes 2D objects such as rivers, roads whereas Areas denotes 3D objects such as forest areas, administrative blocks, etc. However, the use of point, line, and area as basic entity varies upon the scale of the map. For instance, in a world map city are denoted by point.

(b) Attribute data

Attribute data can be both textual and numeric and it gives an idea about the whereabouts of object, i.e., its location, latitude, etc.

In short, 'spatial data' gives an idea about the object whereas 'attribute data' gives an idea about where the object is.

Functioning of GIS

The following steps outlines the functioning of GIS.

1. **Data-Entry**– Data is entered into the system using keyboard, printers, scanners etc. All the data collected from several sources is standardised before further processing.
2. **Data Storage**– Spatial data can be stored into the system in two formats namely raster and vector format. In raster format, entitles of spatial data, i.e., point, line and areas are arranged into individual square calls which are organized into rows and columns. In the figure, grid represent the entire study and data is stored in individual cells of the gird.

NOTES

NOTES

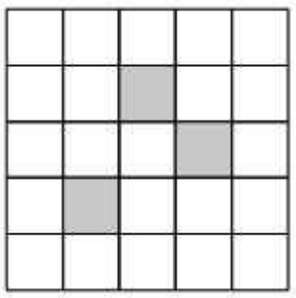


Fig. 1.4 *Representing Spatial Data Stored In Raster Format.*

In vector format, entitles of spatial data are stored by using coordinate system**.**

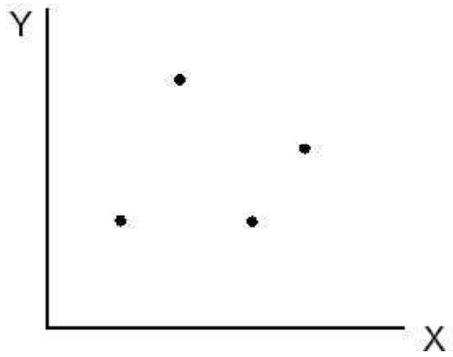


Fig. 1.5 *Representing Spatial Data Stored in Vector Format.*

In both raster and vector format, points are represented by individual cells or singe coordinate pair respectively. Lines are denoted by connecting cells or points and similarly, areas are denoted by connecting individual cells or points into polygons in both the formats.

3. **Data Interpretation**– Spatial data from different sources regarding area of interest can be clubbed together using specific software to arrive at specific conclusion. GIS can perform several analyses on the data which can ultimately help the researchers, industries, etc. to plan and execute.

Real Life Application of Remote Sensing and GIS

The primary applications of the Remote Sensing are as follows:-

- **Analysing the Condition of Rural Roads**: Rural road conditions can be analysed using various Remote sensing and GIS techniques with an inch to inch accuracy. It saves a lot of time and money from transporters.
- **Creating a Base Map for Visual Reference**: Currently, several modern mapping technologies are based on Remote Sensing including Google maps, open street maps, Bing maps, NASA's Globe view, etc.
- **Locating Construction and Building Alteration:** Tax revenue agencies utilizes satellite data in various countries including Greece, Athens, etc. They locate signs of wealth using this technology.

NOTES

- **Urban and Town Planning:** Developers, Builders, Architects, as well as Engineers use spatial datasets to plan on the futuristic township.
- **Controlling forest fires:** Information gathered using Remote Sensing enables firefighters to reach the exact location on time to effectively control fire.
- **Estimating Forest Supplies**: MODIS, AVHRR, and SPOT are frequently used to quantify the increase/decrease in global forests as they are the source of valuable resources like paper, packaging, construction materials, etc.
- **Computing Snow Pack**: Snow melt ratio can be simply understood by using Remote Sensing technology.
- **Collecting Earth's Pictures from Space:** Space organization gathers fascinating patterns of earth's geometry including atmosphere, oceans, land, etc. EO-1, Terra, and Landsat are used to collect this data.
- **Detecting Land Use and Land Cover**: Remote Sensing technologies are used to regulate several physical properties of land and also what it is being used for land use.
- **Figuring Out Fraud Insurance Claims**: Several insurance companies use Landsat's red and infrared channels to detect out vegetation growth in particular land. This data can be utilized to validate seeded crops as well as fight against crop insurance fraud.
- **Observing Climate Changes**: Satellites like CERES, MODIS, AMSRE, TRMM, and MOPITT has made it believable to detect climate changes from the skies.
- **Predicting Potential Landslides**: Natural disaster like landslides cause huge loss of life and property. INSAR uses interferometry remote sensing technique for giving crucial information related to landslides
- **Identifying Crop Conditions**: (NDVI) normalized difference vegetation index as well as satellite imagery technologies are utilized in order to monitor global food supplies. Healthy crops area reflects green colour whereas other areas reflect either red or blue colour.
- **Increasing Precision in Farming**: The strength and wellbeing of crops can be measured by utilizing remote sensing applications.
- **Determining the Moisture Content of the Soil and Water Content of the Field Crops**: Soil's moisture content and water content of the field crops can be determined by sensors of a satellite in space.
- **Forecasting of Crop Production:** Remote Sensing is used to predict crop production as well as yield over a given field and also to determine the quantity of the crop that can be harvested under the specific environmental conditions.
- **Determining Crop Damage and Progress**: Remote sensing techniques can be utilized to determine the quantity and degree of crops damaged in a specific field or area. It also helps to determine the progress of healthy crops under stress situation.
- **Crop Identification**: Remote sensing methodology also helps to identify crop exhibiting mysterious characteristics.

NOTES

- **Analysis of the Crop Condition and Stress Detection**: Remote sensing technology plays crucial role in the valuation of the crop health condition as well as the extent up to which the crop has endured stress. This data can then be utilized effectively to determine the quality of the crop.
- **Disaster Management:** GIS is used to monitor disaster and natural calamity prone areas. For instance, data collected from Remote sensing technology is used to monitor the weather patterns like rainfall, drought etc. over a specified area.
- **Pest Control:** Spatial data obtained by remote sensing and analysed by GIS technology allow the governing body as well as farmers to plan out on numerous things.
- **Oil Spill:** Oil spills leads to the formation of a thick layer of oil on the surface of water. This thick oil layer can stop marine plants from receiving enough light for carrying out the process of photosynthesis as well as it can disturb the free flow of oxygen in the water. This severely affects the floral and faunal biodiversity. GIS and geospatial data sets are used to curb such havoc spreading spills.
- **Mapping and Navigation**: One of the most common world mapping and navigation tool is Google Maps. People use it on day-to-day basis for travelling purpose. Not only this, it has become a popular tool within Cab and carpool service providers too. GPS, with the help of GIS, adds crisper and edge to the experience of navigation.
- **Reservoir and Dam Site Location**: Geo-Spatial data can be used to find the suitable location for constructing a reservoir or dam.
- **Deforestation and Vegetation Management:** Geospatial data of forest lands lets organizations as well as governments to keep track of the rate of deforestation. The data obtained can be classified as well as visualized to take further actions.
- **GIS for Business, Marketing, and Sales:** GIS also has unfamiliar usage in making business as well as marketing sales. Geospatial databases collect information like target customers in a particular area, marketing campaigns and sales territories. This utility enables companies and organizations to become strategically more competitive and stronger in the market.

Check Your Progress

14. Why is food considered as a biological parameter?
15. What is breeding cover?
16. Define the term browse line?
17. What is forage?
18. Define remote sensing.
19. What is GIS?
20. What is Secondary succession?

1.4 MANAGEMENT OF HABITATS

NOTES

Habitat restoration/management/manipulation is one of the most essential methodologies of wildlife management. Generally, habitat can be described as all of the food, water and cover resources, that wildlife requires to service. All these three resources must be present in sufficient or ample amount to maintain a healthy wildlife population. Habitat requirement may vary from species to species or some species can have the same habitat requirement. For example, bobwhite quail and wild turkey both can thrive well in very similar habitats. Now, let us see each of the three basic component one by one.

1. **Food**– It is the most essential part of wildlife habitat as animals require adequate nutrition to survive, grow, mate, produce healthy offspring, for developing natural immunity against diseases as well for offence and defence purposes. Different species of wild animals have different food preferences and requirements and this keeps on changing seasonally. Thus, it is essential to manage the habitat for providing high-quality forage to wild-life throughout the year.
2. **Water**– Every living organism on earth requires water to survive. In fact, presence of water on earth makes it more habitable. It is required by wildlife for quenching thirst, regulating body temperature as well as for digestion and other physiological and basic life processes. Adequate arrangement of water in the form of lakes, ponds, streams, springs, should be made available to wild animals.
3. **Cover**– Every wild animal requires a sense of protection to thrive well in its area or location. Cover is a habitat's ability to provide the protection that animals need to survive. It protects or shelters animals from bad weather conditions as well as from external predators. As with other two basic components, i.e., food and water, cover needs also varies from species to species. For example, a raccoon can live anywhere from garbage dumps to cities, on the other hand, bob white quail requires grasses and forbs at ground level to protect them from avian predations.

Now, for the wildlife species to thrive, all three basic habitat resources should be available within the location or area used by that species. Unfortunately, natural conditions sometimes do not provide the much-needed resource on its own to support the number of wildlife animals we wish them to. Hence, arises the need for habitat management to create the right conditions for the animal to survive. One advantage of this is that a single management practice may provide extra advantage to other species also. Thus, the main aim of the wildlife management is to improve existing habitats to provide maximum benefits to wild animals. We can simply, increase the total number of wild animals in the area or improve their health or quality by manipulating the existing natural ecosystem. Further, if we look closely, we will realize that an area's ability to produce healthy wild animals depends primarily on its soil fertility. High quality soils will boost the vegetation of that area and hence produce better wildlife than sandy, poor-quality soils.

NOTES

However, before beginning with the task of wildlife management, following principles should be followed:

- Proper research should be conducted by wildlife managers to have right knowledge about the needs of the wildlife.
- Habitat management project should be framed in accordance with the needs of wildlife.
- Project should be thoroughly evaluated for its good and bad effects on the other species and natural resources apart from the target species.
- Type of habitat management should be clearly mentioned, i.e., either it is for improving the existing natural conditions or for altering them altogether. Improving the natural conditions must involve sustaining the natural fauna and flora of the location whereas, manipulative management should involve the careful observation and research on topography of location before carrying out the drive for introduction of both plant and animal species in that area.
- The entire project should be evaluated carefully at regular intervals to check whether it is serving the right purpose or not.
- Last but not least, Habitat management project should be economical and practical.

1.4.1 Succession

Succession refers to the series of changes in ecosystems when a new environment is formed or after an established environment is disturbed by anthropogenic or some natural calamity.

All ecosystem ranging from wetlands, oceans to deserts, bare rocks or forests, etc., exhibits succession. Looking back, we would see that some currently established forested lands did not show any sign of trees earlier. However, over a period of time, a specific order of plants colonized the barren or disturbed site. The colonization order of trees depends upon a lot of factors like competition, differential needs of plants and the effects of surrounding environment on its living beings. As the types of plants found in forest habitat changes with succession, the list of wildlife animals living inside the forest also changes in an orderly sequence. The succession of both plants and animals goes hand in hand.

Types of Succession

1. Primary Succession

Primary succession occurs when some natural calamity like earthquake, volcanoes, glacier eruption, landslide, floods, etc., completely eliminate the entire soil and organisms from a site leaving behind bare lands, gravel, slit, sand or rock. This word 'primary' is used for such type of succession because soil formation – which is the foundation for everything else – starts here. The formation of soil begins with the slow breakdown of rocks by weathering. Dust, silt and sand collect in these pockets of mineral soil. The following steps describe the process of primary succession.

NOTES

- Establishment of a new environment due to some natural disturbance.
- The new environments formed due to natural calamities lacks soil as well as other living organisms.
- The process of primary succession starts with the weathering of rocks and dust.
- Slit and sand start collecting in the pockets of mineral soil.
- As soon as, a little amount of soil is formed, the first groups of living organisms. begins colonizing the environment.
- This first group of organisms are termed as 'pioneer organisms' or 'pioneer species'.
- 'Pioneer' species is generally composed of microscopic organisms like lichens, algae and fungi and thrive well in the newly created environment due to their low soil requirement.
- 'Pioneer species enters this newly established system from some different ecosystem.
- These species further assist the breakdown of mineral-based rocks formed of lava or glaciers to make the soil more habitable for other species.
- The pioneer species continues to thrive well in the existing environment. Growth, reproduction, death and decomposition of pioneer species creates pockets of soil where other species can grow and propagate.
- Decomposition of pioneer species enriches the soil by adding up to its organic content.
- These entire steps discussed above are repeated several times throughout the process of primary succession.
- Each stage is also called a sere by foresters.
- At every stage, next species move into the new enriched environment created by the preceding species.
- Sometimes, the newly established environment becomes inhospitable to the previous species and is thus replaced by the new habitants.
- Over a period of time, fast-growing vegetation inhabits these areas covering most of the land.
- Eventually, seeds of large trees reach the newly established environment via pollinating agents such as birds or wind which further appeals animals from other species.
- A more stable state of ecosystem is achieved by continuously changing vegetation and wildlife species.
- The irreplaceable community that gets established towards the end of succession is referred to as 'climax community'.

'Primary succession' is a very time-consuming process in which each stage is distinguishable from the other stage in terms of vegetation and its habitants, however the changes from one stage to other is very gradual. To conclude, the

NOTES

stages of primary succession are as follows, each stage is referred to as sere by foresters:

- Pioneer species
- Tall Shrub
- Young Forest
- Mature Forest
- Climax (or Old-Growth) Forest

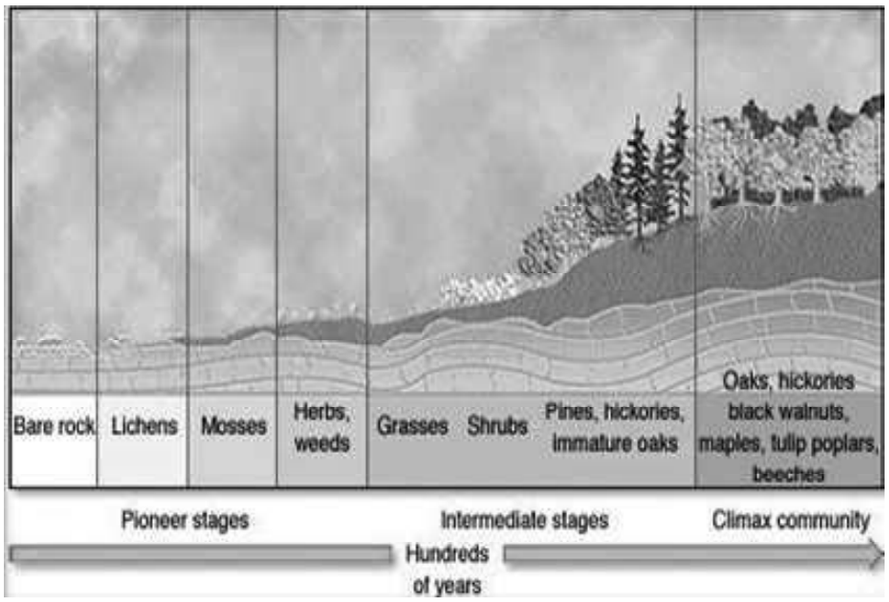


Fig.1.6 *Primary Succession*

Figure 1.6 is depicting primary succession.

2. Secondary Succession

Secondary succession refers to a type of ecological succession which happens in an already established ecosystem that gets disrupted due to events like wind storms, insect outbreaks, logging, avalanches, bulldozers, or fire, however they leave the soil intact as such along with seeds, spores, and roots usually remain as well. The following steps describe the process of secondary succession:-

- Secondary succession begins in an environment having pre-existing soil, i.e. it takes place in such an environment where the original succession has been disturbed due to some environmental factor, but some plants and animals from the previous succession might still exist.
- External factors act as an initiating agent for the secondary succession.

NOTES

- Unlike primary succession, pioneer species in secondary succession arises mostly from the pre-existing groups of organisms in the community.
- Over a period of time, variations in the environment initiated due to the progression of grasses promotes the growth and propagation of new plant species like shrubs and herbs.
- These plant species are referred to as 'intermediate species' which escalates variations to the environment enabling the growth of taller plants.
- The course of succession is affected by other factors such as pollination, germination of seeds, soil quality, climate, soil texture etc.
- Lastly, the composition of the environment changes back to its original state.
- Communities established after the secondary succession depends on a lot of factors such as the trophic interaction, original composition of the environment as well as the competition-colonization processes.
- Due to the presence of pre-existing soil, time required for the course of secondary succession is less compared to primary succession.

To conclude, the stages of secondary succession are as follows.

- IN COASTAL RAINFOREST
  - o Regrowth Stage
  - o Second-Growth Forest
  - o Old-Growth Forest
- In BOREAL FOREST
  - o Regrowth Herb Stage
  - o Regrowth Shrub Thicket
  - o Regrowth Young Forest
  - o Mature Forest
  - o Climax Forest

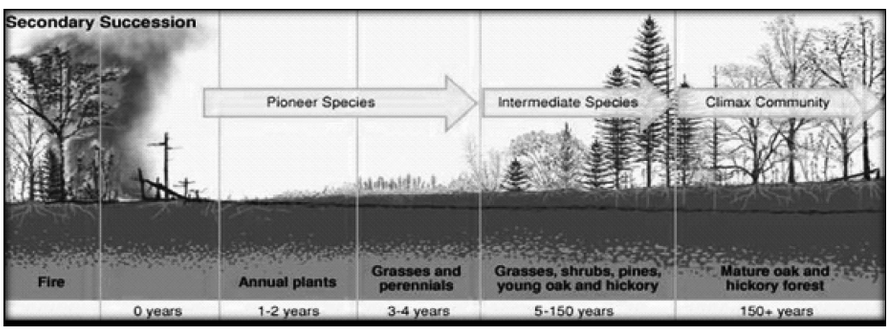


Fig 1.7 *Depicting Secondary Succession*

NOTES

Below, we have summarized the key differences between the primary and secondary succession on the basis of some common parameters:-

Parameter	Primary succession	Secondary succession
Definition	Primary succession occurs when some natural calamity like earthquake, volcanoes, glacier eruption, landslide, floods, etc., completely eliminates the entire soil and organisms from a site leaving behind bare lands, gravel, slit, sand or rock. This word 'primary' is used for such type of succession because soil, the foundation for everything else, starts here. The formation of soil begins with the slow breakdown of rocks by weathering. Dust, silt, and sand collect in these pockets of mineral soil.	Secondary succession refers to a type of ecological succession which happens in an already established ecosystem that gets disrupted due to events like wind storms, insect outbreaks, logging, avalanches, bulldozers, or fire, however they leaves the soil intact as such along with seeds, spores, and roots usually remain as well.
Initial vegetation	Absence of any initial vegetation in the area	Initial vegetation is present in the area
Initiation Factor	It can be a biological factor or an external agent.	Secondary succession is always initiated by an external factor.
Soil	Surface soil is absent, and the new soil is formed by weathering of rocks.	Secondary succession begins in an area having pre-existing soil.
Organic matter	Absence of pre-existing organic matter in the area undergoing primary succession.	Organic matter is pre-existing in the environment undergoing secondary succession
Environment	Initially the environment is inhospitable for both plant and animal species. It slowly becomes more and more favourable with each passing stage.	The environment is favorable for the life to thrive right from the very beginning.
Pioneer species	Pioneer species consisting of organisms like algae, fungi, etc., enter the ecosystem from the outside environment.	Here, the pioneer species like grasses are already present within the previous ecosystem.
Intermediate community	A large number of intermediate seral stages are present before the succession reached the climax.	A few intermediate communities are formed during secondary succession.
Previous community	Absence of previous community in the ecosystem prior to succession.	Previous communities are present in the environment prior to secondary succession.
Time	It is a gradual process.	It takes less time when compared to primary succession.
Examples	Formation of a new ecosystem after natural disaster such as, volcano, earthquake, flood glacier or a nuclear explosion.	It involves succession after fire, logging, harvesting, abandonment of land or the renewal after a disease outbreak in the previous ecosystem.

Variations in the forest environment leads to huge changes in the wildlife inhabiting the environment. Over a period of time, all living beings are adapted to survive and flourish in a particular kind of environment. To be able to survive, grow and reproduce, animal exhibit several kinds of adaptations like structural adaptations

(body shape and size), physiological adaptations (diet, cold- or drought-tolerance), or behavioural adaptations (finding mates or defending territory). Now, an animal can thrive well in an environment created by the succession, only when plenty of food, water, space are available for the animal in that particular habitat. In the absence of vegetation, the habitat is open and windy during early successional stage and hence lots of sunlight can easily reach to the ground. Due to this, the temperature fluctuates rapidly which in turn influence other climatic parameters like rain and snow. In such stages, residents are restricted to those that can nest or hide near the ground. Similarly, the next successional stage can fulfil the diet and shelter requirement of different species of animals. Thus, we can conclude that the animal residents keep on changing along with each successional stage.

Figure 1.8 illustrates variation in animal residents with change in vegetation in a boreal forest succession.

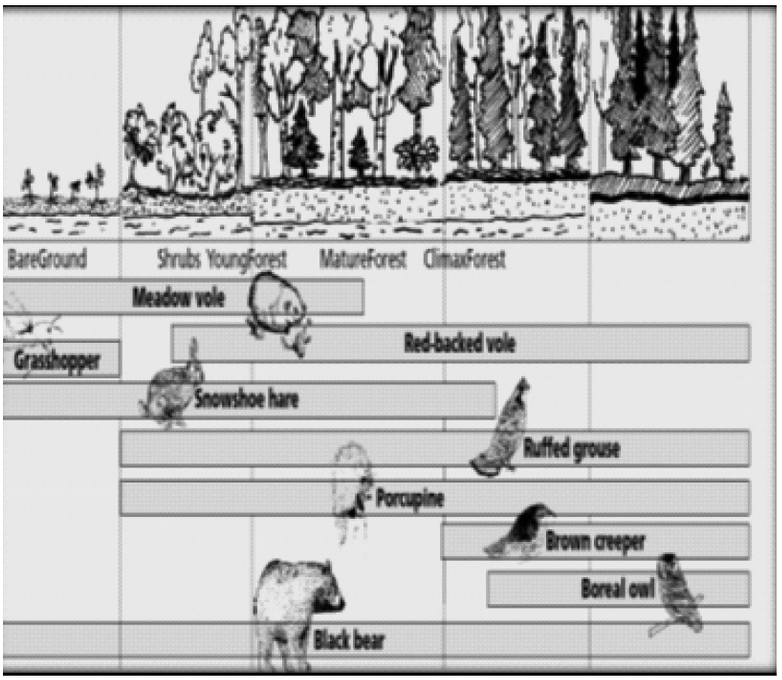


Fig.1.8 *Variation in Animal Residents with Change in Vegetation in a Boreal Forest Succession.*

1.4.1 Setting Back Succession

Set-back succession refers to the moving succession to an earlier stage. During early succession stages plant communities consist of a mixture of grasses, forbs and shrubs which serve as habitat to a variety of wildlife species. An area having favourable climatic conditions, i.e., receiving abundant rainfall, light, temperature and a rich soil can soon be dominated by shrubs and trees quickly. In the absence of natural disturbances like wildfires or flooding the quality, quantity, diversity and maintenance of these plant communities (found in early succession) is largely dependent upon management. Methods such as fire, disking, moving, grazing, logging, herbicide application etc. are used periodically to maintain early successional plant communities for several wildlife species.

NOTES

- **Management Techniques for Setting Back Succession**

Wildlife managers uses different management practice to set-back succession. Different practices result in a very different quality of the habitat for the wildlife species. The type of methodology followed, its frequency, timing and successional trajectory influences the quality of habitat. Below, we will discuss a list of methodologies adopted for setting back succession:

1. Mowing– Mowing refers to the act of cutting down grass, crops, etc. with a hand implement/tool or machine. The advantages of using mowing as set-back succession technique includes:-

a) Keeps the vegetation healthy that is highly competitive against weeds and flourish better under stress conditions

b) Eliminates some pests as well as prevent invasion

c) Promotes healthy growth

d) Debris are removed

e) Increases density of vegetation

f) Promotes deep root growth

g) Keeping vegetation in an early successional stage creates good habitat for pollinators, birds and mammals.

h) Last but not the least, mowing is a relatively inexpensive technique.

i) Mowing is used to manage herbaceous groundcover and small shrubs. It helps in maintaining trails and roads and also aims at achieving certain land management objectives.

j) It helps in the restoration, growth and propagation of viable and desirable herbaceous groundcover.

k) Reduction of wild shrubs

l) Reduction of wild shrubs leads to controlled wildfires

m) It aims at restoring habitats for several plant and animal species and also birds after the grass starts increasing in size.

However, mowing has certain disadvantages too: -

a) It sometimes eliminates habitats, kills nesting, feeding, resting and critters.

b) Other disadvantage of mowing is that it is not effective in reducing woody competition.

c) Another disadvantages of mowing is that when vegetation is not cut properly but simply removed from the field, a deep thatch layer is created at ground level which limits the mobility and feeding ability of birds especially that of game birds and animals.

d) Further, seed-bank is suppressed leading to reduced vegetative diversity.

Effective way of using mowing for set-back succession

a) Mow the lawns and paths once per year-This enables the small mammals, birds, and pollinators, etc. to reproduce successfully

b) **Mow the area when plants are dormant-** Dormant plants are an essential part of the landscape as they fulfil the food and shelter need (winter homes) of several small animals, mammals, birds ,etc. However, mowing at the bloom stages of plants leads to destruction of several life stages like eggs, young as well as adult animals. On the contrary, mowing the dormant plants is less destructive.

c) **Using rotational mowing-** Rotational mowing involves keeping some patches un-mowed between mowed areas as it preserves habitats for the wild creatures, creates structural diversity in the landscape as well as give small mobile creatures a safe shelter.

d) **Raising mower blades-** Mower having raised blades prevents ground habitats like ground nest from being getting destroyed.

e) **Keeping the edge un-mowed-** Edge areas encompass diverse vegetation and thus support a rich diversity of wild species. Keeping the edge areas un-mowed helps in preserving rich diverse vegetation as well as wild species.

f) **Mowing slowly-** Last but not the least, mow down very slowly as mowing down with high speed prevents chances of wildlife to escape.

2. Burning: In the early 20th century, it is one of the most common practice followed to increase the palatability of vegetation. However, unskilled labour, increasing pollution and its harmful effects on natural flora and fauna, it is no longer taken as a desirable method of setting back succession. Mowing has several disadvantages like when vegetation is not cut properly but simply removed from the field, a deep thatch layer is created at ground level. This limits the mobility and feeding ability of birds especially that of game birds and animals. Further, seed-bank is suppressed leading to reduced vegetative diversity. However, fire clean the fields of debris, generates an open field like structure at ground level and also stimulates the seed bank to germinate, thus enhancing diversity of vegetation at ground level. To meet the aim and objectives of habitat management, timing of burning is very essential for the growth and propagation of desirable species. Further, frequency of burning should be estimated by the structure and composition of the subsequent plant communities. If the burning is done annually, then it will shift the vegetation to a grass and forbs dominated vegetation, however if burning is done after 2-3 years, it will cause more of a herbaceous community with scattered shrubs. Despite several advantages of burning, it should be done with utmost care under the watchful eye of experienced personnel.

3. Use of Herbicides: Herbicides are generally avoided during the establishment of early successional vegetation. However, it becomes necessary to use herbicides in managing non-native invasive species.

Eradication of the non-desirable, non-native invasive species is must before target or desirable species can flourish. Herbicides can be applied in three ways i.e. broadcast full, alternate nozzle closed and spot-sprayed.

(a) **Broadcast full**– It is used for restoring fields fully covered with non-native grasses.

NOTES

(b) **Alternate nozzle closed**– It can be used when the field gets covered 70 to 100% with native grass species.

(c) **Spot-sprayed**– They are useful in eradicating unwanted woody growth.

4. Browsing: Grazing and browsing are two different methods by which herbivore eat their food. Browsing refers to a type of herbivory where an herbivore feeds on leaves, soft shoots or fruits of woody plants such as shrubs. However, in grazing, animal feeds on grass or other lower vegetations. In other words, grazers feeds on grass whereas browsers feeds on woody and herbaceous dicots. For example, sheep are grazers whereas goats are browsers. The plant material eaten up by a browser referred to as browse.

Thus, to conclude, several wildlife species which are dependent on early successional plant communities for their food and cover need are declining at a very rapid rate. This include both ecologically and economically important animal species such as invertebrates, amphibians, reptiles, birds and mammals. Hence, different set-back succession can be used in combination to meet the aims and objectives of habitat management for these species. In the absence of natural disturbance, succession can be practiced every 2 to 4 years depending upon the response of vegetation and wildlife species. Such man-caused disturbances at proper interval and with proper planning creates a variety of cover types for different species.

1.4.2 Grazing

Grazing can be used as an essential tool for habitat management. It can be both beneficial and damaging depending upon how it is utilized. The utility of grazing as a tool for habitat management was clearly explained by 'Aldo Leopold' in his book 'Game Management' (1993).

However, grazing can have both positive and negative effects, and the outcome of this application depends upon the aims and objectives of the habitat management plan by wildlife planners and managers. Before using grazing as a tool for habitat management there is need to understand several basic concepts.

a. Evolutionary role of grazing on rangeland plants

Grazing animals graze internally in an area removing mature or dead plants and hence stimulating the growth of new plants by disturbing the soil with the hooves which in turn aerate the soil and makes the water percolation easier. Further, dead and decaying old plants adds organic matter to the soil and increases its fertility.

b. Carrying capacity

It refers to the number of animals that can sustain on an area without it being damaged. Carrying capacity is affected by several factors such as amount of food and water available in the area, amount of rainfall, sunlight obtained by the area, other physical parameters like PH, soil texture, soil quality, temperature of the area, predator-prey interaction in the area and a lot of other variables. For an effective and accurate estimation of the carrying capacity, wildlife managers take into account both livestock (domesticated animals) and wildlife. Further, it should be noted while planning habitat management that livestock can be easily

manipulated, however it is not that easy to manage wildlife population. Thus, wildlife managers determine the carrying capacity during 'drought' and 'normal' years and can plan accordingly the habitat management of wildlife.

NOTES

Types of Grazing

Continuous Vs rotational grazing.

a. **Continuous Grazing**– Continuous grazing is less labour extensive as it involves putting livestock in an area and leaving them there as long as the area is supporting them. However, there is one problem associated with continuous grazing system, as grazers like cow, sheep etc. can have certain food preferences, i.e., they might find some food to be more palatable than others and hence they keep on returning back to that particular food-plant or grass and hence the area will be soon deprived of that first choice or desirable plant. After the disappearance of first plant, grazers will start looking for other palatable plant species and will put the same intense pressure on that plant also. In this way, the cycle will keep on repeating ultimately decreasing plant-diversity and overall productivity of the area.

b. **Rotational Grazing**– In the rotational grazing system, wildlife managers control the grazing pressure applied to the pastures by balancing the number of animals, forage and time spent on the individual pastures to be grazed. This methodology allows the pasture to recover fully between the two grazing periods. Forage condition and its rate of growth are the two determining factors for setting the schedule of rotational grazing.

Grazing as a Habitat Management Tool

Grazing can be used as a cheap, less labour extensive and easiest tool for habitat management. Below we are listing a few advantages of using 'grazing' as a habitat management tool:

- It is economically viable. Unlike, other chemical or mechanical methods for habitat management which requires several chemicals and tools, 'grazing' does not require any extensive equipment or labour.
- Secondly, grazing is a natural ecological and evolutionary process, so wildlife managers can just harness the power of nature to manage the habitat.
- Thirdly, a well-managed grazing methodology can stimulate the new plant growth in the area by making the soil more fertile and healthy which further adds to the diversity and richness of plant species found in that area.

Thus, we can conclude, that a sensible use of grazing as a habitat management tool can solve the problems of habitat management in a natural way.

Logging as a Habitat Management Tool

Logging is both an ecological and economical viable activity. It involves the process of cutting, processing and moving trees to a location for transport. This activity basically provides raw-material for several industries worldwide like energy, construction and housing. Logging activity helps the wildlife managers to manage wildlife habitat and reduce the risk of uncontrolled dangerous fires as well as in restoration of the ecosystem. There is a difference between the logging and

NOTES

harvesting. Logging is generally referred to as the process of felling and extracting timber from forests whereas timber harvesting involves pre-harvest planning, technical supervision as well as post-harvest assessments also that reflects the concern about non-timber resource value and about the future state of the forest.

1.4.3 Mechanical Treatment

Fire is good for both people as well as the land. Removal of fire from the landscape can lead to unhealthy ecosystem. The absence of fire can cause overcrowding of the trees, disappearance of fire-dependent species or it can also lead to the continuous build-up of hazardous materials. Under controlled conditions, fire can help to replace hard and old vegetation with soft and delicate grass. Also, as it stimulates the growth and propagation of new vegetation and kills the old-hard vegetation, it checks natural-succession, which itself depends upon the intensity of fire. However, at some places fire is not a desirable management practice as it can lead to huge loss of economically viable tree-species. Moreover, under some conditions it becomes impossible to control fire leading to burning of plants and animals causing extensive damage to natural resources. Under such conditions, mechanical treatment can be used as a valuable tool for habitat management. It aims at reducing the amount of build-up vegetation in the environment so that they can withstand the fire in a better way. Mechanical treatment generally involves thinning dense strands of tree, pruning lower branches of tree, piling brush or generating fuel breaks to encourage controlled fire in the area. Tools used for mechanical treatment can vary from simple hand tools to large machines. Below, we will describe a few tools which are used regularly to carry out the mechanical treatment.

1. Roller - Chopping

- It is a low-cost mechanical treatment involving a tractor pulling a heavy metal drum with protruding cutting edges across vegetation. It chops off the shrubs and small trees and is used frequently to achieve several aims and objectives of several land-management practices.
- It prepares the desirable site for carrying out controlled burning thus reducing the extensive speed of fire and killing of plants and animals.
- It prepares the site for seed germination.
- It allows natural regeneration of some essential plants in harvested area.
- It promotes growth and propagation of herbaceous ground cover
- It aims at restoring habitat for several species.

2. Mowing

Mowing refers to the act of cutting down grass, crops, etc. with a hand implement/ tool or machine.

3. Harvesting

Tree harvesting is an economically and ecologically variable activity. Below, we have discussed a few harvest methods:-

NOTES

a) **Salvage harvest**– This method aims at removing damaged plants or killed plants. This methodology is used in response to mortality from wildfires, wind, flooding, insect infestation and diseases.

b) **Thinning**– This management practice aims at removing trees from an area. It aims at improving wildlife habitat and ground cover diversity as well as improving the health of remaining plants.

c) **Clear cutting**– It involves the removal of all kinds of trees. Generally, it is avoided, as it involves cutting down a lot of economically and ecologically important trees. However, forest managers use this technique to aid in the control of diseases or insects. It is also used to replace unwanted plant species with desirable plant species which are favourable for the habitat.

Thus, all in all mechanical treatment aims at improving the structure and composition of a habitat's vegetation. In the absence of management practices, such vegetation often becomes uncontrolled and inhospitable to several plant and animal species. It also helps in reducing the catastrophic fires and promotes healthy and stable ecosystem. Mechanical treatment can be used alone or in conjunction with other techniques such as controlled fire or herbicide as an effective habitat management tool.

Visitors often observe an altered landscape having chopped or harvested area after mechanical treatment. However, over a period of time, the landscape rejuvenates with rich flora and fauna signalling towards a healthy ecosystem.

1.4.4 Advancing the Successional Process

The most natural way to create a wildlife habitat is to allow a selected area to grow on its own into the desired vegetation type. The process mentioned above is known as natural vegetation and does not require much labour or funds. Natural vegetation depends upon the process of natural succession. Succession, as discussed in the previous section, is a gradual sequential process of changes in plant communities in an area over a period of time. The sequential change observed in an area in natural succession is described below:

1. Annual grasses and forbs.
2. Perennial grasses and forbs.
3. Shrubs, vines and briars
4. Young forest tree species
5. A mature/climax forest

Establishment of natural vegetation at a place depends upon dormant plants lying in the soil as root or seed or those plants which are already available on the site or pollination, i.e., seeds coming from nearby areas by pollinating agents such as wind, insects etc. Though, natural vegetation is a cheap, economical method yet the biggest disadvantage of this method is that it requires a lot of time and hence it is essential to plan wildlife habitat management. For habitat management, first wildlife managers identify the wildlife species and then its habitat requirements. After completing the habitat assessment, it is essential to lay down the plan on how natural vegetation can fulfil the need of basic habitat components.

NOTES

Selected Characteristics of Successional Stages

Stage of Succession	Years Needed to Reach Stage	Typical Plants	Benefits to Wildlife	Wildlife Benefitted
Annual grassesand forbs	1	foxtail grass, ragweed	areas of bare soil for dusting, seeds andinsects for food, nesting cover	quail, pheasant, turkey, grassland songbirds
Perennial grasses and forbs	2-5	warm and cool season grasses, goldenrod, milkweed, daisys, ironweed	nesting cover, green browse, insects	quail, pheasant, turkey, rabbit, deer, grassland songbirds, snakes
Briars, brambles, vines, shrubs	3-10	blackberry, raspberry, dewberry, roses, grapevines, dogwoods,sumacs, red cedar	escape, nesting and winter cover, berries,fruits, buds, green browse	quail, pheasant, rabbit, deer, turkey songbirds, woodcock, snakes
Young forest	15-30	sassafras, cherry, cedar, tulip, persimmon, ash, elm	seeds, fruits, buds, nesting and winter cover, green browse	deer, turkey, squirrels, woodland songbirds, snakes, woodcock, ruffed grouse, amphibians, reptiles
Mature forest	50-100	oak, hickory, maple, beech, walnut	nuts, green browse, nesting cavities, winter cover denningsites	deer, turkey, squirrels, woodland songbirds, snakes, amphibians, reptiles, bats

Table is depicting different stages of a succeeding vegetation support different kind of wildlife

Source of Information: Prepared by the Indiana Department of Natural Resources, Division of Fish and Wildlife.

As shown in the table above, different stages of a succeeding vegetation support different kind of wildlife species, so it is natural that wildlife species will increase, decrease, appear or disappear in response to the change in vegetation. So, all in all, we can say that some wildlife species requires early-stage vegetation (early succession stage) whereas other wildlife species needs vegetation seen in later stages of succession.

Thus, in order to achieve a rich diversity of wildlife species, it is essential to maintain both early and late stages of vegetation at a point of time in a single habitat. However, the process of natural vegetation leads to progress of vegetation from early to late stages. Thus, to maintain all stages of vegetation, wildlife managers adopt both set back succession and advance succession strategies. As we have discussed in the previous section, early stages of vegetation can be maintained by set-back succession strategies such as grazing, mowing, use of herbicides, prescribed burning, etc.

NOTES

Natural vegetation is one of the easiest ways to attain advance succession. However, it is a time-consuming process. It is must for wildlife manages to accelerate the process of natural vegetation by adopting several methods. For example one of the way to speed up the process of vegetation is to erect an artificial fence wire along the length of the desired area. Birds perching on the wire will deposit droppings which are a rich source of seeds. Most of these seeds will germinate to form different species of plants. Cover construction is another method of establishing the advance succession vegetation in a habitat for different species of wildlife.

Hence, we can conclude that though natural vegetation requires minimal efforts and funds, yet to maintain the population of a desirable species a specific kind of vegetation is required which cannot be maintain sustainably by the process of natural vegetation. Thus, wildlife managers adopt several set-back and advance succession strategies to achieve the aims and objectives of habitat management for maintaining the population of wildlife species.

1.4.5 Cover Construction

Shelter refers to the area which fulfil biological needs of the animal as well as provide protection and safe breeding place. Shelter is generally divided as cover and space.

Cover– Cover refers to the area which provides safety, shade and protection to the animal under unfavourable environmental conditions.

1. Development of Natural shelter– In Natural cover or natural shelter development can be carried out in two ways:-

(i) In the first situation, if the succession of the plants is going in the desirable direction for the concerned species, then shelter management or manipulation or development techniques only involves the ways to speed up the ongoing succession by methods such as afforestation of required plant species, control-grazing (especially by domesticated animals) and fire management.

(ii) In the second situation, if the already, established plant succession is beneficial for the target species, then shelter manipulation/development techniques involves the ways to retain the established succession by preventing unnecessary deforestation, grazing and also by adopting essential fire management techniques.

2. Development of artificial shelter– As we have seen in the previous discussions, each and every wild species has some specific shelter requirement depending upon its biological need, shape and size of the animal. So, all these factors should be kept in mind, before adopting any management or shelter improving techniques. The following methodology is generally adopted for shelter improvement:

(i) **Afforestation**– This serves the dual purpose of food as well as cover to the wild species. Plant, chosen should be on the basis of soil condition, topography, weather conditions, rainfall received by the area.

(ii) **Cave shelter**– Cave also serve as shelter to the wild animal. There should be thorough investigation of the area to look for the number of caves in the

NOTES

habitat, caves which are used preferably by the wild animals and caves which are abandoned by the animal. Efforts should be made to improvise the already serving caves and also thorough research should be done to find out the obstacles or limiting factor in the caves abandoned by the wild species. Special effort should be made to remove those obstacles and improve the caves condition to make it more habitable and hospitable to the animal by making adequate arrangement of both food and water near the cave/ shelter.

(iii) **Development of Artificial Nest**– Birds uses nest as their escape cover, breeding place, resting place, laying eggs and also for development of young ones. To make the habitat more hospitable to the wild animal artificial nest made up of woods, or other material should be hanged to the trees.

(iv) **Bushes as shelter of wild animals**– Bushes serves as shelter to several small animals and birds. During commercial exploitation of forest, a lot of tree branches, leaves etc. fell off. All such material should be collected and developed as artificial bush shelter for small wild animal and birds.

(v) **Development of Migration cover**– Wild animal species are free mobile creatures which love to move from one place to other sometime in search of water, food, shelter or mate and sometime without any specific purpose. However, they are prone to road accidents or starvation during such trips leading to their death. Hence, adequate provision should be made to develop certain spots of migratory routes as cover or shelter for animal with adequate arrangement of food and water.

Food, water and shelter are the basic requirements of any animal. Food is essential for any living being as oxidation of food provide energy to the animal for walking, breeding, hunting, mating as well as other basic and physiological functions performed in day-to-day life.

Plants are referred to as producer as they synthesize their own food (organic matter) by fixing inorganic matter (like CO2, water) in the presence of sunlight. Animals are consumers in the ecosystem and they can be either herbivores, carnivores or omnivores. Herbivores feeds only on plants, carnivores feeds only on other animals whereas omnivores feeds both on plants and animals.

Further, these consumers are categorized as primary, secondary or tertiary consumers depending upon their place in the hierarchy or trophic level. The choice of food varies between different species and depends upon a lot of factors like immediate environment, habitat of the animal, type of vegetation/food plant present in the habitat (for herbivore species), type of other animal species present in the home range of the animal species (for carnivorous animals), taste of the animal (a particular food kind may be edible for one consumer species but not for the other) and also the nutritive value of the food. Now, animal consume different type of food depending upon their food choice of different levels i.e. primary, secondary or tertiary and also depending upon the seasonal variations. Accordingly, the food can be classified as follws.

NOTES

(i) **Choice Food**– A food is referred to as choice food if it is the most preferred food of the animal. The animal enjoys eating this tasteful food.

(ii) **Staple Food**– As humans also have a staple diet (made up of cereals like rice, wheat, maize etc.) wild animals also do have a staple food which is essential for its survival as this food is available to the animal for long duration.

(iii) **Stuffing-Food**– As the name suggest, (stuffing literally means to fulfil) animal consume this type of food only to fill its stomach in the absence of nutritive food, staple or preferred food. Such food is generally deprived of essential nutrients required by the animal.

(iv **Emergency Food**– In between the staple food which is highly nutritive and stuffing food which is non-nutritive, animal consume another food known as emergency food. This is neither tasty nor highly nutritive but yet somewhat more nutritive than stuffing food and helps the animal to survive. However, such food cannot sustain the animal for long duration as it is not highly nutritive.

(v) **Varied or Miscellaneous Food**– Sometimes in adverse environmental factors animal start consuming food which is not into the range of food described above. Such unusual food taken by the animal out of their habit is known as miscellaneous food. Animal generally consume such food only during pinch period, i.e., the period where seasonal food is not abundantly present and forces the animal to look for different variety of food outside its food range.

Hence, food is required by the animal for its survival and propagation. Hence, improvement in the production of food is the most common and favoured technique to manipulate the habitat of wild animals while planning wildlife management. The following methods are adopted to improve the food quality and quantity:-

- **Plantation of Edible Fruit Plants**– Herbivores 'preferred' or 'choice' food are fruit and seeds of several plants. Special efforts should be taken to prevent the cutting down of such fruit trees as well as plantation drive should be conducted from time to time to propagate such plant species.
- **Production of Browsing and Grazing Food**– Different animal species have different choice food. Grazing animals (herbivores like cows, goat, etc.) prefer to move over its habitat and graze on a variety of grasses, shrubs, herbs, small trees, etc. However, all these are not beneficial or of interest or of high nutritive value to the animal. Thus, efforts should be taken to remove, weeds (unwanted plants), or less nutritive food and replace them with highly nutritive foods for the animal.
- **Creation of Pasture Land**– Pasture land refers to the area which is used for browsing and grazing activities. There are the areas used for grazing by herbivores such as horse, cattle, sheep etc. The vegetation of the pasture land majorly consists of grasses with an interspersion of legumes and other forbs. Legumes are the plants whose seeds or fruit are known as pulse. (For example, chickens, soybean, lentils, peas,

NOTES

etc.) And forbs refers to the herbaceous flowering plants. Pastures are different from meadows which are ungrazed area or used for grazing only after being mown to hay for animal folder. For effective improvement in the quantity and quality food, existing pastures lands should be improvised and efforts must be made to improve the pasture lands which have undergone severe damage due to over-grazing or some other environment factors. Management of the pasture lands includes important factors such as soil type, temperature conditions, rainfall received by the area, etc. Also, a complete ban on browsing and grazing activities should be imposed till the proper growth and propagation of the desirable vegetation in the damaged pasture lands.

- **Controlled Burning and Grazing Activities for Improvement in Food Quality**– In order to allow the proper growth and propagation of the desirable vegetation both controlled grazing and burning practices should be followed on periodic basis. Controlled grazing helps in proper development of vegetation as well as germination of seeds and thus prevents the huge damage to pasture lands. Controlled burning practice should be followed in area having hard and unpalatable bushes and vegetation. Herbivores loves to feed on the soft and delicate grass which is palatable as well as do have high nutritive values. Controlled burning removes the old and hard plant and vegetation and replace them with new nutritive soft vegetation. However, adequate measures should be adopted to prevent the spread of fire in the entire area as well as care should be taken to avoid burning of small wild animals and desirable plant species.

These are some of the practices which needs to be followed to improve both the quantity and quality of the food. However, under adverse climatic conditions, artificial mode of feeding should be adopted to protect the wild animals. However, such artificial feeding should be avoided in general, because this makes the animal weak, lazy and also animal tends to forget its basic wild characters. For example, food searching and hunting skills are best developed in animals protected in their natural setting with minimal human interference when compared to animals kept in zoo (where animals are fed artificially throughout their lives).

Like food, water is also a basic necessity and is an important constituent of habitat. Water can be managed by two methods:

a. **Natural method**: - Natural waterholes, having run-off water are already present in the wild areas. These water-holes should be improved under the eye of an experienced personnel to make it more available to wildlife animals. Further, adequate measures should be adopted to collect water which is coming drop by drop from a particular space to make it more useful for the wildlife species.

b. **Artificial methods**– To make water readily available to the wildlife, artificial arrangements in the form of ponds, lakes, tanks, reservoirs, wells should be made according to the suitability and requirements of the habitat.

1.4.6 Preservation of General Genetic Diversity

Diversity refers to the range of variations observed among set of entities. Bio-diversity is studied in terms of three hierarchical levels:

NOTES

1. Genetic diversity
2. Species diversity
3. Ecosystem diversity.

1. **Genetic Diversity–** Genetic diversity refers to the changes present in the DNA sequence and hence it can be observed as differences among the individuals of the same species. These minor variations among the individual of same species helps them to adapt to their immediate environment and these traits are also passed on to the future generations. The variants, thus obtained are referred to as strains of a single species.
2. **Species Diversity–** Species diversity refers to the total number of different species occupying a particular region. Species diversity in a region depends upon two parameters: -
   (a) **Species Richness–** Total number of different species present in an area.
   (b) **Species Evenness**– It defines relative abundance of the different species in an area.
3. **Ecosystem Diversity–** Ecosystem is a self-sustaining system having both abiotic and biotic components. Abiotic components of the ecosystem are light, temperature, pH, altitude, temperature whereas biotic components include all its living organisms. The interaction between the abiotic and biotic components determines functional processes such as nutrient cycling, energy flow as seen in several ecological cycles like water, carbon or nitrogen cycles as well as food chains and food webs. Quantitatively, ecosystem diversity can be assessed as:
   (a) Alpha-Diversity– It basically refers to the diversity within the community or we can say it is the diversity of organism living together in the same area (study area or area of concern) and sharing its resources. For ex- diversity of a forest or lake or pond. Both species richness and evenness make up for the alpha – diversity.
   (b) Beta-Diversity– It refers to the diversity within the communities or we can simply say that it is the difference in the species composition and representation between two habitats. This is largely due to change in both biotic and abiotic components of the ecosystem. For ex- Diversity difference is observed between the two different habitats i.e. pond and forest.
   (c) Gamma Diversity– It refers to the diversity in a large geographical area or landscape. The total number of habitats present defines the diversity of a geographical area. The larger the number of habitats, the more is the diversity. For ex- Diversity in a Brazilian forest.

NOTES

Conservation refers to the protection, preservation, management or restoration of wildlife and natural resources such as forests and water. Anthropogenic activities pose a threat to species diversity as well as to their habitats and hence there is an urgent need to conserve them. The conservation of species in their habitat leads to the restoration of the degraded ecosystem. Conservation of floral and faunal species can be broadly divided into two types:

1. In-Situ Conservation
2. Ex-Situ Conservation

1. In-Situ Conservation– It refers to the on-site conservation i.e. this approach involves protection of total ecosystem via network of protected areas or in other words we can say that it refers to the process of protecting an endangered floral or faunal species in its natural habitat via protecting the habitat or by defending the species from predators. In-Situ conservation includes following types of natural habitats:

- **National Parks**: National Park refers to the area reserved for the protection of the wildlife. The following are the features of the National Parks:
  - o National park are large extensive area.
  - o They protect not only wildlife but entire ecosystem composed of flora, fauna, landscape, historical objects, etc.
  - o National parks are exclusively designated by the government for the conservation of wildlife and biodiversity due to its natural, cultural and historical significance.
  - o They provide safe habitat to several species organisms such as microorganisms, insects, birds, animals.
  - o National parks also acts as source of recreation and produces an amusement of the environmental and scenic heritage, without harming the wildlife.
  - o Human interference is strictly prohibited.
  - o Activities like grazing, hunting, plantation, cultivation, predation, destruction of flowering non-flowering plants is highly prohibited.
  - o IUCN has declared national parks in category II of protected Areas.
  - o Visit to national parks requires permission from the concerned authorities.
- The first National park in India was established in the year 1935. Now known as famous 'Jim Corbett National Park', it was earlier referred to as 'Hailey National Park'. By the year 1970, India had only five national park with the implementation of wildlife protection Act (1972), for the conservation of endangered species, the number of national parks in India has witnessed a huge rise. The following is the list of National Parks in India:-

Table depicting List of National Parks in India

Name	State	Established	Area (in km^2)	Notability
Balphakram National Park	Meghalaya	2013	220	wild water buffalo,red panda, elephant and eight cat species, including the tiger andmarbled cat
Bandhavgarh National Park	Madhya Pradesh	1968	400.85(core are	highest known Tiger population in India,White Tiger, 1336 species of endemic plants
Bandipur National Park	Karnataka	1974	874.2	chital, Gray langurs,Indian giant squirrel,Gaur, leopard Sambarand indian elephants,honey buzzard, red-headed vulture, and other animals.
Bannerghatta National Park	Karnataka	1974	106.27	
Betla National Park	Jharkhand	1986	231.67	Tiger,Sloth Bear,Peacock,Elephant,Sambar, and other animals.
Bhitarkanika National Park	Odisha	1988	145	Mangroves. Saltwater crocodile, white crocodile, Indian python, black ibis, wild pigs, rhesus monkeys, chitals, and other animals
Blackbuck National Park, Velavadar	Gujarat	1976	34.08	
Buxa Tiger Reserve	West Bengal	1992	760	
Campbell Bay National Park	Andaman and Nicobar Islands	1992	426.23	
Chandoli National Park	Maharashtra	2004	317.67	
Dachigam National Park	Jammu and Kashmir	1981	141	Only area where Kashmir stag is found[citation needed]
Darrah National Park	Rajasthan	2004	250	
Desert National Park	Rajasthan	1980	3162	
Dibru-Saikhowa National Park	Assam	1999	340	
Dudhwa National Park	Uttar Pradesh	1977	490.29	
Eravikulam National Park	Kerala	1978	97	Asiatic lion

NOTES

NOTES

Galathea National Park	Andaman and Nicobar Islands	1992	110	
Gangotri National Park	Uttarakhand	1989	1552.73	UNESCO World Heritage Site
Gir Forest National Park	Gujarat	1965	258.71	
Gorumara National Park	West Bengal	1994	79.45	
Govind Pashu Vihar Wildlife Sanctuary	Uttarakhand	1955	957.5	
Great Himalayan National Park	Himachal Pradesh	1984	754.4	
Gugamal National Park	Maharashtra	1974	1673.93	Indian rhinoceros,UNESCO World Heritage Site
Guindy National Park	Tamil Nadu	1976	2.82	
Gulf of Mannar Marine National Park	Tamil Nadu	1980	6.23	only floating park in the world
Harike Wetland	Punjab	1990	41	
Hazaribagh National Park	Jharkhand	1976	186.25	
Hemis National Park	Jammu and Kashmir	1981	4400	UNESCO World Heritage Site
Indira Gandhi Wildlife Sanctuary and National Park	Tamil Nadu	1976	958	
Indravati National Park	Chhattisgarh	1983	2799.08	
Intangki National Park	Nagaland	1993	202.02	Dugong, Dolphin, Water Monitor Lizard, Blue Whale
Jaldapara National Park	West Bengal	2012	216	
Jim Corbett National Park	Uttarakhand	1936	1318.5	
Kalesar National Park	Haryana	2003	100.88	
Kanger Ghati National Park	Chhattisgarh	1982	200	important bird area as attributed by BirdLife International, new species frog named Rana CharlesDarwini
Kanha National Park	Madhya Pradesh	1955	940	
Kasu Brahmananda Reddy National Park	Telangana	1994	1.42	
Kaziranga National Park	Assam	1905	471.71	
Keibul Lamjao National Park	Manipur	1977	40	
Keoladeo National Park	Rajasthan	1981	28.73	
Khangchendzonga National Park	Sikkim	1977	1784	
Kishtwar National Park	Jammu and Kashmir	1981	400	
Kudremukh National Park	Karnataka	1987	600.32	
Madhav National Park	Madhya Pradesh	1959	375.22	

Mahatma Gandhi Marine National Park	Andaman and Nicobar Islands	1983	281.5	
Mahavir Harina Vanasthali National Park	Telangana	1975	14.59	
Manas National Park	Assam	1990	950	
Mandla Plant Fossils National Park	Madhya Pradesh	1983	0.27	
Marine National Park, Gulf of Kutch	Gujarat	1980	162.89	
Mathikettan Shola National Park	Kerala	2003	12.82	
Middle Button Island National Park	Andaman and Nicobar Islands	1979	64	
Mollem National Park	Goa	1978	107	
Mouling National Park	Arunachal Pradesh	1986	483	
Mount Abu Wildlife Sanctuary	Rajasthan	1960	288.84	
Mount Harriet National Park	Andaman and Nicobar Islands	1979	46.62	
Mrugavani National Park	Telangana	1994	3.5	
Mudumalai National Park	Tamil Nadu	1940	321.55	
Mukurthi National Park	Tamil Nadu	2001	78.46	
Murlen National Park	Mizoram	1991	200	
Nagarhole National Park	Karnataka	1988	643.39	
Namdapha National Park	Arunachal Pradesh	1974	1985.24	
Nameri National Park	Assam	1978	200	
Nanda Devi National Park	Uttarakhand	1982	630.33	
Nandankanan Zoological Park	Odisha	1960	4.006	
Navegaon National Park	Maharashtra	1975	133.88	
Neora Valley National Park	West Bengal	1986	88	
Nokrek National Park	Meghalaya		47.48	Tiger, Leopard, Asian elephant, Sambar, Barking deer, Gaur, Jungle cat, Wild boar, and other animals.
North Button Island National Park	Andaman and Nicobar Islands	1979	114	
Orang National Park	Assam	1999	78.81	
Palani Hills National Park	Tamil Nadu	2007	736.87	
Panna National Park	Madhya Pradesh	1981	542.67	UNESCO World Heritage Site

NOTES

NOTES

Papikonda National Park	Andhra Pradesh	2008	1012.85	
Pench National Park	Madhya Pradesh	1977	758	
Periyar National Park	Kerala	1982	305	
Phawngpui Blue Mountain National Park	Mizoram	1992	50	
Pin Valley National Park	Himachal Pradesh	1987	807.36	
Rajaji National Park	Uttarakhand	1983	820	
Rani Jhansi Marine National Park	Andaman and Nicobar Islands	1996	256.14	
Ranthambore National Park	Rajasthan	1981	392	
Saddle Peak National Park	Andaman and Nicobar Islands	1979	85	
Salim Ali National Park	Jammu and Kashmir	1986	9.07	
Sanjay Gandhi National Park	Maharashtra	1969	104	
Sanjay National Park	Madhya Pradesh	1981	466.7	
Sariska Tiger Reserve	Rajasthan	1955	866	
Satpura National Park	Madhya Pradesh	1981	524	
Silent Valley National Park	Kerala	1980	237.52	
Simlipal National Park	Odisha	1980	845.7	
Singalila National Park	West Bengal	1986	78.6	
Sirohi National Park	Manipur	1982	41.3	
South Button Island National Park	Andaman and Nicobar Islands	1977	5	
Sri Venkateswara National Park	Andhra Pradesh	1989	353	
Sultanpur National Park	Haryana	1989	1.43	
Sundarbans National Park	West Bengal	1984	1330.12	
Tadoba National Park	Maharashtra	1955	625.4	
Valley of Flowers National Park	Uttarakhand	1982	87.5	
Valmiki National Park	Bihar	1976	898.45	
Vansda National Park	Gujarat	1979	23.99	

Source of Information: List of National Parks in India, Map of National Parks in India (mapsofindia.com)

- **Wildlife Sanctuary**– A wildlife sanctuary refers to the protected area reserved only for the conservation of wild animals only. The following are the features of the wildlife sanctuaries:-
  - o These places are reserved exclusively for wild animals such as insects, reptiles, birds, mammals, etc.
  - o It provides safe habitat to these wild animals where they can live, reproduce and maintains a healthy population.
  - o Boundaries of a wildlife sanctuary are not fixed.
  - o Human activities such as collecting minor forest products, harvesting of timber, private ownership and etc. are allowed till such activities are not hampering the interest of wild animals.

o Controlled biotic interference such as tourist activity are permitted.

The following is the list of top National Parks/wildlife sanctuary in India:-

NOTES

S.No.	Name	Located at (District, State)	Established Year	Area in Km	Attractions
1	Corbett National Park (Jim Corbett National Park)	Nainital, Uttarakhand	1936	521 km2	The imposing Bengal Tigers
2	Ranthambore National Park	Sawai Madhopur, Rajasthan	1980	392 km2	Majestic Tigers
3	Bandipur National Park	Gundlupet, Chamarajanagar District, Bandipur, Karnataka	1974	874 km2	Tiger, Asian elephant and many types of biomes
4	Keoladeo Ghana National Park	Bharatpur, Rajasthan	1905	28.7 km2	Avifauna Birds
5	Nagarhole National Park	Kodagu district and Mysore district, Karnataka	1988	642.39 km2	Tigers, Indian bison and elephants
6	Sariska National Park	Near Kraska, Alwar District, Sariska, Rajasthan	1955	866 km2	Bengal tigers
7	Kaziranga National Park	Kanchanjuri, Assam	1908	430 km2	One horned Rhinos, Tigers and Wild Buffaloes
8	Bhadra Wildlife Sanctuary	Chikkamagaluru town, Karnataka	1951	492.46 km2	Tiger,
9	Kanha National Park	Madla/ Balaghat districts, Madhya Pradesh	1955	940 km2	Tigers
10	Sunderbans National Park	Dayapur, Gosaba, West Bengal	1984	1,330.12 km2	Bengal tigers
11	Bandhavgarh National Park	Badhavgarh, District Umaria, Madhya Pradesh	1968	1,536 km2	White tiger
12	Gir National Park and Sasan Gir Sanctuary	Junagadh District, Gir Somnath District and Amreli District Gujarat, India	1965	1,412 km2	Asiatic lion
13	Periyar National Park	Idukki, Kottayam and Pathanamthitta, Kerala state, India	1982	305 km2	Asian Elephants, Periyar Lake
14	Pench National Park	Turia, Seoni Dist, Kurai, Madhya Pradesh	1983	758 km2	Inspired Rudyard Kiplingto write 'The Jungle Book', While Tigers
15	Manas National Park	Fatemabad - Mathanguri Road, Jyoti Gaon, Assam	1990	490.3 km2	wild water buffalo, Assam roofed turtle, hispid hare, golden langur and pygmy hog
16	Dudhwa National Park	Palia Kalan, Uttar Pradesh	1977	542.67 km2	Tiger and swamp deer

NOTES

17	Panna National Park	Panna and Chhatarpur districts, Madhya Pradesh, India	1981	625.4 km2	tiger
18	Tadoba Andhari Tiger Reserve	Chandrapur, Maharashtra, India	1955	90.44 km2	Tiger
19	Chinnar Wildlife Sanctuary	Munnar - Udumalpet Road, Munnar, Kerala	1984	1,171 km2	Endangered grizzled giant squirrel
20	The Great Himalayan National Park	SaiRopa, Kullu, Himachal Pradesh	1984	866.41 km2	Globally threatened,musk deer and the western horned tragopan
21	Dandeli Wildlife Sanctuary	Uttara Kannada District , Karnataka India	NA	2.36 km2	Crocodiles, great hornbill and Malabar pied hornbill
22	Silent Valley National Park	Mannarkkad, Palakkad District, Kerala	1905	820 km2	Lion Tailed Macaque
23	Rajaji National Park	Dehradun, Uttarakhand	1983	107 km2	Asian elephants, Bengal tigers
24	Bhagwan Mahavir Wildlife Sanctuary	Caranzol, Goa	1978	4,400 km2	Snakes, particularly the king cobra and black panther
25	Hemis National Park	Leh, Jammu and Kashmir	1981	101 km2	Snow leopards , gompas and holy chortens
26	Interview Island Wildlife Sanctuary	Andaman and Nicobar Islands, Bay of Bengal	NA	7506.22 km2	Elephants
27	Kachchh/ Kutch Desert WLS	Great Rann of Kutch, Kutch district, Gujarat, India	1986	5000 Km2	Greater flamingo
28	Nelapattu Bird Sanctuary	Andhra Pradesh	1976	4953.71 km2	" Largest habitat for pelicans, also Babblers, Flamingos, Open Billed Stork etc
"					
29	Karakoram Wildlife Sanctuary	Leh District, Jammu and Kashmir, India	1987	4,149 km2	Chiru or "Tibetan Antelope, ibetan gazalle, Himalayan ibex
30	Indian Wild Ass Sanctuary (Wild Ass WLS)	Little Rann of Kutch, Gujarat, India	1973	3,568 km2	Endangered Indian Wild Ass/ ghudkhar
31	Dibang Wildlife Sanctuary	Dibang Valley , Arunachal Pradesh, India	1991	6.14 km2	rare species - mishmi takin, asiatic black bear, gongshan muntjac, red panda, red goral and musk deer
32	Nagarjuna Sagar-Srisailam WLS/ Rajiv Gandhi WLS	Nalgonda and Mahaboobnagar, Telangana	1978	861.95 km2	Bengal tiger
33	Rollapadu Wildlife Sanctuary	Kurnool District, Rollapadu, Andhra Pradesh	1988	783 Km2	Great Indian Bustard and Lesser Florican
34	Papikonda Wildlife Sanctuary	Andhra Pradesh	1978	282 km2	Tiger, Wild water buffalo was seen here till 1980s, but appears to be extinct in this region
35	Pakhui/ Pakke Tiger Reserve	Kameng district, Arunachal Pradesh, India	1977	26.22 km2	Large cats - tiger, leopard and clouded leopard
36	Kamlang Wildlife Sanctuary	Lohit District, Arunachal Pradesh, India	1989	6.05 km2	Elephant , Tiger, giant flying squirrel
37	Mehao Wildlife Sanctuary	Lower Dibang Valley district, Arunachal Pradesh	1980	20.98.62 km2	Bengal tiger, hoolock gibbon, leopard and clouded leopard.

NOTES

38	Eaglenest Wildlife Sanctuary	Arunachal Pradesh	1989	681.99 km2	Birdwatcher's Paradise. Main attraction is Bugun liocichla , Asian elephant, capped langur (endangered), red panda, gaur, Asiatic black bear, Arunachal macaque
39	Bornadi Wildlife Sanctuary	Udalguri Districtand Baksa District Assam, India	1980	551.55 Km2	Pygmy hog, hispid hare (both protected)
40	Garampani Wildlife Sanctuary	Karbi Anglong district, Assam	1952	607.70 km2	hoolock gibbons and golden langurs, hot springs
41	Hoollongapar Gibbon Sanctuary	Jorhat, Assam	1997	608.55 km2	Western hoolock gibbon and 15 species of apes
42	Bhimbandh Wildlife Sanctuary	Munger district, Bihar	1976	485.20 Km2	Tigers, panthers, birds
43	Achanakmar Wildlife Sanctuary	Bilaspur, Chhattisgarh	1975	1,027.53 km2	Tiger, leopard, bison
44	Shoolpaneshwar Wildlife Sanctuary	Narmada district of Gujarat	1982	975 km2	Python, pangolin, Flying squirrels
45	Tamor Pingla Wildlife Sanctuary	Surajpur District, Chhattisgarh	1978	2073 km2	Elephant
46	Shenbagathoppu Grizzled Squirrel Wildlife Sanctuary	Virudhunagar and Madurai districts, Tamil Nadu	1988	423.55 km2	Grizzled giant squirrel (vulnerable species), Periyar Tiger
47	Cauvery Wildlife Sanctuary	Karnataka, India	1987	219 Km2	popular for Mahseer fish, birds
48	Kedarnath Wildlife Sanctuary	Chamoli and Rudraprayag, Uttarakhand	1972	975 km2	Endangered Himalayan musk deer
49	Hastinapur WLS	Meerut, Hapur, Bijnore and Amroha, in Uttar Pradesh, India	1986	2073 km2.	Twelve - Horned Deer or "Baara Singha", the State Bird - Saaras [Crane],crocodiles, turtles, playful Ganga Dolphins, Birds
50	Koyna Wildlife Sanctuary	Satara, Maharashtra	1985	423.55 km2	Royal Bengal Tiger and King Cobra
51	Ramgarh Vishdhari Wildlife Sanctuary	Alwar District, Rajasthan	1955	219 Km2	Bengal tigers, leopards

Source of Information: Wildlife Sanctuaries in India (mapsofindia.com)

A. Tiger Reserves

Tiger reserves are areas reserved for protection of tiger in the country.

- The **State Government** on the recommendation of the National Tiger Conservation Authority (NTCA) may notify an area as a tiger reserve, for which it first has to prepare a Tiger Conservation Plan.
- Environment Minister is the Chairman of the NTCA.
- (NTCA) is a statutory body of the Ministry, with an overarching supervisory/ coordination role, performing functions as provided in the Wildlife (Protection) Act, 1972**.**
- NTCA was launched in 2005, following the recommendations of the Tiger Task Force.

NOTES

- NTCA was given statutory status by 2006 amendment of Wildlife (Protection) Act, 1972**.**
- Project Tiger was launched in 1973 with 9 tiger reserves for conserving our national animal, the tiger.
- Currently, the Project Tiger coverage has increased to 50, spread out in 18 tiger range states.
- Jim Corbett National Park is the oldest national park in India
- It was established in 1936 as Hailey National Park to protect the endangered Bengal tiger.
- It became the tiger reserve in 1973.
- The tiger reserves are established on a **core/buffer strategy**.
- The **core areas have the** legal status of a national park or a sanctuary,
- The buffer or peripheral areas represent a mix of forest as well as non-forest land, managed as a multiple use area.
- Ministry of Environment, Forests and Climate Change (MoEFCc) provides central assistance to the tiger States for tiger conservation in selected tiger reserves.

- **Conservation Reserve**
  - Conservation reserves and Community reserves act as buffer zones and migration corridors between established national parks, wildlife sanctuaries and other reserved as well as protected forests of India.
  - These protected areas (PAs) were first introduced in the wildlife (Protection) Amendment Act of 2003.
  - The State Government after discussions with local communities can announce/declare any specific area owned by the Government especially those located adjacently to national parks/sanctuaries, as conservation reserves.
  - The state government can also constitute conservation reserve 'Management Committee' to look after or manage the conservation reserve effectively.
  - Community reserves are managed by local people as well as local agencies like the gram panchayat.

B. Community Reserves

- The State Government after detailed discussion with the community or an individual who has actively volunteered to conserve wildlife can declare any private or community land as a community reserve.
- The state government can also constitute community reserve 'Management Committee' to look after or manage the community reserve effectively.

- Community reserves represents the first instances of private land being given protection under the Indian legislature.
- It opens up the avenues of communally owned for-profit wildlife resorts, and also causes privately held areas under non-profit organizations like land trusts to be given protection.

F. Biosphere Reserves

Biosphere reserve refers to the protected areas where human population also forms an integral part of the system.

They are huge protected areas with area more than 5000 sq. km. The area of a biosphere reserve is divided into three zones:

(i) Core-Zone– Core zone refers to the innermost zone of the biosphere reserve. This is the undisturbed and legally protected area.

(ii) Buffer-Zone– This is the area surrounding the core zone or we can say that this is the area present in between the core zone and transition zone. Research and educational activities are allowed in this area; however, they should not interfere with the conservation objectives of the core area.

(iii) Transition Zone– This is the outermost zone of the biosphere reserve. Activities like forestry, cropping, recreation, fishery, etc., are allowed in this area.

Thus, biosphere reserves are referred to as areas of terrestrial and coastal ecosystems which are internationally recognized within the framework of UNESCO's Man and Biosphere (MAB) programme. Following are the major functions of a Biosphere reserve:

(i) Conservation– Biosphere ensures the conservation of genetic variation, species, ecosystem, landscapes.

(ii) Development– Biosphere reserve ensures economic development in harmony with cultural, social and ecological identity.

(iii) Logistic Function– Biosphere reserve provides ample support for monitoring, educational research and information exchange related to local, national or global issues of development as well as conservation.

Thus, in a way, biosphere reserve serves as 'Living Laboratories' for demonstrating integrated management of natural resources such as wildlife, land and water.

NOTES

The following is the list of Biosphere reserve in India:

Year	Name	Location	State	Type	Key fauna	Area (km^2)
1986	Nilgiri Biosphere Reserve	Part of Waynad, Nagarhole, Bandipur andMudumalai, Nilambur, Silent Valley	Tamil Nadu,Kerala andKarnataka	Western Ghats	Nilgiri tahr, lion-tailed macaque	5520
1988	Nanda Devi National Park and Biosphere Reserve	Parts of Chamoli District, Pithoragarh District andBageshwar District	Uttarakhand	WesternHimalayas	Snow Leopard, Himalayan Black Bear	5860
1989	Gulf of Mannar	Indian part of Gulf of Mannar extending from Rameswaram island in the North to Kanyakumari in the South of Tamil Nadu and Sri Lanka	Tamil Nadu	Coasts	Dugong or sea cow	10500
1988	Nokrek	In west Garo Hills	Meghalaya	East Himalayas	Red panda	820
1989	Sundarbans	Part of delta of Ganges and Brahmaputra river system	West Bengal	Gangetic Delta	Royal Bengal tiger	9630
1989	Manas	Part of Kokrajhar, Bongaigaon, Barpeta,Nalbari, Kamrup and Darrang Districts	Assam	East Himalayas	Golden langur, red panda	2837
1994	Simlipal	Part of Mayurbhanj district	Odisha	Deccan Peninsula	Gaur, royal Bengal tiger, elephant	4374
1998	Dihang-Dibang	Part of Siang and Dibang Valley	Arunachal Pradesh	Eastern Himalaya	Mishmi Takin, Musk Deer	5112
1999	Pachmarhi Biosphere Reserve	Parts of Betul District, Hoshangabad Districtand Chhindwara District	Madhya Pradesh	Semi-Arid	Giant squirrel, flying squirrel	4981.72
2005	Achanakmar-Amarkantak Biosphere Reserve	Part of Annupur, Dindori and Bilaspur districts	Madhya Pradesh,Chhattisgarh	Maikala Hills	Four-horned antelope, Indian wild dog,Sarus crane, White-rumped vulture,Philautus sanctisilvaticus (Sacred grove bush frog)	3835
2008	Great Rann of Kutch	Part of Kutch, Rajkot, Surendranagar and Patan Districts	Gujarat	Desert	Indian wild ass	12454
2009	Cold Desert	Pin Valley National Park and surroundings;Chandratal and Sarchu and Kibber Wildlife Sancturary	Himachal Pradesh	WesternHimalayas	Snow leopard	7770
2000	Khangchendzonga	Parts of Kangchenjunga	Sikkim	East Himalayas	Snow leopard, red panda	2620

2001	Agasthyamalai Biosphere Reserve	Neyyar, Peppara and Shenduruny Wildlife Sanctuary and their adjoining areas	Kerala,Tamil Nadu	Western Ghats	Nilgiri tahr, elephants	3500.08
1989	Great Nicobar Biosphere Reserve	Southern most islands of Andaman and Nicobar Islands	Andaman and Nicobar Islands	Islands	Saltwater crocodile	885
1997	Dibru-Saikhowa	Part of Dibrugarh and Tinsukia districts	Assam	East Himalayas	Golden langur	765
2010	Seshachalam Hills	Seshachalam Hill Ranges covering parts of Chittoor and Kadapa districts	Andhra Pradesh	Eastern Ghats	Slender Loris	4755
2011	Panna	Part of Panna District and Chhatarpur District	Madhya Pradesh	Catchment Area of the Ken River	Tiger, chital, chinkara, sambhar and sloth bear	2998.98

Source of Information: Biosphere Reserves of India, Map of Biosphere Reserves in India (mapsofindia.com)

Advantages of In-Situ Preservation

1. Conservation of wild flora and fauna in their natural habitat
2. Natural life cycle progression of the species.
3. Protection of the environment.
4. Economical and manageable.
5. Interest of indigenous population is also protected.

2. Ex-Situ Conservation

Ex-situ conservation literally means 'Off-Site Conservation'. This process involves the conservation of endangered breed or variety or species of plants and animals outside their natural habitat. In other words, it refers to the rearing and cultivation of threatened animal and plant species outside their natural habitats as well as the preservation of plant species in the form of seeds in seed banks etc. by mean of scientific techniques and facilities. Example,Situ conservation strategies include establishment of zoological garden, botanical garden, zoos, gene bank, DNA Bank, etc. Below, we will be discussing some of the strategies of ex-Situ conservation. All these modes of ex-situ conservation can be divided into two:

1. Conventional methods.
2. Biotechnological aspects.

1. Conventional Methods

Under conventional methods of ex-situ conservation, we will discuss the following methods namely Gene Bank, Community Seed Banks, Seed Banks, Field gene banks, zoos, botanical gardens, long term captive breeding, etc.

(i) Gene Banks– Gene bank conserve genetic resources. In a gene bank, a sample is treated in such a way that its viability is prolonged. Gene bank operations requires that the nearly collected plant samples be periodically grown-out, regenerated and new seeds harvested as samples are prone to

NOTES

become non-viable when stored for a long duration of time. Gene banks not only collect, conserve and regenerate genetic resources, but they also make sure that these resources are aptly used by farmers, breeders, researchers. Hence, all the conserved resources are properly documented and characterized ensuring their convenient use in the future.

i. **Community Seed Bank**– Community seed banks are essential in the 'preservation and conservation' of local varieties of crops for agricultural purposes. In this method, farmers depend upon the local breeders for seed-retention from previous harvest. This is an informal seed bank; however, it is the primary method of seed-exchange and information within the communities. However, this relatively cheap, economical method has its own limitations such as the seeds becomes non-viable when stored for a long period of time as well as are prone to attack by pathogens or insects.

ii. **Seed-Banks**– This is relatively cost-effective process for long term ex-situ conservation. Seed bank refers to the cold-storage where seeds are preserved under optimal conditions of temperature and humidity. This is one of the easiest modes of storage and seeds remains viable for long duration. One of the biggest advantages of this method is the long-term preservation of endangered plants under optimal conditions as well as minimal genetic erosion. By this method, endangered plants can be preserved for a long duration without actually losing their viability and fertility. However, the success of this strategy depends upon, timely monitoring, re-generation and re-collection of the sample as or when the sample viability or fertility decreases during storage.

iii. **Botanical Gardens and Zoos**– Botanical gardens and zoos are one of the most visited ex-situ conservation sites. This method involves the conservation of whole sample or specimen for the purpose of breeding and re-introduction wherever it is possible or necessary. These botanical gardens and zoo's serves economical, research, recreation purpose apart from the conservation. Botanical gardens aim at keeping exotic plants whereas in zoos wild animals are maintained in captivity and conservation of rare and endangered species of wild animals. In India, first zoo was established at 'Barrackpore' in 1800.

iv. **Long-Term Captive Breeding**– This method is for the conservation of endangered species that have lost their habitat permanently. In this method, endangered species which have lost their habitat permanently due to unfavourable environmental conditions are captured, maintained or bred.

v. **Field Gene Banks**– Field gene banks are for the preservation and conservation of long-lived perennials, vegetative propagated species, etc. This methodology is used for species like coconut, rubber, banana, garlic, sugarcane, etc. They have huge educational and research value. However, they have some disadvantages like requirement of great deal of space for conservation and propagation; prone to diseases, pest, pathogens and predators; susceptible to natural disaster; however sometimes it is the only option for the conservation of some essential germplasm.

2. Biotechnological Methods

Biotechnology methods involves the application of scientific and engineering methods to modify a product or to improve plants or animals breeds and also to develop microorganism for specific use. These methods can be used effectively for the conservation, preservation and propagation of plant and animal species. Some of the common biotechnology methods are:

(A) In-Vitro Conservation– In-Vitro conservation depends upon the techniques of plant cell, tissue or organ culture. This methodology is used in cases where seed storage is not possible. This method is specifically used for vegetative propagated species. The material used for in-vitro conservation can be protoplast, isolated cells grown in suspension, meristem cultures or organized plantlet depending upon the requirement of threatened species a multitude of mode of propagation methods can be used:

i. **Clonal Propagation**– It refers to the process of a sexual reproduction by multiplication of genetically identical copies of individual plants. Here, the term clone refers to a plant population derived from a single individual by asexual reproduction.

ii. **Somatic Embryogenesis**– It refers to the process in which a single somatic cell give rise to entire embryo. Somatic embryos are produced from plant cells which are not involved in the generation of ordinary plant tissue or normal embryos. Somatic embryo lacks seed coat or endosperm.

iii. **Organogenesis in Vitro**– In-vitro organogenesis involves several aspects such as phytohormone perception, de-differentiation of differentiated cells to acquire organogenic competence, further organization of cell division to form organ primordia and meristems**.**

iv. **Callus Differentiation**– The term callus refers to tissue arising from the disorganized proliferation of cells from segments (explants) of plant organs. Callus cells are not primarily homogenous in nature (i.e., of same type) as the callus is often derived from structural tissue and not from individual cells. A plant cells, in the presence of plant hormones (in a culture medium) can differentiate to form a whole plant.

(B) Cryopreservation– This is one of the latest technologies used for the preservation of biotic samples. In this method, samples are preserved at very low temperature (–196°C) in liquid nitrogen. Such cold temperature halts the metabolic activities of the sample and hence it remains viable for long duration. However, even at such low temperature certain chemical reactions can occur leading to the formation of free radicals that can damage the nucleic acids, hence making the hereditary material unstable. Dimethyl Sulphoxide also commonly known as DNS, is the most commonly used cryoprotectant in-vitro preservation.

(C) Cold Storage– This method is used for slowing down the age of bio-samples. In this method of germplasm conservation, biotic samples are stored at very low temperatures (low but not freezing temperature) leading to the slowdown of metabolic activities and hence slows down the ageing of the biotic sample.

NOTES

Advantages of using ex-situ conservation

1. It helps in the presentation and conservation of threatened germplasm.
2. It provides material for research purpose.
3. Germplasm of threatened and desirable species are stored in ample quantities.
4. When compared to in-situ conservation, it stores or maintains seeds that cannot be maintained in seed store.
5. Apart from research, display of culture and facilities helps in imparting scientific knowledge to students.
6. It also produces ample material for habitat restoration, reinforcement or re-introduction.

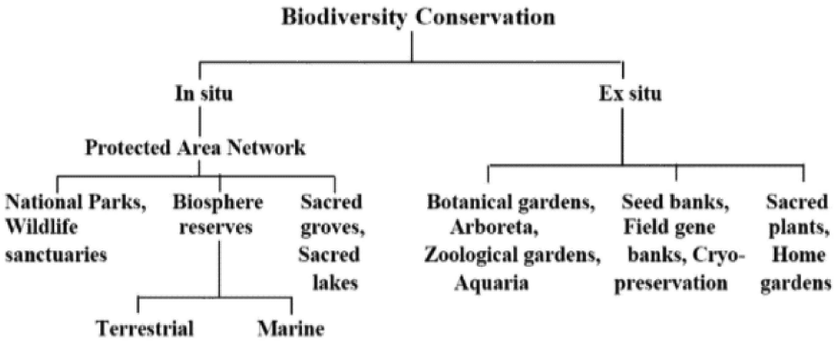


Fig. 1.9 *Flow Chart of Biodiversity Conservation*

Figure depicting the flow-chart of biodiversity conservation/preservation

Check Your Progress

21. What are the stages of primary succession?
22. Define setting back succession.
23. What is Carrying capacity of a habitat?
24. Define genetic diversity.

1.5 ANSWERS TO 'CHECK YOUR PROGRESS'

1. Wildlife traditionally refers to the animal species that are found growing or living wild in an area without being introduced by humans.
2. Economic Value– Wildlife is huge source of income for individual, industries, nation etc. It can be used to earn money by trading wild plant products like medicine, food, timber, fibres etc. as well as wild animal products such as medicines, ivory, meat, lac, silk, etc.
3. Wildlife management refers to the conservation of Wildlife along with the management of wildlife resources in such a way that they can meet the specific objective and requirements of human beings.

NOTES

4. Conservation ethics refers to the ethics of natural resources utilization, allocation, exploitation and protection.
5. Based on the International Union for Conservation of Nature and Natural Resources (IUCN), we can classify species as follows:
   - Extinct (EX)
   - Extinct in the wild (EW)
   - Critically endangered (CR)
   - Endangered (EN)
   - Vulnerable (VU)
   - Near threatened (NT)
   - Least concern (LC)
   - Data deficient (DD)
   - Not evaluated (NE
6. Habitat refers to the natural environment (constituting living & non-living entities on earth's surface) in which a particular species of organism lives.
7. Microhabitat refers to the physical and biological factors present in the immediate vicinity of a living organism i.e., either plant or animal or we can also say that microhabitat is a habitat within a habitat that possesses unique properties where new variations of life can exist and thrive due to the unique conditions that microhabitat offers.
8. Monotypic habitat is defined as a habitat in which a single species of animal or plant is the only species of its type to be found in a specific habitat and forms a monoculture.
9. Wildlife management includes three aspects namely wildlife (flora & fauna), its habitat and its stakeholders (people related to wildlife management.
10. Econometrics refers to the use of statistical methods using quantitative data to develop theories or test existing hypotheses.
11. Two general type of wildlife management are:-
    a. Manipulative Management: This type of management involves regulating the number of wild animals by harvesting or by altering food supply, density of predators and habitat.
    b. Custodial Management– This is a protective or preventive kind of management which involves minimal external influence on the population as well as their habitat. This type of management involves setting up of national parks and sanctuaries where ecological conditions are protected and threatened species are conserved by law.
12. Geology is very strongly linked to biodiversity in a way that the nature of the substrate which is determined by the nature of the rock, is a key factor in determining the distribution of habitats and species.
13. Bergman's rule states that mammals in warmer areas are smaller when compared to mammals in colder areas, i.e., mammals in colder areas are larger in size than in warmer climates.

NOTES

14. Food is required by the animal for its survival and propagation. Hence, improvement in the production of food is the most common and favoured technique to manipulate the habitat of wild animals while planning wildlife management.
15. Breeding Cover refers to the area where animal can feel comfortable and safe to mate, reproduce, lay eggs or nursing the young ones. Shape and size of the breeding cover varies with the shape and size of the animal as well as physical and biological requirements of the animal.
16. The level below which a few or no leaves are present is referred to as the browse line.
17. Forage refers to the plant material taken as food by grazing livestock (cows, horses, sheep, goats, llamas), and wildlife (deer, elk, moose, rabbits).
18. Remote Sensing is the practice of deriving information about the earth's land and water surfaces using images acquired from an overhead perspective, using electromagnetic radiation in one or more regions of the electromagnetic spectrum, reflected or emitted from earth's surface.
19. GIS refers to a computerised system or mechanism that can store and interpret the vast geographical data collected by the remote sensing process.
20. Secondary succession refers to a type of ecological succession which happens in an already established ecosystem that gets disrupted due to events like wind storms, insect outbreaks, logging, avalanches, bulldozers, or fire, however they leave the soil intact as such along with seeds, spores, and roots usually remain as well.
21. The stages of primary succession are as follows, each stage is referred to as sere by foresters:
    - Pioneer species
    - Tall Shrub
    - Young Forest
    - Mature Forest
    - Climax (or Old-Growth) Forest
22. Set-back succession refers to the moving succession to an earlier stage. During early succession stages plant communities consist of a mixture of grasses, forbs and shrubs which serve as habitat to a variety of wildlife species. An area having favourable climatic conditions, i.e., receiving abundant rainfall, light, temperature and a rich soil can soon be dominated by shrubs and trees quickly.
23. Carrying capacity refers to the number of animals that can sustain on an area without it being damaged. Carrying capacity is affected by several factors such as amount of food and water available in the area, amount of rainfall, sunlight obtained by the area, other physical parameters like PH, soil texture, soil quality, temperature of the area, predator-prey interaction in the area and a lot of other variables.

24. Genetic diversity refers to the changes present in the DNA sequence and hence it can be observed as differences among the individuals of the same species.

NOTES

1.6 SUMMARY

- Wildlife is a renewable natural resource and supports the life on planet earth.
- Wildlife conservation refers to the protection, preservation and propagation of rare species of plants and animals in their natural habitats.
- Wildlife management refers to the conservation of Wildlife along with the management of wildlife resources in such a way that they can meet the specific objective and requirements of human beings.
- Conservation ethics refers to the ethics of natural resources utilization, allocation, exploitation and protection.
- Ethics refers to a branch of philosophy defining a set of cultural values which guide people's behaviour at individual, social, institutional, regional and global levels.
- Conservation refers to the management of natural resource and their utilization in such a way that it can fulfil the needs of both present & future generation without disturbing the ecological balance.
- Floral diversity refers to the diversity of naturally occurring indigenous or native plants.
- The floral diversity of India is concentrated in four phytogeographically unique regions namely Himalayas, Western Ghats, Northeast India and Andaman and Nicobar Islands.
- Wildlife depletion refers to the loss of biodiversity.
- Reckless hunting of wild animals for leisure, fun and fulfilling selfish motives have caused the extinction of wild animals
- World conservation strategy (1980) is the first international documentation on living resources conservation produced with inputs from government, non-governmental organizations and other conversationalist experts.
- Habitat refers to the natural environment (constituting living & non-living entities on earth's surface) in which a particular species of organism lives.
- Polytypic habitat means different species thrives well within the same habitat.
- Wild flora and fauna helps in maintaining food chain and food web in the ecosystem.
- Conservation and preservation of wildlife includes a balance between the wildlife and human populations
- Poikilothermic or ectotherms or cold-blooded animals are those animals in which the body temperature varies along with the environmental temperature. For ex:- amphibians and reptiles

NOTES

- Homeotherms or Endotherms or warm-blood animals are the animals in which the body temperature remains constant and is independent of outside environmental temperature. For example birds and mammals.
- Geology refers to the study of earth.
- The Littoral Zone is known as the shore area of the aquatic body.
- The Limnetic Zone is known as the open water area of the aquatic system.
- The upper layer of the limnetic zone near the surface of the water is known as euphotic zone or epilimnion (warm water region).
- Benthic Zone is the bottom of the aquatic system.
- Pasture land refers to the area which is used for browsing and grazing activities. There are the areas used for grazing by herbivores such as horse, cattle, sheep, etc.
- Shelter refers to the area which fulfil biological needs of the animal as well as provide protection and safe breeding place. Shelter is generally divided as cover and space.
- Space refers to the multi-dimensional entity having both horizontal and vertical components.
- Escape cover refers to the area where animal can hide to protect itself from predators and hunters.
- Home range is referred to the space which is not defended exclusively by the animal.
- The level below which a few or no leaves are present is referred to as the browse line.
- The plant material eaten is referred to as browse.
- Habitat restoration/management/manipulation is one of the most essential methodologies of wildlife management
- Succession refers to the series of changes in ecosystems when a new environment is formed or after an established environment is disturbed by anthropogenic or some natural calamity.
- Set-back succession refers to the moving succession to an earlier stage.
- Mowing refers to the act of cutting down grass, crops, etc. with a hand implement/tool or machine.
- Species Density involves counting the total number of species within the quadrat.
- Abundance refers to the total number of individuals in a species divided by the number of quadrates per unit in which they occur.
- Species diversity is referred to as species richness and relative abundance of different species in a community and it can be calculated by using diversity index which is also known as mathematical measure of species diversity in a community.

- Remote Sensors are the instruments, which can detect objects on earth's surface via measuring the EMR (electromagnetic radiation) emitted by them.
- GIS (Geographical Information System) refers to a computerized system or mechanism that can store and interpret the vast geographical data collected by the remote sensing process.
- Cover is a habitat's ability to provide the protection that animals need to survive.
- Succession refers to the series of changes in ecosystems when a new environment is formed or after an established environment is disturbed by anthropogenic or some natural calamity.
- Set-back succession refers to the moving succession to an earlier stage.
- Mowing refers to the act of cutting down grass, crops, etc. with a hand implement/tool or machine.
- Continuous grazing involves putting livestock in an area and leaving them there as long as the area is supporting them.
- In the rotational grazing system, wildlife managers control the grazing pressure applied to the pastures by balancing the number of animals, forage and time spent on the individual pastures to be grazed.
- Logging is both an ecological and economical viable activity. It involves the process of cutting, processing and moving trees to a location for transport.
- Space refers to the multi-dimensional entity having both horizontal and vertical components
- Cover refers to the area which provides safety, shade and protection to the animal under unfavourable environmental conditions.
- The level below which a few or no leaves are present is referred to as the browse line.
- Resting cover refers to the area where animal can rest to overcome stress, tiredness or to rejuvenate after consuming food.

1.7 KEY TERMS

- **Bergman's rule:** This rule states that mammals in warmer areas are smaller when compared to mammals in colder areas i.e. mammals in colder areas are larger in size than in warmer climates
- **Gloger's rule:** This rule states that animals in the topic region are pigmented and darker than animals in the colder parts.
- **Integrated Forest Protection Scheme (IFPS):** Integrated Forest Protection Scheme was implemented during the 10th five-year plan and is continued during 11th plan.
- **Terrestrial habitat:** It includes grasslands, forests, deserts, wetlands, etc.
- **Fresh-water habitats:** It includes reservoirs of fresh-water like ponds, lakes, well, rivers, streams, etc.

NOTES

- **Marine habitats:** Marine Habitats includes sea, estuaries, intertidal zones, sea bed, reefs, brackish water, bags, etc.
- **Monotypic habitat:** Monotypic habitat is defined as a habitat in which a single species of animal or plant is the only species of its type to be found in a specific habitat and forms a monoculture.
- **Physical parameters:** Physical parameters of the habitat include topography of the habitat, soil quality & texture, availability of water, etc.
- **Topography:** Topography is defined as the form of the landscape – its shape, steepness and slope aspect, i.e., the direction at which a slope is oriented.
- **Pasture land:** Pasture land refers to the area which is used for browsing and grazing activities. There are the areas used for grazing by herbivores such as horse, cattle, sheep, etc.
- **Space:** Space refers to the multi-dimensional entity having both horizontal and vertical components.
- **Escape cover:** Escape cover refers to the area where animal can hide to protect itself from predators and hunters.
- **Home range:** Home range is referred to the space which is not defended exclusively by the animal.
- **Mowing:** Mowing refers to the act of cutting down grass, crops, etc. with a hand implement/tool or machine.
- **Species density:** species density involves counting the total number of species within the quadrat.
- **Abundance:** Abundances refers to the total number of individuals in a species divided by the number of quadrates per unit in which they occur.
- **Species diversity:** It is referred to as species richness and relative abundance of different species in a community and it can be calculated by using diversity index which is also known as mathematical measure of species diversity in a community.
- **Remote sensors:** As the name suggests, they are the instruments, which can detect objects on earth's surface via measuring the EMR (electromagnetic radiation) emitted by them.
- **GIS:** GIS (Geographical Information System) refers to a computerized system or mechanism that can store and interpret the vast geographical data collected by the remote sensing process.
- **Succession:** Succession refers to the series of changes in ecosystems when a new environment is formed or after an established environment is disturbed by anthropogenic or some natural calamity.
- **Set-Back succession:** Set-back succession refers to the moving succession to an earlier stage.
- **Mowing:** Mowing refers to the act of cutting down grass, crops, etc. with a hand implement/tool or machine.

- **Continuous grazing:** Continuous grazing involves putting livestock in an area and leaving them there as long as the area is supporting them.
- **Rotational grazing:** In the rotational grazing system, wildlife managers control the grazing pressure applied to the pastures by balancing the number of animals, forage and time spent on the individual pastures to be grazed.
- **Space**: Space refers to the multi-dimensional entity having both horizontal and vertical components.
- **Cover:** Cover refers to the area which provides safety, shade and protection to the animal under unfavourable environmental conditions.
- **Genetic diversity:** Genetic diversity refers to the changes present in the DNA sequence and hence it can be observed as differences among the individuals of the same species.
- **National parks:** National Park are the areas reserved for the protection of the wildlife.

1.8 SELF-ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions

1. Who proposed the five-kingdom classification? Which are these five kingdoms?
2. Write the scientific value of wild life?
3. What is the economic value of wild life?
4. Write about some negative values of wild life.
5. What is red data book?
6. What are the aims of World Conservation Strategy?
7. How topology is important in wildlife?
8. Why wildlife Management is important?
9. How Geo-diversity affects biodiversity?
10. What is the difference between hibernation and aestivation?
11. How the temperature effects the distribution of animal and plants?
12. Write the difference between poikilothermic and homoeothermic Animals.
13. Define Geospatial analysis.
14. What are biological effects of light on organisms?
15. How controlled grazing is helpful in proper development of vegetation?
16. Discuss the principle of Point Centred Quarter Method (PCQM).
17. What is a forage crop?
18. How the interpretation of the data is done in remote sensing.

NOTES

19. Write the real life application of remote sensing and GIS.
20. What are the various Components for GIS?
21. Write are the principals of wild life management.
22. What are the advantages of using mowing as set-back succession technique?

Long- Answer Questions

1. Discuss the criteria for the classification of threatened species.
2. Write a short note on importance of forests.
3. Elaborate on the major aim and objectives of wildlife management in India.
4. Analyse the tools and techniques of habitat analysis.
5. Briefly analyse the difference between primary and secondary succession.
6. Describe cover and its types in detail.
7. What is cover estimation? How vegetative cover can serve as ecological and management indicator.
8. Briefly describe the various shelter improvement techniques.
9. Explain the quadrate method used for ground cover estimation in detail.
10. Give a detail account of remote sensors and its types giving suitable examples.
11. Discuss the real life application of remote sensing and GIS.
12. Elaborate on succession and its types in detail.
13. Briefly explain grazing and its types.
14. Describe a few tools which are used regularly to carry out the mechanical treatment.
15. Elaborate on the various zones of a biosphere reserve.

1.9 FURTHER READING

Sinclair, Anthony R. E., John M. Fryxell and Graeme Caughley. 2009. *Wildlife Ecology, Conservation and Management.* New Jersey: Wiley.

Gupta, Tapashi. 2017. *Ecology, Wild Life Conservation and Management.* Guwahati (Assam): Eastern Book House.

Murphy, Chloe. 2020. *Wildlife Conservation and Management: Principles and Practices.* US: Syrawood Publishing House.

Newman, Michael C. 2013. *Quantitative Ecotoxicology*, 2nd Edition. UK: Taylor & Francis.

Walker C.H., R.M. Sibly, S.P. Hopkin, and D.B. Peakall. 2012. *Principles of Ecotoxicology*. 4th Edition, UK: Taylor & Francis.

Sparling, Donald W. 2017. *Basics of Ecotoxicology.* US: CRC Press.

Connell, Des W., Paul Lam, Bruce Richardson, and Rudolf Wu. 2009. *Introduction to Ecotoxicology.* US: Blackwell Publishing.

UNIT 2 WILD LIFE CONSERVATION-II

NOTES

Structure

2.0 Introduction
2.1 Objectives
2.2 Population Estimation
- 2.2.1 Population Density
- 2.2.2 Natality
- 2.2.3 Mortality
- 2.2.4 Sex-Ratio Computation
- 2.2.5 Fertility Schedules

2.3 Faecal Analysis of Ungulates and Carnivores
- 2.3.1 Faecal Samples from Carnivores
- 2.3.2 Fecal Samples from Ungulates
- 2.3.3 Hair Identification
- 2.3.4 Slide Preparation- Hair Samples
- 2.3.5 Pug-Marks
- 2.3.6 Wildlife Census

2.4 National Organization
- 2.4.1 BNHS (Bombay Natural History Society)
- 2.4.2 WII (Wildlife Institute of India)
- 2.4.3 IBWL (Indian Board for Wildlife)
- 2.4.4 WPSI (Wildlife Preservation Society of India)
- 2.4.5 WWF (Worldwide Fund for Nature)
- 2.4.6 IUCN (International Union for Conservation of Nature of Natural Resources)
- 2.4.7 CAMP (Conservation Assessment of Management Plan)
- 2.4.8 Constitutional Provisions for the Wildlife Act

2.5 Wildlife Protection Act, 1972
- 2.5.1 Drawbacks of the Wildlife (Protection) Act, 1972

2.6 Answers to 'Check Your Progress'
2.7 Summary
2.8 Key Terms
2.9 Self-Assessment Questions and Exercises
2.10 Further Reading

2.0 INTRODUCTION

Wildlife conservation is the preservation and protection of animals, plants, and their habitats. By conserving wildlife, we're ensuring that future generations can enjoy our natural world and the incredible species that live within it. To help protect wildlife, it's important to understand how species interact within their ecosystems, and how they're affected by environmental and human influences.

It is estimated that, because of human activities, current species extinction rates are about 1000 times greater than the background extinction rate (the 'normal' extinction rate that occurs without additional influence). According to the IUCN, out of all species assessed, over 27,000 are at risk of extinction and should be

NOTES

under conservation. Of these, 25% are mammals, 14% are birds, and 40% are amphibians. However, because not all species have been assessed, these numbers could be even higher.

The primary aim of 'Wildlife Management' is to protect endangered and threatened species and sub-species along with their habitats as well as those of non-threatened agricultural animals and game species. Wildlife management puts emphasis on both basic as well as applied research in education, ecology and management.

Wildlife management involves ecological principles such as habitat management which includes studying the carrying capacity of the habitat, preservation of habitat, control of habitat. Also, wildlife management ecological principles involves predator control, re-introduction of extinct species, reforestation and capture and reallocation of abundant species as well as management of desirable and undesirable species. However, for scientific management of wildlife, it is essential to know the biological background of the species involved. The inherent biological characteristics of a species such as density, migration, natality, mortality, dispersion, fertility, fecundity, breeding potential, sex-ratio, breeding season, biotic potential, growth-form, extinction threshold, etc., favor or hampers the scientific wildlife management of a species.

The three essential components of wildlife management are wildlife population, its habitat and stake holders. The conservation and management of wildlife is possible only by establishing the proper coordination and connection between these three components. Wildlife population is the major component among all the three components. The knowledge of structure and dynamics of concerned wildlife species in its habitat along with the understanding of all other species inhabiting that particular geographical area is essential in forming the basis of wildlife management.

In this unit you will study about various wild life policies population estimation, population ,population density, natality, birth rate, mortality, sex-ratio computation, fertility schedules, faecal analysis of ungulates and carnivores, hair identification, Preparation of slides for hair sample analysis, pug-marks, wildlife Census, national organizations , BNHS (Bombay Natural History Society) , various organizations involved in wildlife conservation, wildlife protection Act-1972 amendments and implementation

2.1 OBJECTIVES

After going through this unit you will be able to:

- Understand the concepts of population estimation
- Comprehend population Density
- Explain natality, birthrate and mortality
- Understand sex-ratio computation
- Illustrate Fertility schedules

- Do faecal analysis of ungulates and carnivores
- Hair Identification
- Analyze the structure of hair and hair sample
- Understand slide Preparation of hair samples
- Understand pug-marks
- Comprehend wildlife census
- Illustrate about various national organizations
- Understand about IBWL (Indian Board for wildlife) and BNHS (Bombay Natural History Society)
- Analyze various organizations involved in wildlife conservation
- Understand Wildlife protection Act 1972, implementations and amendments

NOTES

2.2 POPULATION ESTIMATION

Population dynamics refers to the study of analyses of the change in the count of wildlife population in a specified area at a particular time. Population dynamics is of key interest to wildlife managers as it lays the basic foundation of wildlife management. Changes in the growth of wildlife population is represented in the form of a curve known as population growth curve or growth form. Initially, wildlife species grows rapidly under favourable environmental conditions. However, as the population reaches the carrying capacity of the habitat, environmental resistance comes into play and its growth slows down. Wildlife population curves can be of several types namely: -

(a) Sigmoid Curve– In this, wildlife population first rises considerably and then slows down until stability is achieved. As we can see in the graph below, an 'S' shaped growth curve is formed.

Figure 2.1 depicting the 'S' shaped growth curve.

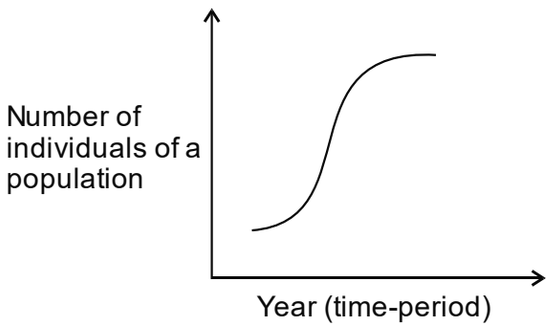


Fig. 2.1 *'S' Shaped Growth Curve*

(b) Flat Curve– In this type of growth-curve, the population remains static or in sync with its environment. As we can see in the graph, a 'J' shaped growth curve is obtained.

NOTES

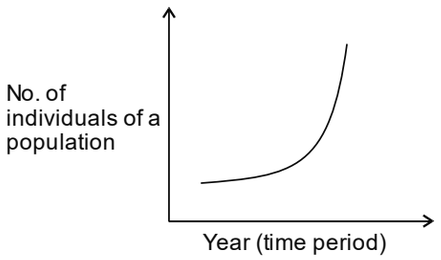


***Fig 2.2** 'J' Shaped Growth Curve.*

Figure 2.2 is depicting the 'j' shaped growth curve.

(c) **Fluctuating Type Curve**– In such curves, there is slow rise in the curve by periodical slow declines. After understanding about the population dynamics, let us understand about the following terms related to the biological basis of wildlife management.

2.2.1 Population Density

Density refers to the number of animals present per unit area. It is expressed as:-

D = P/A, where D = Density, P = Population, A = Area

It is essential to determine the density of a population in a particular habitat, as it helps in planning the management of the target species or area in a scientific way. Density represents the present status of the target species in its habitat and accordingly management can be done by various methods like habitat manipulation. However, density is not a static parameter, it varies from time to time due to several factors such as natality, morality, migration both immigration (moving of an animal into an area) or emigration (moving out of an animal from an area), dispersal (a phenomenon where the animal leaves the space or area permanently), introduction (releasing of an animal from outside into an area), etc. Hence, there should be appropriate measures to record the density on a periodical basis, so that the basic need of the animal like food, water, shelter, cover mate can be managed accordingly. Density is further categorized into following types:

(a) Absolute Density– It refers to the count of a particular species found in a unit area. This is not a fixed value and keeps on changing periodically with factors such as birth, mortality, migration, etc.

(b) Subsistence Density– It refers to the density when the count of species has already reached a stage of the carrying capacity where population can only be subsisted in the habitat. In other words, we can say that basic essentials such as food, water, shelter, cover area enough for only sustenance but not enough for other activities such as proper growth and good health. Subsistence density has a huge impact on wildlife population and its habitat:

- o At subsistence density, population quality and habitat condition will be comparatively poor because this is the ultimate in ecological density.
- o Reproduction is expected to be low and periodic die off is even if there is minor environmental fluctuations as they have no resistance in their bodies.

- o Subsistence density implies that primary implication of this will be on reproduction and health and it also implies that primary limitation to attain them is good quality food or nutrition.

(c) **Optimum Density**– As the name suggest, density is at par with the carrying capacity of the habitat. At such density level, species gets enough supply of basic essential such as food, water, shelter, cover to meet its daily needs as well as it maintains a good health, growth rate and has the high breeding capacity.

Under favourable environmental conditions, there are chances that optimum density can reach up to the level of subsistence density which is a disastrous situation. Hence, their number should be kept in check by allowing activities such as migration, controlled hunting etc.

(d) **Tolerance Density**– It refers to the number of particular species that can be sustained by a specified area. This is the number of animals that a habitat will support when intrinsic behavioural or physiological mechanism are dominant in controlling the population. It is sometimes also known as '**Saturation-Point Density'** of a particular species in a specified habitat. Tolerance density has a huge impact on wildlife population and its habitat.

- o Here, both space and intraspecific competitions become limiting welfare factors.
- o At tolerance density, animals may be in a good condition or they may be in a hierarchy of condition.
- o Subordinate animals will be in poorest of condition showing low survival as well as rate of reproduction.
- o It is a special characteristic of territorial species.
- o In a sigmoid curve, tolerance density is observed at the upper asymptote.
- o Habitat condition is good as the animals tend to defend resources, due to which there is negligible degradation of limiting factors.

(e) **Security Density**– Before understanding security density, let us first understand the concept of carrying capacity. Carrying capacity refers to the number of individuals of a particular species that can be supported or sustained by the habitat. The following are the basic features of carrying capacity.

- o Carrying capacity is the basic property of the habitat
- o It varies as supplies and requirements of limiting factors varies.
- o As carrying capacity is the property of the habitat to sustain or support the basic needs of animals, thus, the quality and productivity of the animals is defined in accordance with the aims and objectives of the management.
- o Now, security density is a concept of carrying capacity only. It refers to the stage of species density where it can be called as safe and protected from the hunters, poachers and predators. Keeping in view, pre-predator relationship, species reaches a stage referred to as 'Threshold of Security' in which species is free from danger of extinction even under adverse

NOTES

environmental conditions. However, in the absence of hunters and predators, the species can reach a disastrous subsistence density. Security density has a huge impact on wildlife population and its habitat.

- o Security density might force some of animals out of the secure habitat due to social intolerance. Due to this, animal might suffer high predation losses.
- o Dominant animals reproduce at very high rate and maintain a good health too.

2.2.2 Natality

The rate of birth in a population is referred to as Natality. Natality is expressed as new birth per unit time i.e., number of new births per 1000 population/year. Suppose, in a particular year, 1000 young ones have been born in a population. So, in that case the natality will be 1000/year. Now, say, there are 100 breeding females in the above-mentioned population. Thus, number of young ones per breeding female per year will be 20. Hence, it is called as **Specific Natality Rate**. Further natality can be categorized as-

- **Absolute Natality**–It is the number of births under ideal conditions, i.e., no competition with abundance of basic resources such as food, water, shelter, cover etc.
- **Realized Natality**– The number of births when environmental pressure comes into play is realised natality.

The following list describe the basic characteristics of natality

- **Litter Or Size of Clutch**– Litter refers to the count of 'eggs' or 'young-ones' laid or delivered by a breeding female in a single delivery. 'Litter' varies from species to species and is generally fixed for a particular species.
- **Duration of Breeding Season**– Natality rate also depends hugely on gestation period or breeding season of the species i.e., number of times per year the species is able to give birth to its offspring. If breeding season or gestation period is short, breeding female will give birth to more young ones per year, however, if the breeding period is long (as in case of elephants) a few off-springs will be produced.
- **Mating Behaviour and Sex-Ratio**– Natality rate depends upon both mating behaviour and sex-ratio. In monogamous species, maximum natality is seen when there is equal sex-ratio. However, in polygamous species, the natality rate increase if the count of female exceeds that of male.

Birth Rate

Natality in 'population ecology' is the scientific term for birth rate. Natality rate as explained above also determines the dynamics of a population and hence gives an idea whether the population (in a given habitat) is increasing declining or stable.

2.2.3 Mortality

Mortality or death rate is referred to as the number of deaths in a particular population scaled to the size of that population per unit of time. It is thus expressed

as count of death per 1000 individuals per year. Mortality is entirely different from morbidity. 'Morbidity' refers to the prevalence or incidence of a disease and 'incidence rate' refers to the number of newly appearing case of the disease per unit time. There are so many factors responsible for mortality rate.

(a) Natural factors such as old age is responsible for increased mortality rate.

(b) Anthropogenic factors including land development, habitat fragmentation as well as direct interactions with automobiles and invasive predators are important causes of wildlife morbidity and mortality.

(c) Another reason is over-production or in excess beyond the carrying capacity of the habitat.

Limiting Environmental Factors: For effective wildlife management, efforts should be taken to increase natality rate and decrease mortality rate. All the un-natural factors responsible for mortality rate are known as decimating factors.

The following decimating factors are given below:

(i) **Wildlife Diseases**– Human activities and other environmental factors and changes results in new infectious disease dynamics and patterns which are favourable to pathogens spreading geographically and between species. Wildlife animals as well as even humans fall victim to these pathogens. Wildlife management techniques involves effective control of pathogens to safeguard the interest of wild animals and their stakeholder.

Below, we will be discussing a few common wildlife diseases:-

1. Name of Disease: Foot-and-Mouth Disease (FMD)

Causative Organism: FMD is a viral disease caused by Picornavirus or Aphthovirus.

Vulnerable animals: Affects cloven-hoofed animals such as bovids including cattle, water buffalo, antelope, bison, deer, goats, etc., it can also affect hedgehogs, llamas, elephants and alpacas.

Mode of Spread:

- FMD is transmitted through animal-to-animal spread, close contact and even aerosol spread and fomites.
- Humans can also transmit this disease through clothes, skin, inanimate objects, feed supplements containing infected animal products, etc.
- Standing water and uncooked food can also contain the virus.
- Animals which are not susceptible to the disease such as wolves and dogs can also spread the disease.

Symptoms:

- Blisters in the mouth, nose and on feet that rupture typically after 24 hours. Blisters on teats of cows has also been observed.
- Weight loss and lack of appetite
- Smacking of lips along with frothing of mouth.

NOTES

- Lameness.
- Drop in production of milk in cows and swelling in testicles of mature males.
- Fever.
- Shivering.

Control of Disease:

- Vaccination is available for FMD but they don't provide cross protection against the other strains of the virus.
- Close monitoring of the animals is required and affected animals have to be quarantined from the other animals quickly. Usually affected animals are culled to prevent further transmission of infection.
- Export restrictions are imposed on countries which have are experiencing an ongoing outbreak.
- Cleaning and disinfection of affected equipment, clothes or buildings.
- Infected carcasses should be safely disposed by burial or incineration away from other animals.
- Decontamination of clothes and equipment used by animal handlers and farmers working with animals.

2. Name of Disease: Bovine spongiform encephalopathy (BSE) or mad cow disease

Causative Organism: Prions which are misfolded protein cause mad cow disease.

Vulnerable Animals: Bovids like cattle are the main victims of the disease.

Mode of Spread:

- Can be directly transmitted when healthy animals come in contact with tainted tissues belonging to infected animals.
- Feed given to animals containing prions.

Symptoms:

- Difficulty in walking and balancing
- Behavioral changes such as aggression, nervousness, etc.
- Weight loss
- Decrease in milk production

Control of Disease:

- Banning feeding of meat and bone meal to cattle.
- Import control and feeding regulations.
- Observing animals carefully to catch affected animals quickly.

3. Name of Disease: African Swine Fever Virus (ASFV)

Causative Organism: It is caused by a large, double stranded DNA virus belonging to the *Asfarviridae* family.

Vulnerable Animals: Warthogs, bushpigs and domestic pigs are mainly affected by it.

Mode of Spread:

- Soft ticks belonging to genus *Ornithodoros* act as a vector which spreads the disease to pigs.
- Swine eating infected pork products also can lead to transmission.
- Can also be transmitted through direct or indirect contact with infected pigs, feces or their bodily fluids.

Symptoms:

- High fever
- Difficulty in standing along with weakness
- Diarrhea
- Vomiting
- Red or blue blotches around ears and snout
- Large number of pigs dying within 10 days in a pig farm

Control of Disease:

- Quarantining the pigs when they are moved to a different place.
- Keeping pigs away from wild pigs and wild boars and the areas where they are found.
- Movement restriction and herd depopulation.
- Culling of pigs before they can infect others

4. Name of Disease: Equine infectious anemia (EIA) or Swamp fever

Causative Organism: Caused by retrovirus called Equine infectious anemia virus and is a lentivirus.

Vulnerable Animals:

It is a disease that only affects horses.

NOTES

NOTES

Mode of Spread:

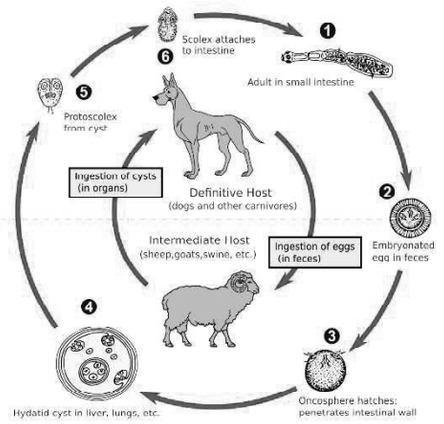
- It is transmitted by bloodsucking insects such horse-fly or deer-fly.
- It is spread through blood, milk or body secretions of infected animal.
- Contaminated surgical equipment can also transmit the disease.
- Mares can also pass on the disease to fetus through placenta.

Symptoms:

- High fever
- Anemia due to breakdown of RBC
- Swollen lower abdomen and legs
- Weak pulse and irregular heart beat

Control of Disease:

- There is no cure for the disease as it's a retrovirus so confirmed cases are euthanized as they are lifelong carriers of disease.
- A vaccine is available called 'Chinese Live Attenuated EIA Vaccine' developed in China and USA is developing one.
- Affected horses are quarantined and branded. Ther equipment is not shared between horses.



5. Name of Disease: Echinococcosis or Hydatid disease

Causative Organism: Tapeworms of *Echinococcus* type.

Vulnerable Animals: Dogs, sheep, kangaroos, pigs, dingoes, etc., are part of the tapeworm's life cycle.

Mode of Spread:

- Animals scavenging on infected carcass can consume cysts or eggs of the tapeworm and become carriers of the disease.
- Coprophagic flies, arthropods and carrion birds can also act as mechanical vectors for the eggs.

Symptoms:

- Reduced production of milk, meat and wool
- Reduced birth rate
- Multiple cysts in liver, kidneys, bones or testes of animals can cause organ damage.
- Bone fractures

Control of Disease:

- Preventing access of dogs to livestock carcasses.
- Giving dogs anthelmintic to kill adult tapeworm
- Vaccinating sheep and other cattle to prevent development of larval stage.
- Using anthelmintic bait for foxes to reduce number of carriers.

6. Name of Disease: Paratuberculosis or Johne's disease

Causative Organism: Caused by bacteria called *Mycobacterium avium* subspecies *paratuberculosis.*

Vulnerable Animals:

Affect ruminants but has also been found in rabbits, foxes and birds.

Mode of Spread:

- Infected animals can spread the bacteria in their excretion which can then infect normal cattle.
- Infected mothers can spread it to their calves through their udder.

Symptoms:

- Diarrhea and wasting
- Weight loss
- Decreased milk production
- Roughening of hair coat

Control of Disease:

- Pasteurization is utilized to kill the causal agent.

NOTES

NOTES

- Avoid overgrazing so that cattle doesn't consume soil or manure.
- Infected cows should be kept away from healthy cattle.

7. Name of Disease: Virulent Newcastle disease (VND)

Causative Organism: Causal agent is Newcastle disease virus (NDV) which is a variant of Avian Ortho Avulavirus 1 that is a negative sense, SS RNA virus.

Vulnerable Animals: Affects both domestic and wild bird species.

Mode of Spread:

- Spreads through direct contact between healthy birds and bodily fluids of infected birds.
- Transmitted through bird droppings and secretion from eyes, mouth and nose.
- Humans can also transmit it by picking up infected discharge unknowingly and bring it to healthy birds.
- Amazon parrots are carriers of disease but don't show symptoms.

Symptoms:

- Production of rough or thin shelled eggs
- Green, watery diarrhea
- Swelling of tissues around eyes and neck
- Drooping wings
- Coughing
- Twisting of head and neck

Control of Disease:

- Infected animals should be isolated immediately.
- Birds should be vaccinated before bringing them to a new flock.
- Immediate disposal of dead infected birds

8. Name of Disease: Rabies

Causative Organism: Rabies *lyssavirus*, a neurotropic virus causes rabies.

NOTES

Vulnerable Animals:

Dogs, wolves, foxes, coyotes, lions, mongoose, skunks, bats, monkeys and cats can be affected by rabies.

Mode of Spread:

- Rabies is transmitted through direct contact with an infected animal such as through broken skin, saliva or mucous membranes of eyes and nose.

Symptoms:

- Weakness
- Fever
- Headaches
- Encephalitis
- Hyper salivation
- Hydrophobia
- Aerophobia
- Confusion
- Difficulty in swallowing

Control of Disease:

- Vaccination of both stray and domestic dogs
- Keeping cattle away from wild animals or bats.
- Oral vaccine in baits to vaccinate wild animals.

9. Name of Disease: Chytridiomycosis

Causative Organism: *Batrachochytrium dendrobatidis,* a fungus is a waterborne pathogen causing the disease.

Vulnerable Animals: This disease is a global killer of amphibians like frogs. Can also affect crayfish.

Mode of Spread:

- The fungus releases its zoospores in the water causing its spread and enter the skin of the amphibians.

NOTES

- Direct contact between frogs and tadpoles or infected frogs leaving spores on ground or other streams.

Symptoms:

- Reddening of ventral skin
- Convulsion with hind limbs extension
- Sloughing of epidermis and its accumulation over the body
- Minute skin tags over the body along with ulcers
- Lethargy
- Loss of reflexes and posture becomes abnormal.

Control of Disease:

Can be controlled by raising juvenile fish in concrete raceways as the parasite lives in mud.

10. Name of Disease: White-nose syndrome (WNS)

Causative Organism: The syndrome is caused by *Pseudogymnoascus destructans* which is a fungus.

Vulnerable Animals:

The syndrome is a fatal disease which affects bats which hibernate and are found primarily in United States and Canada. Examples: Brown bat, Northern long-eared bat, Gray bat, etc.

Mode of Spread:

- A bat coming in physical contact with an infected bat is the primary mode of infection.
- A bat can also get it from infected caves or rocks.
- Human-caused transmission is also a mode of infection by carrying the fungus inadvertently from one bat roost to another through clothes, shoes, etc.

Symptoms:

- Presence of white fungal growth on the membrane of wings, ears, tail and on muzzles of bats infected with the disease.
- Scars and lesions can also be present on the wings of the bat due to the fungus.

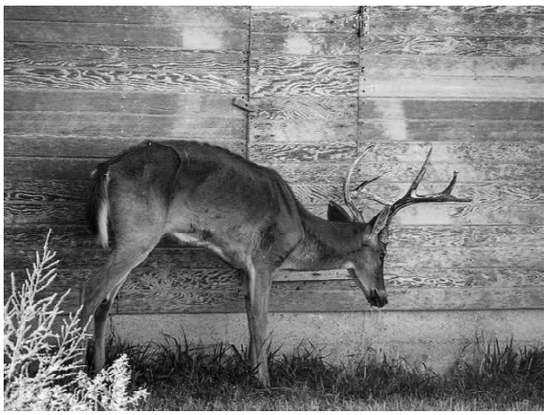
Control of Disease

- Bats treated with probiotic bacteria, *pseudomonas fluorescens* are more likely to survive post-hibernation.
- Closing caves and abandoned mines to all humans except for essential work can limit the spread of disease.

- Decontamination procedures for humans who have come in contact with bats or roosting sites.

11. **Name of Disease:** Chronic Wasting Disease (CWD) Or Zombie Deer Disease

Causative Organism: Caused by misfolded form of prion protein called prions which are found in central and peripheral nervous systems. These prions can then cause other normally folded prion protein to abnormally folded protein.



Vulnerable Animals:

CWD affects members of the deer family such as Mule deer, red deer, elk, moose, etc.

Mode of Spread:

- Can be directly transmitted by infected animals, their bodily fluids or tissue's contact with another animal.
- Infected animal's droppings can contaminate the soil and the grass growing on it and transmit the disease to the animal feeding on the grass.
- Maternal transmission can also occur in animals such as Rocky Mountain Elk.
- Sharing of food and water sources can also help spread the disease.

Symptoms:

- Difficulty in movement.
- Weight loss
- Behavioral changes such as listlessness, lowering of head, and decreased interaction with other animals, tremors and repetitive walking in a set pattern.
- Grinding of teeth and increased salivation.
- Increased drinking and urination.

Control of Disease:

- CWD is a fatal disease and cannot be treated or prevented with vaccines as it is a neurodegenerative disease.

NOTES

- As it is contagious, it is best to isolate the affected animal and then kill it. Keep the carcass away from other animals and incinerate or bury it.
- Observation of animals is crucial to catch the disease before it spreads further.

12. Name of Disease: Sylvatic Plague

Causative Organism: The disease is caused by the plague bacterium, *Yersinia pestis*

Vulnerable Animals: Primarily affects rodents like prairie dogs and some mustelids like the black-footed ferret.

Mode of Spread:

- Transmission primarily occurs through flea bites and contact with infected bodily tissue or fluids.

Symptoms:

- High body temperature
- Weakness and chills
- Dehydration
- Lack of energy and appetite
- Enlarged spleen and lymph nodes

Control of Disease:

- Using pesticide in rodent dens to kill fleas is the primary method right now to control the plague in the wild.
- Oral vaccines are being developed to control the spread of the disease.

13. Name of Disease: Whirling Disease

Causative Organism: *Myxobolus cerebralis*, a parasitic protozoan causes the disease

Vulnerable Animals: Juvenile salmonids are mainly affected by the disease.

NOTES

Mode of Spread:

- Stocking of infected fish with other fish can cause the spread of the parasite.
- Can also be spread by the alimentary tracts of fish-eating migratory birds.

Symptoms:

- Convulsive movements along with backwards jerking movement.
- Increased death rate in fry population
- Increased rate of breathing.
- Erratic darting movements and also chasing their tail.
- Spinal curvature and skull deformation.
- Darkening of skin from vent to tail.
- Gill plates get shortened.

Control of Disease

- Can be controlled by raising juvenile fish in concrete raceways as the parasite lives in mud.
- And taking out the infected fish from the breeding ponds.

14. Name of Disease: Chytridiomycosis

Causative Organism: *Batrachochytrium dendrobatidis,* a fungus is a waterborne pathogen causing the disease.

Vulnerable Animals:

This disease is a global killer of amphibians like frogs. Can also affect crayfish.

NOTES

Mode of Spread:

- The fungus releases its zoospores in the water causing its spread and enter the skin of the amphibians.
- Direct contact between frogs and tadpoles or infected frogs leaving spores on ground or other streams.

Symptoms:

- Reddening of ventral skin
- Convulsion with hind limbs extension
- Sloughing of epidermis and its accumulation over the body
- Minute skin tags over the body along with ulcers
- Lethargy
- Loss of reflexes and posture becomes abnormal.

Control of Disease:

- Can be controlled by raising juvenile fish in concrete raceways as the parasite lives in mud.

15. Name of Disease: Turtle Fibropapillomatosis

Causative Organism: *Chelonid alphaherpesvirus 5* (ChHV-5), a virus that causes epithelial tumors on surface of tissue.

Vulnerable Animals: Sea turtles are mainly affected by this disease.

NOTES

Mode of Spread:

- Turtle leeches act as mechanical vectors which transmit the disease to other turtles. These are turtle ecto-parasites and by feeding on an infected turtle's blood, are able to spread it to other turtles.

Symptoms:

- Large epithelial tumors that can affect swimming, vision, feeding, etc.
- Wartlike masses on skin
- Severe emaciation

Control of Disease

- Surgical removal of tumors is the treatment method mainly used along with electro chemotherapy, photodynamic therapy and CO_2 laser surgery.
- Cleaning of ocean as bio toxins can cause the disease.

16. Name of Disease: African Swine Fever Virus (ASFV)

Causative Organism: It is caused by a large, double stranded DNA virus belonging to the *Asfarviridae* family.

Vulnerable Animals:

Warthogs, bushpigs and domestic pigs are mainly affected by it.

Mode of Spread:

- Soft ticks belonging to genus *Ornithodoros* act as a vector which spreads the disease to pigs.
- Swine eating infected pork products also can lead to transmission.
- Can also be transmitted through direct or indirect contact with infected pigs, feces or their bodily fluids.

Symptoms:

- High fever
- Difficulty in standing along with weakness
- Diarrhea
- Vomiting
- Red or blue blotches around ears and snout
- Large number of pigs dying within 10 days in a pig farm

Control of Disease:

- Quarantining the pigs when they are moved to a different place.
- Keeping pigs away from wild pigs and wild boars and the areas where they are found.
- Movement restriction and herd depopulation.
- Culling of pigs before they can infect others

NOTES

17. Name of Disease: Bluetongue Disease or The Dancing Disease

Causative Organism: Bluetongue virus (BTV) is the causative agent of this disease.

Vulnerable Animals: Bluetongue disease affects ruminants such as sheep, cattle, yaks, goats, deer, elk, pronghorn antelope, etc.

Mode of Spread:

- Virus is transmitted by midges such as *Cullicoides imicola, Cullicoides variipennis*, etc.
- Ticks or sheep keds can also transmit the virus.

Symptoms:

- Nasal discharge and stertorous respiration
- Swelling of lips and tongue makes the tongue blue
- Swelling of face
- Excessive salivation
- High body temperature
- Foot lesions
- Knee-walking
- Torsion of neck

Control of Disease

- Quarantining the affected animal and providing vaccines with live attenuated virus can help stop the spread of disease.
- Reducing the number of midges which act as vectors.
- Preventing animals from going out when the midge activity is at its maximum.

(ii) **Environmental Factors**– Climatic conditions such as rainfall, excess heat, cold, flood, weather conditions, landslide, earthquake, when crosses through the tolerance range of animal than it ultimately leads to its death. Animal population having subsistence density are more prone to adverse climatic conditions as they have a very low tolerance range.

NOTES

(iii) **Accidents**– Wild animals are prone to accidents such as road-crossing, fire either due to natural reasons or man-created fire can cause severe mortality in a habitat.

(iv) **Illegal Hunting, Poaching, Poisoning**– Illegal hunting and poaching by hunters to fulfil their commercial selfish interest also leads to mortality among animals. Further, villagers often poison big carnivores to save themselves, their domesticated animals, fields, crops, etc. This practice leads to casualty in wild animals.

(v) **Anthropogenic Activities**– In order to fulfil the needs of over-increasing population, there is rapid degradation of forest for wood, timber, household land, construction of roads and other raw materials required for setting and running the industries. All these above activities have led to habitat fragmentation. Since, it is the habitat which provides all the basic needs like food, water, shelter, cover, protection to wild-animals. Its rapid destruction leads to high mortality in wild animals.

(vi) **Casual Movement of the Animal**– A casual movement of the animals make them prone to road accidents causing mortality. Further, due to unrestricted movement animal moves to inhabitable or inhospitable environment leading to sharp increase in mortality.

(vii) **Stress**– Animals may also come become stressed due to several reason like starvation (starvation can be due to unavailability of choice food, adverse environmental factors, lack of proper shelter, cover, forage, water,etc., dwindled sex-ratio, attainment of subsistence density by the population, intraspecific or interspecific competition for basic requirements such as forage, food, shelter, mate etc.). All these factors impose stress among animals affecting reproduction and

Hence causing a decline in the birth rate as well as a sharp increase in mortality rate.

2.2.4 Sex-Ratio Computation

Sex-ratio refers to the ratio of males to females in a population. Ideally, for a healthy population, the ratio of sexually reproducing species tends to be 1:1. However, some species such as parthenogenic species, periodically mating organisms deviate either periodically or permanently. There can be several reasons for skewed sex ratios such as age of female (mother) at birth, environmental containments, lack of proper nutrition, stress, exposure to pesticides, pest and predator, accidents as well as other anthropogenic activities chiefly being illegals-hunting, poaching ,etc. There are several sub-divisions of the sex-ratio:-

a) Primary Sex-Ratio– Refers to ratio at fertilization.

b) Secondary Sex-Ratio– Refers to ratio at birth.

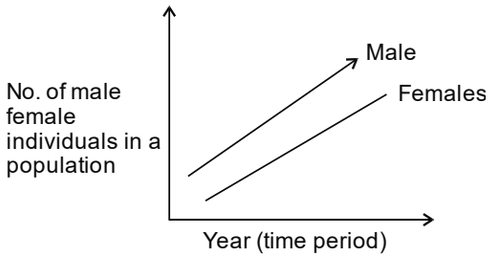
c) Tertiary Sex-Ratio– Refers to ratio in sexually mature organisms.

d) Quaternary sex-ratio– Refers to the ratio in post productive organisms.

NOTES

Now, let us understand the importance of sex-ratio in population structure and population cycles. The division of the population according to the age and sex of the individual comprises of population structure of that population. Together, both age and sex determine the growth pattern as well as the growth rate of the population. There can be several types of population structure based on male-female ratio.

(i) **Expanding Population**– If the male-female ratio is 1: 1, then such population will exhibit an expanding trend.



Such 1 : 1 male - female ratio is good for monogamous species.

The population will be an expanding population even if the number of male will be less than females as in case of polygamous species.

(ii) **Stable Population–** The population becomes stable over a period of time and sex-ratio is also maintained in healthy state.

(iii) **Irregular Population**– Sex-ratio gets irregular over a period of time but is yet not in a declining state.

(iv) **Declining Population**– Irregular declining sex-ratio leads to declining population structure so, a healthy sex-ratio is an essential factor in determining the population structure of a population.

2.2.5 Fertility Schedules

Fertility refers to the reproducing ability of an individual.

The growth and structure of a population depends upon several factor such as birth rate, morality, age, sex-class and speed of development. All these parameters are not constant and keeps on changing depending upon the surrounding environment and innate quality of the organism. The increasing rate of a population is controlled by environmental factors biological agents, age-structure, sex-class etc. even though the natural tendency of any organism is to grow. As, we have studied in the previous section, crude birth rate or birth rate refers to the birth/ 1000 population/per time. Now, two important factors should be considered here: Firstly, in sexually reproducing population only females are capable of giving birth to young ones and secondly number of births given by female varies with her age.

Fertility schedule refers to the number of female offspring produced per female. Only females are considered and counted for fertility schedule as in a sexually reproducing species, only females can give birth to young ones and thus can further produce more females. Now, let us understand this with the help of an example: -

Age of female (X)	Number of female offspring produced (Bx)
0	0
1	2
2	4
3	5
4	3
5	0
Sum	14

So, in the above table, X represent the age of a female at a given time, Bx represent the fertility schedule and summation of Bx represent the gross reproductive rate of the female i.e. average number of females produced by the breeding female in her lifetime.

However, to understand this more deeply, let us dive a bit deep and understand the concept of net reproductive rate denoted as Ro with the help of an example.

To determine the net reproductive rate (Ro), we have to understand another term survivorship value denoted by lx, gives us the probability of an individual surviving from birth to the beginning of age. To understand the calculation of net reproductive rate, let us see the following hypothetical data:

X (Age of female)	lx (Survivorship)	Bx (Fertility schedule)	lxBx (Product of survivorship and fertility schedule)
0	1	0	0.0
1	0.4	2	0.80
2	0.2	4	0.80
3	0.1	5	0.50
4	0.05	3	0.15
5	0.01	0	0.00

The value of lxBx summed over reproductive ages gives net reproductive rate:-

$$R_0 = \frac{\text{Number of female offspring produce in generation } t + 1}{\text{Number of female offspring produced in generation } t}$$

$R_0 = \sum lxbx$, if Ro is greater than 1, then it represents growing population of females.

The difference between gross reproductive and net reproductive age denotes that only a small proportion of female will survive up to maximum age and produce maximum number of offsprings. Net reproductive rate also gives an idea about the level of parental care, breeding time, reproduction time etc. Hence, all in all it gives an idea about the fitness of the individual as well as the consequences of life history characteristics of an individual to an overall population.

Another important concept here is, length of a generation (G) that is referred to as the mean period between the parent's births to production of offspring. The formula given below can be used to calculate the G, i.e., length of generation: -

$$G = \frac{\Sigma\ lxbx\ X}{R_o\ (\text{net reproductive age})}$$

NOTES

So, finally, we can also calculate the intrinsic capacity of increase by using the given formula:-

$$r = \log e\ (Ro)/G$$

Where r = intrinsic capacity

R0 = Net reproductive age

G = length of generation

Check Your Progress

1. What is Population dynamics?
2. Why it is essential to determine the density of a population?
3. What do you understand by saturation-point density?
4. What is flat curve?
5. What is the scientific term for birth rate in 'population ecology'?
6. Define mortality or death rate.
7. What do you understand by the term fertility schedule?
8. What do you understand by term Sex-ratio?

2.3 FAECAL ANALYSIS OF UNGULATES AND CARNIVORES

Collecting animal scat also known as faeces, poop, droppings is an excellent non-invasive way to study animal populations and communities. The following are the advantages of collecting animal's scat or faeces: -

- Scats Offer an insight diet as well as activity of the concerned animal
- Presently, Scat collection is an excellent non-invasive method available to study animal diets.
- Scats provides ample information about regular diet of the animal as well as where and when they eat different things.
- Provides accurate data on animal diets.
- With the advancement in technology, scientists are now able to identify species in scats that have no remaining physical parts.

Identifying Scats

Scats can be identified by:

- Carefully observing the geographical location, i.e., place from where the scat is collected.
- By observing the size of the collected scat.

- By observing the shape of the scat.
- By observing composition of the scat, i.e., what is present inside it like hair, berries, etc.?

Key For Identifying Scat

NOTES

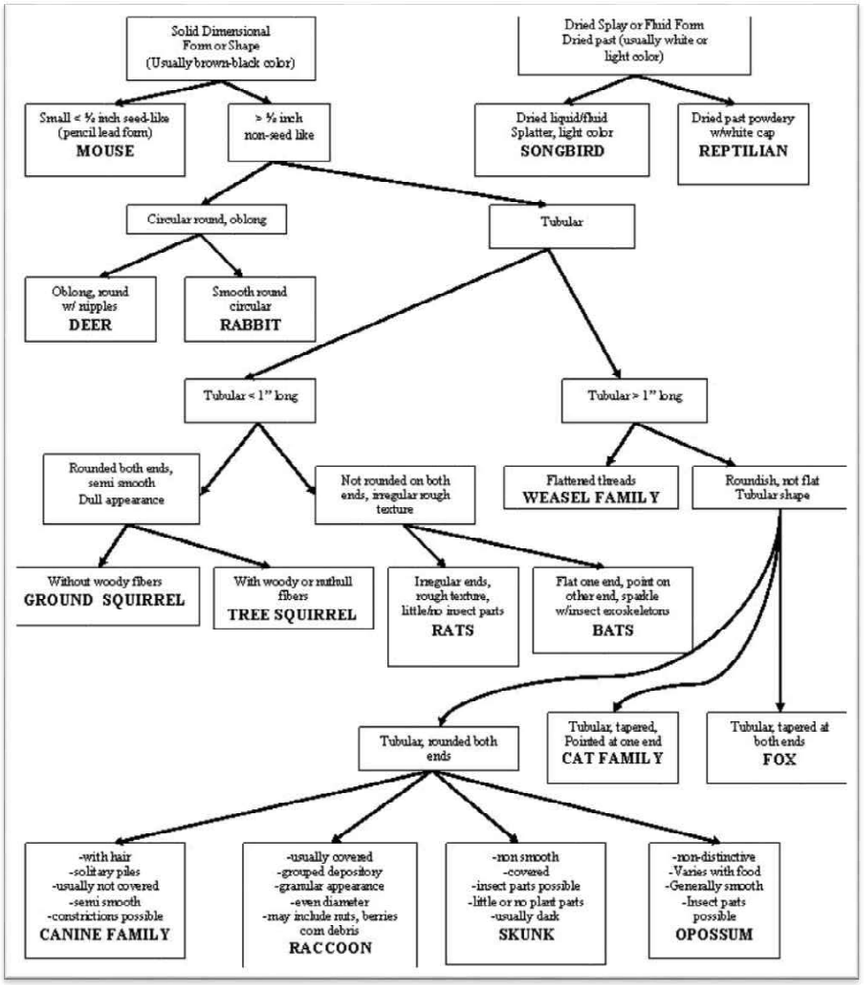


Fig. 2.3 *Key for Identifying Scat*

Figure 2.3 is Depicting the Key for Identifying Scat

Source of Information- Identification Key to wildlife Scat by Dennis Ferraro

Diet Vs Scat Morphology

The morphology of the scat varies with the diet of the animal:-

1. **Diet- Fruit diet:** Scat Morphology- Shapeless or loose tubes of crumbly material Blunt ends
2. **Diet- Meat and Organs:** Scat Morphology- Tubular with little to no twisting, Smooth , Blunt or tapered ends
3. **Hair and Bones:** Scat Morphology- Twisted, tapered ropes, Pointy Ends

NOTES

2.3.1 Faecal Samples from Carnivores

Fecal samples obtained from carnivores are cylindrical (sausage-shaped)/tubular, with sub-divisions, tapered at one of the extremities.

- Weasels (extremely twisted and narrow; one cord; long thin tapered ends)
- Canines (sometimes twisted; one cord; one or more tapered ends)
- Felines (without twist; segmented; blunt ends)
- Racoons (without twist; blunt ends)
- Beer (without twist; blunt ends)

Red Fox Faeces

- Small in size
- Tubular, tapered at one end
- With meat diet is twisted
- Fox musky scent

Coyote (Omnivorous Diet) Faeces

- Tubular
- Tapered
- Often full of bones/hair
- Often on trails and trail crossings
- Multiple scats deposits are common

Wolf Faeces

- Large
- Tubular
- Tapered on one or both ends
- Often found on trails and trail crossings

NOTES

Black Bear Faeces

- Very Large
- Multiple tubes dropped
- With a fruit diet the scat becomes a seed filled deposit either lightly packed or loose

Bobcat Faeces

- Usually segmented
- Often found middle of trail or at trail intersection
- Rarely find bones and hair in scat (excellent digestive system)
- May be accompanied by scrape on ground

Cougar Sub-Adult (Deer Fur) Mountain Lion Faeces

- Segmented, tubular, dense
- Tapered on one end
- Smooth surface
- Strong odour
- Hair and bones present
- May be accompanied by a scrape the ground
- Covered with debris

NOTES

Racoon Faeces

- Segmented, tubular
- Found at base of trees and on trails
- With a fruit diet the scat becomes a seed filled deposit either lightly packed or loose
- Known to carry parasitic roundworms

Skunk Faeces

- Small
- Tubular
- Skunky scent
- Midst of trail
- May be made up of insect parts, contains seeds or be smooth.

2.3.2 Fecal Samples from Ungulates

- Flattened faeces that accumulate in circular piles including faeces of domestic cattle, buffalo, and bison. (Stuart and Stuart 1996).

- Cylindrical or rounded pellets usually pointed at one end and concave in the other extremity. Such faecal samples are seen in all of Artiodactyls except those of Bovini tribe that includes the bisons, the buffalos and domestic cattle. Such faecal samples are well suited to semi-arid environments (Kingdom 2001).

Whitetail Deer Faeces

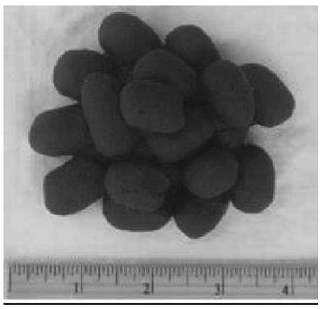
High moisture in diet will cause scat to clump Similar in size to chocolate covered raisins

Elk Faeces

Similar in size to chocolate covered almonds.

Moose-

Larger than elk, Summer diet of aquatic vegetation and herbaceous plants results in large plops



NOTES

Single Riniform (Kidney-Shaped) Faeces

This group just includes faeces of the family Equidae (Perissodactyla; Ungulata) and warthog (*Phacochoerus africanus*) (*Suidae).*

Big And Cylindrical Faeces Like Bars

That characterize large ungulates such as the elephants, hippopotamus, and rhinoceros.

Pellet/Dung Count Method

Relative abundance as well as population size estimations can be done using fecal counts. Faecal analysis helps to determine the presence/absence of a particular species in a habitat. Faecal sample analysis can be easily done for estimating the population of species like large ungulates, rabbits, small mammal as well as deer.

Thus, to conclude, modern fecal analysis can give information about:-

- Census population size
- Home range and territory size
- Effective population size
- Genetic variation
- Diet and Disease

Source of information

http://www.bear-tracker.com/

http://www.conservationscats.com/#!whyscat/c6g

NOTES

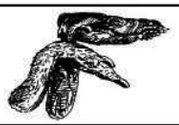
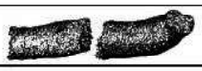
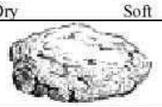
Mammals' species	Feces' measures L x W cm ∅ cm	Feces' shape	References
Felidae			
Lynx rufus (Bobcat or Wild cat)	L = 5-12.7 cm L = 10 cm		Russo & Olhausen 1987 Murie 1982 Stokes & Stokes 1986
Puma concolor (Mountain Lion or Cougar or Puma)	L = 7.6-22.8 cm 13 x 3.2 cm > 2.5 cm ∅		Russo & Olhausen 1987 Murie 1982 Johnson et al.1984
Panthera onca (Jaguar)	10.8 x 2.2 cm > 2.5 cm ∅		Murie 1982 Johnson et al.1984
Leopardus pardalis (Ocelot)	12.7 x 1.6 cm		Murie 1982
PINNIPEDIA			
Otariidae			
Eumetopias jubata (Northern Sea lion)	L = 5-6.3 cm		Murie 1982
UNGULATA (Super Order)			
ARTIOCADTYLA			
Bovidae			
Ovis canadensis (Bighorn Sheep)	L = 1.3-1.6 cm Cakes: 8 cm 1-1.3 x 0.6-0.9 cm	 Dry Soft	Russo & Olhausen 1987 Murie 1982
Oreamnos americanus (Mountain Goat)	1 x 0.4-0.6 cm Cakes: 4.3 x 2.3 cm	 Dry Soft	Murie 1982
Bison bison (Bison or Buffalo)	Cakes: 30.5 cm		Murie 1982
Ovibos moschatus (Muskox)	1 x 0.6-1 cm		Murie 1982
Antilocapridae			
Antilocapra americana (Pronghorn Antelope)	L = 1.8 cm Cakes: 4 x 0.6-1.8 x 0.8-1cm	 Dry Soft	Russo & Olhausen 1987 Murie 1982

Fig. 2.4 *Morphometric Summary of Different Mammals*

Figure 2.4 is depicting the morphometric summary of different mammals.

Source of Information: +Bioline International Official Site

2.3.3 Hair Identification

Hair is composed of dead cells that retain their structure, appearance, etc., even if detached from the animal's skin. Additionally, structure and appearance of hair is uniform among all the members of same species. This characteristics property of hair forms the basis of hair analysis. Consequently, hairs collected during field

surveys can be compared with hairs obtained from known animal pelts for identification.

The Structure of Hair

NOTES

A hair is composed of central medulla, surrounded by an outer cortex which may contain pigment granules. The surface, or cuticle, is usually composed of overlapping cuticular scales.

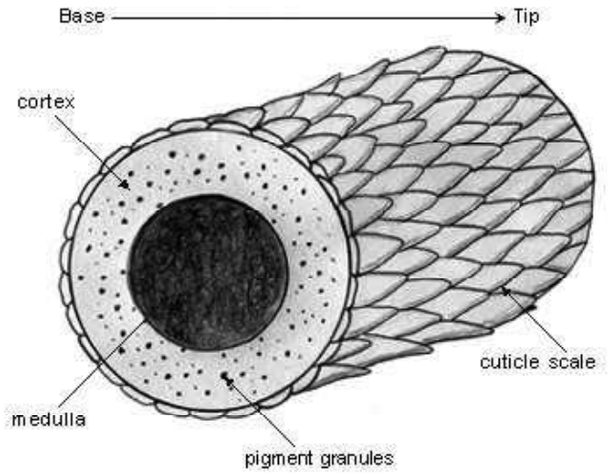


Fig.2.5 *Basic Structure of a Hair*

Figure 2.5 is illustrating the basic structure of a hair

Diagnostic Characteristics of Hair

The composition of the hair remains consistent among different species, yet the appearance of the hair can differ between species. The following diagnostic features of hair are useful for identification:

1. The general profile of the hair including the length, diameter, color and degree of wave.

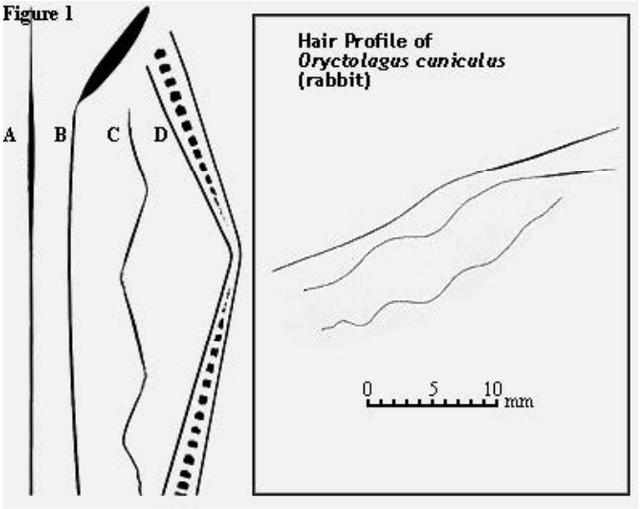


Fig. 2.6 *Typical Hair Profile.*

Figure 2.6 is depicting Typical Hair Profile.

(A) Depicts a straight hair with a shield region,

(B) Depicts a hair with a flattened and enlarged shield tip,

(C) Depicts a wavy under hair,

(D) Depicts a close-up of a constriction, which is a slight narrowing of a hair.

2. The shape of the medulla also acts as key diagnostic feature of hair. The central medulla of hair is a hollow space which is filled with shrunken cells and air. The pattern of arrangement of the cells and air spaces helps to identify the animal from which it has been collected. The medulla can be observed as a whole mount section. Figure 2.7 is depicting the medulla of the rabbit.

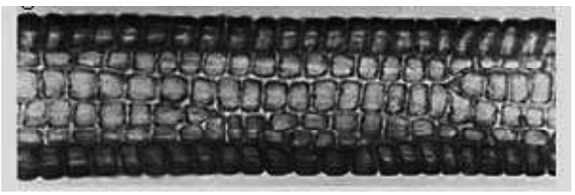


***Fig. 2.7** Medulla of the Rabbit*

3. The shape as well as appearance of the cross-section also helps in the identification of the hair. The cross-section shape of hair varies among species. It varies from being oval, eye-shaped to some other pattern. Figure 2.8 is depicting the cross-section of hair obtained from rabbit.

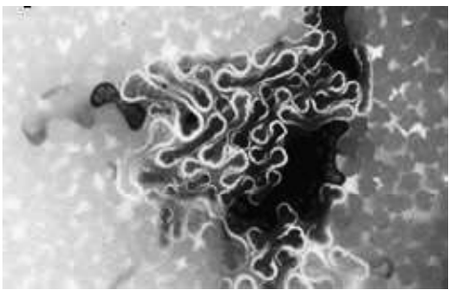


***Fig. 2.8** Cross-Section of Hair Obtained From Rabbit*

4. The pattern of scale on the hair surface helps in identifying the species. (Refer figure 2.9)

***Fig. 2.9** Scales on Hair Obtained from Rabbit*

NOTES

Hair analysis involves collecting the sample from the field, analysing it and then comparing it against the diagnostic features of previously identified hair samples. The major limitation of hair sample identification is that the researcher need to have on hand identified hair samples in order to make comparison possible. The steps for hair sample identification are as follows:

1. Examination of the hair profile
2. Examination of medulla (whole mount)
3. Examination of cross-section
4. Examination of cuticle scales

Source of Information: - http://ecobyte.com.au/analysis.html

Hair ID has been developed by Ecobyte Pvt Ltd in association with Australia's leading experts in the identification of mammals from analysis of hair samples. (Refer figure 2.10 and 2.11)

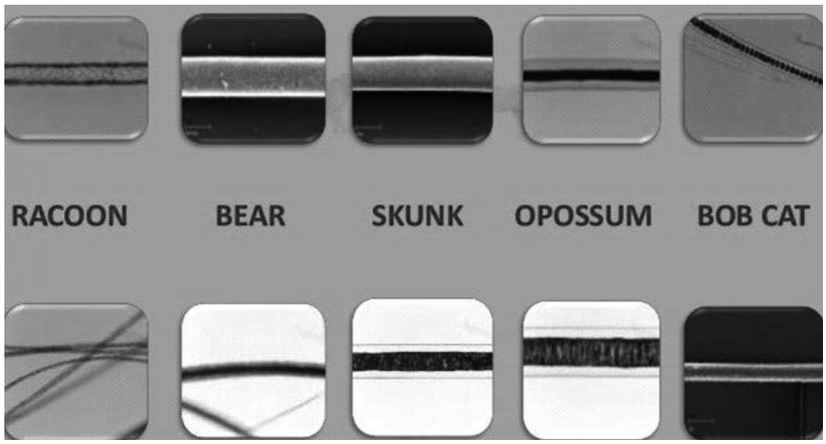


Fig. 2.10 *Hair of Different Animals*

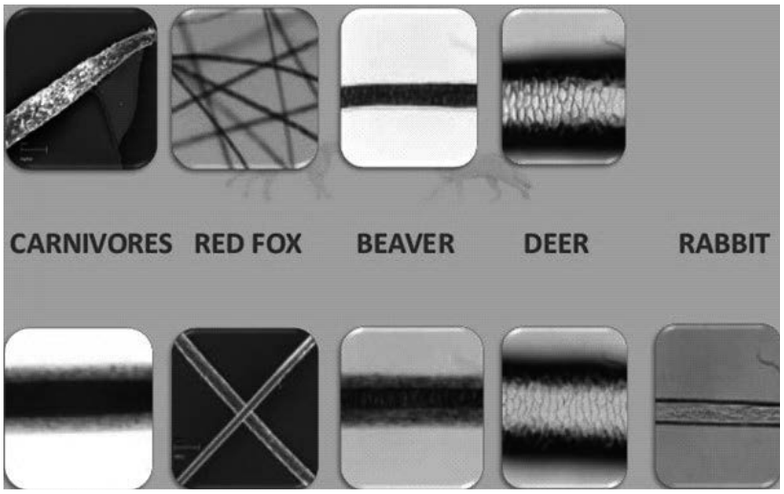


Fig. 2.11 *Hair of Different Animals*

2.3.4 Slide Preparation- Hair Samples

NOTES

Animal as well as human hairs are the best examples of natural fibres. Hair of different species varies from each other. The composition of the hair remains consistent among different species, yet the appearance of the hair can differ between species. When observed microscopically, the following diagnostic features of hair are useful for identification:

- The general profile of the hair including the length, diameter, colour and degree of wave.
- The shape of the medulla also acts as key diagnostic feature of hair. The central medulla of hair is a hollow space which is filled with shrunken cells and air. The pattern of arrangement of the cells and air spaces helps to identify the animal from which it has been collected. The medulla can be observed as a whole mount section.
- The shape as well as appearance of the cross-section also helps in the identification of the hair. The cross-section shape of hair varies among species. It varies from being oval, eye-shaped to some other pattern.
- The pattern of scale on the hair surface helps in identifying the species.

Microscopic difference in structure and appearance forms the basis for the identifying and classifying unknown hair samples.

Preparation of Slides for Hair Sample Analysis

- Take a clean microscope slide on a flat surface.
- Obtain a hair sample and label it.
- Wet a small area of the surface of the slide with the mounting medium.
- Place the hair sample in this wet area to secure the hair in place.
- Mount 1 hair on the slide.
- To observe a whole hair that is 8 inches or longer, place the hair on the slide in a figure 8 pattern and use three areas of tacking.
- Make sure that the ends and shaft are restrained enough to be completely covered by the cover slip.
- Holding the cover slip horizontally in one hand, add the mounting medium to the cover slip.
- Use about 2 drops of medium for small cover slips and about 4 drops for larger cover slips.
- Quickly invert the cover slip onto the slide starting at one edge and pivoting the other edge down.
- This helps eliminate air trapped in the hair amount.
- Observe the slides under a transmitted light microscope at 4x, 10x, and 40x.
- Examine any roots (if present) and record your observations on the worksheet.

NOTES

- Note that some variations may exist within a single hair sample.
- Scan several of the hair samples from the proximal end (root) to the distal end (tip) and observe the medullary characteristics.
- Sketch and record your observations on the worksheet.

Source of Procedure: - Chemical Principles (Experiment-7)

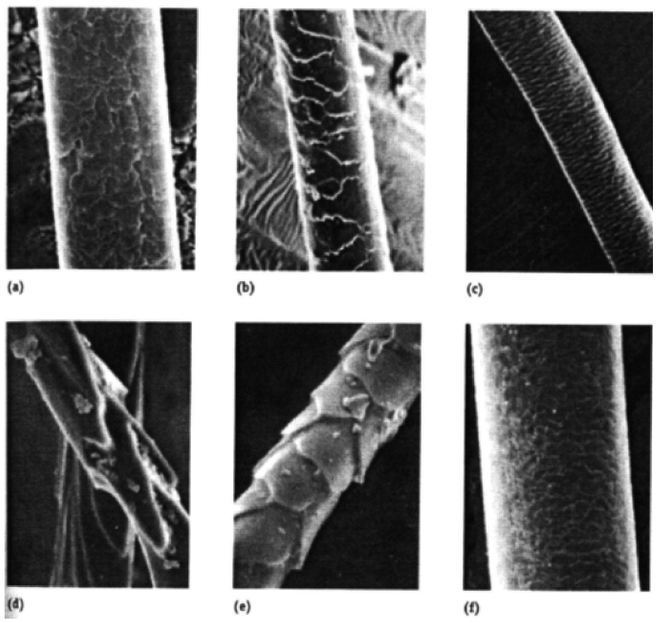


Fig. 2.12 *Medulla Patterns and Scale Patterns for Various Types of Hair*

(a) Human head hair
(b) Dog hair
(c) Deer hair
(d) Rabbit hair
(e) Cat hair
(f) Horse hair

Source of Information:International Scientific Instruments, Mountain View, Calif and New Jersey State Police

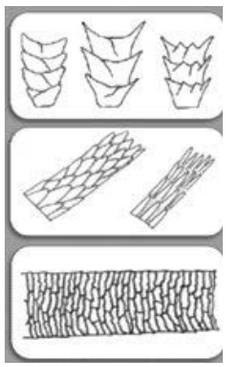


Fig.2.13 *Cuticle (Outer Covering of Hair)*

1. Coronal- Crown like scales (seen in rodents)
2. Spinous- Petal like scales (seen in cats)
3. Imbricate- Flattened scales (seen in humans as well as other animals)

NOTES

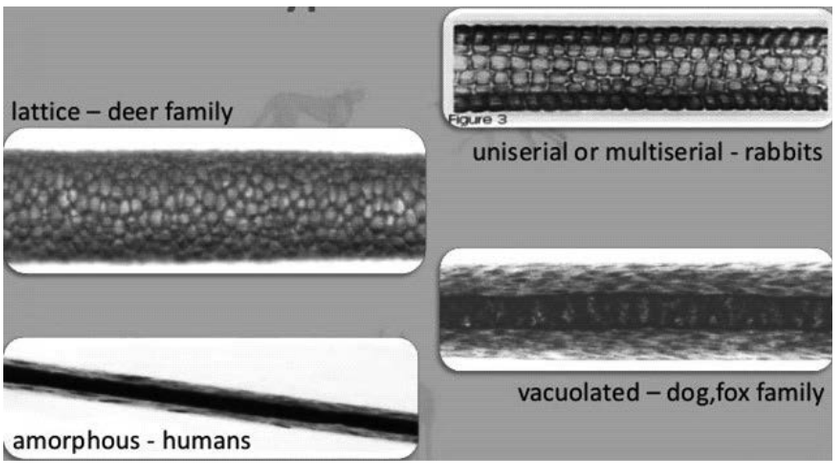


Fig. 2.14 *Medulla Type of Different Animals*

2.3.5 Pug-Marks

Pugmarks refers to the footprints of almost all the animals. Every individual animal species have distinct pugmarks as well as several other features contained in it. It can be used to identify the animal. In other words, they serve as the indirect evidence of an animal presence. Careful observation of these pugmarks can tell about animal's age, sex, health condition as well as the route and direction taken by an animal to move. Many people have learned the skill to read wildlife pugmarks for hunting purposes. Further, pugmarks serve as valuable evidence in wildlife forensics. The detailed analysis and the scientific evaluation of pugmarks obtained from crime scenes can link with a suspect and a victim. Pugmarks are produced under the following circumstance:

1. 3D-Pugmarks - The depressed pug-mark impressions are the most common type of pugmark impression formed in mud, dust, sand, snow or similar surfaces. Such pug-marks are known as three-dimensional type or sunken pug mark impressions.
2. 2D- Pugmarks- 2D pugmarks which are also referred to as surface pugmark are formed by deposition of material like dust, dirt, blood, coloured powdery substance, etc., on hard and smooth surfaces.
3. Pugmark's impression may also be produced by lifting dust or liquid material in such cases a negative print will be left on the surface.

Pug-Marks of Different Animals

Generally, the large carnivores leave the soft padded four-toed pugmarks in the jungle. These pugmarks are divided into two broad categories i.e. 'Dog family' or the 'Canidae' and 'Cat family' or the 'Felids'.

NOTES

1. Dog Family or the Canidae

- Claw marks can be easily observed in front of the toe pads.
- In the dog family, (the only exception being hyaena) the gap between the top of the pad and the two middle toes is distinctly more when compared to cats.
- Toes comparatively larger in dogs than pads. Larger toes helps them to hunt down the prey.

Fig 2.15 *Pugmark of Hyena*

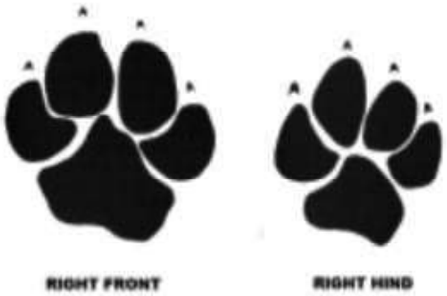


Fig. 2.16 *Pugmark of Dog (Canidae)*

2. Cat Family or the Felidae

- Claw marks are not visible easily, until they are walking on some slippery surface.
- In the dog family, (the only exception being hyena) the gap between the top of the pad and the two middle toes is distinctly more when compared to cats.
- Pad comparatively larger in cats.
- The middle toes of the felids are at different levels, especially for the hind paws.

NOTES

***Fig. 2.17** Pugmark of Cat (Felidae)*

3. Pugmarks of Sloth Bear, Elephant, Fox and Tiger

- The pug marks of sloth bear seem to be flat due to the presence of flat sole in their limbs.
- The huge size of the pugmark itself reveals the elephant's footmarks.
- The pug marks of fox is very close to the median line, creating an impression of rope walking.
- The pugmark of Tiger comprises of a pad and four-toes. A fifth toe known as the dewclaw, placed high on the front limbs only and it does not contact the ground. However, at the rear end, the pad is 3-lobed.

***Fig. 2.18** Tiger's Pugmark*

NOTES

Measurement of Pugmark

- Pugmark Length or PML refers to the measurement from the tip of the farthest toe to the base of the pad along the line of walk.
- Pugmark Breadth or PMB refers to the measurement between the outer edges of the first and last toe.
- PML as well PMB are measured by drawing a box (all corners at 90 degrees) touching the extreme ends of the pugmark.

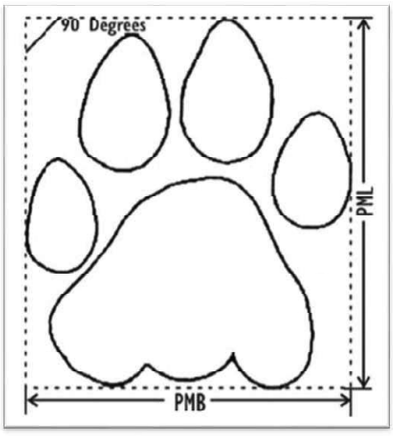


Fig. 2.19 *Measurement of PML and PMB of Pugmark*

Hind Vs Front Pug Mark

- On careful observation, it can be easily seen that front pugs are larger than hind pugs in all the carnivores.
- In a front pug, the forward most points of the two middle toes are practically at the same level.
- In hind paws, the forward most points of the two middle toes are markedly at separate levels.
- In male tigers, the PMB of the front pug is mostly greater than its PML.
- Injuries are present on front pugs as they are used for hunting down the prey

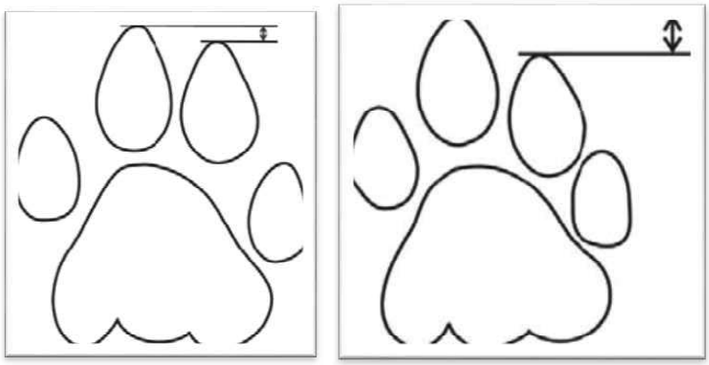


Fig. 2.20 *Depicting the Right Front and Hind Pugmark*

NOTES

Right Vs Left Pugmark

- Fold-in the thumbs of both your hands.
- Stretch out the remaining four fingers in each hand.
- In your left hand, you will observe that the third finger from the left is the longest. The same thing occurs in the tiger too.
- In your right hand, you will observe that the third finger from the right is the longest. The same thing occurs in the tiger too.

Male Vs Female Hind Pugmark

- Measurement of PML and PMB helps to determine male or female pugmark
- The pugmark of a male almost fits into a square.
- The shape of toes in a male is more rounded.
- The pugmark of a female fits into a rectangle.
- The shape of toes in a female is elongated.
- If the difference between PML and PMB is less than1.5 cms, the pugmark is likely to be that of a male.
- If the difference between PML and PMB is more than1.5 cms, the pugmark is likely to be that of a female.

Fig. 2.21 *Pugmark of 'Male'.*

Fig. 2.22 *Pugmark of 'Female'*

NOTES

Significance of Pugmarks

- They help to determine the presence of different species in the area of study.
- They help to estimate the population of large cats.
- They help in determining the sex ratio of large cats.
- They help in the identification of individual animals.

2.3.6 Wildlife Census

As we have discussed earlier, the three basic components of wildlife management are: wildlife population, habitat within which the wildlife population resides and wildlife Managers. For better wildlife management practices, coordination between all three components is essential. However, population of wildlife is one of the major components among these basic components. To have a broad idea regarding the structure of wildlife populations it is must to have an account of all wildlife species in that particular habitat or area. An inventory is prepared for the available wildlife species in that area. 'Inventory' refers to taking into account of the biological contents of a given area. Resource inventory is a pre-requisite for any management process and is mandatory for wildlife management also. The practice of managing areas for wildlife started growing across the world due to its cultural, ecological and socio-religious values leading to the making of systematic inventory of wildlife resources at all levels, i.e., from a small wildlife protected area to big national parks. Along with the attempts were made to estimate the population of a wild species in an area. This methodology of estimating the population of a particular species is referred to as census. Over a period of time the methodology of wildlife census has developed from simple counting of the annual or individual of a species to complex statistical analysis. However, wildlife census is just not limited to the number of individuals in a species, it also involves the division of the individuals in to age/sex-classes in a particular area at a particular time. Wildlife census is conducted on periodical basis as the number of individuals of a species occupying a particular area varies from season to season.

Types of Census

Types of census are broadly classified into two categories namely:

1. **Direct Count**– As the name suggests, it involves looking and counting of the individuals in a given area.
2. **Indirect Count**– As the name suggests, it involves looking for the evidences left by animals and then recording them to estimate the population. In the following sections, we will be discussing both the methods one by one: -

1. Direct Count: – It involves counting either all the animals present in the area or can also be done by sample counts. Accordingly direct count method involves: -

(a) Total Count Method– This method involves counting all the animals in a given area. However, counting all the animals in an area, particularly a large area is not an easy task at all and involves huge resources. Moreover, it is not considered a feasible method for several wild species such as birds and mammals. Further,

there is no certainty whether all the individual of the species are counted or not. Hence, total count method is not a popular choice of 'census' among wildlife managers, yet it is used at some locations or area such as:

- This method is employed where either the wildlife area is limited or wildlife population is not very large.
- It can be used in area where there is very dense forest having lots of small hills.
- It can be used where wildlife species to be counted should be large for easy visibility and recognition.
- If the number is less, then the chances of duplication or double counting of the animal increases.
- However, even if all the above conditions are met, this method is not suitable for small, solitary or nocturnal method.

Total count method can be further divided into two more types namely: -

(i) **Spatial Method**– This method involves counting at a particular time for the entire area. It can be done by:

- **Direct Method**– This method is generally used for deer, pheasants as well as for prairie chicken on booming grounds. This method survey deer within enclosure and to sample habitat with well-defined boundaries. In states, where road system is laid on the sugar mile this unit is used as the boundary of the area to be surveyed. The short coming of this method is that it requires tremendous man-power, but on the other hand even inexperienced scouts can work well with some guidance and training. In this method, scouts or observers are stationed at three sides of the square mile and then count all the deer passing to their right between them and the next observer. All the other observers line up on the fourth side of the square mile and walk through it driving the deer (or any wild animal or target animal species) past the counters. The observers (drivers) count all the deer that run back through the drive line. The methodology is known as 'drive method' because animal or target species are driven from their hidden places in the area of census.
- **Territory Mapping Method**– Another method included in the spatial census is territory mapping methods. This method is generally used for quail, song birds etc. This method involves either mapping of a true territory (defended area) or mapping something in between a home range and territory. The individual flocks of a target species are differentiated on the basis of sex and age composition of the flocks, special track or most importantly the size of the flock. These separate flocks are than plotted on maps to avoid duplicate counting. The principal observer or investigator utilizes his own observations and those of other either working on the same or living nearby to the area of interest with the arrival of modern methods like radio telemetry, territorial mapping methods have become more refined and advanced.

NOTES

- o **Visual Methods**– These methodologies can be applied successfully to the open area or in the locations where target species approach collectively at a specific time. Counting is then performed by positioning the observer near to them with the help of binoculars. Such exercise should be repeated for a few days before reaching a final conclusion.
- o **Photographic Methods**– This method is generally used for small species or species which gather together in large number in groups for ex:- photographs of birds may be clicked and its number can then be counted later on.

(ii) **Temporal Methods**– In this methodology, a 'point' is considered as a spatial dimension and the count is made of all animals passing the point during some interval of time. Temporal census methods are adapted for the migratory animals that cross from one habitat to other. However, this is a tedious task and also not very reliable when compared to other spatial methods.

(b) **Sample Count Method**– As the total count method involves huge expenditure, energy and man-power, another methodology known as sample or incomplete count is used in which only a part of the population is directly counted. In this method, a representative sample of the target species is chosen in a particular area. In the representative sample, individuals of the target species are then counted by 'total count' method. Finally, to get the total number of animals in the area, whole area is multiplied by the density of the population of the sample area.

Note– Here, sample refers to the small representative group or fraction picked from the 'aggregate of population' regarding which we want to collect information is called as 'sample'. The methodology of forming a sample is referred to as sampling.

Thus, counting by the 'total count' method is carried out only in the sample area and the results obtained in thus extrapolated for the entire area of interest. This method involves a lot of mathematical and statistical analysis but is generally quick, reliable, less taxing, and less expensive and requires low man-power when compared to 'total count' method. The following are the types of sample count method:

(i) **Block Count**– In this methodology, the entire area is divided into smaller parts based on habitat's nature as well as the density of the animal species. A single part may be divided into sub-parts if the animal's density varies within it. Further, each part is distinguished based on dominating species or forest density or pasture area etc. Finally, total area of each stratum is calculated by adding the parts of each stratum. Now, some representative 'sample area' should be picked from each part/sub part. Finally, as mentioned above, counting of target species should be carried by applying 'total count' method. After this, density in each sample area for each species is obtained.

$$\text{Density} = \frac{\text{Number of species in the sample area}}{\text{Area of the plot of interest}}$$

Followed by calculating average density in each stratum. Now, for each stratum, population of each species is obtained by multiplying into total area of the stratum with average density of the species and then 95% confidence limit is calculated.

NOTES

Methodology mentioned above is explained with the help of a simple example given below:-

Total area of census — 1200 km^2

Stratum A – 400 km^2

Stratum B – 400 km^2

Stratum C — 400 km^2

Suppose, the sample size is 10%

In that case, individual sample size in each area will be 40 km^2 and total sample size of all three stratum will be 120 km^2.

Now, suppose each sample area in each stratum is having '10' (ten) sample plots of 4 km^2, then in this case total number of sample plots in all three stratum will be '30'. Hence, from each stratum ten sample plots will be picked and total count method is applied for different type of species and noted down in the proforma.

(ii) **Vehicle Transect or Road-Count Method:** This methodology involves counting of animals on roads by travelling in a vehicle at a specific time with a fixed speed. The distance for such transects is fixed and the counting is regularly done on the transect.

$$\text{Density of animal} = \frac{\text{Number of animals observed}}{\text{Length of transect}}$$

When the width of the transect is fixed on either side of the road, it is referred to as the fixed width transect. In the open-width transect method, animals are counted on both side of transect up to sighting distance and the angular distance from the observer is also counted. After carrying out several observations, a suitable sighting distance is calculated for each species, after that this suitable distance or optimum distance serves as mean perpendicular sighting distance. During counting, all animals will be counted along this distance only.

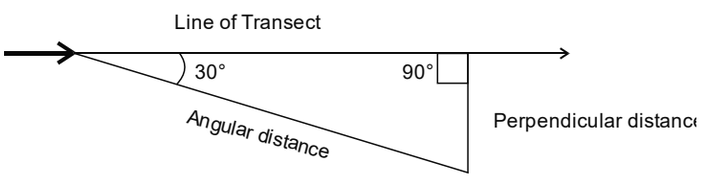


Fig. 2.23 *Showing Different Distances In Transect – Count.*

Mean Density, $D = \frac{N}{L \times 2 \times r}$, where

N – Total number of particular species seen in transect

L — Length of transect in Km

2 — Multiplying for both side of transect

r — Mean angular sighting distance in Km.

Average value of r = 1.6 × (where, X = Mean perpendicular distance)

NOTES

(iii) **King-Census Method: –** In this method, data is collected by the investigator or observer by walking along the transect. Transects are laid over the entire area. Individual transects should be laid making sure it covers all the ecosystems present in that location or area. For example: - suppose, a census area is having a different ecosystem namely grassland, shrub land, etc., then in that case transects should be placed in all these three vegetation types. This type of method becomes important in area where there is no road and hence the observer has to cover the transect on foot. Again, as mentioned above also, angular distance and angle of sighting the perpendicular distance of animals from the transect line is calculated. This perpendicular distance is used for calculating the area of the transect walked. The density of the animal is observed with the use of the formula mentioned above. Again, here also line of transect could be fixed or open as explained in road-transect method also. Density calculated for a particular transect is then extrapolated for similar areas to arrive at density figures for the entire census area.

2. Indirect Count: – In the indirect count method, evidences left by animals such as pellet, dung, faecal matter, nests, etc., are recorded to estimate the relative abundance of that animal. The following are the type of indirect count method:

- **Pug-mark Technique**– This methodology is generally used for large carnivores such as leopard and tiger. The fundamental basis behind this technique is that pug-marks of different species varies from each other in terms of size, shape etc. and hence are characteristic of a particular species. This method does not give only count of the species but also divide the individuals into different sex-class as the pug-marks or foot-prints of the male, female and cubs of a species are different from each other. Animal leaves behind pug-marks or foot prints while walking on mud, sand or snow. Detailed Pug-mark key is mentioned in the previous section.
- **Dung-pellet Count**– Dung/pellet count is generally used to estimate the population of ungulates. Ungulates are members of primarily large animals with hooves. Ungulates involves animals such as cattle, pigs, camels, sheep, deer, giraffes etc. In this method, pellet groups are counted in sample plots preferably on the transect as observed in the king's census method above. Species wise density of the animal is then calculated based on the data collected on the number of pellet groups. The pre-requisite for this methodology is information on defecation rate of animal surveyed, knowledge on pellet size and pellet rate in a day. Detailed dung-pellet count key is mentioned in the previous section.

Apart from the direct and indirect methods, there are other methods also, which are collectively referred to as miscellaneous methods. So, we can say that wildlife census method can be direct, indirect or miscellaneous.

(3) Miscellaneous Method: Under the miscellaneous methods, following are two different type of method:

- **Water-Hole Census**– In this methodology, data is collected by seeing and counting the animal collected at water hole. This recording is done for 24 hours, i.e., preferably from 6 am to 6 pm on full moon days. This method is based on the assumption that every animal has a basic need to drink water at least once in a day and will probability visit the water bodies or holes once a day. A counting of different species of animals can then be performed and later on the data is compiled species wise to arrive at density figures. This method gives an index regarding the population and not the estimate of the population. If the information on frequency of water consumption by animals for the area is collected, figures compiled can be corrected for the repeat visitors and hence the trend can be refined a bit. In India, this is one of the most popular methodology, as it does not require much skill and training.
- **Capture-Recapture Method** This methodology is somewhat between direct and indirect methods. In this method, few animals are captured and tagged or marked and then released and the procedure is repeated and checked for the tagged animals.

Problems with Wildlife Census

The following are problems or disadvantages of wildlife census:

1. Animal may be staying in thick vegetation and hence it becomes difficult to trace it via any of the above method.
2. Animal may be active at certain time of the day or certain season and may be left out from the counting.
3. Random distribution or clumped distribution or gregarious behaviour makes the sampling tedious when compared to systematic distribution.
4. As animals are mobile, they keep on moving from one place to other, hence, census should be conducted at short intervals.
5. Rate of reproduction of animal is another concern which should be kept in mind while conducting wildlife census.
6. Mortality or introduction of animal to the ecosystem should also be considered.
7. Another, problem with the inventory technique is that it considers all the members of the population have an equal probability of being included in the census, though this is not the case.

Advantages of Wildlife Census

1. It gives a fair idea about the population of a particular species at a habitat in a specified time.
2. It gives wildlife managers an idea about the status of the wild species i.e. endangered or about to extinct etc. Hence, it provides an opportunity to

NOTES

wildlife manages to properly plan and execute their wildlife management methods in scientific way.

3. This also gives an idea about the species-population in different seasons as well as to determine their growth rate, longevity, rate of reproduction, carrying capacity etc.
4. It gives an idea about area-wise or habitat wise density on map, graph, table etc.
5. In census, there is detailed description of data, time, area methodology, sample size, habitat etc. and all this data lays a strong foundation for the key wildlife management practices as well as conservation.
6. Thus, all in all census forms the basis of habitat and wildlife management.

Check Your Progress

9. How Scats can be identified?
10. Define 3D-Pugmarks.
11. Which characteristics property of hair forms the basis of hair analysis?
12. What do you understand by the term inventory in wildlife ecology?

2.4 NATIONAL ORGANIZATION

All organic forms of life on earth i.e. human, plants and animals are interlinked to each other and any disturbance or degradation of one life form may threaten the existence of other life form on planet earth. All life forms on earth are organized as producers, consumers or decomposes which in turn are linked to each other via food chain i.e. a hierarchal process of energy transfer from one life form to other. Several food chains may be connected to each other in a complicated process known as food web where several species are present at each tropic level. Thus, degradation at any level in the food web may lead to huge imbalance in the ecosystem which may further threaten the existence of man on this planet. Now, nature maintain all their life forms especially plant and animals which constitute the life support system on earth in well balanced cycles. Over a period of time, technological advancement and development has acted as an intervention to these will balanced cycles of the nature. To maintain sustainability, a balance between the nature's life supporting systems (renewable and non-renewable resources) and man's development activity is required. To achieve this, we require what is called as 'Wildlife-Conservation'. However, due to over 'Commercial Exploitation' as well as lack of awareness regarding the advantages of conservation of earth's natural (wild) flora and fauna are the primary reason of depletion of 'Wildlife' and hence there is an urgent need for 'Wildlife Conservation'. 'Wildlife Management' is the potent solution to this global issue of achieving eco-balance. It aims at achieving ecological balance or protecting the natural flora and fauna of earth by applying scientific technologies.

Now, for effective conservation and management of wildlife, there are three basic requirements:

1. Adequate food and water for the survival of different wild species.
2. Adequate free space for different species to move freely as well as to co-exist without interference.
3. Safe place to breed or reproduce leading to propagation of the species.

To achieve this, following measures have been adopted over a period of time.

- Reserve forest, national parks, sanctuaries should be left unexploited.
- Cutting- zone or cutting area should be restricted in limited blocks at a time.
- Mixed vegetation should be encouraged instead of single crop.
- Natural opening of the water poles, riversides and forests should be protected or fiercely guarded against poachers
- Controlled burning of grassland should be promoted
- Grazing by domestic livestock should be discouraged in the areas marked as 'Wildlife Zone'. Grazing by domestic animal in the 'Wildlife Zone' is responsible for transmission of several contagious disease from domestic animals to wildlife. Moreover, this should also be done to prevent intense competition between the domestic and wild animals for the available food and space.
- Cultivation should be discouraged near 'Wildlife-Zone' to prevent the risk of ecological hazards due to use of pesticides.
- To maintain the normal health of the wild animals, provision for dust-baths and artificial salt-licks should be made in the 'Wildlife Zone'.
- Scientific studies should be encouraged by research institutes, wildlife workers, researchers and several other recognized government and non-government organizations to assess the situation of threatened species or endangered species of wild-animals. Accordingly, adequate provisions should be made to improve their health-status or to provide them with safer breeding grounds.

To attain the above-mentioned goals, several government organizations, non-governmental organizations, voluntary organizations as well as advisory bodies are actively engaged to the cause of wildlife conservation.

CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora)

Habitat destruction and unchecked commercial exploitation of animals are the primary reason behind the declining wildlife species. For example:- Trading of horns of rhinoceros, fur of jackal, musk-pods, (crocodile skins etc.) is popular among smugglers, poachers and traders as they get heavy compensation in exchange of all these products in the international trade market. As, there is little check on such illegal trades within and between the nations, it become one of the major problems faced by countries all over the world.

NOTES

To prevent the unchecked commercial exploitation of wild fauna and flora through International trade, CITES, i.e., 'Convention On International Trade In Endangered Species Of Fauna And Flora' was signed at Washington on 3rd March, 1973 and subsequently came into effect on 1st July, 1975 after formal ratification (approval) by ten countries. CITES consists of 183 member-countries till date that abide by CITES regulations by implementing legislation within their own borders to implement those rules and regulations. CITES is located in Geneva, Switzerland and is administered by the United Nations under its UNEP (United Nations Environment Programme) Wing. Even though, CITES is legally binding on the Parties, however, it does not take the place of national laws. CITES provides the basic outline to be respected by each Party, which has to implement its own native/ national legislation to ensure that CITES is executed at the national level. The government of India formally signed this in July, 1974 and became a member to it from 18th October, 1976. Accordingly, Inspector general of forest and Director of wildlife preservation are the management authorities in India, supported by three scientific authorities namely:

1. Director, Zoological survey of India (ZSI)
2. Director, Botanical survey of India (BSI)
3. Director, central Marine Fishers Research Institute

The representatives from all the state holders meet every two to three years to discuss the convention and its implementation.

Aims and Objectives of the Convention: -

(i) Different species of wild flora and fauna-forms an irreplaceable part of earth's natural system.

(ii) Nations should be aware of scientific, cultural, aesthetic recreational and economic value of these wild species.

(iii) People of states – are the best protectors of their own natural wild flora and fauna

(iv) Mutual cooperation between the nations is must to prevent illegal trade as well as selfish unchecked over exploitation of wild flora and fauna species. All the necessary steps should be taken to ensure the implementation of above-mentioned objectives.

CITES Classification of CITES Appendix

Subsequently, rules and regulations were framed by the contracting nation of the 'CITES', to prevent the illegal trade of wildlife and its products. CITES classified plants as well as animals into three categories, based on how threatened they are. Approximately, 5,600 species of animals and 30,000 species of plants are protected by CITES against over-exploitation through international trade. All of them are listed under the three CITES Appendices that are mentioned below:

NOTES

Appendix	Description	Examples
CITES Appendix-I	Appendix I consist of species that are in **risk of extinction** Commercial trade is prohibited for all the species covered by the Appendix-I Special permission is required for import as well as export. Commercial trade is permitted just for research purpose and that too only if the origin country safeguards the trade in such a way that it will not harm the chance of survival of that particular species.	Approximately 1200 species on the list Appendix I include:- Red Panda (*Ailurus fulgens*) Western Gorilla (*Gorilla gorilla*) Chimpanzee species (*Pan sp.*) Tigers (*Panthera tigris* subspecies) Asiatic lion (*Panthera leo persica*) Leopards (*Panthera pardus*) Jaguar (*Panthera onca*) Cheetah (*Acinonyx jubatus*) Asian Elephant (*Elephas maximus*) some populations of African Bush Elephant (*Loxodonta africana*) The Dugong And Manatees (Sirenia), and all Rhinoceros species (except some Southern African subspecies populations)
CITES Appendix-II	Appendix II include species that aren't facing the risk of imminent extinction, however, they need to be monitored so that any commercial trade does not become a threat to their existence Commercial trade permits are obtained legally and only if the native country ensures that its harvesting and trade will not harm the chance of survival of that particular species	Approximately, 34,419 species on the list. Examples of species listed on Appendix II are: The Great White Shark (*Carcharodon carcharias*) the American Black Bear (*Ursus americanus*) Hartmann's Mountain Zebra (*Equus zebra hartmannae*) Green Iguana (*Iguana iguana*) Queen Conch (*Strombus gigas*) Emperor Scorpion (*Pandinus imperator*) Mertens' water monitor (*Varanus mertensi*) Big Leaf Mahogany (*Swietenia macrophylla*) Lignum Vitae 'Ironwood' (*Guaiacum officinale*).
CITES Appendix-III	Appendix III includes species that are protected in at least one country. Regulations for these species included in Appendix III varies However, the country that requested the listing can issue export permits Export from other countries requires a certificate of origin.	Approximately, 170 species are included in the list Examples of species listed on Appendix III:- Two-Toed Sloth (*Choloepus hoffmanni*) by Costa Rica Sitatunga (*Tragelaphus spekii*) by Ghana African Civet (*Civettictis civetta*) by Botswana Alligator Snapping Turtle (*Macrochelys temminckii*) by the USA

Special Note:-

- A species may be added to or removed from both Appendix I as well as Appendix II, or a species can be moved between them, only by the Conference of the Parties.

- Though, from Appendix III, a species may be added or removed at any time and by any Party individually.

Source of Information: Convention on International Trade in Endangered Species of Wild Fauna and Flora | CITES

NOTES

GTF (Global Tiger Forum)

Under the chairmanship of Mr. Kamalnath Choudhary, India established this forum in March, 1993 (Delhi) to discuss the protection of tiger population in world. Tiger is an endangered species and its rate of extinction is so rapid that wildlife workers predicted its extinction within a few decades. Skin, Bones and meat of tigers are in high demand as they are used for ornamental purpose, line production as well as manufacture of medicines. To prevent the illegal traders of products derived from Tiger, GTF has been formed by India with following aims and objectives.

- Cooperation among the countries to prevent illegal trafficking of products derived from Tiger
- Improving the habitat conditions.
- Promoting conservation programme.
- Fund raising activities for conservation of Tigers.
- Establishments of new natural parks.
- Establishment of new wildlife sanctuaries
- Establishment of special squad to prevent illegals hunting and poaching of tigers by traders, poachers and smugglers.

2.4.1 BNHS (Bombay Natural History Society)

- In 1883, eight nature-loving residents of Bombay namely Dr. D. MacDonald, Mr. E. H. Aitken, Col. C. Swinhoe, Mr. J. C. Anderson, Mr. J. Johnston, Dr. Atmaram Pandurang, Dr. G. A. Maconochie and Dr. Sakharam Arjun decided to exchange notes and exhibit interesting specimens of natural history. They came together at Bombay's Victoria and Albert Museum on September 15 and constituted the Bombay Natural History Society.
- Consequently, Bombay Natural History Society(BNHS) was founded on 15 September, 1883
- It is one of the largest non-governmental organisations in India.
- Several prominent naturalists, including the ornithologists Salim Ali and S. Dillon Ripley, have been associated with this organization.
- BNHS is the partner of Birdlife International in India.
- The logo of BNHS is great hornbill.
- The logo was created in 1933.
- This organization is engaged in conservation and biodiversity research.
- The primary goal of the organization is to spread awareness about nature via science-based research, conservation advocacy, education, scientific publications, nature tours as well as other programmes.

NOTES

- BNHS gives financial aids to several research projects.
- It has been designated as 'Scientific and Industrial Research Organization' by the department of science and technology (DST).
- It also publishes the esteemed '*Journal of the Bombay Natural History Society*'.
- BNHS primarily focus on 'Conservation Research' that includes species research, landscape research, and sea scale research.
- BNHS also focuses on 'Conservation Action'.
- IT also focuses on 'Conservation Education'.
- **The Bombay Natural History Society (BNHS)** is a pan-India wildlife research organization that has been promoting the cause of nature conservation since 1883.
- **BNHS Mission:** Conservation of nature, primarily biological diversity through action based on research, education and public awareness.
- **BNHS Vision:** Premier independent scientific organization with a broad based constituency, excelling in the conservation of threatened species and habitats.

Various Initiatives of BNHS

(a) National Dragonflies Festival:

- National Dragonflies festival was started in 2018.
- The major role of this festival is to update the public about the essential role played by dragonflies in our environment.
- BNHS has been organising 'National Dragonflies Festival' since then in association with WWF India, 'United Nations Development Programme', 'United Nations Environment Programme' and 'National Biodiversity Board of India'.
- The local events which are the part of this nationwide festival are also organised by WWF India in association with various state agencies.
- For example, 'Thumbi Mahotsavam' is a state butterfly festival of Kerala which is organised as a part of National Dragonfly festival.

(b) Asian Water Bird Census

- Asian water bird census is an annual exercise undertaken in India by BNHS in association with Wetland International
- Asian water bird census is conducted in the month of January every year
- This exercise is a part of 'International Water Bird Census', an international exercise.
- In this, passionate bird watchers count the birds by observing them near their respective breeding grounds.
- This exercise also creates awareness among public regarding bird species and health of the wetlands, which are facing threat due to extreme human intervention.

Source of Information: (Home page of BNHS)

NOTES

2.4.2 WII (Wildlife Institute of India)

- Wildlife Institute of India was established in 1982.
- The institute is based in Dehradun, Uttarakhand, India.
- It is located in Chandrabani, which is close to the southern forests of Dehradun
- It is an internationally acclaimed Institution
- The Institute's peaceful campus that has been cautiously developed to make state of the art infrastructure inspires research scholars.
- It offers several training programs, academic courses and advisory in wildlife research and management.
- Wildlife institute of India is actively involved in research activities/programmes throughout the country on issues related to biodiversity
- The primary objective of the campus is to build up scientific knowledge on wildlife resources.
- It also aims at training workers at several levels for conservation and management of wildlife.
- It actively carries out research relevant to management including the development of techniques appropriate to Indian conditions.
- Apart from the above-mentioned objectives, it also advices on specific wildlife management problems.
- Wildlife institute of India actively work together with international organizations on wildlife research, management and training.
- Wildlife institute of India has developed as a regional centre of international importance on wildlife and natural resource conservation.

Source of Information: Wildlife Institute of India, an Autonomous Institute of MoEF, Govt. of India (wii.gov.in)

2.4.3 IBWL (Indian Board for Wildlife)

- In 1952, keeping in view the rapid decline of wild flora and fauna, the government of India had constituted an advisory body designated as 'The Indian Board for Wildlife' (IBWL).
- The Indian Board for Wildlife was chaired by the Prime Minister.
- Since its initiation, twenty-one meetings have been organized and numerous significant decisions has been taken concerning the conservation of wildlife
- During the 1970's, the Government of India appointed a committee for recommending legislative measures and administrative machinery for ensuring environmental protection.
- Consequently, a comprehensive central legislation was enacted in 1972 called the Wildlife (Protection) Act for providing special legal protection to our wildlife as well as to the endangered species of fauna in particular.

- The Wildlife (Protection) Act, 1972 has been amended, the latest being in 2006.

As per the amendment of the Act in 2002, a provision was incorporated for 'The Constitution of 'The National Board for Wildlife' (NBWL), replacing the original 'Indian Board for Wildlife' (IBWL).

National Board for Wildlife (NBWL) is a statutory board constituted on 22nd September 2003 under section 5 of the wild life protection Act, 1972.

The NBWL is chaired by the honourable Prime Minister.

The NBWL consist 47 members including The Chairman.

Amongst 47 members, 19 members are ex-officio members.

National Board of Wildlife (NBWL) performs following functions:

(a) NBWL is involved with the development of protected areas as well as to provide them with required support. Eligible protected areas are: National parks, wildlife sanctuaries, conservation reserves and community reserves, other than those availing central assistance under the CSS- Project Tiger, which is duly notified under the Wildlife Protection Act, 1972 and is under the control of the chief wildlife wardens.

(b) NBWL is also involved with providing protection to wildlife outside the protected areas. Considerable wildlife as well as natural resources are present outside the protected areas. This element seeks to support the conservation of wildlife in these areas. Eligible areas under this category are high value biodiversity areas outside Pass; Areas contiguous to pass corridors are given priority.

(c) NBWL also aims at funding and managing recovery Programme for critically endangered species as well as habitats. Initially 17 species namely: Snow Leopard, Bustard (including Floricans), Dolphin, Hangul, Nilgiri Tahr, Marine Turtles, Dugongs, Edible Nest Swiftlet, Asian Wild Buffalo, Nicobar Megapode, Manipur Brow-antlered Deer, Vultures, Malabar Civet, Indian Rhinoceros, Asiatic Lion, Swamp Deer and Jerdon's Courser have been regarded as endangered species.

(d) The Director, Wildlife Preservation, Government of India, in consultation with the Wildlife Institute of India or the relevant scientific bodies and with due approval of the standing committee of the NBWL can initiate other recovery programmes or wind up an ongoing programme.

(e) NBWL on 21st January, 2002 considered 'Wild Life Conservation Strategy', 2002 and recommended that lands falling within 10 km of the boundaries of National Parks and Sanctuaries should be notified as eco-fragile zones under Section 3(v) of the Environment (Protection) Act and Rule 5 Sub-Rule 5(viii) and (x) of Environment (Protection) Rules.

(f) The following criteria, as proposed by the ministry were decided by the NBWL for declaration of 'Eco-Sensitive Zones' around National Parks or Sanctuaries:

NOTES

- o Full protection to the endemic species in its entire range.
- o Development processes should be carried out in such a way as to not damage or destroy the habitat of critically endangered or any other threatened species.
- o Full protection to biological corridors.
- o Complete protection to highly complex as well as diversified ecosystems vulnerable to permanent damage, like coral reefs, mangroves, etc.
- o Sites concerning with reproductive, breeding or nurturing behaviour of rare as well as threatened species.
- o Presence of pristine forests.
- o Steep slopes (more than 60º).

Source of Information: Introduction | The Official Website of Ministry of Environment, Forest and Climate Change, Government of India (moef.gov.in)

2.4.4 WPSI (Wildlife Preservation Society of India)

- This society was launched at the instance of Shri P.D. Stracey, an IFS officer on 13th April 1958.
- The headquarter of WPSI is based at Dehradun.
- The aim and objective of the WPSI is to tackle the problem of India's vanishing wildlife from the 'public' side.
- H.H. Maharaja Pratap Singh of Nabha became the first President of the society.
- Society published its first wildlife journal titled '*Çheetal*' on 13th October, 1958.
- Emblem of a *Cheetal* bust was designed by Maharaj Kumar of Rajpipla for *Cheetal* Journal.
- In April, 1960, WPSI broadened its horizon into an all-India body and was re-named as 'The Wildlife Preservation Society of India'.
- The constitution of the society was adopted on 15th April, 1960.
- The Society was re-registered in 2017 as 'The Wildlife Preservation Society' (WPS).
- WPS encourages awareness and information among people in the field of conservation, preservation and management of numerous flora and fauna.
- WPS aids in implementation of Wildlife Protection Act.
- WPS actively encourages wildlife tourism.
- WPS collaborates with state Government of India and other societies as well as institutions for the interest of wildlife protection.
- WPS actively engages in activities related to protection, propagation and conservation of wildlife.

Source of Information: WPSI - Wildlife Protection Society of India

2.4.5 WWF (Worldwide Fund for Nature)

NOTES

- WWF- Worldwide fund for Nature is an international non-profit organization which is dedicated to the preservation as well as conservation of nature and its different species.
- It is the world's biggest conservation organization.
- It was founded on 29th April, 1961.
- Its precursor organisation was the Conservation Foundation.
- Its original name was 'World Wildlife Fund'.
- WWF headquarters is located in Gland, Switzerland.
- The Logo of WWF is the 'Panda'.
- Panda is chosen as the logo of WWF as giant panda called as 'Chi-Chi' was brought to London Zoo in 1958 even before the establishment of WWF.
- WWF supports more than 1000 projects throughout the world in partnership with people, bodies and governments.
- Through its various projects, WWF Nature aims to check the degradation of the earth's natural environment as well as to create a future in which human beings live in absolute agreement/synchronization with the nature.
- "To conserve nature and reduce the most pressing threats to the diversity of life on Earth." is the mission statement of WWF Nature.
- WWF works predominantly in the areas of wildlife, climate, food, forests, freshwater and oceans.
- WWF Nature majorly focus on the conservation of elephants, gorillas, sea turtles, polar bears, giant pandas, whales, tigers, rhinos, whales and elephants.
- The well-known 'Living Planet Report' (Began in 1998) is published by the WWF every two years.
- 'Living Planet Report' talks about the health of the planet and the effect of anthropogenic activities on nature
- 'Living Planet Report' is based on the 'Living Planet Index' and the calculations of ecological footprints.
- 'Living Planet Index' is a measure of the state of the world's biological diversity based on population trends of vertebrate species in terrestrial, freshwater, and marine habitats.

Source of Information: Welcome to WWF-India | WWF India

WWF India (World Wide Fund for Nature- India)

- WWF- India was established in November 1969 as the charitable public trust.
- The major aim and objectives of the World Wide Fund for Nature – India are as follows:
- To conserve the worldwide biological diversity
- To promote the sustained use of renewable resources

NOTES

- To reduce pollution and wasteful consumption
- WWF-India works actively in the following landscapes as well as critical regions for its conservation programme: Satpuda, Maikal, Terai Arc, Sunderbans, Kanchendzonga, Western Himalayas ,Western Arunachal, North Bank, Western Ghats, Nilgiris, Kaziranga, Karbi, Anglong, Bharatpur and Western India
- There are a few priority species for which WWF-India plans its work:
  - o Bengal tiger
  - o Asian elephant
  - o Indian or greater one-horned rhino
  - o Ganges river dolphin
  - o Snow leopard
  - o Red panda

Source of Information: Welcome to WWF-India | WWF India

2.4.6 IUCN (International Union for Conservation of Nature of Natural resources)

- IUCN is an international organization that works in the field of conservation of the world's flora and fauna.
- The IUCN is a global union comprising of government as well as civil society organisations.
- IUCN members include States, non-governmental organizations, indigenous peoples, organisations, experts, and government agencies, etc.
- IUCN was established in the year 1948.
- When it was first set up in Fontainebleau (France), it was the first international environmental union.
- With more than 1400 organisations as its members, the IUCN is an international authority on the status of the natural world.
- The IUCN's Secretariat is in Gland, Switzerland.
- The Secretariat is headed by a Director-General.
- The IUCN has 8 regional offices and other offices in over 50 countries.
- IUCN has the essential tools and knowledge repository to help the entire world in conservation of nature as well as to ensure sustainable development.
- It works actively in the area of sustainable development and also recommends actions to tackle the rapid depletion of resources.
- It works actively to conserve the numerous flora and fauna species.
- The primary objective of this organization is to promote international cooperation, provide scientific knowledge and essential tools to aid conservation action.
- In the year 1964, IUCN established the 'IUCN Red List of Threatened Species'.

NOTES

- IUCN played a major role in the establishment of major international conventions like the Ramsar Convention on Wetlands, the Convention on International Trade in Endangered Species etc.
- In the year 1980, in association with the UNEP and the 'World Wildlife Fund' (WWF), IUCN published the 'World Conservation Strategy'.
- In the year 1992, the United Nations granted official observer status to the IUCN.
- The IUCN convenes the IUCN 'World Conservation Congress' every four years.
- The objective of the Congress is to bring together its various members, who vote on recommendations and set the agenda for the global conservation efforts.
- The chief governing body of the IUCN is the IUCN Council that guides the organisation in between the Congress sessions.
- The members elect Commission Chairs who serve for a four-year term.
- IUCN Red Data list categories and criteria is the easiest and broadly accepted system for classifying species at high risk of global extinction.

A-E criteria used to evaluate whether the taxon belongs to the IUCN Red List category is as follows:

Population size reduction. Population reduction measured over the longer of 10 years or 3 generations

A- Geographic range of the taxon

B- Small population size and decline

C- Very small or restricted population

D- Quantitative Analysis- Indicating the probability of extinction in the wild

The nine categories in the IUCN red list are as follows:

1. **Extinct (EX)** – Taxon is referred to extinct when no known individuals are remaining. A taxon is referred in the 'EX' category only when the exhaustive surveys failed to record the individual in its historic range.
2. **Extinct in the Wild (EW)** – This taxon is known to survive only in captivity, or as a naturalized population outside its historic range. A taxon is referred in the 'EW' category only when the exhaustive surveys failed to record the individual in its historic range.
3. **Critically Endangered (CR)** – Taxon that is facing extremely high risk of extinction in the wild. All the collected evidences for the taxon indicates that it meets any of the criteria A to E for critically endangered.
4. **Endangered (EN)** – Taxon that is facing high risk of extinction in the wild. All the collected evidences for the taxon indicates that it meets any of the criteria A to E for Endangered.
5. **Vulnerable (VU)** – Taxon that is facing high risk of endangerment in the wild. All the collected evidences for the taxon indicates that it meets any of the criteria A to E for vulnerable.

NOTES

6. **Near Threatened (NT)** – Taxon that is likely to become endangered soon i.e. in the near future.
7. **Least Concern (LC)** – Taxon has been carefully evaluated against the 'Red List Criteria' but does not qualify for critically endangered, endangered, vulnerable of near threatened categories.
8. **Data Deficient (DD)** – Not enough data is available on the abundance and distribution of the taxon to assess its risk of extinction.
9. **Not Evaluated (NE) –** Taxon has not yet been evaluated against the IUCN criteria

The information cited in the IUCN Red List is used by several organizations as follows**:**

(a) International Agreements such as CITES, Ramsar Convention use the IUCN Red List data to make significant decisions in sync with the status of nature

(b) World Bank Group performance standard uses the IUCN Red List data to evaluate the risk of damage to biodiversity due to ever increasing infrastructure as well as global projects

(c) Zoos and National parks also use the information in IUCN Red data list to upgrade important policies like parks regulations on a routine basis.

Source of Information: International Union for Conservation of Nature - IUCN

Source of Information: IUCN Red List of Threatened Species

SSC (Species Survival Commission) (IUCN-SSC)

- This is a science-based network consisting of more than 90,000 volunteer experts from almost every country of the world
- All these experts work together towards achieving the vision of **"**A just world that values and conserves nature through positive action to reduce the loss of diversity of life on earth".
- These experts works independently as well as with the IUCN 'Global Species Programme' to build knowledge on the status of species and threats to them, as well as to provide advice, develop policies, guidelines and facilitate conservation planning.
- SSC acts as a catalyst in conservation action and enables IUCN to influence policy and assist societies in biodiversity conservation.

Source of Information: Species Survival Commission | IUCN

2.4.7 CAMP (Conservation Assessment of Management Plan)

- The primary objective of the 'Conservation Assessment and Management Plan' (CAMP) process is to facilitate objective and systematic prioritization of research and management actions required for both *in situ* and *ex situ* species conservation.

- To date, more than 50 taxon-based CAMPs have been organized, including Antelope, Galliformes, Boid and Python snakes, Hornbills, Tapirs, Varanid and Iguanas lizards, Falconiformes, small carnivores penguins, Equids, Rhinos and Wild Cattle.
- The process has been effectively applied to invertebrates as well as plants including Indian medicinal plants and *Partula* snails
- The CAMP process assembles 10 to 40 experts including SSC, wildlife managers, Specialist group members, research scholars, representatives of the academic community and private sector to assess threat status of all taxa in a broad taxonomic group
- William Conway (1995) stated that **"***The CAMP's proven heuristic value and constant refinement and expansion have made it one of the most imaginative and productive organizing forces for species conservation today"*.
- Data gathering is majorly focused on the most recent available stats, evaluations, estimates, informed speculations and presumptions as well as identification of needed knowledge that allow:
  (a) Assignment to IUCN category of threat.
  (b) Broad-based management recommendations.
  (c) Specific conservation-oriented research approvals, sanctions, recommendations suitable to generate the much-needed knowledge to develop supplementary comprehensive management and recovery programs both *in situ* or *ex situ*.

Source of Information: CAMP - Conservation Assessment and Management Plan (frlht.org)

WPSI- (Wildlife Protection Society of India)

- WPSI was founded in 1994 by Belinda Wright, its Executive Director.
- Belinda Wright was an award-winning wildlife photographer as well as filmmaker till she took up the cause of conservation.
- WPSI is a registered non-profit organisation, funded by a wide range of Indian and international donors.
- The Society's Board Members include leading conservationists and business people.
- The major objective of the WPSI is to focus on India's growing wildlife crisis.
- WPSI provides support as well as significant information to government authorities to fight illegal poaching and wildlife trade - chiefly of wild tigers.
- It also aims at protecting endangered species in their native habitat through support, training as well as awareness by working actively with both local communities and government agencies.
- WPSI has now widened its efforts to deal with human-animal conflicts and also to provide support for research projects.

Source of Information: WPSI - Wildlife Protection Society of India - News (wpsi-india.org)

NOTES

Due to human activities, we are observing the disturbed ecosystem as well as life support system. Due to reckless hunting of wild animals and birds, several species have been brought to endangered or threatened category and other are on the verge of extinction. To protect wildlife, several measures have been adopted in history from time to time before wildlife protection Act, 1972:-

- First forest conservator was appointed in the year 1806 at madras presidency.
- In Bombay, an eminent botanist was appointed as forest conservator in 1847.
- Administrative structure of forest department was framed in the year 1855.
- In 1864, Sir Brandis was chosen as the first forest Inspector General.
- Wild Birds protection act came into force in the year 1887.
- Wild Birds and Animals Protection Act, was passed in 1912 to prevent their reckless hunting.
- Wild Birds and Animals Protection Act, 1912 was amended in the year 1935 and came to known as Wild Birds and Animals Protection Act, 1935.
- However, all these laws did not give much importance to the conservation and propagation of wild animals throughout the country.
- Wildlife and its products are the sole responsibility of forest officers under Indian forest Act, 1927.
- To prevent the depletion of wildlife, British rulers implemented several acts from time to time like Rhino Protection Act, Arms act, Elephant protection Act.
- BNHS (Bombay Natural History Society) formulated 'Bombay Wild Animals and Wild Birds Protection Act, 1951'.
- An advisory board named as Central Board for wildlife was set up in 1952.
- This board was later renamed as Indian Board for Wildlife (IBWL).

2.4.8 Constitutional Provisions for the Wildlife Act

- **Article 48A** of the Constitution of India directs the state to protect as well as improve the environment and safeguard wildlife and forests.
- This article was added to the Constitution by the 42nd Amendment in 1976.
- **Article 51A** imposes certain fundamental duties for the people of India.
- One of the fundamental duties of the citizens of India is to protect and improve the natural environment including lakes, forests, and rivers as well as to have consideration, concern, sympathy, kindness, and love for living creatures.

Need for the 'Wildlife Protection Act'

1. There was an urgent need to prevent rapid decline of India's wildlife population. It required legal protection from illegal activities like poaching, smuggling, etc. For example, it was reported by Edward Pritchard Gee (A naturalist), that at the turn of the 20th century, India was home to close

approximately 40000 tigers. However, a census in 1972 showed this number radically reduced to about 1827.

2. Such drastic decline in wild flora and fauna can lead to severe ecological imbalance, which in long term affects several aspects of climate and ecosystem.
3. The Wild Birds and Animals Protection Act, 1935 had become completely outdated.
4. The outdated laws had the provision for punishments, which were not proportionate with the severity of the offence as well as financial benefits that occurred from illegal activities such as poaching and trading in wildlife produce.

2.5 WILDLIFE PROTECTION ACT, 1972

- Wildlife protection Act was formulated in the year 1972.
- It covers all the aspects of wildlife conservation like conservation, propagation, protection, trading, scientific management and administration.
- Act aimed at opening natural parks of sanctuaries to preserve the wild flora and fauna.
- It acts as a deterrent to illegal hunting, poaching and smuggling activities.
- The Act provides for the formation of wildlife advisory boards, wildlife wardens, specifies their powers and duties, etc.
- It helped India become a party to the 'Convention on International Trade in Endangered Species' (CITES) of wild fauna and flora.
- To present the unchecked commercial exploitation of wild fauna and flora through International trade, CITES, i.e., +546 convention on 'International Trade in Endangered Species of Fauna and Flora' was signed at Washington on 3rd March, 1973 and subsequently came into effect on 1st July, 1975 after formal ratification (approval) by ten countries.
- The government of India formally signed this in July, 1974 and became a member to it from 18th October, 1976.
- For the first time, a comprehensive list of the endangered wildlife of the country was prepared.
- The Act imposes a ban on the trade or commerce in scheduled animals.
- It provides for legal powers to officers and punishment to offenders.
- It provides for captive breeding programme for endangered species.
- Its provisions paved the way for the formation of the **Central Zoo Authority** (CZA)
- CZA is the central body responsible for the oversight of zoos in India. It was established in 1992.
- CZA consist of a chair person, team members and a member secretary.
- They shall hold office for a period of three years.

NOTES

- The following are the functions of 'Central Zoo Authority':
  - o To specify the minimum standards for housing, maintenance and veterinary care of the animals kept in a zoo.
  - o To evaluate and assess the functioning of zoos with respect to the prescribed standards or norms.
  - o To recognize or derecognize zoos.
  - o To identify the endangered species of wild animals for purposes of captive breeding as well as to assign duty in this respect to a zoo.
  - o To manage the acquisition, exchange and loaning of animals for breeding purposes.
  - o To ensure availability and maintenance of stud-books of endangered species of wild animals bred in captivity.
  - o To identify urgencies and themes with regard to display of captive animals in a zoo.
  - o To manage training of zoo employees/workers in India as well as outside India.
  - o To manage and organize research in captive breeding.
  - o To manage educational programmes for the purposes of zoos.
  - o To provide technical assistance to zoos for the purpose of proper management as well as development on scientific lines.
  - o To perform other activities that might be necessary to convey the purposes of this Act with regard to zoos.
- Act has been framed in VII chapters consisting of 66 sections and VI schedules.
- Chapter I deals with definitions related to wildlife.
- Chapter II deals with appointment of wildlife officers.
- Chapter III consists of six schedules and aimed at controlling illegal hunting of wild animals.
- **Schedule I**
  - o Schedule I covers '**Endangered Species'**.
  - o These species require absolute protection
  - o Stringent/Strict punishments are there for violating the laws under this Schedule.
  - o Species under Schedule I are prohibited from hunting throughout India, except under special circumstances like threat to human life.
  - o The Trade of these animals is prohibited.
  - o Examples include: tiger, blackbuck, Himalayan Brown Bear, Brow-Antlered Deer, Blue whale, Common Dolphin, Cheetah, Clouded Leopard, hornbills, Indian Gazelle, etc.

- **Schedule II**
  - Animals listed under Schedule II are also rendered very high protection.
  - Trade is prohibited.
  - Animals listed under Schedule II cannot be hunted except under threat to human life.
  - Examples include : Kohinoor (insect), Assamese Macaque, Bengal Hanuman langur, Large Indian Civet, Indian Fox, Larger Kashmir Flying Squirrel, Kashmir Fox, etc.
- **Schedule III and IV**.
  - Schedule III and IV also have roughly the same provisions as mentioned above; however, they cover animals that are not in danger of becoming extinct or endangered
  - The punishments under this section are less when compared to Schedule I and II.
  - Examples include: hyena, Himalayan rat, porcupine, flying fox, Malabar tree toad, etc.
- **Schedule V**
  - Schedule V include the list of vermin animals
  - Schedule V include animals that can be hunted.
  - For hunting purpose, the hunter has to apply for a license to the District Forest Officer who will permit a hunter to shoot for a specific season in a very restricted area.
  - Any violation can lead to termination of the hunting license.
  - Examples include: mice, rat, common crow, fruit bats, etc.
  - Vermin means wild mammals as well as birds which are harmful to crops, farm animals or which carry disease.
  - In India, wild animals can be stated as vermin under specific criteria: they have become dangerous to human life or property or standing crop; they have become disabled or diseased as to be beyond recovery.
  - The Central Government via notification may declare any wild animal other than those specified to be vermin for any given area for a fixed period of time.
  - The hunted wildlife is regarded as government property
- **Schedule VI**
  - Schedule VI contains plants that are prohibited from cultivation and planting
  - Examples include: pitcher plant, blue Vanda, Red Vanda, Kuth, etc.
- Chapter IV promotes the creation of closed areas, sanctuaries, National parts for the conservation, preservation and propagation of wildlife.
- Chapter V deals with penalties and punishments against the offenders.

NOTES

- Chapter VI deals with official power of the officers in preventing offence as well as enforcing the act to punish the violators of the act.
- Chapter VII is a Miscellaneous Chapter having details about rewards to person, state government etc.
- Wild life (protection) Act 1972, was amended in 1982, 1986, 1991, 1993
  - o The **National Board for Wildlife (NBWL)** was constituted as a statutory organization under the provisions of this Act.
  - o In 1952, keeping in view the rapid decline of wild flora and fauna, the Government of India had constituted an advisory body designated as the Indian Board for Wildlife (IBWL).
  - o During the 1970's, the Government of India appointed a committee for recommending legislative measures and administrative machinery for ensuring environmental protection.
  - o Consequently, a comprehensive central legislation was enacted in 1972 called the Wildlife (Protection) Act for providing special legal protection to our wildlife as well as to the endangered species of fauna in particular.
  - o The Wildlife (Protection) Act, 1972 has been amended, the latest being in 2006.
  - o As per the amendment of the Act in 2002, a provision was incorporated for the constitution of the National Board for Wildlife (NBWL), replacing the original Indian Board for Wildlife (IBWL).
  - o National Board for Wildlife (NBWL) is a statutory Board constituted on 22nd September 2003 under Section 5 of the Wild Life (Protection) Act, 1972.
  - o Wildlife protection act 1972, also provided for the establishment of the National Tiger Conservation Authority (NTCA).
  - o The primary aim and objective of NTCA is to strengthen tiger conservation in India.
  - o It is a statutory body of the Ministry of Environment, Forest and Climate Change (MoEFCC) with an overall supervisory and coordination part, performing capacities as given in the Act.
  - o It gives statutory authority to Project Tiger which was launched in 1973 and has put the endangered tiger on a guaranteed path of revival by protecting it from extinction.

Protected Areas under the Wildlife Protection Act

There are five types of protected areas as provided under the Act. They are described below:

1. National Parks: National Park refers to the area reserved for the protection of the wildlife. The following are the features of the National Parks:

- They protect not only wildlife but entire ecosystem composed of flora, fauna, landscape, historical objects etc.

NOTES

- National parks are exclusively designated by the government for the conservation of wildlife and biodiversity due to its natural, cultural and historical significance.
- They provide safe habitat to several species organisms such as microorganisms, insects, birds, animals.
- National parks also acts as source of recreation and produces an amusement of the environmental and scenic heritage, without harming the wildlife.
- Human interference is strictly prohibited.
- Activities like grazing, hunting, plantation, cultivation, predation, destruction of flowering non-flowering plants is highly prohibited.
- IUCN has declared national parks in category II of protected areas.
- Visit to national parks requires permission from the concerned authorities.

The first National park in India was established in the year 1935. Now known as famous 'Jim Corbett National Park', it was earlier referred to as 'Hailey National Park'. By the year 1970, India had only five national park with the implementation of wildlife protection Act (1972), for the conservation of endangered species, the number of national parks in India has witnessed a huge rise.

2. Wildlife Sanctuary: A wildlife sanctuary refers to the protected area reserved only for the conservation of wild animals only. The following are the features of the wildlife sanctuaries:-

- These places are reserved exclusively for wild animals such as insects, reptiles, birds, mammals etc.
- It provides safe habitat to these wild animals where they can live, reproduce and maintains a healthy population.
- Boundaries of a wildlife sanctuary are not fixed.
- Human activities such as collecting minor forest products, harvesting of timber, private ownership and etc. are allowed till such activities are not hampering the interest of wild animals.
- Controlled biotic interference such as tourist activity are permitted.

3. Tiger Reserves: Tiger reserves are areas reserved for protection of tiger in the country.

- The State government on the recommendation of the 'National Tiger Conservation Authority' (NTCA) may notify an area as a tiger reserve, for which it first has to prepare a tiger conservation plan.
- Environment Minister is the Chairman of the NTCA.
- (NTCA) is a statutory body of the Ministry, with an overarching supervisory/ coordination role, performing functions as provided in the Wildlife (Protection) Act, 1972**.**
- NTCA was launched in 2005, following the recommendations of the Tiger Task Force.
- NTCA was given statutory status by 2006 amendment of Wildlife (Protection) Act, 1972**.**

NOTES

- Project Tiger was launched in 1973 with 9 tiger reserves for conserving our national animal, the tiger.
- Currently, the Project Tiger coverage has increased to 50**,** spread out in 18 tiger range states.
- Jim Corbett National Park is the oldest national park in India.
- It was established in 1936 as Hailey National Park to protect the endangered Bengal tiger.
- It became the tiger reserve in 1973.
- The tiger reserves are established on a core/buffer strategy.
- The core areas have the legal status of a national park or a sanctuary,
- The buffer or peripheral areas represent a mix of forest as well as non-forest land, managed as a multiple use area.
- Ministry of 'Environment, Forests and Climate Change' provides central assistance to the tiger States for tiger conservation in selected tiger reserves.

4. Conservation Reserve:

- Conservation reserves and community reserves act as buffer zones and migration corridors between established national parks, wildlife sanctuaries and other reserved as well as protected forests of India.
- These Protected Areas (PAs) were first introduced in the wildlife (Protection) Amendment Act of 2003.
- The State Government after discussions with local communities can announce/declare any specific area owned by the Government especially those located adjacently to national parks/sanctuaries, as conservation reserves.
- The state government can also constitute conservation reserve 'Management Committee' to look after or manage the conservation reserve effectively.
- Community reserves are managed by local people as well as local agencies like the *gram panchayat*.

5. Community Reserves:

- The State Government after detailed discussion with the community or an individual who has actively volunteered to conserve wildlife can declare any private or community land as a community reserve.
- The state government can also constitute community reserve 'Management Committee' to look after or manage the community reserve effectively.
- Community reserves represents the first instances of private land being given protection under the Indian legislature.
- It opens up the avenues of communally owned for-profit wildlife resorts, and also causes privately held areas under non-profit organizations like land trusts to be given protection.

2.5.1 Drawbacks of the Wildlife (Protection) Act, 1972

NOTES

- The personal ownership certificates for animal articles (tiger, leopard skins, etc.) are permissible which usually aids in illegal trading.
- No coverage of foreign endangered wildlife
- Miserable condition of wildlife in mobile zoos
- Wildlife (Protection) Act, 1972 has been accepted and adopted by all the states except Jammu and Kashmir. This opens avenues for illegal hunting, poaching and trading of wild animals.
- Wildlife protection act lays less emphasis on the protection of plant genetic resources.
- Punishment to the offender is not very stringent/severe.
- The offender gets up to 3 years of imprisonment or a fine of Rs. 25000 or both.

Check Your Progress

13 What are three basic requirements for effective conservation and management of wildlife?

14 Write the mission statement of WWF Nature.

15 What is Living Planet Index'?

16 When did the Bombay Natural History Society (BNHS) founded.

17 Where is the wildlife Institute of India situated?

18 Who is the chairman of the Indian Board for Wildlife?

19 Why Panda is chosen as the logo of WWF?

20 What is Living Planet Index'?

21 Define critically endangered species.

2.6 ANSWERS TO 'CHECK YOUR PROGRESS'

1. Population dynamics refers to the study of analyses of the change in the count of wildlife population in a specified area at a particular time.
2. It is essential to determine the density of a population in a particular habitat, as it helps in planning the management of the target species or area in a scientific way.
3. Tolerance density refers to the number of particular species that can be sustained by a specified area. This is the number of animals that a habitat will support when intrinsic behavioral or physiological mechanism are dominant in controlling the population. It is known as 'Saturation-Point Density' of a particular species in a specified habitat.

NOTES

4. In flat Curve type of growth-curve, the population remains static or in sync with its environment. A 'J' shaped growth curve is obtained in this type of growth curve.
5. Natality in 'population ecology' is the scientific term for birth rate.
6. Mortality or death rate is referred to as the number of deaths in a particular population scaled to the size of that population per unit of time. It is thus expressed as count of death per 1000 individuals per year.
7. Fertility schedule refers to the number of female offspring produced per female. Only females are considered and counted for fertility schedule as in a sexually reproducing species, only females can give birth to young ones and thus can further produce more females.
8. Sex-ratio refers to the ratio of males to females in a population. Ideally, for a healthy population, the ratio of sexually reproducing species tends to be 1:1.
9. Scats can be identified by: -
   - Carefully observing the geographical location, i.e. place from where the scat is collected
   - By observing the size of the collected scat
   - By observing the shape of the scat.
   - By observing composition of the scat, i.e., what is present inside it like hair, berries, etc.?
10. 3D-Pugmarks are depressed pug-mark impressions. It is the most common type of pugmark impression formed in mud, dust, sand, snow or similar surfaces. Such pug-marks are known as three-dimensional type or sunken pug mark impressions.
11. Hair is composed of dead cells that retain their structure, appearance, etc., even if detached from the animal's skin. Additionally, structure and appearance of hair is uniform among all the members of same species. This characteristics property of hair forms the basis of hair analysis.
12. Inventory' refers to taking into account of the biological contents of a given area. An inventory is prepared for the available wildlife species in that area.
13. For effective conservation and management of wildlife, there are three basic requirements:
    - Adequate food and water for the survival of different wild species.
    - Adequate free space for different species to move freely as well as to co-exist without interference.
    - Safe place to breed or reproduce leading to propagation of the species.
14. "To conserve nature and reduce the most pressing threats to the diversity of life on Earth." is the mission statement of WWF Nature.
15. Living Planet Index' is a measure of the state of the world's biological diversity based on population trends of vertebrate species in terrestrial, freshwater, and marine habitats.

16. Bombay Natural History Society(BNHS) was founded on 15 September, 1883
17. Wildlife Institute of India was established in 1982. The institute is based in Dehradun, Uttarakhand, India. It is located in Chandrabani, which is close to the southern forests of Dehradun.
18. The Indian Board for Wildlife is chaired by the Prime Minister of India.
19. Panda is chosen as the logo of WWF as giant panda called as 'Chi-Chi' was brought to London Zoo in 1958 even before the establishment of WWF.
20. 'Living Planet Index' is a measure of the state of the world's biological diversity based on population trends of vertebrate species in terrestrial, freshwater, and marine habitats.
21. Taxon that is facing extremely high risk of extinction in the wild are called critically endangered species.

2.7 SUMMARY

- Population dynamics refers to the study of analyses of the change in the count of wildlife population in a specified area at a particular time.
- Density refers to the number of animals present per unit area.
- The rate of birth in a population is referred to as natality.
- Mortality or death rate is referred to as the number of deaths in a particular population scaled to the size of that population per unit of time. It is thus expressed as count of death per 1000 individuals per year.
- Sex-ratio refers to the ratio of males to females in a population. Ideally, for a healthy population, the ratio of sexually reproducing species tends to be 1:1.
- The growth and structure of a population depends upon several factor such as birth rate, morality, age, sex-class and speed of development.
- Hair is composed of dead cells that retain their structure, appearance etc. even if detached from the animal's skin.
- A hair is composed of central medulla, surrounded by an outer cortex which may contain pigment granules. The surface, or cuticle, is usually composed of overlapping cuticular scales.
- The composition of the hair remains consistent among different species, yet the appearance of the hair can differ between species.
- Hair analysis involves collecting the sample from the field, analyzing it and then comparing it against the diagnostic features of previously identified hair samples.
- Pugmarks refers to the footprints of almost all the animals. Every individual animal species have distinct pugmarks as well as several other features contained in it. It can be used to identify the animal.

NOTES

- Methodology of estimating the population of a particular species is referred to as census.
- Ungulates are members of primarily large animals with hooves. Ungulates involves animals such as cattle, pigs, camels, sheep, deer, giraffes, etc.
- Dung/pellet count is generally used to estimate the population of ungulates.
- Nature maintain all their life forms especially plant and animals which constitute the life support system on earth in well balanced cycles.
- Habitat destruction and unchecked commercial exploitation of animals are the primary reason behind the declining wildlife species.
- Different species of wild flora and fauna-forms an irreplaceable part of earth's natural system.
- Tiger is an endangered species and its rate of extinction is so rapid that wildlife workers predicted its extinction within a few decades.
- Bombay Natural History Society (BNHS) was founded on 15 September, 1883.
- BNHS gives financial aids to several research projects.
- BNHS primarily focus on 'Conservation Research' that includes species research, landscape research, and sea scale research.
- Wildlife Institute of India was established in 1982
- Wildlife institute of India actively work together with international organizations on wildlife research, management and training.
- National Board for Wildlife (NBWL) is a statutory board constituted on 22nd September 2003 under section 5 of the wild life protection Act, 1972.
- WWF- Worldwide fund for Nature is an international non-profit organization which is dedicated to the preservation as well as conservation of nature and its different species.
- IUCN (International Union for Conservation of Nature of Natural resources) is an international organization that works in the field of conservation of the world's flora and fauna.
- One of the fundamental duties of the citizens of India is to protect and improve the natural environment including lakes, forests, and rivers as well as to have consideration, concern, sympathy, kindness, and love for living creatures.

2.8 KEY TERMS

- **Absolute density**– It refers to the count of a particular species found in a unit area.
- **Subsistence density**– It refers to the density when the count of species has already reached a stage of the carrying capacity where population can only be subsisted in the habitat.

NOTES

- **Tolerance density**– It refers to the number of particular species that can be sustained by a specified area.
- **Carrying capacity-** It refers to the number of individuals of a particular species that can be supported or sustained by the habitat.
- **Natality**- The rate of birth in a population is referred to as natality.
- **Absolute natality**–It is the number of births under ideal conditions, i.e., no competition with abundance of basic resources such as food, water, shelter, cover, etc.
- **Mortality**- Mortality or death rate is referred to as the number of deaths in a particular population scaled to the size of that population per unit of time.
- **Fertility schedule** - Fertility schedule refers to the number of female offspring produced per female. Only females are considered and counted for fertility schedule.
- **Pugmarks:** Pugmarks refers to the footprints of almost all the animals. Every individual animal species have distinct pugmarks as well as several other features contained in it. It can be used to identify the animal
- **Water-Hole census**– In this methodology, data is collected by seeing and counting the animal collected at water hole. This recording is done for 24 hours.
- **Vulnerable (VU)** – Taxon that is facing high risk of endangerment in the wild. All the collected evidences for the taxon indicates that it meets any of the criteria A to E for vulnerable**.**
- **Living planet index**: 'Living Planet Index' is a measure of the state of the world's biological diversity based on population trends of vertebrate species in terrestrial, freshwater, and marine habitats.

2.9 SELF-ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions

1. What is the impact of tolerance density on wildlife population and its habitat?
2. What are the basic characteristics of natality?
3. List down some factors responsible for mortality rate.
4. What are the advantages of collecting animal's scat or faeces?
5. Write Pellet/Dung count method shortly.
6. How is measurement of pugmark done?
7. How will you differentiate between the male and female pugmarks of carnivores?
8. What is the Significance of Pugmarks?
9. What is a resource inventory? Why it is prepared?

NOTES

10. Write about the problems with wildlife census.
11. Give some advantages of Wildlife census.
12. What are the measures adopted for conservation of wild life?
13. For which few priority species WWF-India plans its work?
14. What are the criteria used to evaluate whether the taxon belongs to the IUCN Red List category?
15. What is the primary objective of the Conservation Assessment and Management Plan (CAMP)?
16. What is the need for the 'Wildlife Protection Act'?

Long-Answer Questions

1. Describe population density and its types in detail.
2. Discuss different types of population structure based on male-female ratio.
3. Describe the structure of hair and its diagnostic characteristics.
4. Explain the method of preparation of slides for hair sample analysis in detail.
5. What are pug marks? How pugmarks are produced?
6. What do you understand by term census? What are its types? Give a detail account.
7. Discuss the direct count of census and its types in detail.
8. Give a detail account on the aims and objectives of GTF.
9. Write a short note on BNHS (Bombay Natural History Society).
10. Discuss the nine categories in the IUCN red list in detail.
11. Briefly describe the various type of protected areas under the Wildlife Protection Act.
12. Elaborate on the functions of Central Zoo Authority (CZA).

2.10 FURTHER READING

Sinclair, Anthony R. E., John M. Fryxell and Graeme Caughley. 2009. *Wildlife Ecology, Conservation and Management.* New Jersey: Wiley.

Gupta, Tapashi. 2017. *Ecology, Wild Life Conservation and Management.* Guwahati (Assam): Eastern Book House.

Murphy, Chloe. 2020. *Wildlife Conservation and Management: Principles and Practices.* US: Syrawood Publishing House.

Newman, Michael C. 2013. *Quantitative Ecotoxicology*, 2nd Edition. UK: Taylor & Francis.

Walker C.H., R.M. Sibly, S.P. Hopkin, and D.B. Peakall. 2012. *Principles of Ecotoxicology*. 4th Edition, UK: Taylor & Francis.

Sparling, Donald W. 2017. *Basics of Ecotoxicology.* US: CRC Press.

Connell, Des W., Paul Lam, Bruce Richardson, and Rudolf Wu. 2009. *Introduction to Ecotoxicology.* US: Blackwell Publishing.

UNIT 3 ECOTOXICOLGY-I

NOTES

Structure

3.0 Introduction
3.1 Objectives
3.2 Basic Concepts of Toxicolgy
  3.2.1 History of Toxicology
  3.2.2 Prehistory of Toxicology
3.3 Toxicants and Toxicity
  3.3.1 Xenobiotic
  3.3.2 Toxicants
  3.3.3 Toxicity
3.4 Absorption and Translocation of Toxicants
  3.4.1 Absorption of Toxicants
  3.4.2 Translocation and Distribution of Toxicants
  3.4.3 Transport of Toxicants by Blood and Lymph
3.5 Elimination and Excretion of Toxicants
  3.5.1 Elimination of Toxicants
  3.5.2 Excretion of Toxicants
  3.5.3 Biotransformation of Toxicants
3.6 Effects and Response
3.7 Dose and Response Relationship
3.8 LD_{50} and ED_{50}
  3.8.1 NOEL and LOEL
3.9 Factors Influencing Toxicity-Response Relationships
  3.9.1 Variation in Toxic Responses
3.10 Toxicological Testing Techniques
  3.10.1 General Test Design
  3.10.2 Acute Toxicity Test
  3.10.3 LD_{50}/LC_{50} Test
  3.10.4 Skin and Eye Test
  3.10.5 Toxicity Curves
3.11 Answers to 'Check Your Progress'
3.12 Summary
3.13 Key Terms
3.14 Self-Assessment Questions and Exercises
3.15 Further Reading

3.0 INTRODUCTION

Ecotoxicology is the study of the effects of toxic chemicals on biological organisms, especially at the population, community, ecosystem, and biosphere levels. Ecotoxicology is a multidisciplinary field, which integrates toxicology and ecology.

In those ecosystems that are already affected by pollution, Eco toxicological studies can inform the choice of action to restore ecosystem services, structures, and functions efficiently and effectively. It offers fundamental research on the effects of toxic chemicals on populations and communities and shows how chemicals exert effects on ecosystems, examines their impact at the population and community level.

NOTES

Ecotoxicology is a multidisciplinary field, which integrates toxicology, ecology, chemistry, biochemistry and genetics. Ecotoxicology is the study of the effects of toxic chemicals on organisms at the population, community, ecosystem level. All organisms are connected in the web of life. If a chemical affects some of the organisms, other organisms in the ecosystem may suffer from its ecotoxicity since organisms depend on one another. The principles of ecotoxicology identify the major classes of organic and inorganic pollutants, their properties, release and environmental fate, transference in air, water and along food chains, before considering the effects that they might have upon individual organisms and ultimately whole ecosystems.

Toxicology is the study of adverse effects of chemical substances on living organisms. The Society of Toxicology more broadly defined toxicology as 'the study of adverse effects of chemical, physical, or biological agents on living organisms and the ecosystem, including the prevention and amelioration of such adverse effects'. This definition still leaves some loose ends, for example; a toxicologist could study the macromolecular interactions of a toxicant and the receptor with which it binds to elicit a toxic response, without evaluating an intact living organism or system. On the other end of the spectrum, a toxicologist can study the effects of a contaminant on an entire ecosystem with multiple interacting species across the taxonomic spectrum.

The Ecotoxicology is focused on new findings, communications, and opinions about the various aspects of environmental toxicology and chemical stress ecology of toxic chemicals. The goal of ecotoxicology is to understand the concentration of chemicals at which organisms in the environment will be affected. To study the possibility that a chemical is toxic, ecotoxicologists usually start with simple approaches. They progress to more complex approaches only when more accurate information is needed.

In this unit you will study about history of toxicology, toxicants and toxicity, exposure of toxicants, elimination and excretion of toxicants, biotransformation of toxicants, effects and response, dose and response relationship, absorption and translocation of toxicants, factors influencing toxicity-response relationships, toxicological testing techniques ,general test design, acute toxicity test, LD50/ LC50 test ,skin and eye test, and toxicity curves.

3.1 OBJECTIVES

After going through this unit, you will be able to:

- Understand history of toxicology
- Comprehend toxicants and toxicity
- Analyse the exposure of toxicants
- Understand absorption and translocation of toxicants
- Explain elimination and excretion of toxicants
- Comprehend biotransformation of toxicants

- Analyse the effects and response of toxins
- Understand the dose and response relationship
- Elaborate on exposure determinations
- Analyse the factors influencing toxicity-response relationship
- Explain toxicological testing methods, general test design.

NOTES

3.2 BASIC CONCEPTS OF TOXICOLGY

Toxicology is the investigation of unfavorable impacts of synthetic substances on living individuals. The Society of Toxicology more comprehensively described toxicology as 'The investigation of antagonistic impacts of substance, physical, or natural agents on living life forms and the environment, including the counteraction and amelioration of such unpleasant impacts'. This definition actually leaves some 'Unwind End,' e.g., a toxicologist might consider the macromolecular connections of a poison and the 'Receptor' through that it ties to get a harmful reaction, without assessing a flawless living being or framework. On the opposite end of the range, a toxicologist can consider the impacts of a foreign substance on a whole environment with various interfacing species across the ordered range.

The 'Adverse' is the key word of toxicology. An adverse impact can be characterized as a reaction to a substance which is hurtful or troublesome. Thus toxicologists learn factors which evoke destructive or ominous consequences for living framework. While a few substances can inspire verifiably adverse impacts under specific conditions, those equivalent substances might evoke no change or some change which is hard to be characterized plainly as being destructive under different conditions. The wide scope of substances getting harmful reactions can be delegated either toxicants (normally happening or manufactured xenobiotic) or toxins (substances created by other living life forms that get poisonous reactions).

The overlying idea of this unit is an introduction to toxicology from manifold levels of organization and unreliable perspectives. Multiple emphasis areas fit under the umbrella of ecotoxicology and its unfriendly results centers around how organ arrangement of more unpredictable species are influenced comparable to generally speaking portion reactions. In this way ecotoxicology concentrates what substances mean for numerous degrees of association from the atomic through the organismal level, and the resulting impacts on populaces and additionally networks inside an environment. The toxicology may seem to target only poisonings, but some toxic substances can have positive effects. Animal venoms including bees, wasps, snakes, or Gila monsters are comprising several constituents and used in treatments for human diseases like Type-2 diabetes using exantide, derived from Gila monster saliva. Captopril, utilized to treat blood pressure and cardiovascular failure, was created from concentrates on the synthetic Bradykinin-Potentiating Factor (BPF) in the toxin of snake. Melitten which comes from honeybee venom (apitoxin) is being examined for its anticancer, antifungal, antibacterial, anthelmintic, development advancing and anti-hypertension properties.

NOTES

3.2.1 History of Toxicology

The conventionally toxicology is defined as 'The Study of Toxins' or 'The Study of Poisons'. The more informative and suitable definition of toxicology is 'The Study of the Adverse Effects of Chemicals or Physical Agents on Living Organisms'. The negative impacts may happen in numerous structures, going from prompt demise to inconspicuous changes. These might come about at diverse levels inside the body, like an organ, a kind of cell, or a specific biochemical. It is presently realized that different detectable changes in life structures or body works really result from already unnoticed changes in specific biochemicals in the body.

3.2.2 Prehistory of Toxicology

The toxicological studies started with ancient cave dwellers who recognized poisonous plants and animals and used their extracts for hunting or warfare.

Toxicology During 1500 BC

By 1500 BC, written recordings showed that hemlock, opium, arrow poisons, and certain metals were employed to poison enemies or for state executions.

Toxicology by Moses Maimonides (12th Century)

As the time passes, people started to designee sophistication between exposure to a specific substance and illness or death. In 1198, Moses Maimonides wrote what may be the first collection of writings on toxicology '*The treatise on poisons and their antidotes'*. The notable poisoning victims include Socrates, Cleopatra, and Claudius.

Renaissance and Age of Enlightenment

Along the 'Renaissance and Age of Enlightenment', certain ideas to toxicology started to come to new structure. Essential examinations remember those by Paracelsus for the 16th century and Orfila in the 19th century.

Toxicology by Paracelsus (16th Century)

The studies of Paracelsus (~1500AD) resolute that precise chemicals were actually responsible for the toxicity of an organism poison. He also reported that the responses of body against the said chemicals depended on the dose administered. His findings revealed that little doses of a material might be safe or useful while higher doses could be toxic. Such phenomenon called '**Dose-Response Relationship'**, a major concept of toxicology. Founder of modern toxicology, Paracelsus quoted that: *"All substances are poisons; there is none which is not a poison. The right dose differentiates a poison and a remedy". It means the dose is the factor which makes the* substances as poison.

Toxicology by Orfila (19th Century)

Orfila (~1800 AD), a Spanish physician, is often referred to as the '*Founder of Toxicology*'. It was Orfila who first prepared a systematic correlation between the chemical and biological properties of poisons of the time. He demonstrated effects of poisons on definite organs by analyzing autopsy materials for poisons and their associated tissue damage.

NOTES

Toxicology by 20th to 21st Centuries

The 20th century is noticeable by a highly developed level of knowledge of toxicology. DNA and various biochemical that sustain body functions were invented. The extent of knowledge of adverse impact on organs and cells is right now being exposed at molecular level. It is documented that almost all toxic effects are offered by alterations in certain cellular molecules and biochemical.

3.3 TOXICANTS AND TOXICITY

Toxicology is the investigation of the negative impacts of synthetic substances or actual substances of living entities. A toxicologist is a researcher that decides the unsafe impacts of agents and the cell, biochemical, and sub-atomic instruments answerable for the impacts. Toxicant, toxin, and poison substance are regularly utilized reciprocally in the writing; in any case, there are unpretentious contrasts as tabulated. Toxic materials may be systemic or organ toxins that affects the complete body or various organs rather than an exact site. Such as, potassium cyanide is a systemic toxicant in that it influences practically every cell and organ in the body by interfering with the cell's ability to utilize oxygen. Poisons may likewise influence just targeted tissues or organs while not creating harm to the body in general. These particular locales are known as the target organs or target tissues. A few models: Benzene is a particular organ poison in that it is fundamentally harmful to the blood-framing tissues. Lead is additionally a particular organ poison; in any case, it has three objective organs (focal sensory system, kidney, and hematopoietic system).

Toxicants	The substances that produce adverse biological effects of any nature called toxicants. It may be chemical or physical in nature. The effect of these substances may be of various types including acute, chronic, etc.
Toxins	There are some specific proteins produced by living organisms called as toxins. For examples: mushroom toxin, tetanus toxin, apitoxin, etc.
Poisons	The toxicants that cause immediate death or illness when experienced in any small amount are called poisons. For example, potassium cyanide.

NOTES

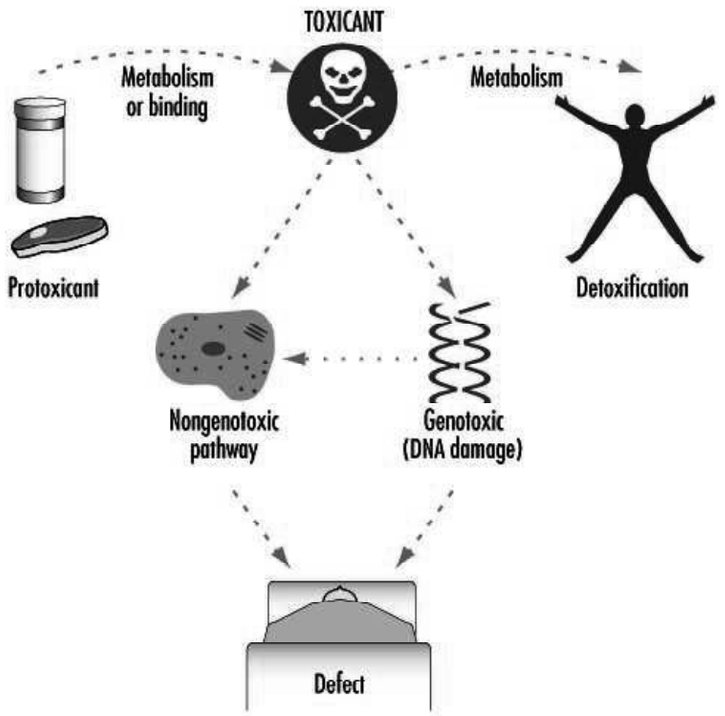


Fig. 3.1 *The General Means by Which Toxicity Occurs*

3.3.1 Xenobiotic

Xenobiotic is the universal term that is employed for a foreign material taken into the body. It is derived from the Greek word '*xeno*' means foreigner. Xenobiotics may bring into beneficial effects (if pharmaceuticals) or may be toxic (e.g., lead). As Paracelsus projected centuries ago, doses are responsible whether an agent will be a remedy or a poison.

3.3.2 Toxicants

Toxicant or poisonous material is anything that can turn out an adverse biological result. It may be chemical (e.g., cyanide), physical (e.g., radiation), or biological (e.g., snake venom, bee toxin, etc.) in form. A division is made for diseases due to biological factors. The organisms that invade and multiply within the organism and produce its effects by biological action are not classified as toxicants. Such as virus that damages cell membranes resulting in cell death. When invading organisms excrete chemical and basis for toxicity, then the excreted materials are known as bio toxins and organisms as toxic organisms (e.g., tetanus). *Clostridium tetani* causes tetanus by invading and destroying cells through the excreted toxin and affect the nervous system (a neurotoxin). So, a toxic substance is just a material with hazardous efficacy, for example, lead chromate (discrete toxin), asbestos, gasoline, etc. The toxicants may be organic or inorganic as well as systemic toxins or organ toxins also.

Organic toxins	The substances that were originally derived from living organisms are called organic toxins. These contain carbon and often are large molecules can be synthesized as well as from natural sources. Thus the organic toxins are organisms derived and can be man-made.
Inorganic toxins	The specific chemicals that are not derived from living organisms are called inorganic toxins. Thus these are minerals and generally small molecules consisting only of a few forms (e.g., nitrogen oxide)

Systemic toxicant

A systemic toxicant or systemic toxin is one that affects the complete body or lots of organs rather than a specific site. For example, potassium cyanide is a systemic toxicant which affects virtually every cell and organ in the body by interfering with the cell's ability to utilize oxygen.

Organ toxicant

Toxicants may also affect only target tissues or organs while not producing damage to entire body. These exact sites are known as the target organs or target tissues. For example, Benzene is a specific organ toxin and chiefly toxic to the blood-forming tissues. However, Lead is also a target organ toxin to central nervous system, kidney, and hematopoietic system. The toxicity to germ cells can cause adverse on the developing fetus (such as birth defects, abortions). On contrary toxicity to somatic cells lead to diversity of toxic property to exposed individual or cell or tissues (e.g., dermatitis, death, and cancer).

3.3.3 Toxicity

Toxicity is the intrinsic ability of a chemical factor to affect an organism negatively. However, hazard is the potential for the toxicity to be realized in a specific situation. On the other hand risk is the probability of a specific adverse effect to taken place and often reported as percentage of cases in selected population in particular period. The toxicity score or categorization can be used for regulatory point is a prejudiced grading of doses and its exposure levels revealing toxic effects. The grading might be as supertoxic, highly toxic, moderately toxic, etc. The most widespread ratings focus to acute toxicity which includes allergenic, neurotoxic, carcinogenic, etc. The intrinsic toxicity affected by the toxicant dose, contact conditions and response of host. Other than these there are several factors including chemical, such as molecular structure, functional groups, solubility, insolubility, volatility, stability (in light, water, acids, and enzymes) and reactivity; and physical properties, such as gas (density), liquid (vapor pressure), solid (crystal structure, size, and shape), etc.

Properties of Toxicants

In 1854 the Russian toxicologist E.V. Pelikan started studies on chemical structure biological activity of toxicants using 'Structure-Activity Relationship (SAR)'. To express the chemical structure, there are numerous parameters that can be chosen as descriptors and divided into various groups:

NOTES

1. **Physico-Chemical Properties:**
   a. **General:** Melting point, boiling point, vapor pressure, dissociation constant (pK_a), Nernst partition coefficient (P), activation energy, heat of reaction, reduction potential, etc.
   b. **Electric:** Ionization potential, dielectric constant, dipole moment, mass/ charge ratio, etc.
   c. **Quantum Chemical:** Atomic charge, bond energy, resonance energy, electron density, molecular reactivity, etc.
2. **Steric Properties:** Molecular volume, shape and surface area, substructure shape, molecular reactivity, etc.
2. **Structural Properties:**

   The occurrence of various bond, rings in polycyclic compounds and level of of branching, etc. correlated to the structural properties of chemical for toxicokinetic point. There are some key parameters summarized below:

   a. **'The Nernst Partition Coefficient'** (P) establishes the solubility of toxicant molecules in the two-phase octanol (oil)-water system, associating to their lipo- or hydro solubility. It greatly affects the distribution and accumulation of toxicants in the organism.
   b. The degree of ionization can be defined by the dissociation constant (pK_a) of a molecules with toxic effect. This constant denotes the pH at which 50% ionization is achieved.
   c. The particle size, shape, surface area and density of inhaled dusts and aerosols might manipulate their toxicokinetics and toxicodynamics.

Exposure of Toxicants

A toxic agent gives toxicity when it reaches to contact with the organisms and subsequently absorbed in its biological parts. The toxic ailment of toxins depends on the exposure duration and its concentration. Exposure to a toxic substance is normally followed by absorption and its entry into the blood vascular system. There are following types of exposure described:

Brief Exposures

Such exposures are confined to small concentration of a toxic agent below the threshold of toxicity. Such exposures produce little or no effect on a biological system. These infect help the organism to build up tolerance for a particular toxic agent.

Repeated Exposures

Sometimes an organism is repeatedly exposed to low concentrations of a toxic agent. When the rate of admission of the toxic agent is somewhat higher than the rate of its removal, then toxicants begin accumulating in the body to reach the threshold level. Thus a toxicity which develops by the gradual accumulation of small amounts of toxic agent over lengthened duration is termed chronic toxicity. Hence toxicity reflected only when the cumulative action of the small doses of toxins crosses the threshold level of toxicity.

Exposure to Large Doses of Toxic Agents

As organism gets exposed or intentionally administers higher and lethal doses of a toxic agent, it results in extreme symptoms of adverse effect. Because of lethality dose of toxins, its concentration rises sharply in the blood leading death of the organism known as acute toxicity. Acute exposure is an exposure of short duration, while chronic exposure is long-term (sometimes life-long) exposure.

3.4 ABSORPTION AND TRANSLOCATION OF TOXICANTS

To incite a toxic impact, local or systemic the harmful material should initially come into contact with an uncovered body surface in request to enter the creature and arrive at a site where harm is delivered. This may happen for little water-soluble molecules by passage through fluid gateways or, for fat-solvent ones, by dissolution into and dissemination through the lipid part of the film. The entry of a substance might be worked with via transporters in the membrane, protein intervened, exceptionally specific, and saturable. However, some materials are actively transported through plasma membrane mediated by some carrier proteins which analogous to that enzymes. Active transport is analogous to promote and swift diffusion, but it may occur alongside a concentration gradient. It needs energy input and a metabolic inhibitor can chunk the process. Many environmental pollutants may not transport actively.

3.4.1 Absorption of Toxicants

Absorption is the taken in of a substance from the environment into the organism. The term typically includes not only the entrance into the barrier tissue but also the further transport into circulating blood. There are a variety of routs of exposure and absorption of toxicants to organism including respiratory channels, dermal channels, gastrointestinal channels and some special routs for certain toxicants.

Pulmonary Absorption

The lungs are the primary route of storage and absorption of small airborne particles, gases, vapors and aerosols. The rate of absorption is reliant on flow (pulmonary ventilation, cardiac output) and solubility (blood: air partition coefficient). The physical process results in augmented pulmonary ventilation and cardiac output, and decreased liver blood flow, hence, biotransformation rate. Thus many xenobiotics or chemical agents enter the circulation by diffusion through the alveolar membrane of the lungs. The carbon monoxide poisoning and silicosis are caused by the entry of toxic substances through this route.

Percutaneous Absorption

Skin comes in contact to many chemicals accidentally and principal route of environmental toxicant exposure. Apart from its thermoregulatory role, it is a very competent barrier designed to protect the organism from factors including micro-organisms, ultraviolet radiation, other harmful agents, and excessive water loss. Skin also acts as a significant route for the absorption of system toxic materials.

NOTES

Nevertheless, significant dermal absorption resulting in toxicity may occur for some substances—highly toxic, fat-soluble substances such as organ phosphorous insecticides and organic solvents, for example. Factors affecting the level of absorptions depend on the site of contamination, integrity of skin, temperature, formulation of the material, molecular weight and hydrophilic and lipophilic characteristics.

a. Carbon tetrachloride and other organic solvent penetrate the skin and produce liver toxicity and other serious toxic effects.

b. DDT when sprayed on skin is less toxic to mammals than insects. But when injected, it's LD so is almost the same.

c. Malathion and parathion may cause death in agricultural workers when absorbed through the skin.

d. Chemicals like dimethyl sulfoxide injure the cell barriers of skin and thus facilitate the absorption of toxicants through the skin.

Gastrointestinal Absorption

Gastrointestinal absorption occurs after accidental or intentional ingestion. The sufficient irritant or caustic chemical engulfing may cause local ailment in the mouth, oesophagus, stomach and the intestine. Strong acid, several enzymes present in the stomach and microbes live in the intestine alter the toxic agent drastically and render it ineffective. Practically all soluble substances are efficiently absorbed in the gastrointestinal tract. The low pH of the gut may facilitate absorption, for instance, of metals. For example, snake venom becomes non-toxic when taken orally because it is made harmless by the enzymes of the alimentary canal.

Sometimes it has been found that the harmless substances may be transformed into harmful ones of the low pH, the enzymes and the microbes' present in the alimentary canal. For example, aromatic nitro compounds transformed into goiter-forming or carcinogenic by intestinal microbes. Several materials absorbed from the intestine get ahead of hepatic portal system and liver for biotransformation. Thus, before a toxic agent passes into blood stream it is detoxified and converted into harmless metabolites.

Other Routes Absorption

In toxicity checking and other experiments, unique routes of administration are frequently used for convenience. These routes include Intravenous (IV), Subcutaneous (SC), Intraperitoneal (IP) annd Intramuscular (IM) Injections. This leads to short-lasting but high concentration peaks that may increase the toxicity of a dose. Because of this reason, patient suffering from violent emesis and gastric hyper motility, medicines are given by intramuscular or intravenous injections. In such cases oral administration of drugs causes immediate vomiting.

3.4.2 Translocation and Distribution of Toxicants

Translocation is the movement of substance (a pesticide, toxicants or any metal) from the site of exposure to the target site. A toxic agent causes toxicity only when it is absorbed into the biological system and translocated to the site of action in active state. The toxic agent has to pass through membrane barriers to reach the

site of action. For example, when the toxins taken through the respiratory or alimentary tract it passes through the mucosal lining into the extra-cellular interstitial fluid followed to blood stream through capillary walls. However, materials that cannot enter blood stream are transported by lymphatic vessels. Once the toxic agent reaches the blood stream, it is distributed to a range of body parts. The occurrence and storage of a substance within the organism is a dynamic phenomenon that based on the rate of uptake and elimination as well as blood flow and their affinities. The materials soluble in water, small, uncharged in nature, monovalent cations and the majority anions diffuse effortlessly and distributed evenly throughout body.

Barriers

The blood capillaries, arteries and veins in the brain, testes and placenta have characteristic anatomy that restrains passage of macro molecules (e.g., proteins). These characters frequently referred to as blood-brain, blood-testes, and blood-placenta barriers. These terminologies may give the fake intuition to prevent passage of any substance. Even though these barriers are of little or no importance for xenobiotics that may diffuse through cell membranes.

a. **Membrane Barrier:** For most of the toxic agents, plasma membrane acts as an efficient and selective barrier. Toxic agent has to cross this membranous barrier to enter the intracellular compartments of the biological system of the body. In higher organisms some specialized membrane barriers occur within the body. These are:

    i. **Blood-Brain Barrier:** The blood-brain barrier exists between the blood and the brain. Many toxic agents are not able to reach the brain. As matter of fact this barrier represents a location that is less permeable to toxicants. The various factors for low permeability of blood-brain barrier are: (i) Reduced permeability of capillaries; (ii) Very small extra-cellular spaces; (iii) Presence of a layer of glial cells closely surrounding the capillaries and myelin sheath. The blood-brain barrier is highly selective for non-polar lipid soluble substances which enter the brain rapidly. High-polar water soluble substances cross this barrier with difficulty.

Placental Barrier: This barrier in found in pregnant females between the foetal blood and mother's blood circulation. The maternal blood is in contact with foetal blood across the trophoblastic layer, mesenchymal tissue and capillary endothelium. Placenta acts as a selective barrier. The transfer mechanisms operating here are passive diffusion, active transport and pinocytosis. This barrier is also more permeable to the lipid soluble substances but highly polar water soluble substances pass through it with difficulty.

Blood-Testes Barrier: This barrier exists between the blood and the sertoli cells in the seminiferous epithelium of testes. Blood-tissue barrier is playing key protective function in conservation the germinal lining from injurious influences emerging both within and outside. It also helps in shielding meiotic cells from environmental mutagens.

NOTES

Blood-Liver Barrier: Liver also provides an effective barrier to the passage of toxic chemicals. Liver removes the toxic chemicals from blood and prevents their distribution in the body. Compounds may be excreted directly into the bile without re-entering the blood stream and this passes into the small intestine.

Passage Through Cell Membrane: Foreign substances pass across the cell membrane or plasma lemma in any of the following four possible ways: (i) By passive diffusion of the membrane; (ii) By filtration through the pores in the membrane; (iii) Specialized transport system employing lipid soluble carrier molecules; (iv) By pinocytosis, phagocytosis, etc.

3.4.3 Transport of Toxicants by Blood and Lymph

After absorption by any portals of entry, toxicants will arrive to the blood, lymph or other body fluids. The blood denotes the main vehicle for transport of toxicants and their metabolites. The lymphatic system represents the drainage system, in the form of a fine mesh of small, thin-walled lymph capillaries. Blood is a mixture of a liquid phase (plasma, 55%) and solid blood cells like erythrocytes (Er), leukocytes, reticulocytes, monocytes, and platelets (45%). Plasma contains proteins (albumins, globulins, fibrinogen), organic acids (lactic, glutamic, citric) and numerous other substances (lipids, lipoproteins, glycoproteins, enzymes, salts, xenobiotics, etc.). Toxicants are absorbed as molecules and ions have various promises for transport in blood: (i) Physically or chemically chelated to the blood components (e.g., RBCs); (ii) Dissolved in plasma; (iii) Bound to one or more types of plasma proteins; (iv) Complexes with organic acids; (v) Attached to other fractions of plasma.

Most of the toxicants in blood exist partially in a free state in plasma and partially bound to erythrocytes and plasma constituents. The distribution depends on the resemblance of toxicants to these constituents. Some toxicants are transported by the blood elements—mostly by erythrocytes (e.g., arsenic, cesium, thorium, radon, lead and sodium), very rarely by leukocytes. The majority of toxicants are transported by plasma or plasma proteins (albumin carries copper, zinc and cadmium; and globulin transport copper, zinc, iron and colloid particles). Fibrinogen shows affinity for certain small molecules. All these complexes are usually diffusible and easily distributed in tissues and organs.

Check Your Progress

1. Define toxicology.
2. Who is a toxicologist?
3. What is xenobiotic?
4. Define a systematic toxin.
5. When a toxic agent gives toxicity?
6. Define 'The Nernst Partition Coefficient' (P).
7. What is the effect of exposure to large doses of toxic agents?

3.5 ELIMINATION AND EXCRETION OF TOXICANTS

NOTES

Elimination or removal is the vanishing of a material in the body through excretion or transformation.

3.5.1 Elimination of Toxicants

The degree of removal and disappearance can be denoted by the elimination rate constant, biological half-time or clearance.

Biotransformation and Elimination of Toxicants

During retention in cells of various tissues and organs, toxicants are exposed to enzymes which can bio transform (metabolize) them, producing metabolites. There are many pathways for the elimination of toxicants and/or metabolites: by exhaled air via the lungs, by urine via the kidneys, by bile via the GIT, by sweat via the skin, by saliva via the mouth mucosa, by milk via the mammary glands, and by hair and nails via normal growth and cell turnover. The elimination of an absorbed toxicant depends on the portal of entry. In the lungs the absorption/desorption process starts immediately and toxicants are partially eliminated by exhaled air. Elimination of toxicants absorbed by other paths of entry is prolonged and starts after transport by blood, eventually being completed after distribution and biotransformation. During absorption an equilibrium exists between the concentrations of a toxicant in the blood and in tissues and organs. Excretion decreases toxicant blood concentration and may induce mobilization of a toxicant from tissues into blood. Many factors can influence the elimination rate of toxicants and their metabolites from the body.

a. Physio-chemical properties of toxicants, especially the Nernst Partition Coefficient (P), Dissociation Constant (pKa), polarity, molecular structure, shape and weight,
b. Level of exposure and time of post-exposure elimination,
c. Portal of entry,
d. Distribution in the body compartments, which differ in exchange rate with the blood and blood perfusion,
e. Rate of biotransformation of lipophilic toxicants to more hydrophilic metabolites,
f. Overall health condition of organism and, especially, of excretory organs (lungs, kidneys, GIT, skin, etc.)
g. Presence of other toxicants which can interfere with elimination.

We can distinguish two groups of compartments:

(1) **The Rapid-Exchange System**: In these compartments, tissue concentration of toxicant is similar to that of the blood; and

(2) **The Slow-Exchange System**: Where tissue concentration of toxicant is higher than in blood due to binding and accumulation- adipose tissue. Skeleton and kidneys can temporarily retain some toxicants, e.g., arsenic

NOTES

and zinc. A toxicant can be excreted simultaneously by two or more excretion routes. However, usually one route is dominant. Scientists are developing mathematical models for describing the excretion of a particular toxicant. These models are based on the movement from one or both compartments (exchange systems), biotransformation and so on.

Elimination by Exhaled Air via Lungs

1. Elimination via the lungs (desorption) is typical for toxicants with high volatility (e.g., organic solvents). Gases and vapors with low solubility in blood will be quickly eliminated this way, whereas toxicants with high blood solubility will be eliminated by other routes. Organic solvents absorbed by the GIT or skin are excreted partially by exhaled air in each passage of blood through the lungs, if they have a sufficient vapors pressure. The Breath analyzer test used for suspected drunk drivers is based on this fact. The concentration of CO2 in exhaled air is in equilibrium with the CO2 in Hb blood content. The radioactive gas radon appears in exhaled air due to the decay of radium accumulated in the skeleton. Elimination of a toxicant by exhaled air in relation to the post-exposure period of time usually is expressed by a three-phase curve. The first phase represents elimination of toxicant from the blood, showing a short half-life. The second, slower phase represents elimination due to exchange of blood with tissues and organs (quick-exchange system). The third, very slow phase is due to exchange of blood with fatty tissue and skeleton. If a toxicant is not accumulated in such compartments, the curve will be two-phase. In some cases a four-phase curve is also possible. Determination of gases and vapors in exhaled air in the post-exposure period is sometimes used for evaluation of exposures in workers

Elimination via Renal Excretion

The kidney is an organ specialized in the excretion of numerous water-soluble toxicants and metabolites, maintaining homeostasis of the organism. Each kidney possesses about one million nephrons able to perform excretion. Renal excretion represents a very complex event encompassing three different mechanisms:

(a) Glomerular filtration by Bowman's capsule,

(b) Active transport in the proximal tubule, and

(c) Passive transport in the distal tubule.

Excretion of a toxicant via the kidneys to urine depends on the Nernst partition coefficient, dissociation constant and pH of urine, molecular size and shape, rate of metabolism to more hydrophilic metabolites, as well as health status of the kidneys. The kinetics of renal excretion of a toxicant or its metabolite can be expressed by a two, three or four-phase excretion curve, depending on the distribution of the particular toxicant in various body compartments differing in the rate of exchange with the blood.

Elimination via Saliva

Some drugs and metallic ions can be excreted through the mucosa of the mouth by saliva—for example, lead, mercury, arsenic, copper, as well as bromides,

iodides, ethyl alcohol, alkaloids, and so on. The toxicants are then swallowed, reaching the GIT, where they can be reabsorbed or eliminated by faeces.

Elimination via Sweat

Many non-electrolytes can be partially eliminated via skin by sweat: ethyl alcohol, acetone, phenols, carbon disulphide and chlorinated hydrocarbons.

Elimination via Milk

Many metals, organic solvents and some organochlorine pesticides (DDT) are secreted via the mammary gland in mother's milk. This pathway can represent a danger for nursing infants.

Elimination via Hair

Analysis of hair can be used as an indicator of homeostasis of some physiological substances. Also exposure to some toxicants, especially heavy metals, can be evaluated by this kind of bioassay. Elimination of toxicants from the body can be increased by

a. Mechanical translocation via gastric lavage, blood transfusion or dialysis.
b. Creating physiological conditions which mobilize toxicants by diet, change of hormonal balance, improving renal function by application of diuretics.
c. Administration of complexing agents (citrates, oxalates, salicilates, phosphates), or chelating agents (Ca-EDTA, BAL, ATA, DMSA, penicillamine); this method is indicated only in persons under strict medical control. Application of chelating agents is often used for elimination of heavy metals from the body of exposed workers in the course of their medical treatment. This method is also used for evaluation of total body burden and level of past exposure.

Concentration-Time Curve: The concentration curve in blood or plasma *vs.* time is an expedient approach of telling uptake and disposition of xenobiotic. The curvature area or 'Area under Curve (AUC)' is the essential of toxicants concentration in blood or plasma over time. When metabolic saturation and other non-linear processes are not present, then AUC is relative to the absorbed quantity of material.

Biological Half-Life: The biological half-time is the moment needed after the finish of exposure to diminish the quantity to one-half in exposed organism. The half-time should be applied with caution, as it may possibly change with dose and duration of exposure. Additionally it was notices that several toxicants have complex decay curves with more than a few biological half-times.

Bioavailability: It is the fraction of a dose entering the systemic circulation. In oral exposure presystemic permission may be due to metabolism inside the intestinal content, gut wall or liver. First-pass metabolism will decrease the systemic absorption of the material and instead augment the absorption of metabolites. This may escort to a diverse toxicity prototype.

Clearance: Clearance is the volume of blood or plasma per unit time entirely cleaned of a stuff. Intrinsic clearance is the ability of endogenous enzymes to transform a material, and also denoted in volume per unit time. When intrinsic

clearance in an organ is effectively lower than the blood flow, then metabolism is said to be capacity limited. On contrary, if the intrinsic clearance is significantly higher than the blood flow, the metabolism is known to be flow limited.

NOTES

3.5.2 Excretion of Toxicants

There are a variety of pathways of toxicants excretion and few of these are summarized below are:

a. **Excretion by Urine and Bile:** The kidneys are the principal excretory organs. However, some stuffs particularly acids with high molecular weights are excreted with bile. While fraction of biliary excreted materials may be reabsorbed in gut as well through intestinal hydrolysis of the conjugate.

b. **Other Routes of Excretion:** The additional paths of excretions are renal excretion, saliva, sweat, milk, and maar. Some volatile organic substances and their fraction may excreted by exhalation. Some polar soluble and lipophilic molecules are willingly secreted to the foetus *via* the placenta, and milk as well in mothers. Few water-soluble compounds at some degree excreted in sweat and saliva also. Some metals like mercury are excreted by conjugating enduringly to the sulfhydryl groups of the keratin in hair.

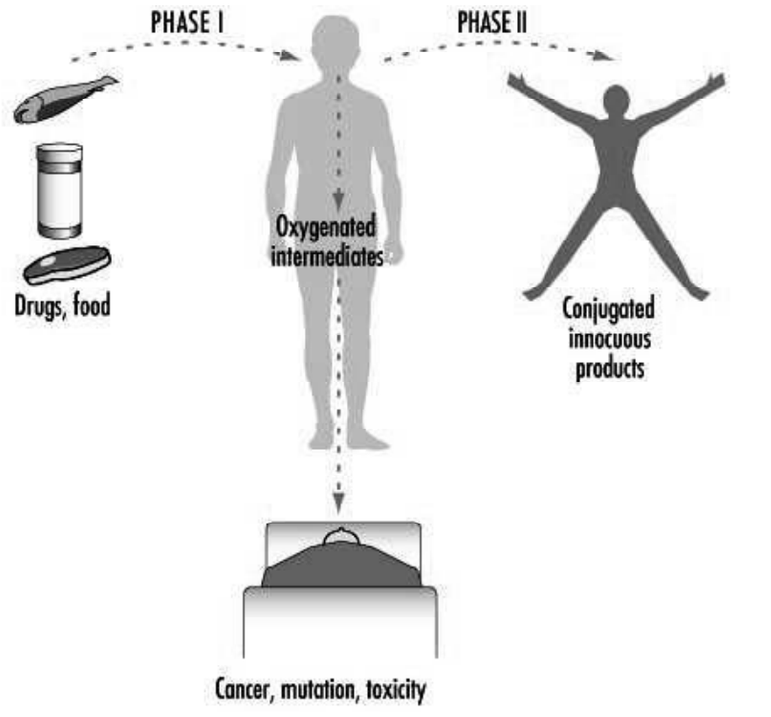


Fig.3.2 *The Classical Designation of Phase I and Phase II Xenobiotic- Or Drug-Metabolizing Enzymes*

3.5.3 Biotransformation of Toxicants

NOTES

Biotransformation is a technique which results to a metabolic conversion of foreign materials (xenobiotic) in the body. As widespread bylaws, metabolism transforms lipid-soluble xenobiotic to large water soluble metabolites for facilitated excretion. The liver is the principal site of biotransformation. All the xenobiotic passes through intestine are transported to the liver by vena porta. However, inhaled xenobiotic are dispersed *via* the common circulation to the liver. Liver cells comprise many enzymes to oxidize xenobiotic which further metabolized by additional enzymes in a 2nd phase to facilitate excretion *via* kidney or bile. The bacteria population in intestine may also add to biotransformation. Thus biotransformation can be appears as an essential course of action for survival and protection against toxicity. The mechanism of can be increased many folds few enzyme after the few days of exposure to toxic substances, called induction. The induction is often balanced so that both Phase 1 and Phase 2 reactions are augmented or amplified simultaneously. This way of action may escort more rapid biotransformation.

Check Your Progress

8. Which type of toxin are absorb via lung?
9. What is absorption?
10. If the snake's venom taken orally what will be the effect and what is the reason of it.
11. Define translocation.

3.6 EFFECTS AND RESPONSE

The human body represents a complex biological system on diverse levels of organization including from molecular-cellular level to tissues-organs level. The organism is working as an open system during exchange of matters and energy with the environment *via* immense biochemical reactions in a dynamic equilibrium. The penetration of molecules or ions of toxic substances from the work or living environment into biological system can upset normal cellular-biochemical phenomenon, or even destroy the cell also. This penetration of a toxicant from environment to the sites of toxicity within the organism can be alienated into three phases:

- The exposure phase encompasses all processes occurring between various toxicants and/or the influence on them of environmental factors (light, temperature, humidity, etc.). Chemical transformations, degradation, biodegradation (by micro-organisms) as well as disintegration of toxicants can occur.
- The toxicokinetic phase encompasses absorption of toxicants into the organism and all processes which follow: transport by body fluids, distribution and accumulation in tissues and organs, biotransformation to metabolites and elimination (excretion) of toxicants and/or metabolites from the organism.

NOTES

- The toxicodynamic phase refers to the interaction of toxicants (molecules, ions, colloids) with specific sites of action on, or inside the cells receptors ultimately producing a toxic effect.

Toxicokinetics

The elemental forms of toxic substances available in environment will go through the organism via skin, mucosa and epithelial cells of the respiratory and intestinal tracts based on the spot of entry. All toxicokinetic and toxicodynamic mechanism take place on the molecular-cellular level which is influenced by number of factors. The mechanism of action categorized in into two fundamental groups:

(i) Chemical constitution and physicochemical properties of toxicants;

(ii) Structure of the cell especially properties and function of membranes around the cell and its interior organelles.

Accumulation

Accumulation is the build-up of a material in a tissues and organs to augmented levels in comparison to blood and blood and plasma. It can also be defined as the gradual build-up of substances with time in the organism. There are several xenobiotic which show greater affinity of lipids and have a propensity to accumulate in adipose tissue, while others have an extraordinary affinity to bone. For example, calcium in bone could be exchanged for cations of lead, strontium, barium and radium, while hydroxyl ions for fluoride. The well-perfused internal organs in general attain the maximum concentration of toxicants in shortest time. However, the taken up capacity of hazardous substances by less perfused tissues is much slower, but its retention is higher which provoke the accumulation. Three components are of major importance for the intracellular distribution of toxicants: content of water, lipids and proteins in the cells of various tissues and organs. Retention of toxicant in a particular compartment is generally temporary and redistribution into other tissues can occur. Retention and accumulation is based on the difference between the rates of absorption and elimination. The duration of retention in a compartment is expressed by the biological half-life. This is the time interval in which 50% of the toxicant is cleared from the tissue or organ and redistributed, translocated or eliminated from the organism. The toxicants can be divided into four main groups according to their affinity, predominant retention and accumulation in a particular compartment:

1. Toxicants soluble in the body fluids are uniformly distributed according to the water content of compartments. Many monovalent cations (e.g., lithium, sodium, potassium, rubidium) and some anions (e.g., chlorine, bromine), are distributed according to this pattern.
2. Lipophilic toxicants show a high affinity for lipid-rich organs (CNS) and tissues (fatty, adipose).
3. Toxicants forming colloid particles are then trapped by specialized cells of the reticuloendothelial system (RES) of organs and tissues. Tri and quadrivalent cations (lanthanum, cesium, and hafnium) are distributed in the RES of tissues and organs.

NOTES

4. Toxicants showing a high affinity for bones and connective tissue (osteotropic elements, bone seekers) include divalent cations (e.g., calcium, barium, strontium, radon, beryllium, aluminum, cadmium and lead).

   a. **Accumulation in Lipid-Rich Tissues:** The standard man of 70kg body weight contains about 15% of body weight in the form of adipose tissue, increasing with obesity to 50%. However, this lipid fraction is not uniformly distributed. The brain (CNS) is a lipid-rich organ, and peripheral nerves are wrapped with a lipid-rich myelin sheath and Schwann cells. All these tissues offer possibilities for accumulation of lipophilic toxicants. Adipose tissue will accumulate toxicants due to its low vascularization and lower rate of biotransformation. Here accumulation of toxicants may represent a kind of temporary 'neutralization' because of lack of targets for toxic effect.

   b. **Retention in the Reticuloendothelial System:** In each tissue and organ a certain percentage of cells is specialized for phagocytic activity, engulfing micro-organisms, particles, colloid particles, and so on. This system is called the reticuloendothelial system (RES), comprising fixed cells as well as moving cells (phagocytes). Toxicants in the form of colloids will be captured by the RES of organs and tissues. Distribution depends on the colloid particle size, for example, larger particles retained in the liver, while smaller colloid particles occur in spleen, bone marrow and liver.

   c. **Accumulation in Bones:** About 60 elements can be identified as osteotropic elements, or bone seekers to form the skeletal system accounting 10 to 15% of the total body weight. Osteotropic elements can be divided into three groups:

      1. Elements representing or replacing physiological constituents of the bone. Twenty such elements are present in higher quantities. The others appear in trace quantities. Under conditions of chronic exposure, toxic metals such as lead, aluminum and mercury can also enter the mineral matrix of bone cells.
      2. Alkaline earths and other elements forming cations with an ionic diameter similar to that of calcium are exchangeable with it in bone mineral. Also, some anions are exchangeable with anions (phosphate, hydroxyl) of bone mineral.
      3. Elements forming micro colloids (rare earths) may be adsorbed on the surface of bone mineral.

The skeletons are representing a large potential storage depot for osteotropic toxicants based on the metabolic activity of the bones: (a) Active, metabolic bone (extensive resorption and new bone formation, or remodeling); (b) Stable bone (Slow remodeling or growth).

   a. **Accumulation in Hair and Nails:** The hair and nails contain keratin, with sulfhydryl groups able to chelate metallic cations such as mercury and lead.

NOTES

3.7 DOSE AND RESPONSE RELATIONSHIP

The exposure, dose-effect and response relationship is the association ship between dose and effect on the individual level. An increase in dose may raise the intensity of an effect, or results more harsh adverse effect. A dose-effect illustration may be obtained at the level of the entire organism, the cell or the target molecule. It is necessary to toxicology to set up dose-effect and dose-response relationships. In medical (epidemiological) field a criterion often used for accepting a causal relationship between an agent and a disease is that effect or response is proportional to dose. Several dose-response curves can be drawn for one type chemical effect. The dose-response curve for most toxic effects has a sigmoid shape when studied in large populations. The dose-response curve reflects the variations among individuals in a population. The slope of the curve varies from chemical to chemical and between different types of effects. For some chemicals with specific effects (carcinogens, initiators, mutagens) the dose-response curve might be linear from dose zero within a certain dose range. This means that no threshold exists and that even small doses represent a risk.

Effect of Exposure

Variation in exposure during the day and the total length of exposure during one's lifetime may be as important for the outcome (response) as mean or average or even integrated dose level. High peak exposures may be more harmful than a more even exposure level. This is the case for some organic solvents. On the other hand, for some carcinogens, it has been experimentally shown that the fractionation of a single dose into several exposures with the same total dose may be more effective in producing tumors.

Effect of Dose

A dose is often expressed as the quantity of a xenobiotic entering an organism (in units such as mg/kg body weight). The dose may be expressed in diverse (more or less informative) ways, an exposure dose, which is the air concentration of pollutant inhaled during a certain time period (in work hygiene usually eight hours), or the stored or absorbed dose (in industrial hygiene also called the body burden), which is the amount present in the body at a certain time during or after exposure. The tissue dose is the amount of substance in a specific tissue and the target dose is the amount of substance (usually a metabolite) bound to the critical molecule. The target dose can be expressed as mg chemical bound per mg of a specific macromolecule in the tissue. To apply this concept, information on the mechanism of toxic action on the molecular level is needed. The target dose is more exactly associated with the toxic effect. The exposure dose or body burden may be more easily available, but these are less precisely related to the effect.

In the dose concept a time aspect is often included, even if it is not always expressed. The theoretical dose according to Haber's law is: D = CT. where D is dose, 'C' is concentration of the xenobiotic in the air and 'T' the duration of exposure to the chemical.

Effect vs Response

Additive effects occur as a result of exposure to a combination of chemicals, where the individual toxicities are simply added to each other (1+1=2). Interaction between chemicals may result in an inhibition (antagonism), with a smaller effect than that expected from addition of the effects of the individual chemicals (1+1<2). Alternatively, a combination of chemicals may produce a more pronounced effect than would be expected by addition, this is called synergism (1+1>2). Systemic effects are toxic effects in tissues distant from the route of absorption. Target organ is the primary or most sensitive organ affected after exposure. The same chemical entering the body by different routes of exposure dose, dose rate, sex and species may affect different target organs. However, acute effects occur after limited exposure and shortly (hours, days) after exposure and may be reversible or irreversible. On the other hand chronic effects occur after prolonged exposure (months, years, decades) and/or persist after exposure has ceased.

Latency

Latency time is the time between first exposure and the appearance of a detectable effect or response. The term is often used for carcinogenic effects, where tumors may appear a long time after the start of exposure and sometimes long after the cessation of exposure.

Threshold Dose

A dose threshold is a dose level below which no observable effect occurs. Thresholds are thought to exist for certain effects, like acute toxic effects; but not for others, like carcinogenic effects (by DNA-adduct-forming initiators). The mere absence of a response in a given population should not, however, be taken as evidence for the existence of a threshold. Absence of response could be due to simple statistical phenomena: an adverse effect occurring at low frequency may not be detectable in a small population.

Check Your Progress

12. What is biological half-time?
13. What is elimination?
14. Define accumulation.
15. Define 'Reticuloendothelial System' (RES)'.

3.8 LD_{50} AND ED_{50}

LD_{50} (Effective Dose) is the dose causing 50% lethality in an animal population. The LD_{50} is often given in older literature as a measure of acute toxicity of chemicals. The higher the LD_{50}, the lower is the acute toxicity. A highly toxic chemical (with a low LD_{50}) is said to be potent. There is no necessary correlation between acute and chronic toxicity. ED_{50} (Effective Dose) is the dose causing a specific effect other than lethality in 50% of the animals.

NOTES

3.8.1 NOEL and LOEL

The NOEL means the 'No Observed (Adverse) Effect Level', or the highest dose that does not cause a toxic effect. To establish a NOEL requires multiple doses, a large population and additional information to make sure that absence of a response is not merely a statistical phenomenon. LOEL is the 'Lowest Observed Effective Dose' on a dose-response curve, or the lowest dose that causes an effect.

Safety Factor

A safety factor is a formal, arbitrary number with which one divides the NOEL or LOEL derived from animal experiments to obtain a tentative permissible dose for humans. This is often used in the area of food toxicology, but may be used also in occupational toxicology. A safety factor may also be used for extrapolation of data from small populations to larger populations. Safety factors range from 10^0 to 10^3. A safety factor of two may typically be sufficient to protect from a less serious effect (such as irritation) and a factor as large as 1,000 may be used for very serious effects (such as cancer). The term safety factor could be better replaced by the term protection factor or, even, uncertainty factor. The use of the latter term reflects scientific uncertainties, such as whether exact dose-response data can be translated from animals to humans for the particular chemical, toxic effect or exposure situation.

Extrapolations

Extrapolations are theoretical qualitative or quantitative estimates of toxicity (risk extrapolations) resultant from translation of data from one species to another or from one set of dose-response data to regions of dose-response where no data exist. Extrapolations usually made to predict toxic responses outside the observation range. Mathematical modelling is used for extrapolations based upon an understanding of the behavior of the chemical in the organism (toxicokinetic modelling) or based upon the understanding of statistical probabilities that specific biological events will occur (biologically or mechanistically based models).

Exposure determinations

Determination of toxicants and metabolites in blood, exhaled air, urine, sweat, faeces and hair is more and more used for evaluation of human exposure (exposure tests) and/or evaluation of the degree of intoxication. Therefore biological exposure limits (Biological MAC Values, Biological Exposure Indices—BEI) have recently been established. These bioassays demonstrate 'Internal Exposure' of the organism, that is, total exposure of the body in both the work and living environments by all portals of entry. Public in the work and/or residing environment are usually exposed simultaneously or consecutively to various physical and chemical agents. Also it is necessary to take into consideration that some persons use medications, smoke, consume alcohol and food containing additives and so on. It means that usually multiple exposure is occurring to produce three possible effects:

1. **Independent Effects:** Each agent produces a different effect due to a different mechanism of action.

2. **Synergistic Effects:** The combined effect is greater than that of each single agent. Here we differentiate two types:
   (a) Additive, where the combined effect is equal to the sum of the effects produced by each agent separately and (b) Potentiating, where the combined effect is greater than additive.
3. **Antagonistic Effects:** The combined effect is lower than additive.

However, studies on combined effects are rare. Therefore, priority objective of occupational and environmental toxicology is to improve the prevention or substantial limitation of health effects of exposure to hazardous agents in the general and occupational environments. Although heavy metals including lead, cadmium and mercury, belong to a specific group of toxic substances where the chronic effect of activity is dependent on their accumulation in the organs and depends on following:

a) **Critical Concentration for a Cell:** The concentration at which adverse functional changes, reversible or irreversible, occur in the cell.

b) **Critical Organ Concentration:** The mean concentration in the organ at the time at which the most sensitive type of cells in the organ reach critical concentration.

c) **Critical Organ:** That particular organ which first attains the critical concentration of metal under specified circumstances of exposure and for a given population.

d) **Critical Effect:** Defined point in the relationship between dose and effect in the individual, namely the point at which an adverse effect occurs in cellular function of the critical organ. At an exposure level lower than that giving a critical concentration of metal in the critical organ, some effects may occur that do not impair cellular function per se, yet are detectable by means of biochemical and other tests.

3.9 FACTORS INFLUENCING TOXICITY-RESPONSE RELATIONSHIPS

There are often large differences among humans in the intensity of response to toxic chemicals, and variations in susceptibility of an individual over a lifetime. These can be attributed to a variety of factors capable of influencing absorption rate, distribution in the body, biotransformation and/or excretion rate of a particular chemical. Apart from the known hereditary factors which have been clearly demonstrated to be linked with increased susceptibility to chemical toxicity in humans. The other factors include, constitutional characteristics related to age and sex, pre-existing disease states or a reduction in organ function (non-hereditary, i.e., acquired); dietary habits, smoking, alcohol consumption and use of medications; concomitant exposure to biotoxins (various microorganisms) and physical factors (radiation, humidity, extremely low or high temperatures or barometric pressures particularly relevant to the partial pressure of a gas), as well as concomitant physical exercise or psychological stress situations; previous occupational and/or

NOTES

environmental exposure to a particular chemical, and in particular concomitant exposure to other chemicals, not necessarily toxic (e.g., essential metals). According to the stage at which these factors act (absorption, distribution, biotransformation or excretion of a particular chemical), the mechanisms can be roughly categorized according to two basic consequences of interaction: (1) A change in the quantity of the chemical in a target organ, that is, at the site(s) of its effect in the organism (toxicokinetic interactions), or (2) A change in the intensity of a specific response to the quantity of the chemical in a target organ (toxicodynamic interactions).

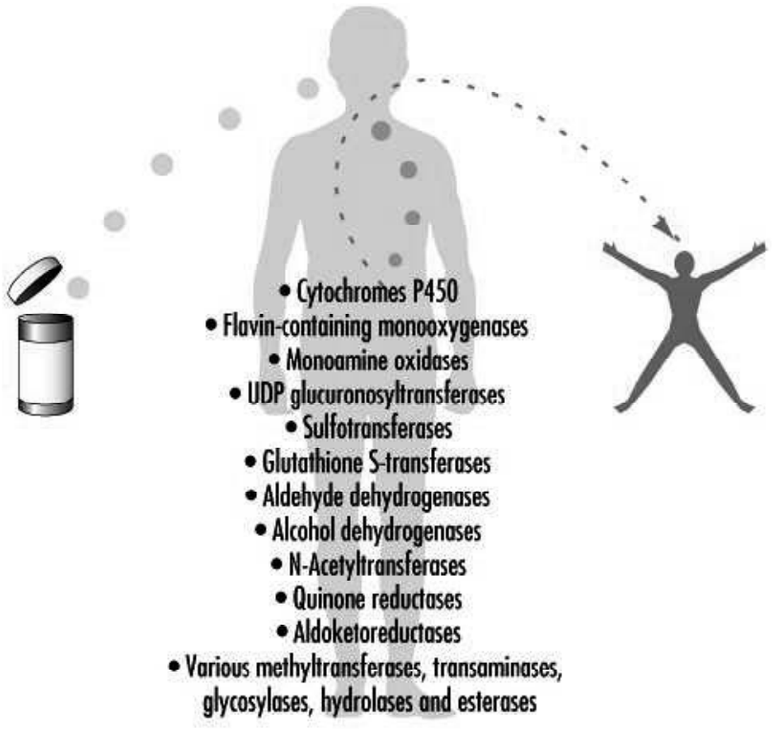


Fig.3.3 *Examples of drug-metabolizing enzymes*

Influence of Age

Compared to adults, very young children are often more susceptible to chemical toxicity because of their relatively greater inhalation volumes and gastrointestinal absorption rate due to greater permeability of the intestinal epithelium, and because of immature detoxification enzyme systems and a relatively smaller excretion rate of toxic chemicals. The central nervous system appears to be particularly susceptible at the early stage of development with regard to neurotoxicity of various chemicals, for example, lead and methyl mercury. On the other hand, the elderly may be susceptible because of chemical exposure history and increased body stores of some xenobiotic, or pre-existing compromised function of target organs and/or relevant enzymes resulting in lowered detoxification and excretion rate. Each of these factors can contribute to weakening of the body's defenses—a decrease in reserve capacity, causing increased susceptibility to subsequent exposure to other hazards.

Influence of Gender

Gender-related differences in susceptibility have been described for a large number of toxic chemicals (approximately 200), and such differences are found in many mammalian species. It appears that males are generally more susceptible to renal toxins and females to liver toxins. The causes of the different response between males and females have been related to differences in a variety of physiological processes (e.g., females are capable of additional excretion of some toxic chemicals through menstrual blood loss, breast milk and/or transfer to the foetus, but they experience additional stress during pregnancy, delivery and lactation).

Influence of Dietary Habits

Dietary habits have an important influence on susceptibility to chemical toxicity, mostly because adequate nutrition is essential for the functioning of the body's chemical defense system in maintaining good health. Adequate intake of essential metals (including metalloids) and proteins, especially the sulphur-containing amino acids, is necessary for the biosynthesis of various detoxificating enzymes and the provision of glycine and glutathione for conjugation reactions with endogenous and exogenous compounds. Lipids, especially phospholipids, and lipotropes (methyl group donors) are necessary for the synthesis of biological membranes. Carbohydrates provide the energy required for various detoxification processes and provide glucuronic acid for conjugation of toxic chemicals and their metabolites. Selenium (an essential metalloid), glutathione, and vitamins such as vitamin 'C' (water soluble), vitamin 'E' and vitamin 'A' (lipid soluble), have an important role as antioxidants and free-radical scavengers for protection against toxic chemicals. However, diet itself can be an additional source of individual exposure to various toxic chemicals (e.g., considerably increased daily intakes and accumulation of arsenic, mercury, cadmium and/or lead in subjects who consume contaminated seafood).

Influence of Smoking

The habit of smoking can influence individual susceptibility to many toxic chemicals because of the variety of possible interactions involving the great number of compounds present in cigarette smoke (especially polycyclic aromatic hydrocarbons, carbon monoxide, benzene, nicotine, acrolein, some pesticides, cadmium, and, to a lesser extent, lead and other toxic metals, etc.), some of which are capable of accumulating in the human body over a lifetime, including pre-natal life (e.g., lead and cadmium). Heavy cigarette smoking over a long period can considerably reduce the body's defense mechanisms by decreasing reserve capacity to cope with the adverse influence of other life-style factors.

Influence of Alcohol

Consumption of alcohol (ethanol) can influence susceptibility to many toxic chemicals in several ways. It can influence the absorption rate and distribution of certain chemicals in the body, for example, increase the gastrointestinal absorption rate of lead, or decrease the pulmonary absorption rate of mercury vapor by inhibiting oxidation which is necessary for retention of inhaled mercury vapor. Ethanol can also influence susceptibility to various chemicals through short-term changes

NOTES

in tissue pH and increase in the redox potential resulting from ethanol metabolism. Because the affinity of both essential and toxic metals and metalloids for binding to various compounds and tissues is influenced by pH and changes in the redox potential, even a moderate intake of ethanol may result in a series of consequences, such as:

(1) Redistribution of long-term accumulated lead in the human organism in favor of a biologically active lead fraction,

(2) Replacement of essential zinc by lead in zinc-containing enzyme(s), thus affecting enzyme activity, or influence of mobilized lead on the distribution of other essential metals and metalloids in the organism such as calcium, iron, copper and selenium,

(3) Increased urinary excretion of zinc and so on. The effect of possible aforementioned events can be augmented due to the fact that alcoholic beverages can contain an appreciable amount of lead from vessels or processing.

Influence of Medications

The common use of various medications can influence susceptibility to toxic chemicals mainly because many drugs bind to serum proteins and thus influence the transport, distribution or excretion rate of various toxic chemicals, or because many drugs are capable of inducing relevant detoxifying enzymes or depressing their activity, thus affecting the toxicity of chemicals with the same biotransformation pathway. Characteristic for either of the mechanisms is increased urinary excretion of trichloroacetic acid when using salicylate, sulphonamide or phenylbutazone, and an increased hepato-nephrotoxicity of carbon tetrachloride when using phenobarbital. In addition, some medications contain a considerable amount of a potentially toxic chemical, for example, the aluminum-containing antacids or preparations used for therapeutic management of the hypophosphatemia arising in chronic renal failure.

Influence of Concomitant Exposure to Other Chemicals

The changes in susceptibility to adverse health effects due to interaction of various chemicals (i.e., possible additive, synergistic or antagonistic effects) have been studied almost exclusively in experimental animals, mostly in the rat. Relevant epidemiological and clinical studies are lacking. This is of concern particularly considering the relatively greater intensity of response or the variety of adverse health effects of several toxic chemicals in humans compared to the rat and other mammals. Combined exposure to various organic solvents can result in various additive, synergistic or antagonistic effects mainly due to the capability of influencing each other's biotransformation.

Influence of Genetic Constituents

It has long been recognized that each person's response to environmental chemicals is different. Major determinants of individual response to chemicals include important differences among more than a dozen superfamilies' of enzymes, collectively termed xenobiotic (foreign to the body) or drug-metabolizing enzymes. Although the role

of these enzymes has classically been regarded as detoxification, these same enzymes also convert a number of inert compounds to highly toxic intermediates. It is now clear that each individual possesses a distinct complement of xenobiotic-metabolizing enzyme activities; this diversity might be thought of as a "metabolic fingerprint".

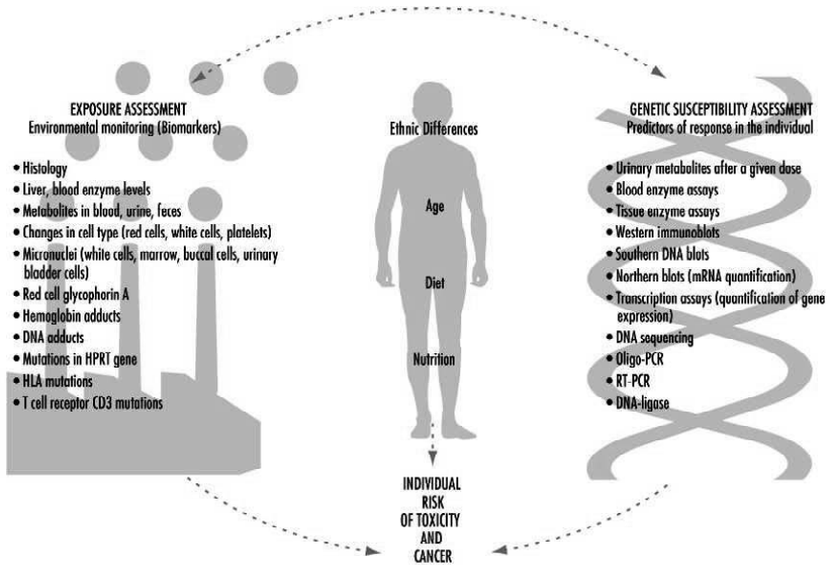


Fig.3.4 *The Interrelationships among Exposure Assessment, Ethnic Differences, Age, Diet, Nutrition and Genetic Susceptibility in the Individual Risk of Toxicity and Cancer*

3.9.1 Variation in Toxic Responses

Toxicologists and pharmacologists commonly speak about the 'Average Lethal Dose' for 50% of the population (LD_{50}), the 'Average Maximal Tolerated Dose' for 50% of the population (MTD_{50}), and the 'Average Effective Dose of a Particular Drug' for 50% of the population (ED_{50}). However, how do these doses affect each of us on an individual basis? In other words, a highly sensitive individual may be 500 times more affected or 500 times more likely to be affected than the most resistant individual in a population; for these people, the LD_{50}, MTD_{50} and ED_{50} values would have little meaning. LD_{50}, MTD_{50} and ED_{50} values are only relevant when referring to the population as a whole. Most of the population will exhibit the mean and standard deviation of toxic response as a function of dose. The 'Resistant Outlier' is an individual having less of a response at higher doses or exposures. A 'Sensitive Outlier' is an individual having an exaggerated response to a relatively small dose or exposure. These outliers, with extreme differences in response compared to the majority of individuals in the population, may represent important genetic variants that can help scientists in attempting to understand the underlying molecular mechanisms of a toxic response.

NOTES

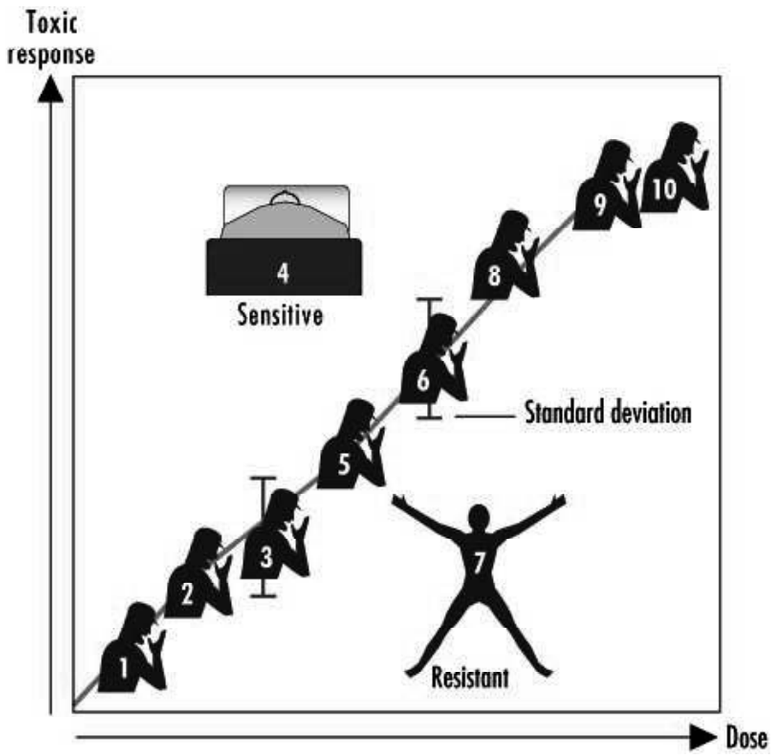


Fig.3.5 *Generic Relationship between Any Toxic Response and the Dose of Any Environmental, Chemical or Physical Agent*

Check Your Progress

16. What is a dose?
17. Define NOEL and LOEL.
18. What is a safety factor?
19. What are synergistic effects?

3.10 TOXICOLOGICAL TESTING TECHNIQUES

The majority of mechanistic studies begin with a descriptive toxicological study in animals or clinical observations in humans. Ideally, animal studies include careful behavioral and clinical observations, careful biochemical examination of elements of the blood and urine for signs of adverse function of major biological systems in the body, and a post-mortem evaluation of all organ systems by microscopic examination to check for injury. This is analogous to a thorough human physical examination that would take place in a hospital over a two- to three-day time period except for the post-mortem examination. Understanding mechanisms of toxicity is the art and science of observation, creativity in the selection of techniques to test various hypotheses, and innovative integration of signs and symptoms into

NOTES

a causal relationship. Mechanistic studies start with exposure, follow the time-related distribution and fate in the body (pharmacokinetics), and measure the resulting toxic effect at some level of the system and at some dose level. The processes involved in a risk assessment for human health can be broken down into four steps as illustrated in the diagram below from the US Environmental Protection Agency (EPA).

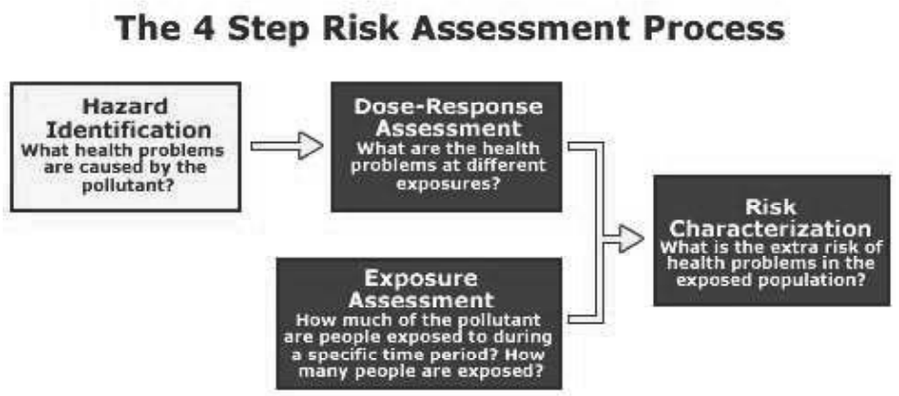


Fig. 3.6 *The Four Step Risk Assessment Process*

3.10.1 General Test Design

The hazard identification and dose-response assessment steps are primarily based on a number of different tests where animals are exposed to the chemical or test substance. These tests are called toxicity tests. Government regulations often prescribe a specific regimen of toxicity testing to generate the data that enable regulators to determine the chemical's risks to human health and/or the environment. Companies producing the chemical/product are responsible for the generation and submission of this 'Safety Data' to regulatory authorities such as the US EPA, the European Chemicals Agency (ECHA), and Japan's Ministry of the Environment (MOE). A toxicity test, by extension, is designed to generate data concerning the adverse effects of a substance on human or animal health, or the environment. Many toxicity tests examine specific types of adverse effects, known as endpoints, such as eye irritation or cancer. Other tests are more general in nature, ranging from acute (single-exposure) studies to repeat dose (multiple-exposure) studies, in which animals are administered daily doses of a test substance.

There is a long history in the use of animals as models for toxicity testing. During the 20th century, as regulatory agencies were established by national governments to address regulatory requirements that products need to be "safe" for consumers. There are many advantages, including scientific, ethical, and economic ones, for replacing the animal toxicity tests with non-animal (*in vitro* and *in silico*) test systems.

NOTES

Table 3.1 *Summary of Toxicity Endpoints Covered and Their Description*

Endpoint	Description
Acute Systemic Toxicity	Adverse effects occurring within a relatively short time after administration of a single (typically high) dose of a substance via one or more of the following exposure routes: oral, inhalation, skin, or injection.
Carcinogenicity	Chemically-induced cancer, whether through genotoxic or non-genotoxic (e.g., growth-promoting) mechanisms.
Dermal Penetration	Extent and rate by which a chemical is able to enter the body via the skin; also known as skin or percutaneous absorption.
Ecotoxicity	Chemically-induced adverse effects on organisms in the environment, including mammals, birds, fish, amphibians, crustaceans, other aquatic invertebrates, and even plants; common study designs include acute systemic, dietary, and reproductive (also known as life-cycle) toxicity, and bioaccumulation.
Endocrine Disruptors	Substances that interact with the hormonal systems of humans and/or wildlife, and thereby disrupt normal biological functions.
Eye Irritation/Corrosion	Chemically-induced eye damage that is reversible (irritation) or irreversible (corrosion).
Genotoxicity	Chemically-induced mutations and/or other alterations in the structure, information content, or segregation of genetic material (e.g., DNA strand breaks or a gain/loss in chromosome number).
Neurotoxicity	Chemically-induced adverse effects on the brain, spinal cord, and/or peripheral nervous system (e.g., deficits in learning or sensory ability).
Pharmacokinetics & Metabolism	Study of the absorption, distribution, metabolism, and elimination (ADME) of drugs or chemicals in the body; also known as toxicokinetics.
Phototoxicity	Toxic responses from a substance (applied to the body or ingested) following exposure to light or skin irradiation.
Repeated Dose/Organ Toxicity	General toxicological effects occurring as a result of repeated daily exposure to a substance (via oral, inhalation, dermal, or injection routes) for a portion of the expected life span (i.e., sub acute or sub chronic exposure), or for the majority of the life span (i.e., chronic exposure).
Reproductive & Developmental Toxicity	Chemically-induced adverse effects on sexual function, fertility, and/or normal offspring development (e.g., spontaneous abortion, premature delivery, or birth defects); generally determined through the breeding of one or more generations of offspring.
Skin Irritation/Corrosion	Chemically-induced skin damage that is reversible (irritation) or irreversible (corrosion).
Skin Sensitization	The induction of allergic contact dermatitis following exposure to a chemical substance.

3.10.2 Acute Toxicity Test

Acute toxicity describes the adverse effects of a substance that result either from a single exposure or from multiple exposures in a short period of time (usually less than 24 hours). To be described as 'Acute Toxicity', the adverse effects should occur within 14 days of the administration of the substance. Acute toxicity is distinguished from chronic toxicity which describes the adverse health effects from repeated exposures, often at lower levels, to a substance over a longer time period (months or years). There are many substances which are capable of producing adverse effects to exposed humans and animals. Individuals' and species' susceptibility, route of exposure, dose, and duration of the exposure may influence the presence or severity of the effect. Acute toxicity testing is conducted to determine the effects of a single exposure to a substance. Acute effects typically become manifest almost immediately after a single exposure, although depending on the causative material and the mechanism of its action, a latent period may precede

the manifestation of the effect(s). Sub chronic and chronic toxicity testing is conducted to determine the existence of effects that become evident after an exposure of extended duration.

NOTES

The objectives of acute lethal toxicity testing include the following: defining the degree of hazard that may result from exposure to a test substance; determining susceptible populations and species; identifying target organs or systems; providing information that can be used in developing risk evaluations; and providing information to clinicians that will enable them to predict, diagnose, and/or provide treatment for acute exposures. Acute toxicity testing requires test materials to be given to animals for a finite but short period of time, usually as a single exposure. A test material can be administered by various routes to determine its ability to induce toxicity, including oral, dermal, and inhalation exposures. For acute lethality testing, rats and mice are usually the species of choice, largely due to the vast amount of background data that has been assembled through history. Death is no longer required as the endpoint indicative of acute toxicity. Endpoints have been developed and validated that permit animals to be humanely killed when in a moribund condition while still fulfilling their role in the development of toxicological information.

3.10.3 LD_{50}/LC_{50} Test

The minimum concentration or the smallest dose of the chemical agent that causes adverse effects in an organism is known as the 'Threshold Dose'. In other words, a threshold dose of a chemical agent is the concentration at which its toxic action just starts. The limit of this concentration is known as threshold limit. As a matter of fact, below this limit the use of chemical agent in a biological system is considered as relatively safe. The sub lethal dose is the amount of chemical agent required to develop some visible symptoms without causing death to the test organisms. Thus, the range of concentration of the toxic agent between the threshold and the lethal doses may be called the sub lethal dose. Under its effect the organism manifests itself in the form of certain responses the organism under observation exhibits. The response or symptoms exhibited by an organism, on the administration of sub lethal dose may determine the effective dose or concentration. This is another index of toxicity and is denoted as ED (Effective Dose) or EC (Effective Concentration).

A median lethal dose or concentration of a toxic agent is its concentration which can kill 50% of the organisms of the group concerned. This toxicity is denoted by the symbol LD_{50} or LC_{50}. Likewise LD_{10}/LC_{10} concentration denotes the quantity which can kill 10% of the organisms of a group. Similarly, LD_{90}/LC_{90} denotes the dose concentration which causes 90% mortality in the group concerned. In a dose-response curve observed in a hypothetical case, the percentage mortality observed for a series of gradually increasing doses takes the shape of a sigmoid curve. There is a point where there is no response. This point or limit is termed as the threshold of lethal toxicity. With the increase in dose, percentage of mortality rises till LD_{50}/LC_{50} which represents the dose concentration capable of eliminating 50% individuals of the group. At LD_{100}, the toxicity is maximum and is sufficient to kill all the individuals of the group. (Refer figure 3.7)

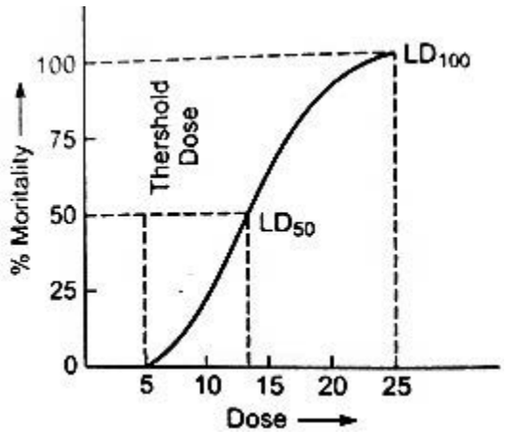


Fig.3.7 *The Sigmoid Dose-Response Curve Showing LD_{50} and LD_{100}*

The chronic toxicity indicates the percentage of the acute LD 50 (1 dose) to be given daily to produce 50% mortality over a specified number of days. Thus, higher the value of the 100-day LD_{50} index, the greater is the percentage of the acute LD_{50} (1 dose) which is to be given to produce 50% mortalities over a period of 100 days, and the toxic agent is more safe for chronic daily administration. The Cumulative Toxic Factor (CTF) is calculated by dividing the acute LD_{50} by cumulative LD_{50} (CLD_{50}) at weekly time intervals. The CTF varies from 2.06 for di-isobutyl to 258.6 for DEHP. Thus, a numerical rating of 1-6 has been proposed to characterize the cumulative hazardous potentials of any compound by any route. Range of one is assigned to compounds having CTF less than 1.5 and is considered to be practically non-hazardous. Range 6 is assigned with CTF value of more than 100 and is classified as supercumulative.

3.10.4 Skin and Eye Test

Chemicals and substances such as personal care products, pesticides, and cleaning supplies are tested to determine if they might injure eyes or skin and to classify them for appropriate labeling and packaging. Nearly all of these tests, referred to as ocular and dermal irritation tests. The main goal of toxicological scientific endeavors is to safeguard human beings against the possible adverse effects of diverse types of chemicals, including pharmaceuticals, cosmetics, household products, industrial chemicals, and agrochemicals. The exposure can be incidental, accidental, or intentional, as with cosmetics and certain drugs. One of the possible effects of the exposition and accidental contact with new chemicals is eye and skin irritation. In general, the physiological response to a chemical stimulus is irritation, which involves objective changes (e.g., local redness and oedema) and subjective sensations (e.g., pruritus and pain). The Draize eye test involves several phases and based on applying the test substance to the rabbit eye and evaluating the damage caused to the cornea, iris, and conjunctiva. The acute skin irritation is evaluated *in vivo* in rabbits after they have been shaved. The scoring system enables products to be classified from nonirritant to very irritant. Alternative parameters to erythema and oedema have also been developed including cutaneous blood flow, as measured by 'Laser Doppler Flowmetry', infrared detection of skin temperature, and skin thickness assessment.

3.10.5 Toxicity Curves

NOTES

When a toxicity test such as 96-h LC_{50} is conducted, mortality data is obtained for various intermediate time periods. The LC_{50} for these time periods can be used during the test to plot a toxicity curve with the help of exposure time and concentration. Such a curve gives an idea of how the test is progressing and also indicates when the acute lethality has ceased. This is indicated where the curve is asymptotic to the time axis. The LC_{50} for a specific exposure time in the asymptotic part of the curve is called the threshold or incipient LC_{50} or the lethal threshold concentration. This is the concentration at which 50% of the test population can survive for an indefinite time. For chemical A, the vertical asymptote after approximately 24 hours indicates that acute mortality has ceased. Thus, the test may be terminated at this stage. For chemical B, there is no asymptote at the end of the test. This indicates that acute mortality is continuing. Therefore, the test may be continued beyond 96 hours to determine whether the threshold limit exists. The toxicity curve may assume different shapes rather than a curve. The shape of the curve provides information about the mode of action of the chemical agent. (Refer figure 3.8)

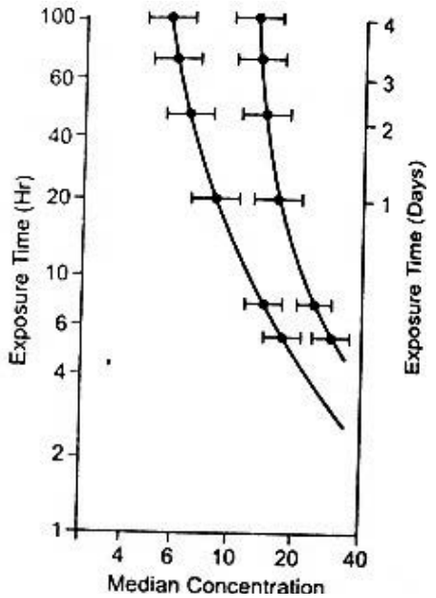


Fig.3.8 *Hypothetical Time-Toxicity Curves for Two Chemical A & B to Evaluate Incipient* LC_{50}

Safety Margin and Therapeutic Index

The therapeutic margin or margin of safety indicates the closeness of lethal dose to the therapeutically effective dose:

Therapeutic margin (TM) = LD_{50}/ED_{50}

The margin of safety is of great importance to a biochemist or physician because it indicates the safety margin of a particular drug by showing that how much extra concentration of a therapeutic drug will turn it into lethal dose. Thus, greater the therapeutic value, greater is the margin of safety. Use of chemical agents is hazardous for a biological system but a large number of chemical agents are used as medicines, pesticides, preservatives and flavoring agents. In therapeutic

NOTES

practice, the knowledge of threshold dose, the effective dose and the lethal dose of a chemical agent is essential. When the effective dose of a chemical agent is fairly close to the lethal dose, the chances of over-dosing are obvious and the relative margin of safety becomes very low. On the other hand if the effective dose is very low but the lethal dose is very high, the chances of over-dosing are negligible. The relative margin of safety, therefore, may be defined as the ratio between the effective dose and the lethal dose. In the clinical medicine, the ratio between the lethal dose and effective dose is termed as therapeutic index. It is calculated with reference to LD_1 and ED_{99}, i.e., the dose of chemical agent which is effective in 99% cases whereas it is lethal by only in 1% individuals. (Refer figure 3.9)

Therefore, Therapeutic index (TI) = LD_1/ED_{99}

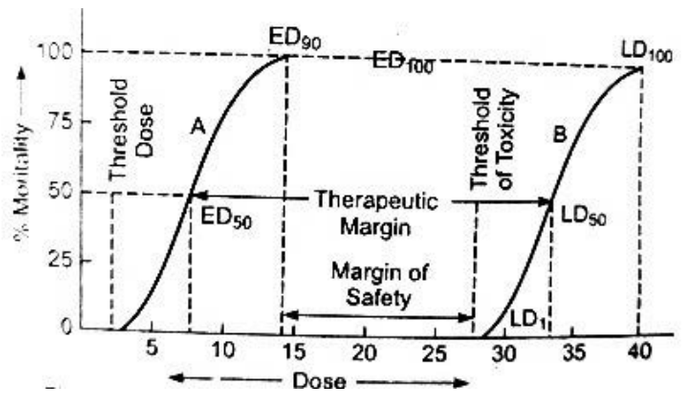


Fig.3.9 *Therapeutic Dose-Response Curve (A) And Toxic Dose-Response Curve (B) For the Same Chemical Showing Margin of Safety*

Toxicity Curve of Chemical Mixtures

When a new drug is formulated, its effect is studied in combination with other drugs. The study starts with an LD_{50} determination of a single ingredient. Now, a graph is plotted. Next step is the division of two LD_{50} into LD_{50} equivalents. In case the toxicities are strictly additive, the LD_{50} of any combination when plotted on the coordinate system lies on the line drawn from LD_{50} of compound A to the LD_{50} of B. (Refer figure 3.10)

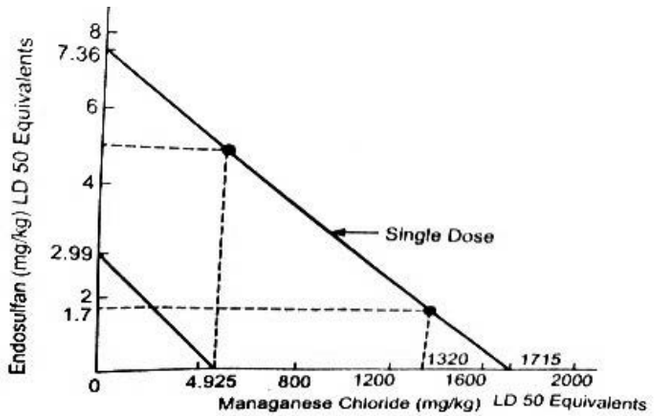


Fig. 3.10 *Toxicity Testing of Endosulfan and Manganese Chloride Combination in Mice*

NOTES

Point 'O' on the Graph Indicates Antagonising Effect of the Two Chemicals

In the figure, LD_{50} of insecticide endosulfan and that of $MnCl_2$ are plotted. The LD_{50} equivalents of both the compounds are connected by a straight line. These compounds when given in combination antagonize each other because their combined LD_{50} lies above the straight line. In case two compounds have additive effect, the point O will lie below the line connecting the LD_{50} of these two compounds. Such tests are of utility only for those drugs which are intended to be used as combination.

Toxic Dose-Response Curve

The amount of drug or medicine introduced into an organism or man by ingestion or by injection called dose. The effective dose or concentration of a toxic agent is the amount required to produce a particular response or symptom in an organism. However, the minimum concentration or the smallest dose of the chemical agent that causes the adverse effects in an organism is known as the threshold dose and the limit of this concentration is called threshold limit. On the other hand sub lethal dose is the amount of chemical agent required to develop some visible symptoms without causing death to the test organism is called as sub lethal dose. It is the range of concentration of the toxic agent between the threshold and the lethal doses. The dose or concentration of a chemical agent which kills an individual is known as 'Toxic Lethal Dose' (LD) or 'Toxic Lethal Concentration' (LC). As the toxicity of chemicals varies from individual to individual, it is usually assessed on group of individuals. A gradually increasing of chemical agent is administered equally to individuals in a group of animals and the percentage mortality is determined. It is ensured that each group consists of individuals of approximately same age and vitality while conditions during the administration and observations are similar. From the data thus, obtained a graph may be plotted between the concentrations of the chemical agent administrated and the percentage mortality which results due to it. The graph so obtained is a typical sigmoid form of concentration-response curve. With the help of experiments and statistical methods accurate results may be obtained. From this data toxic lethal dose or concentration can be determined. (Refer figure 3.11)

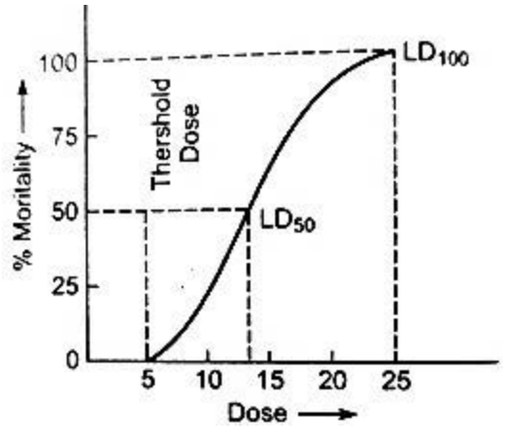


Fig. 3.11 *The sigmoid Toxic Dose-Response Curve*

For the evaluation of toxicity of chemical agents, it is not necessary to deal with quantities that may result in 100% mortality of the individuals of the group but

NOTES

the dose which is enough to kill 50% of the individuals of the group against the chemical. For this reason, the term median lethal dose is often used. If the dose response curve plotted in that reference for the appearance of any desirable symptom is termed as therapeutic dose response curve like that of toxic-response curve, takes a sigmoid shape too.

Time-Action Curves

The relationship between dose and response is established when the effect of drug at a particular dose has reached a maximum or a steady level. The chemical effect of a drug or chemical changes with time. There are four different phases in the time-action curves (Refer figure 3.12):

i. **Phase 1 (Ta):** This is the time of onset of action. Following administration of a chemical to a system, there is some delay before the first signs of effect are visible. For some chemicals, the delay may be so short that it seems to have an instantaneous effect.

ii. **Phase 2 (Tb):** This is the time to peak effect. The maximum response will occur when the most resistant cells have been affected to the maximum or when the chemical has reached the most inaccessible cells of the responsive tissue.

iii. **Phase 3 (Tc):** It is duration of action. It extends from the moment of onset of effects to the time when an action can no longer be measured. It depends at the rate of metabolism, alteration or removal of the chemical from the body.

iv. **Phase 4 (Td):** It shows residual effects. Certain chemicals may exert a residual action even after termination of their primary action.

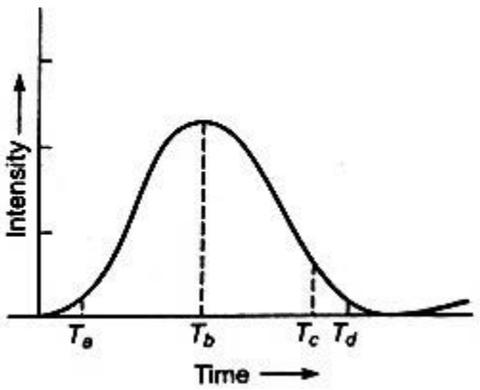


Fig. 3.12 *Time-Action Curve Showing Relationship of Intensity of Toxicant with Time. Where: Ta, Latency Time; Tb, Peak Time; Tc, Persistence Time; Td, Residual Time*

Graded Response Curve

When a dose is administered to a single individual, the response increases in a gradual, smooth fashion provided the dose does not exceed the critical level called the threshold dose. The degree of effect produced by increasing doses of a chemical or drug eventually reaches a steady level, called**, 'Ceiling Effect'**. Ceiling dose

NOTES

does not elicit any further increase in the effect. The shape of the graded curve is a characteristic for a chemical agent or toxicant under specified conditions. The curve may be a symmetrical sigmoid curve or an unsymmetrical sigmoid curve in which either end or even one half of the sigmoid curve may be distorted. Usually the central part of the graded curve is linear for a range so that the rate of change of response is directly related to the rate of change of dose. (Refer figure 3.13)

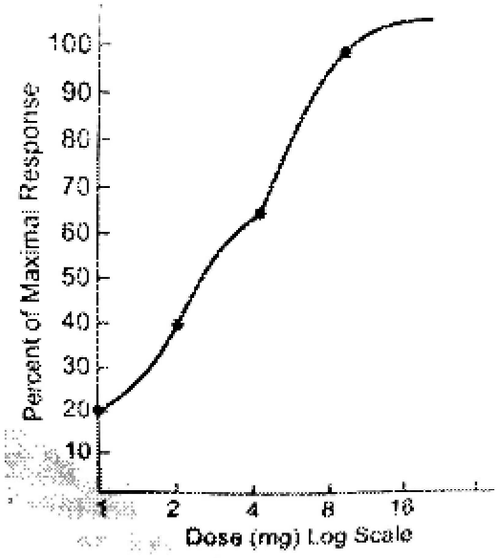


Fig. 3.13 *Response of an Experimental Animal Model to Increasing Concentration of a Toxicant*

Quantal Response Curve

Quantal dose response is the frequency with which any dose of a drug evokes a static, fixed response. The curve for quantal response describes the distribution of minimum dose that produces a given effect in a population of an organism. In its most basic form, the quantal dose-response curve takes the shape of a guassian or normal distribution. The normal distribution expresses the frequency of occurrence of random values of different magnitudes. The doses of a chemical that give quantal responses, the quassian distribution suggests that the bserved variation in doses needed to produce the response is due to simple random variation. If the cause of dose variation is mainly due to random events, the distribution of doses would confirm to a symmetrical normal curve. But the distribution curve describing the reaction to variable doses to a chemical is usually not symmetrical and bell-shaped but is skewed. But the skewed curve can be converted to the normal bell-shaped frequency curve by plotting the doses logarithmically. This method is used in determining the median lethal dose of chemicals in organisms. (Refer figure 3.14)

NOTES

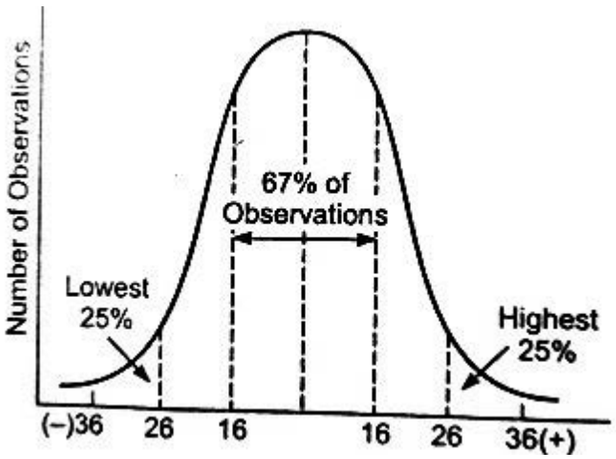


Fig. 3.14 *Quantal Response Curve for A Chemical Administered in a Large Population Showing Normal Bell-Shaped Frequency Curve*

Cumulative response curve

In multi dose studies, when the detoxification and elimination of a toxic agent is incomplete by 24 hours, the toxic effects of the first dose will be added in part to those of second dose and so on. It is called cumulative toxicity. The response to cumulative toxicity is called cumulative response. For the evaluation of cumulative toxicity of chemicals, the 100-day LD_{50} index is used. Daily dose with increasing fractions of the acute LD_{50} is given. The percentage of mortality from each daily dose are tabulated at weekly intervals. From these results LD_1, LD_{50} and LD_{99} are calculated at weekly intervals. LD_{50} calculated at 100 days interval is referred as LD_{50} (100 days). These values indicate the daily dose which will produce the indicated mortality rate when given daily for the number of days specified. The 100 days LD_{50} index is calculated as follows:

$$100 \text{ days } LD_{50} \text{ Index} = (LD_{50}(100 \text{ days}) / LD_{50}(1\text{-day})) \times 100$$

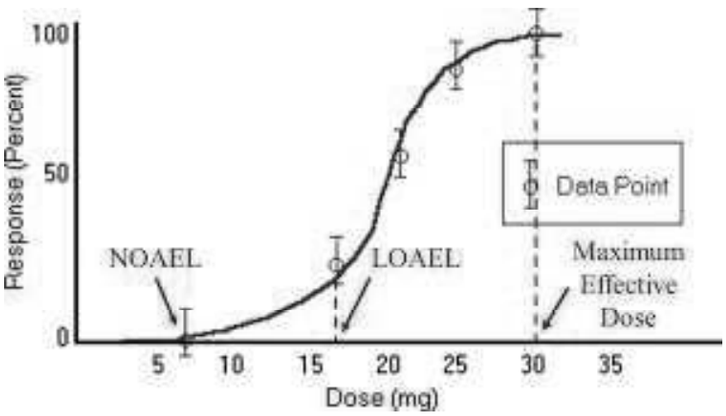


Fig.3.15 *Cumulative Dose-Response Curve Showing NOAEL (No Observable Adverse Effect Level), LOAEL (Lowest Observable Adverse Effect Level) and Maximum Effective Dose (MED)*

Check Your Progress

20. Define toxicity test.
21. What is a threshold dose?
22. Define the lethal threshold concentration.
23. What is the therapeutic margin or margin of safety?
24. What is the method of establishing relationship between dose and response**?**

NOTES

3.11 ANSWERS TO 'CHECK YOUR PROGRESS'

1. Toxicology is the investigation of unfavourable impacts of synthetic substances on living individuals. Toxicology is defined as the investigation of antagonistic impacts of substance, physical, or natural agents on living life forms and the environment, including the counteraction and amelioration of such unpleasant impacts.
2. A toxicologist is a researcher that decides the unsafe impacts of agents and the cell, biochemical, and sub-atomic instruments answerable for the impacts. Toxicant, toxin, and poison substance are regularly utilized reciprocally in the writing; in any case, there are unpretentious contrasts as tabulated.
3. Xenobiotic is the universal term that is employed for a foreign material taken into the body. It is derived from the Greek word '*xeno*' means foreigner. Xenobiotics may bring into beneficial effects (if pharmaceuticals) or may be toxic (e.g., lead).
4. A systemic toxicant or systemic toxin is one that affects the complete body or lots of organs rather than a specific site. For example, potassium cyanide is a systemic toxicant which affects virtually every cell and organ in the body by interfering with the cell's ability to utilize oxygen.
5. A toxic agent gives toxicity when it reaches to contact with the organisms and subsequently absorbed in its biological parts. The toxic ailment of toxins depends on the exposure duration and its concentration.
6. 'The Nernst Partition Coefficient' (P) establishes the solubility of toxicant molecules in the two-phase octanol (oil)-water system, associating to their lipo- or hydrosolubility. It greatly affects the distribution and accumulation of toxicants in the organism.
7. If an organism gets exposed or intentionally administers higher and lethal doses of a toxic agent, it results in extreme symptoms of adverse effect. Because of lethality dose of toxins, its concentration rises sharply in the blood leading death of the organism known as acute toxicity.
8. Small airborne particles, gases, vapours and aerosols through lungs. The rate of absorption is reliant on flow (pulmonary ventilation, cardiac output) and solubility (blood: air partition coefficient).
9. Absorption is the taken in of a substance from the environment into the organism. The term typically includes not only the entrance into the barrier

NOTES

tissue but also the further transport into circulating blood. There are a variety of routes of exposure and absorption of toxicants to organisms including respiratory channels, dermal channels, gastrointestinal channels and some special routes for certain toxicants.

10. Snake venom becomes non-toxic when taken orally because it is made harmless by the enzymes of the alimentary canal.
11. Translocation is the movement of substance (a pesticide, toxicants or any metal) from the site of exposure to the target site. A toxic agent causes toxicity only when it is absorbed into the biological system and translocated to the site of action in active state.
12. The biological half-time is the moment needed after the finish of exposure to diminish the quantity to one-half in exposed organism. The half-time should be applied with caution, as it may possibly change with dose and duration of exposure.
13. Elimination or removal is the vanishing of a material in the body through excretion or transformation.
14. Accumulation is the build-up of a material in a tissues and organs to augmented levels in comparison to blood and blood and plasma. It can also be defined as the gradual build-up of substances with time in the organism.
15. In each tissue and organ a certain percentage of cells is specialized for phagocytic activity, engulfing micro-organisms, particles, colloid particles, and so on. This system is called the Reticuloendothelial System (RES), comprising fixed cells as well as moving cells (phagocytes).
16. A dose is often expressed as the quantity of a xenobiotic entering an organism (in units such as mg/kg body weight).
17. The NOEL means the 'No Observed (Adverse) Effect Level', or the highest dose that does not cause a toxic effect. To establish a NOEL requires multiple doses, a large population and additional information to make sure that absence of a response is not merely a statistical phenomenon. LOEL is the 'Lowest Observed Effective Dose' on a dose-response curve, or the lowest dose that causes an effect.
18. A safety factor is a formal, arbitrary number with which one divides the NOEL or LOEL derived from animal experiments to obtain a tentative permissible dose for humans.
19. Synergistic effects are when the combined effect is greater than that of each single agent. Here we differentiate two types: (a) Additive, where the combined effect is equal to the sum of the effects produced by each agent separately and (b) Potentiating, where the combined effect is greater than additive.
20. The hazard identification and dose-response assessment steps are primarily based on a number of different tests where animals are exposed to the chemical or test substance. These tests are called toxicity tests.
21. The minimum concentration or the smallest dose of the chemical agent that causes adverse effects in an organism is known as the 'Threshold Dose'. In

other words, a threshold dose of a chemical agent is the concentration at which its toxic action just starts. The limit of this concentration is known as threshold limit.

22. The lethal threshold concentration is the concentration at which 50% of the test population can survive for an indefinite time.
23. The therapeutic margin or margin of safety indicates the closeness of lethal dose to the therapeutically effective dose.
24. Time action curve is used for establishing relationship between dose and response.

3.12 SUMMARY

- Toxicology is the investigation of unfavourable impacts of synthetic substances on living individuals.
- An adverse impact can be characterized as a reaction to a substance which is hurtful or troublesome.
- The conventionally toxicology is defined as 'The Study of Toxins' or 'The Study of Poisons'.
- Orfila (~1800 AD), a Spanish physician, is often referred to as the 'Founder of Toxicology'.
- A toxicologist is a researcher that decides the unsafe impacts of agents and the cell, biochemical, and sub-atomic instruments answerable for the impacts.
- Xenobiotic is the universal term that is employed for a foreign material taken into the body. It is derived from the Greek word '*xeno*' means foreigner.
- The substances that were originally derived from living organisms are called organic toxins.
- The substances that were originally derived from non-living organisms are called inorganic toxins.
- A systemic toxicant or systemic toxin is one that affects the complete body or lots of organs rather than a specific site.
- Toxicity is the intrinsic ability of a chemical factor to affect an organism negatively.
- 'The Nernst Partition Coefficient' (P) establishes the solubility of toxicant molecules in the two-phase octanol (oil)-water system, associating to their lipo or hydro-solubility.
- A toxic agent gives toxicity when it reaches to contact with the organisms and subsequently absorbed in its biological parts.
- To incite a toxic impact, local or systemic the harmful material should initially come into contact with an uncovered body surface in request to enter the creature and arrive at a site where harm is delivered.
- The lungs are the primary route of storage and absorption of small airborne particles, gases, vapours and aerosols.

NOTES

- Gastrointestinal absorption occurs after accidental or intentional ingestion.
- Translocation is the movement of substance (a pesticide, toxicants or any metal) from the site of exposure to the target site.
- The blood capillaries, arteries and veins in the brain, testes and placenta have characteristic anatomy that restrains passage of macro molecules (e.g., proteins).
- Liver also provides an effective barrier to the passage of toxic chemicals. Liver removes the toxic chemicals from blood and prevents their distribution in the body.
- Elimination or removal is the vanishing of a material in the body through excretion or transformation.
- The degree of removal and disappearance can be denoted by the elimination rate constant, biological half-time or clearance.
- The biological half-time is the moment needed after the finish of exposure to diminish the quantity to one-half in exposed organism.
- Intrinsic clearance is the ability of endogenous enzymes to transform a material, and also denoted in volume per unit time.
- Biotransformation is a technique which results to a metabolic conversion of foreign materials (xenobiotics) in the body.
- The human body represents a complex biological system on diverse levels of organization including from molecular-cellular level to tissues-organs level.
- The toxico-kinetic phase encompasses absorption of toxicants into the organism and all processes.
- Accumulation is the build-up of a material in a tissues and organs to augmented levels in comparison to blood and blood and plasma.
- The exposure, dose-effect and response relationship is the association ship between dose and effect on the individual level.
- Variation in exposure during the day and the total length of exposure during one's lifetime may be as important for the outcome (response) as mean or average or even integrated dose level.
- A dose is often expressed as the quantity of a xenobiotic entering an organism (in units such as mg/kg body weight).
- Latency time is the time between first exposure and the appearance of a detectable effect or response.
- LD50 (effective dose) is the dose causing 50% lethality in an animal population.
- The NOEL means the 'No Observed (Adverse) Effect Level', or the highest dose that does not cause a toxic effect.
- A safety factor is a formal, arbitrary number with which one divides the NOEL or LOEL derived from animal experiments to obtain a tentative permissible dose for humans.

- Each agent produces a different effect due to a different mechanism of action.
- Young children are often more susceptible to chemical toxicity.
- Males are generally more susceptible to renal toxins and females to liver toxins.
- The habit of smoking can influence individual susceptibility to many toxic chemicals.
- Consumption of alcohol (ethanol) can influence susceptibility to many toxic chemicals in several ways.
- The 'Resistant Outlier' is an individual having less of a response at higher doses or exposures.
- A 'Sensitive Outlier' is an individual having an exaggerated response to a relatively small dose or exposure.
- The hazard identification and dose-response assessment steps are primarily based on a number of different tests where animals are exposed to the chemical or test substance.
- Acute toxicity describes the adverse effects of a substance that result either from a single exposure or from multiple exposures in a short period of time (usually less than 24 hours).
- A threshold dose of a chemical agent is the concentration at which its toxic action just starts.
- Median lethal dose or concentration of a toxic agent is its concentration which can kill 50% of the organisms of the group concerned.
- The therapeutic margin or margin of safety indicates the closeness of lethal dose to the therapeutically effective dose.
- The effective dose or concentration of a toxic agent is the amount required to produce a particular response or symptom in an organism.
- The dose or concentration of a chemical agent which kills an individual is known as 'Toxic Lethal Dose' (LD) or 'Toxic Lethal Concentration' (LC).
- The degree of effect produced by increasing doses of a chemical or drug eventually reaches a steady level, called, 'Ceiling Effect'.
- Quantal dose response is the frequency with which any dose of a drug evokes a static, fixed response.

3.13 KEY TERMS

- **Toxicology:** Toxicology is the investigation of the negative impacts of synthetic substances or actual substances of living entities.
- **Toxins:** There are some specific proteins produced by living organisms called as toxins. For examples: mushroom toxin, tetanus toxin, apitoxin, etc.
- **Toxicity**: Toxicity is the intrinsic ability of a chemical factor to affect an organism negatively.

NOTES

NOTES

- **'The Nernst Partition Coefficient'** (P): 'The Nernst Partition Coefficient' (P) establishes the solubility of toxicant molecules in the two-phase octanol (oil)-water system, associating to their lipo- or hydrosolubility.
- **Concentration-time curve**: The concentration curve in blood or plasma vs. time is an expedient approach of telling uptake and disposition of xenobiotics.
- **Biological half-life**: The biological half-time is the moment needed after the finish of exposure to diminish the quantity to one-half in exposed organism.
- **Clearance**: Clearance is the volume of blood or plasma per unit time entirely cleaned of a stuff.
- **Accumulation:** Accumulation is the build-up of a material in a tissues and organs to augmented levels in comparison to blood and blood and plasma.
- **Latency time:** Latency time is the time between first exposure and the appearance of a detectable effect or response.
- **Threshold dose:** A threshold is a dose level below which no observable effect occurs.
- **LD50 (Effective dose**): LD50 (effective dose) is the dose causing 50% lethality in an animal population.
- **NOEL**: The NOEL means the 'No Observed (Adverse) Effect Level', or the highest dose that does not cause a toxic effect.
- **Safety factor**: A safety factor is a formal, arbitrary number with which one divides the NOEL or LOEL derived from animal experiments to obtain a tentative permissible dose for humans.
- **Extrapolations**: Extrapolations are theoretical qualitative or quantitative estimates of toxicity (risk extrapolations) resultant from translation of data from one species to another or from one set of dose-response data to regions of dose-response where no data exist.
- **Critical organ concentration**: The mean concentration in the organ at the time at which the most sensitive type of cells in the organ reach critical concentration.
- **Acute toxicity**: Acute toxicity describes the adverse effects of a substance that result either from a single exposure or from multiple exposures in a short period of time (usually less than 24 hour).
- **Median lethal dose**: A median lethal dose or concentration of a toxic agent is its concentration which can kill 50% of the organisms of the group concerned.
- **Therapeutic margin**: The therapeutic margin or margin of safety indicates the closeness of lethal dose to the therapeutically effective dose.
- **Toxic lethal dose**: The dose or concentration of a chemical agent which kills an individual is known as 'Toxic Lethal Dose' (LD) or 'Toxic Lethal Concentration' (LC).

- **Ceiling Effect**: The degree of effect produced by increasing doses of a chemical or drug eventually reaches a steady level, called, 'Ceiling Effect'.

3.14 SELF-ASSESSMENT QUESTIONS AND EXERCISES

NOTES

Short-Answer Questions

1. Can some toxic substances have positive effects? Give some examples.
2. What is the difference between toxins, toxicants and poisons?
3. What is bio-toxin? Give examples.
4. Define organ toxicant.
5. How the toxicity score or categorization can be used to define toxicity of any substance?
6. When a toxic agent does give toxicity.
7. What is percutaneous absorption?
8. What happens to the toxic agents absorbed by the intestine?
9. State the reason why most of the toxin become ineffective if taken orally?
10. What is intrinsic clearance?
11. Define osteotropic elements giving examples.
12. What is dose-effect and response relationship?
13. What is a threshold dose? How it is determined?
14. What is the difference between LD_{50} and ED_{50}?
15. What is extrapolations? How it is used to predict toxic response?
16. Why young children are often more susceptible to chemical toxicity?
17. Define median lethal dose?
18. Why skin and eye test are mandatory before launching products, such as personal care products, pesticides, and cleaning supplies, etc.
19. Why the margin of safety is of great importance to a biochemist or physician?

Long- Answers Questions

1. Briefly describe the properties of toxicants. What is 'Structure-Activity Relationship (SAR)'?
2. Define the toxicants and their toxicity. Also mention the factors influencing the concentration of toxicants.
3. Explain the absorption and translocation of toxicants giving examples.
4. Describe the transport of toxicants by blood and lymph in detail.
5. Describe the three phrases of penetration of a toxicant from environment to the sites of toxicity within the organism.

NOTES

6. Analyze the factors influencing toxicity-response relationships in detail.
7. Explain the variation in toxic responses giving examples.
8. Illustrate on the various methods of toxicological testing.
9. What do you mean by toxicity curves? Discuss the types of toxicity curves studied by you in brief with suitable graphs

3.15 FURTHER READING

Sinclair, Anthony R. E., John M. Fryxell and Graeme Caughley. 2009. *Wildlife Ecology, Conservation and Management.* New Jersey: Wiley.

Gupta, Tapashi. 2017. *Ecology, Wild Life Conservation and Management.* Guwahati (Assam): Eastern Book House.

Murphy, Chloe. 2020. *Wildlife Conservation and Management: Principles and Practices.* US: Syrawood Publishing House.

Newman, Michael C. 2013. *Quantitative Ecotoxicology*, 2nd Edition. UK: Taylor & Francis.

Walker C.H., R.M. Sibly, S.P. Hopkin, and D.B. Peakall. 2012. *Principles of Ecotoxicology*. 4th Edition, UK: Taylor & Francis.

Sparling, Donald W. 2017. *Basics of Ecotoxicology.* US: CRC Press.

Connell, Des W., Paul Lam, Bruce Richardson, and Rudolf Wu. 2009. *Introduction to Ecotoxicology.* US: Blackwell Publishing.

UNIT 4 ECOTOXICOLGY-II

NOTES

Structure

4.0 Introduction
4.1 Objectives
4.2 General Approaches in Toxicolgy
- 4.2.1 Genetic Toxicology and Biological Markers
- 4.2.2 Genetic Toxicology
- 4.2.3 Biological Marker in Toxicology
- 4.2.4 Societal Issues and Safety in Toxicology
- 4.2.5 Distribution of Toxicants in the Organisms
- 4.2.6 Target Organ Toxicity and Critical Effects

4.3 Pathological Techniques in Toxicology
- 4.3.1 Non-Animal Toxicity Tests
- 4.3.2 Animal Toxicity Tests
- 4.3.3 Neurotoxicity Testing
- 4.3.4 Developmental or Embryo Toxicity Testing
- 4.3.5 Genetic Toxicity Testing
- 4.3.6 Target Organ Toxicity Testing
- 4.3.7 In Vitro Ocular Irritation Testing
- 4.3.8 Validation of Testing Methods

4.4 Autopsy and Histological Practices
- 4.4.1 Types of Autopsy
- 4.4.2 Procedure of Autopsy
- 4.4.3 Histological Examination during Autopsy
- 4.4.4 Reconstituting the Body during Autopsy
- 4.4.5 Autopsy Report and Challenges
- 4.4.6 Scopes and Benefits of Autopsies

4.5 Methods Applicable to Specific Organ System
- 4.5.1 Skin Specific Technique
- 4.5.2 Subcutaneous Tissue Specific Technique
- 4.5.3 Pulmonary System Specific Technique
- 4.5.4 Digestive System Specific Technique
- 4.5.5 Urinogenital Tract Specific Technique

4.6 Toxicants of Public Health Hazards
- 4.6.1 Heavy Metals
- 4.6.2 Air Pollutants and Automobile Emissions
- 4.6.3 Persistent Organic Pollutants
- 4.6.4 Pesticides
- 4.6.5 Plant and Animal Toxins
- 4.6.6 Environmental Health Hazards
- 4.6.7 Food Additives
- 4.6.8 Radiation and Radioactive Materials
- 4.6.9 Fertilizers

4.7 Answers to 'Check Your Progress'
4.8 Summary
4.9 Key Terms
4.10 Self-Assessment Questions and Exercises
4.11 Further Reading

NOTES

4.0 INTRODUCTION

Ecotoxicology is a mix of ecology, toxicology, physiology, analytical chemistry, molecular biology, and mathematics. Ecotoxicology looks at the impacts of contaminants including pesticides on individuals, populations, natural communities, and ecosystems. A central concept of toxicology is that the effects of a toxicant are dose-dependent, even water can lead to water intoxication when taken in too high a dose, whereas for even a very toxic substance such as snake venom there is a dose below which there is no detectable toxic effect.

The study of toxic substance ranges from fundamental research investigations on the mechanism of action of toxic agents through the development and explanation of typical tests characterizing the toxic properties of those agents. It gives the key knowledge to both medicine and epidemiology in understanding an etiology including exposures, occupations, and disease. Ecotoxicology integrates the effects of stressors across all levels of biological organization from the molecular to whole communities and ecosystems.

Toxicology can be grouped into clinical, forensic, investigative and regulatory toxicology, immune-toxicology or genetic toxicology, etc. The methods of toxicological studies are widely utilized by industry in the product development, to supply information beneficial in the design of specific molecules or product formulations. Based on the doe dependency, duration and route of exposure, along the host intrinsic factors such as age, many toxic agents can induce a number of effects within organs and organisms. A significant job of toxicology is to recognize the vital effect in order to stop irreparable or devastating disease. It can done by the identification of the organ firstly affected by a toxic substance known as the target organ followed by assessment of changes in physiological mechanism, i.e. critical effect. These theories are imperative in occupational health because of its deployment to toxicity and clinical disease therapies associated with targeted exposures, rather than every effect in every organ.

In this unit you will study about the general approach in toxicology, pathological techniques in toxicology, autopsy and histological practices involved in the process, various organs and tissue specific methods for toxicological studies, the toxicants of public health hazards

4.1 OBJECTIVES

After going through this unit you will be able to:

- Understand the general approach in toxicology
- Comprehended pathological techniques in toxicology
- Illustrate on autopsy and histological practices involved in the process
- Learn the various organs and tissue specific methods for toxicological studies.
- Explain the toxicants of public health hazards

4.2 GENERAL APPROACHES IN TOXICOLGY

NOTES

Toxicology is 'the study of the adverse effects of chemical, physical, or biological agents on living organisms and the ecosystem'. Most developed countries have enacted laws and regulations to control the marketing, labeling, and (in some cases) transportation of chemicals, pesticides, consumer products, medical products, food additives, and other substances of potential toxicological concern. Many of the provisions require manufacturers to conduct testing to identify potential hazards to human and animal health and the environment, and to submit the test data to regulatory authorities. Government agencies conduct human health and ecological *risk assessments* to ascertain the effects of a chemical or other substance on human health and/or the environment, respectively. The processes involved in a risk assessment for human health can be broken down into four steps as illustrated in the diagram below from the US Environmental Protection Agency (EPA).

Toxicology ranges from basic research investigations on the mechanism of action of toxic agents through the development and interpretation of standard tests characterizing the toxic properties of agents. Toxicology provides important information for both medicine and epidemiology in understanding **aetiology** and in providing information as to the plausibility of observed associations between exposures, including occupations, and disease. Toxicology can be divided into standard disciplines, such as clinical, forensic, investigative and regulatory toxicology; toxicology can be considered by target organ system or process, such as immune toxicology or genetic toxicology; toxicology can be presented in functional terms, such as research, testing and risk assessment. In modern society, toxicology has become an important element in environmental and occupational health. This is because many organizations, governmental and non-governmental, utilize information from toxicology to evaluate and regulate hazards in the workplace and non-occupational environment. As part of prevention strategies, toxicology is invaluable, since it is the source of information on potential hazards in the absence of widespread human exposures.

Toxicological methods are also widely used by industry in product development, to provide information useful in the design of specific molecules or product formulations. The concepts of target organ and critical effect have been developed to aid in the interpretation of toxicological data. Depending upon dose, duration and route of exposure, as well as host factors such as age, many toxic agents can induce a number of effects within organs and organisms. An important role of toxicology is to identify the important effect or sets of effects in order to prevent irreversible or debilitating disease. One important part of this task is the identification of the organ first or most affected by a toxic agent; this organ is defined as the 'target organ'. Within the target organ, it is important to identify the important event or events that signals intoxication, or damage, in order to ascertain that the organ has been affected beyond the range of normal variation. This is known as the 'critical effect'; it may represent the first event in a progression of pathophysiological stages (such as the excretion of small-molecular-weight proteins as a critical effect in nephrotoxicity), or it may represent the first and potentially irreversible effect in a disease process (such as formation of a DNA adduct in

NOTES

carcinogenesis). These concepts are important in occupational health because they define the types of toxicity and clinical disease associated with specific exposures, and in most cases reduction of exposure has as a goal the prevention of critical effects in target organs, rather than every effect in every or any organ.

4.2.1 Genetic Toxicology and Biological Markers

Genetic toxicology has become an integral part of the overall risk assessment process and has gained in stature in recent times as a reliable predictor for carcinogenic activity. However, prior to the development of genetic toxicology (before 1970), other methods were and are still being used to identify potential cancer hazards to humans. There are six major categories of methods currently used for identifying human cancer risks: epidemiological studies, long-term in vivo bioassays, mid-term in vivo bioassays, short-term in vivo and in vitro bioassays, artificial intelligence (structure-activity), and mechanism-based inference. Molecular advances in cyto-genetics now permit more detailed evaluation of chromosomal mutations. The single-cell gel electrophoresis assay for DNA breakage (commonly called the 'comet' assay) permits the detection of DNA breaks within single cells and may become an extremely useful tool in combination with cytogenetic techniques for detecting chromosomal damage. In occupational health, a biomarker is generally used as an indicator of health status or disease risk. Biomarkers are used for in vitro as well as in vivo studies that may include humans. Given an acceptable degree of validity, biomarkers may be employed for several purposes. On an individual basis, a biomarker may be used to support or refute a diagnosis of a particular type of poisoning or other chemically-induced adverse effect.

4.2.2 Genetic Toxicology

Genetic toxicity assessment is the evaluation of agents for their ability to induce any of three general types of changes (mutations) in the genetic material (DNA): gene, chromosomal and genomic. In organisms, such as humans, the genes are composed of DNA, which consists of individual units called nucleotide bases. The genes are arranged in discrete physical structures called chromosomes. Genotoxicity can result in significant and irreversible effects upon human health. Genotoxic damage is a critical step in the induction of cancer and it can also be involved in the induction of birth defects and foetal death. The three classes of mutations mentioned above can occur within either of the two types of tissues possessed by organisms such as humans: sperm or eggs (germ cells) and the remaining tissue (somatic cells). Assays that measure gene mutation are those that detect the substitution, addition or deletion of nucleotides within a gene. Assays that measure chromosomal mutation are those that detect breaks or chromosomal rearrangements involving one or more chromosomes. Assays that measure genomic mutation are those that detect changes in the number of chromosomes, a condition called aneuploidy.

The emergence of sophisticated technologies in molecular and cellular biology has spurred a relatively rapid evolution in the life sciences, including toxicology. In effect, the focus of toxicology is shifting from whole animals and populations of whole animals to the cells and molecules of individual animals and humans. Since the mid-1980s, toxicologists have begun to employ these new methodologies in

assessing the effects of chemicals on living systems. As a logical progression, such methods are being adapted for the purposes of toxicity testing. These scientific advances have worked together with social and economic factors to effect change in the evaluation of product safety and potential risk.

4.2.3 Biological Marker in Toxicology

The word **biomarker** is short for biological marker, a term that refers to a measurable event occurring in a biological system, such as the human body. This event is then interpreted as a reflection, or marker, of a more general state of the organism or of life expectancy. In occupational health, a biomarker is generally used as an indicator of health status or disease risk. Biomarkers are used for in vitro as well as in vivo studies that may include humans. Given an acceptable degree of validity, biomarkers may be employed for several purposes. On an individual basis, a biomarker may be used to support or refute a diagnosis of a particular type of poisoning or other chemically-induced adverse effect. An exposure biomarker may be an exogenous compound (or a metabolite) within the body, an interactive product between the compound (or metabolite) and an endogenous component, or another event related to the exposure. Most commonly, biomarkers of exposures to stable compounds, such as metals, comprise measurements of the metal concentrations in appropriate samples, such as blood, serum or urine. With volatile chemicals, their concentration in exhaled breath (after inhalation of contamination-free air) may be assessed. If the compound is metabolized in the body, one or more metabolites may be chosen as a biomarker of the exposure; metabolites are often determined in urine samples. Particularly promising developments have occurred with biomarkers of exposure to mutagenic chemicals. These compounds are reactive and may form adducts with macromolecules, such as proteins or DNA. DNA adducts may be detected in white blood cells or tissue biopsies, and specific DNA fragments may be excreted in the urine.

For example, exposure to ethylene oxide results in reactions with DNA bases, and, after excision of the damaged base, N-7-(2-hydroxyethyl) guanine will be eliminated in the urine. Exposure to mutagenic compounds, or to compounds which are metabolized into mutagens, may also be determined by assessing the mutagenicity of the urine from an exposed individual. The urine sample is incubated with a strain of bacteria in which a specific point mutation is expressed in a way that can be easily measured. If mutagenic chemicals are present in the urine sample, then an increased rate of mutations will occur in the bacteria. Some exposures do not result in enzyme inhibition but rather in increased activity of an enzyme. This is the case with several enzymes that belong to the P450 family (see 'Genetic determinants of toxic response'). They may be induced by exposures to certain solvents and Poly Aromatic Hydrocarbons (PAHs). Since these enzymes are mainly expressed in tissues from which a biopsy may be difficult to obtain, the enzyme activity is determined indirectly in vivo by administering a compound that is metabolized by that particular enzyme, and then the breakdown product is measured in urine or plasma.

shows examples of biomarkers of exposure or biomarkers of effect that are used in toxicological studies in occupational health.

NOTES

Sample	Measurement	Purpose
Exposure biomarkers		
Adipose tissue	Dioxin	Dioxin exposure
Blood	Lead	Lead exposure
Bone	Aluminum	Aluminum exposure
Exhaled breath	Toluene	Toluene exposure
Hair	Mercury	Methyl mercury exposure
Serum	Benzene	Benzene exposure
Urine	Phenol	Benzene exposure
Effect biomarkers		
Blood	Carboxyhaemoglobin	Carbon monoxide exposure
Red blood cells	Zinc-protoporphyrin	Lead exposure
Serum	Cholinesterase	Organophosphate exposure
Urine	Microglobulins	Nephrotoxic exposure
White blood cells	DNA adducts	Mutagen exposure

4.2.4 Societal Issues and Safety in Toxicology

There are also societal issues that relate to public health and safety, as well as increasing public concern about the use of animals for product safety testing. With regard to human safety, public interest and environmental advocacy groups have placed significant pressure on government agencies to apply more stringent regulations on chemicals. A recent example of this has been a movement by some environmental groups to ban chlorine and chlorine-containing compounds in the United States. One of the motivations for such an extreme action lies in the fact that most of these compounds have never been adequately tested. From a toxicological perspective, the concept of banning a whole class of diverse chemicals based simply on the presence of chlorine is both scientifically unsound and irresponsible. The other societal concern that has impacted the area of toxicity testing is animal welfare. The growing numbers of animal protection groups throughout the world have voiced considerable opposition to the use of whole animals for product safety testing. Active campaigns have been waged against manufacturers of cosmetics, household and personal care products and pharmaceuticals in attempts to stop animal testing.

In vitro studies are generally conducted in animal or human cells or tissues outside of the body. In vitro literally means 'in glass', and refers to procedures carried out on living material or components of living material cultured in petri dishes or in test tubes under defined conditions. These may be contrasted with in vivo studies, or those carried out 'in the living animal'. While it is difficult, if not impossible, to project the effects of a chemical on a complex organism when the observations are confined to a single type of cells in a dish, in vitro studies do

provide a significant amount of information about intrinsic toxicity as well as cellular and molecular mechanisms of toxicity. In addition, they offer many advantages over in vivo studies in that they are generally less expensive and they may be conducted under more controlled conditions. In order to interpret the results of in vitro toxicity tests, determine their potential usefulness in assessing toxicity and relate them to the overall toxicological process in vivo, it is necessary to understand which part of the toxicological process is being examined. The entire toxicological process consists of events that begin with the organism's exposure to a physical or chemical agent, progress through cellular and molecular interactions and ultimately manifest themselves in the response of the whole organism. In vitro tests are generally limited to the part of the toxicological process that takes place at the cellular and molecular level. The toxicologists are faced with a situation in which the results of an in vitro test cannot be used as an entirely accurate prediction of in vivo toxicity because the mechanism is unknown. However, frequently during the process of developing an in vitro test, components of the cellular and molecular mechanism(s) of toxicity are elucidated.

4.2.5 Distribution of Toxicants in the Organisms

The human organism can be divided into the following compartments. (1) Internal organs, (2) skin and muscles, (3) adipose tissues, (4) connective tissue and bones. This classification is mostly based on the degree of vascular (blood) perfusion in a decreasing order. For example internal organs (including the brain), which represent only 12% of the total body weight, receive about 75% of the total blood volume. On the other hand, connective tissues and bones (15% of total body weight) receive only 1% of the total blood volume. The well-perfused internal organs generally achieve the highest concentration of toxicants in the shortest time. The uptake of toxicants by less perfused tissues is much slower, but retention is higher and duration of stay much longer (accumulation) due to low perfusion. Three components are of major importance for the intracellular distribution of toxicants in the cells of various tissues and organs: (1) Content of water, (2) Content of lipids and (3) Content of proteins. Hydrophilic toxicants will be more rapidly distributed to the body fluids and cells with high water contents, and lipophilic toxicants to cells with higher lipid content (fatty tissue). The organism possesses some barriers which impair penetration of some groups of toxicants, mostly hydrophilic, to certain organs and tissues, such as:

a. The blood-brain barrier (cerebrospinal barrier), which restricts penetration of large molecules and hydrophilic toxicants to the brain and CNS; This barrier consists of a closely joined layer of endothelial cells; thus, lipophilic toxicants can penetrate through it

b. The placental barrier, which has a similar effect on penetration of toxicants into the foetus from the blood of the mother

c. The histo-hematic barrier in the walls of capillaries, which is permeable for small- and intermediate-sized molecules, and for some larger molecules, as well as ions.

As observed only the free forms of toxicants in plasma (molecules, ions, colloids) are available for penetration through the capillary walls participating in

NOTES

distribution. Concentration of toxicants in blood is in a dynamic equilibrium with their concentration in organs and tissues, governing retention (accumulation) or mobilization from them. The conditions of the organism, functional state of organs (especially neuro-humoral regulation), hormonal balance and other factors play a role in distribution. Retention of toxicant in a particular compartment is generally temporary and redistribution into other tissues can occur. Retention and accumulation is based on the difference between the rates of absorption and elimination. The duration of retention in a compartment is expressed by the biological half-life. This is the time interval in which 50% of the toxicant is cleared from the tissue or organ and redistributed, translocated or eliminated from the organism. Biotransformation processes occur during distribution and retention in various organs and tissues. Biotransformation produces more polar, more hydrophilic metabolites, which are more easily eliminated. A low rate of biotransformation of a lipophilic toxicant will generally cause its accumulation in a compartment. The toxicants can be divided into four main groups according to their affinity, predominant retention and accumulation in a particular compartment:

a. Toxicants soluble in the body fluids are uniformly distributed according to the water content of compartments. Many monovalent cations (e.g., lithium, sodium, potassium, rubidium) and some anions (e.g., chlorine, bromine), are distributed according to this pattern.

b. Lipophilic toxicants show a high affinity for lipid-rich organs (CNS) and tissues (fatty, adipose).

c. Toxicants forming colloid particles are then trapped by specialized cells of the Reticuloendothelial System (RES) of organs and tissues. Tri- and quadric valent cations (lanthanum, cesium, and hafnium) are distributed in the RES of tissues and organs.

d. Toxicants showing a high affinity for bones and connective tissue (osteotropic elements, bone seekers) include divalent cations (e.g., calcium, barium, strontium, radon, beryllium, aluminum, cadmium, lead).

Accumulation in Lipid-Rich Tissues

The standard man of 70kg body weight contains about 15% of body weight in the form of adipose tissue, increasing with obesity to 50%. However, this lipid fraction is not uniformly distributed. The brain (CNS) is a lipid-rich organ, and peripheral nerves are wrapped with a lipid-rich myelin sheath and Schwann cells. All these tissues offer possibilities for accumulation of lipophilic toxicants. Numerous non-electrolytes and non-polar toxicants with a suitable 'Nernst Partition Coefficient' will be distributed to this compartment, as well as numerous organic solvents (alcohols, aldehydes, ketones, etc.), chlorinated hydrocarbons (including organo-chlorine insecticides such as DDT), some inert gases (radon), etc. Adipose tissue will accumulate toxicants due to its low vascularization and lower rate of biotransformation. Here accumulation of toxicants may represent a kind of temporary 'neutralization' because of lack of targets for toxic effect. However, potential danger for the organism is always present due to the possibility of mobilization of toxicants from this compartment back to the circulation.

NOTES

Deposition of toxicants in the brain (CNS) or lipid-rich tissue of the myelin sheath of the peripheral nervous system is very dangerous. The neuro-toxicants are deposited here directly next to their targets. Toxicants retained in lipid-rich tissue of the endocrine glands can produce hormonal disturbances. Despite the blood-brain barrier, numerous neuro-toxicants of a lipophilic nature reach the brain (CNS): Anesthetics, organic solvents, pesticides, tetraethyl lead, organomercurials, etc.

Accumulation in the Reticuloendothelial System

In each tissue and organ a certain percentage of cells is specialized for phagocytic activity, engulfing micro-organisms, particles, colloid particles, and so on. This system is called the Reticuloendothelial System (RES), comprising fixed cells as well as moving cells (phagocytes). These cells are present in non-active form. An increase of the above-mentioned microbes and particles will activate the cells up to a saturation point. Toxicants in the form of colloids will be captured by the RES of organs and tissues. Distribution depends on the colloid particle size. For larger particles, retention in the liver will be favored. With smaller colloid particles, more or less uniform distribution will occur between the spleen, bone marrow and liver. Clearance of colloids from the RES is very slow, although small particles are cleared relatively more quickly.

Accumulation in Bones

The skeleton of a standard man accounts for 10 to 15% of the total body weight, representing a large potential storage depot for osteotropic toxicants. Bone is a highly specialized tissue consisting by volume of 54% minerals and 38% organic matrix. The mineral matrix of bone is hydroxyapatite, $Ca_{10}(PO_4)_6(OH)_2$, in which the ratio of 'Ca' to 'P' is about 1.5 to 1. The surface area of mineral available for adsorption is about 100 m^2 per g of bone. About 60 elements can be identified as osteotropic elements, or bone seekers. Osteotropic elements can be divided into three groups:

a. Elements representing or replacing physiological constituents of the bone. Under conditions of chronic exposure, toxic metals such as lead, aluminum and mercury can also enter the mineral matrix of bone cells.

b. Alkaline earths and other elements forming cations with an ionic diameter similar to that of calcium are exchangeable with it in bone mineral.

c. Elements forming microcolloids (rare earths) may be adsorbed on the surface of bone mineral.

Metabolic activity of the bones of the skeleton can be divided in two categories: (a) active, metabolic bone, in which processes of resorption and new bone formation, or remodeling of existing bone, are very extensive, and (b) stable bone with a low rate of remodeling or growth. In the fetus, infant and young child metabolic bone represents almost 100% of the skeleton. With age this percentage of metabolic bone decreases. Incorporation of toxicants during exposure appears in the metabolic bone and in more slowly turning-over compartments. The incorporation of toxicants into bone occurs in two ways: (a) for ions, an ion exchange occurs with physiologically present calcium cations, or anions (phosphate, hydroxyl), and (b) for toxicants forming colloid particles, adsorption on the mineral surface occurs.

NOTES

Accumulation in Hair and Nails

The hair and nails contain keratin, with sulfhydryl groups able to chelate metallic cations such as mercury and lead.

Accumulation of Toxicant inside the Cell

Recently the distribution of toxicants, especially some heavy metals, within cells of tissues and organs has become of important. With ultracentrifugation techniques, various fractions of the cell can be separated to determine their content of metal ions and other toxicants. Animal studies have revealed that after penetration into the cell, some metal ions are bound to a specific protein, metallothionein. This low molecular weight protein is present in the cells of liver, kidney and other organs and tissues. Its sulfhydryl groups can bind six ions per molecule. Increased presence of metal ions induces the biosynthesis of this protein. Ions of cadmium are the most potent inducer. Metallothionein serves also to maintain homeostasis of vital copper and zinc ions. Metallothionein can bind zinc, copper, cadmium, mercury, bismuth, gold, cobalt and other cations.

4.2.6 Target Organ Toxicity and Critical Effects

The priority objective of occupational and environmental toxicology is to improve the prevention or substantial limitation of health effects of exposure to hazardous agents in the general and occupational environments. To this end systems have been developed for quantitative risk assessment related to a given exposure under regulatory toxicology. The effects of a chemical on particular systems and organs are related to the magnitude of exposure and whether exposure is acute or chronic. In view of the diversity of toxic effects even within one system or organ, a uniform philosophy concerning the critical organ and critical effect has been proposed for the purpose of risk assessment and development of health-based recommended concentration limits of toxic substances in different environmental media. From the point of view of preventive medicine, it is of particular importance to identify early adverse effects, based on the general assumption that preventing or limiting early effects may prevent more severe health effects from developing.

Such an approach has been applied to heavy metals. Although heavy metals, such as lead, cadmium and mercury, belong to a specific group of toxic substances where the chronic effects of activity is dependent on their accumulation in the organs. Whether a given organ or system is regarded as critical depends not only on the toxico-mechanics of the hazardous agent but also on the route of absorption and the exposed population.

a. **Critical Concentration For A Cell:** The concentration at which adverse functional changes, reversible or irreversible, occur in the cell.

b. **Critical Organ Concentration:** The mean concentration in the organ at the time at which the most sensitive type of cells in the organ reach critical concentration.

c. **Critical Organ:** That particular organ which first attains the critical concentration of metal under specified circumstances of exposure and for a given population.

NOTES

d. Critical Effect: Defined point in the relationship between dose and effect in the individual, namely the point at which an adverse effect occurs in cellular function of the critical organ. At an exposure level lower than that giving a critical concentration of metal in the critical organ, some effects may occur that do not impair cellular function per se, yet are detectable by means of biochemical and other tests. Such effects are defined as subcritical effects.

In chronic environmental exposure to cadmium, where the route of absorption is of minor importance (cadmium air concentrations range from 10 to 20 µg/m3 in the urban and 1 to 2 µg/m3 in the rural areas), the critical organ is the kidney. In the occupational setting where the TLV reaches 50 µg/m3 and inhalation constitutes the main route of exposure, two organs, lung and kidney, are regarded as critical. For lead, the critical organs in adults are the hematopoietic and peripheral nervous systems, where the critical effects (e.g., Elevated Free Erythrocyte Protoporphyrin Concentration (FEP), increased excretion of Delta-Aminolevulinic acid in urine, or impaired peripheral nerve conduction) manifest when the blood lead level (an index of lead absorption in the system) approaches 200 to 300 µg/l. In small children the critical organ is the Central Nervous System (CNS), and the symptoms of dysfunction detected with the use of a psychological test battery have been found to appear in the examined populations even at concentrations in the range of about 100 µg/l Pb in blood.

Examples of Critical Organs and Critical Effects

Substance	Critical organ in chronic exposure	Critical effect
Cadmium	Lungs	Non threshold: Lung cancer (unit risk $4.6x10^{-3}$)
	Kidney	Threshold: Increased excretion of low molecular proteins (β2-m, RBP) in urine
	Lungs	Emphysema slight function changes
Adults		
Lead	Hematopoietic system	Increased Delta Aminolevulinic Acid excretion in urine (ALA-U);Increased excretion of free erythrocyte protoporphyrin (FEP) in erythrocytes.
	Peripheral nervous system	Slowing the condition velocities of the slower nerve fibers.
Manganese	Central nervous system	Impairment of psychomotor functions.
Young children		
Mercury (elemental)	Central nervous system	Decrease in IQ and other subtle effects; mercurial tremor (fingers, lips, eyelids)
Mercury (mercuric)	Kidney	Proteinuria
Children		
Manganese	Central nervous system	Impairment of psychomotor functions
	Lungs	Respiratory symptoms
Toluene	Mucous membrane	Irritations
Vinyl chloride	Liver	Cancer (Angiosarcoma unit risk $1x10^{-6}$)
Ethyl acetate	Mucous membrane	Irritations

According to WHO (1989), the critical effect has been defined as 'The first adverse effect which appears when the threshold (critical) concentration or dose is reached in the critical organ'. Adverse effects, such as cancer, with no defined threshold concentration are often regarded as critical. Decision on whether an effect is critical is a matter of expert judgment. In the International Program on Chemical Safety (IPCS) guidelines for developing Environmental Health Criteria

NOTES

Documents, the critical effect is described as 'The adverse effect judged to be most appropriate for determining the tolerable intake'. The latter definition has been formulated directly for the purpose of evaluating the health-based exposure limits in the general environment. In this context the most essential seems to be determining which effect can be regarded as an adverse effect. Following current terminology, the adverse effect is the 'Change in morphology, physiology, growth, development or lifespan of an organism which results in impairment of the capacity to compensate for additional stress or increase in susceptibility to the harmful effects of other environmental influences'. Decision on whether or not any effect is adverse requires expert judgment as well.

The critical effects can be of two types; those considered to have a threshold and those for which there may be some risk at any exposure level (non-threshold, geno-toxic carcinogens and germ mutagens). Whenever possible, appropriate human data should be used as a basis for the risk assessment. In order to determine the threshold effects for the general population, assumptions concerning the exposure level (tolerable intake, biomarkers of exposure) have to be made such that the frequency of the critical effect in the population exposed to a given hazardous agent corresponds to the frequency of that effect in the general population. There is no clear consensus on appropriate methodology for the risk assessment of chemicals for which the critical effect may not have a threshold, such as geno-toxic carcinogens. A number of approaches based largely on characterization of the dose- response relationship have been adopted for the assessment of such effects. Presently, the basic step in undertaking activities for risk assessment is determining the critical organ and critical effects. The definitions of both the critical and adverse effect reflect the responsibility of deciding which of the effects within a given organ or system should be regarded as critical, and this is directly related to the subsequent determination of recommended values for a given chemical in the general environment-for example, Air Quality Guidelines for Europe (WHO 1987) or health-based limits in occupational exposure (WHO 1980). The decision whether or not a given effect should be considered critical remains the responsibility of expert groups who specialize in toxicity and risk

Check Your Progress

1. What is genetic toxicology?
2. Define bio-marker.
3. What do you understand by the term Reticuloendothelial System (RES)?
4. What is the structure of mineral matrix of bone?
5. What are metabolic bones?

4.3 PATHOLOGICAL TECHNIQUES IN TOXICOLOGY

The hazard identification and dose-response assessment steps are primarily based on a number of different tests where animals are exposed to the chemical or test

NOTES

substance. These tests are called **toxicity tests.** Government regulations often prescribe a specific regimen of toxicity testing to generate the data that enable regulators to determine the chemical's risks to human health and/or the environment. Companies producing the chemical/product are responsible for the generation and submission of the 'safety data' to regulatory authorities such as the US EPA, the European Chemicals Agency (ECHA), and Japan's Ministry of the Environment (MOE). Thus a test method is a definitive procedure that produces a test result. Many toxicity tests examine specific types of adverse effects, known as *endpoints*, such as eye irritation or cancer. Other tests are more general in nature, ranging from acute (single-exposure) studies to repeat dose (multiple-exposure) studies, in which animals are administered daily doses of a test substance.

Toxicity Endpoints Covered and Their Description.

Endpoint	Description
Acute Systemic Toxicity	Adverse effects occurring within a relatively short time After administration of a single (typically high) dose of a substance via one or more of the following exposure routes: oral, inhalation, skin, or injection.
Carcinogenicity	Chemically-induced cancer, whether through genotoxic or non-genotoxic (e.g., growth-promoting) mechanisms.
Dermal Penetration	Extent and rate by which a chemical is able to enter the body via the skin; also known as skin or percutaneous absorption.
Eco toxicity	Chemically-induced adverse effects on organisms in the environment, including mammals, birds, fish, amphibians, crustaceans, other aquatic invertebrates, and even plants; common study designs include acute systemic, dietary, and reproductive (also known as life-cycle) toxicity, and bioaccumulation.
Endocrine Disruptors	Substances that interact with the hormonal systems of humans and/or wildlife, and thereby disrupt normal biological functions.
Eye Irritation/ Corrosion	Chemically-induced eye damage that is reversible (irritation) or irreversible (corrosion).
Geno toxicity	Chemically-induced mutations and/or other alterations in the structure, information content, or segregation of genetic material (e.g., DNA strand breaks or a gain/loss in chromosome number)
Neurotoxicity	Chemically-induced adverse effects on the brain, spinal cord, and/or peripheral nervous system (e.g., deficits in learning or sensory ability)
Pharmacokinetics and Metabolism	Study of the absorption, distribution, metabolism, and elimination (ADME) of drugs or chemicals in the body; also known as toxicokinetics.
Photo-toxicity	Toxic responses from a substance (applied to the body or ingested) following exposure to light or skin irradiation
Repeated Dose/Organ Toxicity	General toxicological effects occurring as a result of repeated daily exposure to a substance (via oral, inhalation, dermal, or injection routes) for a portion of the expected life span (i.e., sub-acute or sub chronic exposure), or for the majority of the life span (i.e., chronic exposure)
Reproductive and Developmental Toxicity	Chemically-induced adverse effects on sexual function, fertility, and/or normal offspring development (e.g., spontaneous abortion, premature delivery, or birth defects); generally determined through the breeding of one or more generations of offspring.
Skin Irritation/Corrosion	Chemically-induced skin damage that is reversible (irritation) or irreversible (corrosion).
Skin Sensitization	The induction of allergic contact dermatitis following exposure to a chemical substance.

NOTES

4.3.1 Non-Animal Toxicity Tests

This is only one of the 3Rs. In cases where Replacement methods are not available, Reduction and Refinement methods may be mentioned, but not covered in detail.

The term 'alternative,' in the context of toxicity testing, has been used to describe new or revised test methods that result in the replacement of animal test methods, or that reduce the numbers of animals used, or refine the techniques to alleviate or minimize pain, distress, and/or suffering. This 3Rs (Replacement, Reduction and Refinement) concept of alternatives is rooted in the 1959 publication of Russell and Burch, *The Principles of Humane Experimental Technique*. Since the publication of this seminal work, governments, industry, NGOs, and other stakeholders have invested substantial time and financial resources to advance the 3Rs in research and testing. At this time, the terms 'non-animal' or 'animal-free' are commonly used to describe replacement methods. This avoids confusion due to the multiple uses of alternatives. *Non-animal methods for producing toxicological data include the following:*

Cell and Tissue-Based Methods and Models: Toxicity assays can be conducted using models developed with primary cells, cell lines, stem cells, 3-dimensional cultured cells, excised tissues, or cultured organs. Some cell-based methods have already achieved validation and international acceptance.

Systems: Computer-based methods such as (quantitative) structure-activity relationship ((Q) SAR) models and read-across can be used to predict the biological/toxicological properties of a substance.

: It is often necessary to use more than one non-animal test to assess a single biological endpoint; it is therefore necessary to develop strategies for optimally combining test methods to address specific information needs. Integrated testing strategies combine methods, such as *in silico* methods and *in vitro* assays, along with appropriate statistical analysis, for the prediction of *in vivo* toxicity responses. An understanding of the mechanisms of toxicity and the cellular pathways involved are currently being investigated with the goal of obtaining more predictive integrated test strategies.

4.3.2 Animal Toxicity Tests

The study and characterization of chemicals and other agents for toxic properties is often undertaken on the basis of specific organs and organ systems. The two targets have been selected for in-depth discussion: the immune system and the gene. These examples were chosen to represent a complex target organ system and a molecular target within cells. The International Program on Chemical Safety (IPCS) has also published several criteria documents on target organ toxicology, by organ system.

4.3.3 Neurotoxicity Testing

NOTES

The effects of a test substance on the central nervous system can be studied through neurotoxicity studies. The peripheral nervous system is further divided into the somatic and autonomic nervous systems. Neurotoxic studies may be employed to evaluate the specific histo-pathological and behavioral neurotoxicity of a chemical and are used to characterize neurotoxic responses such as neuro-pathological lesions and neurological dysfunctions (loss of memory, sensory defects, and learning and memory dysfunctions). Usually neuro-toxicological studies are carried out in adult rodents. The test substance may be administered for 28 days or even more than 90 days, and neurological changes are evaluated. In 1998, the *in vitro* model for neurotoxicity was developed, and various regulatory agents now recommend *in vitro* neurotoxicity testing.

Examples of Specialized Tests to Measure Neurotoxicity

Function	Procedure	Representative agents
Neuromuscular		
Weakness	Grip strength; swimming endurance; suspension from rod; discriminative motor function; hind limb splay	n-Hexane, Methyl butyl ketone, Carbaryl
Incoordination	Rotorod, gait measurements	3-Acetylpyridine, Ethanol
Tremor	Rating scale, spectral analysis	Chlordecone, Type I Pyrethroids, DDT
Myoclonia, spasms	Rating scale, spectral analysis	DDT, Type II Pyrethroids
Sensory		
Auditory	Discriminant conditioning, reflex modification	Toluene, Trimethyltin
Visual toxicity	Discriminant conditioning	Methyl Mercury
Somatosensory toxicity	Discriminant conditioning	Acrylamide
Pain sensitivity	Discriminant conditioning (btration); functional observational battery	Parathion
Olfactory toxicity	Discriminant conditioning	3-Methylindole methylbromide
Learning, memory		
Habituation	Startle reflex	Di isopropyl fluorophosphate (DFP)
Classical conditioning	Nictitating membrane, conditioned flavour aversion, passive avoidance, olfactory conditioning	Aluminum, Carbaryl, Trimethyltin, IDPN, Trimethyltin (neonatal)
Operant or instrumental conditioning	One-way avoidance, Two-way avoidance, Y-maze avoidance, Biol water maze, Morris water maze, Radial arm maze, Delayed matching to sample, Repeated acquisition, Visual discrimination learning	Chlordecone, Lead (neonatal), Hypervitaminosis A, Styrene, DFP, Trimethyltin, DFP. Carbaryl, Lead

4.3.4 Developmental or Embryo Toxicity Testing

Embryo-toxicity can be studied using both *in vivo* and *in vitro* methods. Rodents are preferred for *in vivo* toxicity screening. The compound is administered between the 8thand 14thday of pregnancy, and embryo lethal effects are studied. At the end of the study or on the 21st day of the study, a caesarean section is performed and

NOTES

parameters such as fetuses with hemorrhagic bullae, limb malformations, exencephaly, cleft palates, open eyelids, and tail deformities as well as the mortality and the numbers of dead and live pups are noted. Embryo-toxicity studies can be performed using *in vitro* methods such as the Embryonic Stem Cell Test (EST) for embryo-toxicity, micro mass embryo-toxicity assay, and whole rat embryo embryo-toxicity assay.

Endpoints in Reproductive and Developmental Toxicology.

Couple-mediated endpoints	
Multigenerational studies	Other reproductive endpoints
Mating rate, time to mating (time to pregnancy[1]) Pregnancy rate[1] Delivery rate[1] Gestation length[1] Litter size (total and live) Number of live and dead offspring (foetal death rate[1]) Offspring gender[1] Birth weight1 Postnatal weights[1] Offspring survival[1] External malformations and variations[1] Offspring reproduction[1]	Ovulation rate Fertilization rate Preimplantation loss Implantation number Postimplantation loss[1] Internal malformations and variations[1] Postnatal structural and functional development[1]
Male-specific endpoints	
Organ weights	Testes, epididymides, seminal vesicles, prostate, pituitary
Visual examination and histopathology	Testes, epididymides, seminal vesicles, prostate, pituitary
Sperm evaluation[1]	Sperm number (count) and quality (morphology, motility)
Hormone levels[1]	Luteinizing hormone, follicle stimulating hormone, testosterone, oestrogen, prolactin
Developmental	Testis descent[1], preputial separation, sperm production[1], anogenital distance, normality of external genitalia[1]
	Female-specific endpoints
Body weight-mediated endpoints	
Organ weights	Ovary, uterus, vagina, pituitary
Visual examination and histopathology	Ovary, uterus, vagina, pituitary, oviduct, mammary gland
Oestrous (menstrual[1]) cycle normality	Vaginal smear cytology
Hormone levels[1]	LH, FSH, oestrogen, progesterone, prolactin
Lactation[1]	Offspring growth
Development	Normality of external genitalia[1], vaginal opening, vaginal smear cytology, onset of oestrus behaviour (menstruation[1])
Senescence (menopause[1])	Vaginal smear cytology, ovarian histology

[1]*Endpoints that can be obtained relatively noninvasively with humans. Source: EPA 1994.*

4.3.5 Genetic Toxicity Testing

Genetic toxicity tests are used to identify gene mutations, chromosome changes, and alterations in the DNA sequencing. These tests are usually conducted in various species including whole animals, plants, micro-organisms, and mammalian cells. In the whole animal model, rodents are preferred. Genetic toxicity is assessed using the rodent chromosome assay, dominant lethal assay, mouse-specific locus test, micronucleus test, heritable translocation assay, and sister chromatid exchange assay.

4.3.6 Target Organ Toxicity Testing

Target organ toxicology studies are usually undertaken on the basis of information indicating the potential for specific toxic effects of a substance, either from epidemiological data or from general acute or chronic toxicity studies, or on the basis of special concerns to protect certain organ functions, such as reproduction or foetal development. In some cases, specific target organ toxicity tests are expressly mandated by statutory authorities, such as neurotoxicity testing under the US pesticides and mutagenicity testing under the Japanese Chemical Substance Control Law. In vitro tests can also be used to assess specific target organ toxicity. There are a number of difficulties associated with designing such tests, the most notable being the inability of in vitro systems to maintain many of the features of the organ in vivo. Frequently, when cells are taken from animals and placed into culture, they tend either to degenerate quickly and/or to dedifferentiate, that is, lose their organ-like functions or become more generic. This presents a problem in that within a short period of time, usually a few days, the cultures are no longer useful for assessing organ-specific effects of a toxin.

4.3.7 In Vitro Ocular Irritation Testing

Perhaps the most contentious whole-animal toxicity test from an animal welfare perspective is the '**Draize Test'** for eye irritation, which is conducted in rabbits. In this test, a small fixed dose of a chemical is placed in one of the rabbit's eyes while the other eye is used as a control. The degree of irritation and inflammation is scored at various times after exposure. A major effort is being made to develop methodologies to replace this test, which has been criticized not only for humane reasons, but also because of the subjectivity of the observations and variability of the results. It is interesting to note that despite the harsh criticism the Draize test has received, it has proven to be remarkably successful in predicting human eye irritants, particularly slightly to moderately irritating substances, that are difficult to identify by other methods. Thus, the demands on in vitro alternatives are great. The quest for alternatives to the Draize test is a complicated one, albeit one that is predicted to be successful. Numerous in vitro and other alternatives have been developed and in some cases they have been implemented.

Refinement alternatives to the Draize test, which by definition, are less painful or distressful to the animals, include the Low Volume Eye Test, in which smaller amounts of test materials are placed in the rabbits' eyes, not only for humane reasons, but to more closely mimic the amounts to which people may actually be accidentally exposed. Another refinement is that substances which have a pH less than 2 or greater than 11.5 are no longer tested in animals since they are known to be severely irritating to the eye.

Between 1980 and 1989, there has been an estimated 87% decline in the number of rabbits used for eye irritation testing of cosmetics. In vitro tests have been incorporated as part of a tier-testing approach to bring about this vast reduction in whole-animal tests. This approach is a multi-step process that begins with a thorough examination of the historical eye irritation data and physical and chemical analysis of the chemical to be evaluated. If these two processes do not yield enough information, then a battery of in vitro tests is performed. The additional

NOTES

data obtained from the in vitro tests might then be sufficient to assess the safety of the substance. If not, then the final step would be to perform limited in vivo tests. It is easy to see how this approach can eliminate or at least drastically reduce the numbers of animals needed to predict the safety of a test substance.

The cell of in vitro tests that is used as part of this tier-testing strategy depends upon the needs of the particular industry. Eye irritation testing is done by a wide variety of industries from cosmetics to pharmaceuticals to industrial chemicals. The type of information required by each industry varies and therefore it is not possible to define a single cell of in vitro tests. A test cell is generally designed to assess five parameters: cytotoxicity, changes in tissue physiology and biochemistry, quantitative structure-activity relationships, inflammation mediators, and recovery and repair. An example of a test for cytotoxicity, which is one possible cause for irritation, is the neutral red assay using cultured cells (see above). Changes in cellular physiology and biochemistry resulting from exposure to a chemical may be assayed in cultures of human corneal epithelial cells. Many of the endpoints measured in these whole organ cultures are the same as those measured in vivo, such as corneal opacity and corneal swelling. Inflammation is frequently a component of chemical-induced eye injury, and there are a number of assays available to examine this parameter. Various biochemical assays detect the presence of mediators released during the inflammatory process such as arachidonic acid and cytokines. The Chorioallantoic Membrane (CAM) of the hen's egg may also be used as an indicator of inflammation. In the CAM assay, a small piece of the shell of a 10-14-day chick embryo is removed to expose the CAM. The chemical is then applied to the CAM and signs of inflammation, such as vascular hemorrhaging, are scored at various times thereafter.

4.3.8 Validation of Testing Methods

It refers to the process of determining whether a toxicity test method is *reliable* (reproducible) and *relevant* for its intended purpose. *Relevance* in this setting means 'the extent to which the test method correctly measures or predicts the (biological) effect of interest. Criteria and processes for toxicity test method validation were developed in the mid-1990's by *validation authorities* in the EU (European Centre for the Validation of Alternative Methods or ECVAM), the US (Interagency Coordinating Committee on the Validation of Alternative Methods or ICCVAM), and by the international Organization for Economic Cooperation and Development (OECD).

Check Your Progress

6. What is the main objective of occupational and environmental toxicology?
7. What is a critical effect?
8. Define toxicity tests.
9. Write the definition of endocrine disruptors.
10. Why the Genetic toxicity tests are used?

4.4 AUTOPSY AND HISTOLOGICAL PRACTICES

NOTES

What most of us know of autopsies comes from popular television crime dramas, with their super-sleuth forensics teams and equipment so cutting-edge it borders on science fiction. An autopsy is an examination of a dead body to determine cause of death, the effects or indications of disease or, in some cases, to identity the dead person. Forensic pathologists (physicians trained in the study of diseases and abnormalities) perform autopsies with the assistance of autopsy technicians (sometimes called 'dieners,' from the German for 'helper') and autopsy photographers. The autopsies are also performed for disease research and medical training. Before conducting an autopsy, investigators gather all the information they can about the subject and the events leading to his or her demise, consulting medical records, doctors and family members and examining the location and circumstances of death.

Thus an autopsy (also known as a post-mortem examination or necropsy) is the examination of the body of a dead person and is performed primarily to determine the cause of death. The autopsy (obduction, necropsy, or autopsia cadaverum) can be defined as a procedure of post-mortem examination. An autopsy may be restricted to a specific organ or region of the body for cause of death, legal purposes, and for education and research as well. Autopsies are performed by pathologists, medical doctors who have received specialty training in the diagnosis of diseases by the examination of body fluids and tissues. The word autopsy is derived from the Greek word *autopsia*: 'to see with one's own eyes'. The word 'autopsy' has been used since around the 17th century, it refers to the examination of inside the dead human body to discover diseases and cause of death. A medical examiner can order an autopsy without the consent of the next-of-kin. In all other cases, consent must be obtained from the next-of-kin before an autopsy is performed, even at academic institutions or hospitals. The next-of-kin also has the right to limit the scope of the autopsy (for example, excluding the brain from evaluation or limiting the procedure to examination of the abdomen).

4.4.1 Types of Autopsy

There are four main types of autopsy:

a. **Medico-Legal** or Forensic or **Coroner's Autopsies:** This seeks to find the cause and manner of death and to identify the decedent. They are generally performed, as prescribed by applicable law, in cases of violent, suspicious or sudden deaths, deaths without medical assistance or during surgical procedures.

b. **Clinical or Pathological Autopsies**: These are performed to diagnose a particular disease or for research purposes. They aim to determine, clarify, or confirm medical diagnoses that remained unknown or unclear prior to the patient's death.

c. **Anatomical** or **Academic Autopsies** These are performed by students of anatomy for study purpose only.

NOTES

d. Virtual or **Medical Imaging Autopsies:** These are performed utilizing imaging technology only, primarily magnetic resonance imaging (MRI) and computed tomography (CT).

4.4.2 Procedure of Autopsy

An autopsy is performed when there are suspicious circumstances surrounding someone's death; or when no signs of natural causes can be located using following three stages.

External Examination during Autopsy

The autopsy begins with a careful inspection of the body. This can help establish identity, locate evidence or suggest a cause of death. The pathologists weigh and measure the body, noting the subject's clothing, valuables and characteristics such as eye color, hair color and length, ethnicity, sex and age. Removing the subject's clothes, they then examine the body, searching for gunpowder residue, paint flakes or other deposits, identifying marks such as scars or tattoos, or injuries. X-rays are sometimes used to reveal bone abnormalities and the locations of bullets or other objects, and ultraviolet light can help detect certain residues. Pathologists may also take samples of hair and nails at this time. Throughout the autopsy, the pathologist records everything on a body diagram and in recorded verbal notes.

Internal Examination during Autopsy

If a complete internal examination is called for, the pathologist removes and dissects the chest, abdominal and pelvic organs, and (if necessary) the brain. It is unusual to examine the face, arms, hands or legs internally. The cuts into the body produce little blood because without a beating heart the only blood pressure comes from gravity. Prior to cutting, the torso is placed on a rubber block, extending the body's arch and providing greater access to the chest and abdomen. If a brain autopsy is also planned, this block will be moved to support the head once the torso work is complete. The pathologist begins the chest and abdomen autopsy by making a Y-shaped incision, the two arms of the 'Y' running from each shoulder joint, to meet at mid-chest and the stem of the 'Y' running down to the pubic region. The next step is to examine the organs *in situ* (in place), which means removing the rib cage. Using a saw or a rib cutter (similar in appearance to a small pruning shear), the pathologists cut along the boundary between the ribs and the cartilage connected to the breastbone. Alternatively, they might cut the sides of the chest cavity, leaving the ribs attached to the breastbone and removing the entire frontal ribcage as one chest plate.

The abdominal examination begins with a pathologist freeing the intestines by cutting along the attachment tissue with scissors or a scalpel. If a brain autopsy is called for, the pathologist will make a cut across the crown of the head, from the bony bump behind one ear to the bump behind the other. He or she will then open the cranium using a special saw that cuts bone but leaves soft tissue unharmed.

4.4.3 Histological Examination during Autopsy

Once each organ has been examined within the body, it is removed, weighed and examined in further detail. Sometimes organs are removed individually, a procedure

referred to as the Virchow technique; other times, they are removed as a connected group, *via* the Rokitansky technique. Organs, especially the brain, are sometimes placed in formalin for days or even weeks before the dissection is conducted. Formalin preserves organs while also granting them greater firmness, allowing for neater and more accurate dissections. Tissue samples are taken from the organs, some of which may be also be sectioned, and stomach contents are frequently tested. Pathologists and lab technicians also test bodily fluids, such as urine, blood, vitreous gel from the eyes, or bile from the gallbladder for drugs, infection, chemical composition or genetic factors, depending on the purpose of the autopsy. Pathologists will preserve parts of any organs they dissect, particularly if they find something unusual or abnormal.

Thus after the organs are removed from the body, they usually are separated from each other and further dissected to reveal any abnormalities, such as tumors, on the inside. Small samples are typically taken from all organs to be made into slide preparations for examination under a microscope. Pictures of findings may be taken for future reference. Special studies may include cultures to identify infectious agents, chemical analysis for the measurement of drug levels or metabolic abnormalities, or genetic studies. Tissue may be frozen for future diagnostic or further research purposes.

4.4.4 Reconstituting the Body during Autopsy

Following examination, the organs are either returned to the body (minus the pieces preserved for future work or evidence) or cremated, in accordance with the law and the family's wishes. The breastbone and ribs are also usually put back. Prior to being sewn shut with the characteristic baseball stitch, the body is lined with cotton wool or a similar material. If the organs are to be returned to the body, they are first placed in bags to prevent leakage. The body is then sewn shut, washed and prepared for the funeral director. Bodies that have undergone autopsy are still able to have open-casket funerals, even in the case of brain autopsy; A casket pillow hide the cranial cut.

4.4.5 Autopsy Report and Challenges

After all studies are completed, a detailed report is prepared that describes the autopsy procedure and microscopic findings, gives a list of medical diagnoses, and a summary of the case. The report emphasizes the relationship or correlation between clinical findings (the doctor's examination, laboratory tests, radiology findings, etc.) and pathologic findings (those made from the autopsy).

Certainly the relationship between patients and their doctors has changed dramatically over the past 50 years due to factors such as specialization, managed care, and the disappearance of the house call. Physicians no longer are "family doctors" and do not have the same rapport with patients and their families as in past years. This change in the basic doctor-patient relationship may make it increasingly difficult to obtain consent for an autopsy.

Concerns over disfigurement of the remains or delays in funeral arrangements may prevent a vast majority of families from consenting to an autopsy. In reality,

NOTES

however, the visual examination of the body and the removal of tissues and organs for microscopic examination can be completed in a few hours. In the majority of cases and certainly at academic medical centers, there is currently no charge to the family and frequently, no compensation for its performance. More recently, though, some institutions have started to charge and private autopsies at the request of family members that are performed outside of the hospital may cost several thousand dollars.

Most physicians are generally uncomfortable requesting an autopsy because it is not an easy or pleasant task. If, in addition, a physician feels that a family questions the care that their relative was given, the physician may be reluctant to request an autopsy that might prove that the care was indeed incorrect. Some doctors express dissatisfaction with the quality of an autopsy if the pathologist does not provide answers regarding the case. Unfortunately, an autopsy does not guarantee that the cause of death, for example a heart arrhythmia, will be identified. In addition, the autopsy is not one of the favorite activities among the majority of pathologists. For many pathologists, an autopsy is an extra burden with no compensation during a busy day.

The rate of decay within the human body after death is also a critical challenge and normally split into two distinct categories: (a) autolysis, (b) putrefaction. Autolysis is process of self-digestion where the body's enzymes contained within cells begin to go into a post death meltdown. The process can be speeded up by extreme heat and likewise slowed down by extreme cold. However in putrefaction, the bacteria that escape from the body's intestinal tract after the deceased has died are released into the body and begin the process of literally melting the body down.

4.4.6 Scopes and Benefits of Autopsies

For families, the autopsy has both tangible and psychological benefits. Uncertainty regarding the cause of an individual's death can delay payment of insurance benefits. The autopsy can also uncover genetic or environmental (for example, a bacterium or fungus) causes of disease that could affect other family members. Psychologically, the autopsy provides closure by identifying or confirming the cause of death. Lastly, the autopsy is a mechanism that enables the family to participate in medical education and research.

The autopsy findings can be utilized to educate physicians, nurses, residents, and students, thereby contributing to an improved quality of care. Many of the benefits of the autopsy are experienced by society as a whole. The autopsy aids in the evaluation of new diagnostic tests, the assessment of new therapeutic interventions (drugs, devices, surgical techniques), and the investigation of environmental and occupational diseases. Autopsy data are useful in establishing valid mortality statistics as well.

Check Your Progress

11. What do you understand by autopsy?
12. What are clinical or pathological autopsies?
13. Define autolysis.
14. What are the benefits of autopsy?

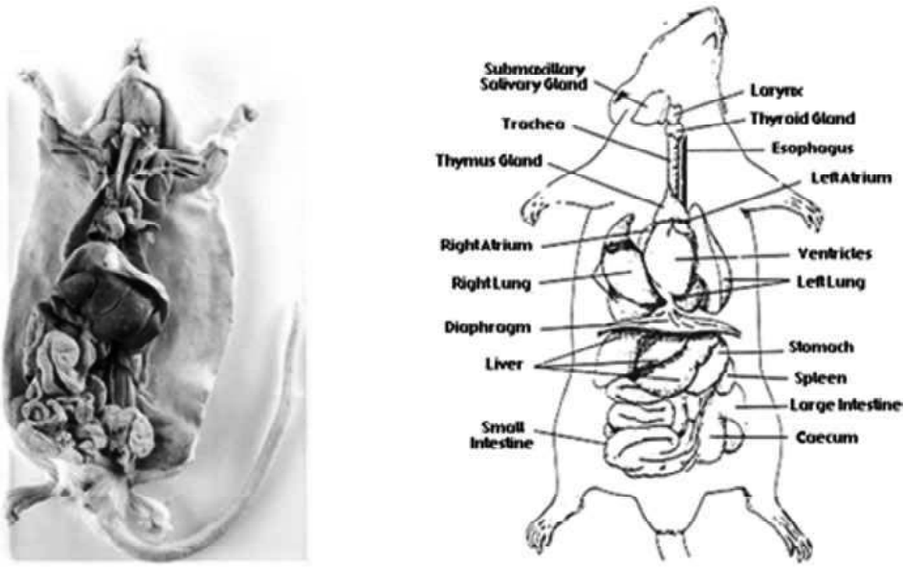
NOTES

4.5 METHODS APPLICABLE TO SPECIFIC ORGAN SYSTEM

Pathology is the study of disease, particularly the structural and functional changes in tissues and organs. Toxicological pathology integrates the disciplines of pathology and toxicology most often in an experimental setting. Pathologists study the nature of disease (pathophysiology), evaluating changes produced in cells, tissues, organs, or body fluids in response to a 'challenge,' whether it is metabolic, infectious, neoplastic, immune-mediated, physical, or toxic in origin. Most diseases leave significant 'footprints' in cells, fluids, and tissues. Thus the toxicological pathology is concerned predominantly with cell and tissue injury in animals treated with introduced chemical compounds or biological drugs. Studies are regulated by international bodies such as the 'Organization for Economic Co-operation and Development' (OECD), 'The US Food and Drug Administration' (FDA) and the 'European Medicines Agency' (EMA). Animal testing to determine the safety of pharmaceuticals, medical devices and food/color additives is required by the FDA before it give approval to begin clinical trials in humans. Pathology data may be quantitative (haematology, chemistry data, organ weights) or qualitative (microscopic diagnoses), and the toxicological pathology report is divided into macroscopic and microscopic findings.

The main species of animal used in the pharmaceutical industry are rats, mice, dogs, non-human primates, mini pigs and rabbits. Occasionally, farm animals, hamsters, cats and gerbils are also used. There are no absolute reasons for selecting a particular animal species for systemic toxicity, but for acute oral, intravenous, dermal and inhalation studies and studies of medical devices, the mouse or rat is preferred, with the option of the rabbit in the case of dermal and implantation studies. Carcinogenicity studies generally use rats and mice. All animal studies must be conducted according to the animal welfare laws of the country in which they are based, and in general studies may use protected animals only if there are no other reasonable, practicable choices for achieving a satisfactory result. Laboratory animals may only be used in minimal numbers, where they have the lowest possible degree of neurophysiological sensitivity and where the study causes minimal pain, suffering, distress and lasting harm. Animal suffering must be balanced against the likely benefits for humanity, other animals and the environment. In general, in the planning of all preclinical studies, due consideration must be given to reduction, refinement and replacement (the '3 Rs') in from through standard operating procedures (SOP).

NOTES

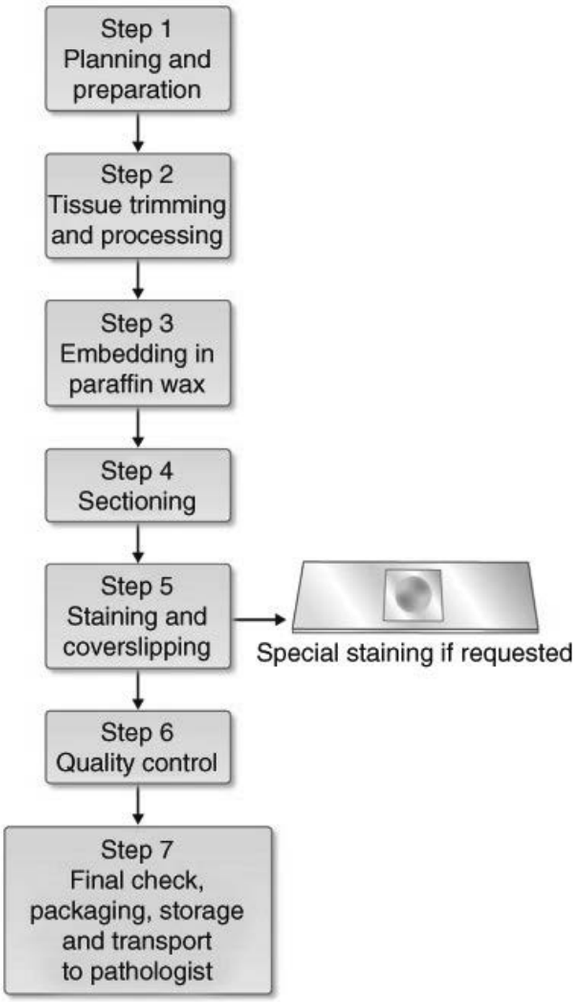


Necropsies or Post Mortem Examinations on Experimental Animals Toxicological Pathology. (A) In Situ; (B) Schematic Presentation

Autolysis occurs within 10 minutes of the death of an animal, so necropsy should be performed as quickly and efficiently as possible, with limited tissue handling, squeezing and tissue damage. Necropsies or post mortem examinations on experimental animals are a fundamental part of toxicological pathology. Post mortem change occurs as a result of autolysis (action of enzymes from the ruptured cells on the dead animal's cells) and putrefaction (degradation of tissue by the invasion of certain microorganisms); changes include rigor mortis (stiffening of limbs and carcass), clotting of the blood, hypostatic congestion (pooling of blood into the dependent side of the carcass, termed 'livor mortis'), imbibition of blood or bile pigment; and gaseous distension of the alimentary tract. In addition, pseudomelanosis (the greenish or blackish discoloration of tissues due to ferrous sulfide) tends to occur in organs that lie adjacent to the intestine, such as the liver. Most of these changes will be visible if an animal dies during the night or on the weekend, and every effort should be made to store the carcass in a fridge and to perform a necropsy as soon as possible thereafter. For improvement in the histology of the target tissue in mice and rats, it is recommended for fixation using standard chemicals/ fixatives. In general, fixation of tissues maintains cellular integrity and slows the breakdown of tissues by autolysis. The most common fixative is 10% neutral buffered formalin, which ensures rapid tissue penetration, is easy to use and is inexpensive. However, formalin is highly toxic and carcinogenic and may have effects on the immune system. Tissues should be fixed at a 1:10 or 1:20 ratio of fixative to tissue for at least 48 hours. Modified Davidson's is the recommended fixative for eyes and testes, as it prevents retinal detachment in the eye and separation of cells lining the seminiferous tubules in the testes. Glutaraldehyde or osmium tetraoxide is used for the fixation of tissues intended for electron microscopy. Artefacts which occur at necropsy include inclusions of foreign material into the tissue (e.g. plant material during brain removal and the incorporation of sharp shafts of hair into soft tissues) and pressure and pinch effects (from forceps).

These can be confused with lesions by an inexperienced pathologist. Thereafter, serial glass slides prepared for the histopathological analysis which involves a number of steps performed in the histology laboratory.

NOTES



Production of Glass Slides Suitable for Histopathological Analysis

Toxins may be evaluated qualitatively or quantitatively. Qualitative analysis provides information about the nature of toxins, but quantitative analysis gives information about the chemistry of the toxins and their concentration. Nonspecific instrumental analyses such as colorimetric and UV-visible spectrophotometric analyses may be used for qualitative analysis of toxins. Sophisticated techniques such as infrared spectroscopy, gas chromatography, High Pressure Liquid Chromatography, and immunoassay techniques may be employed to quantify the toxins.

4.5.1 Skin Specific Technique

Toxicity testing of new compounds is essential for drug development process. The preclinical toxicity testing on various biological systems reveals the species-, organ- and dose- specific toxic effects of an investigational product. The toxicity of

NOTES

substances can be observed by (a) studying the accidental exposures to substance (b) in vitro studies using cells/ cell lines (c) in vivo exposure on experimental animals. Toxicity tests are mostly used to examine specific adverse events or specific end points such as cancer, cardio toxicity, and skin/eye irritation. Toxicity testing also helps calculate the 'No Observed Adverse Effect Level' (NOAEL) dose and is helpful for clinical studies. Usually toxicants are classified based on their chemical nature, mode of action, or class (exposure class and use class). The exposure class classifies toxicants as occurring in food, air, water, or soil. The use class classifies drugs as drugs of abuse, therapeutic drugs, agriculture chemicals, food additives, pesticides, plant toxins (phytotoxins), and cosmetics. The native human skin is a large, complex organ containing multiple types of cells that are positioned relative to each other in highly-specific arrangement; it consists of anisotropic distribution of both cellular and Extracellular Matrix (ECM) components. The use of human-relevant skin tissue models enables more reliable and accurate cosmetics testing; different types of skin toxicology tests have been investigated and are well-documented by the Test Guidelines (TG) under the 'Organization for Economic Cooperation and Development' (OECD) using the United Nations (UN) Globally Harmonized System (GHS) of classification and labeling of chemicals. The four key OECD test guidelines involving in vitro skin tissue models include;

(i) Skin absorption (OECD TG 428),

(ii) Skin corrosion (OECD TG 431),

(iii) Skin irritation (OECD TG 439), and

(iv) Skin sensitization (OECD TG 442D).

There are several practices used to study the toxicology in terms of skin and subcutaneous structures:

(i) Acute dermal toxicity

(ii) Subchronic dermal toxicity,

(iii) Dermal irritation

(iv) Skin corrosion test

(v) Skin sensitization test

(vi) Phototoxicity

(vii) Non-animal models

(viii) In vitro skin irritation assay

(ix) In vitro skin corrosion test

(x) In vitro skin sensitization test

(xi) Phototoxicity and photoallergy

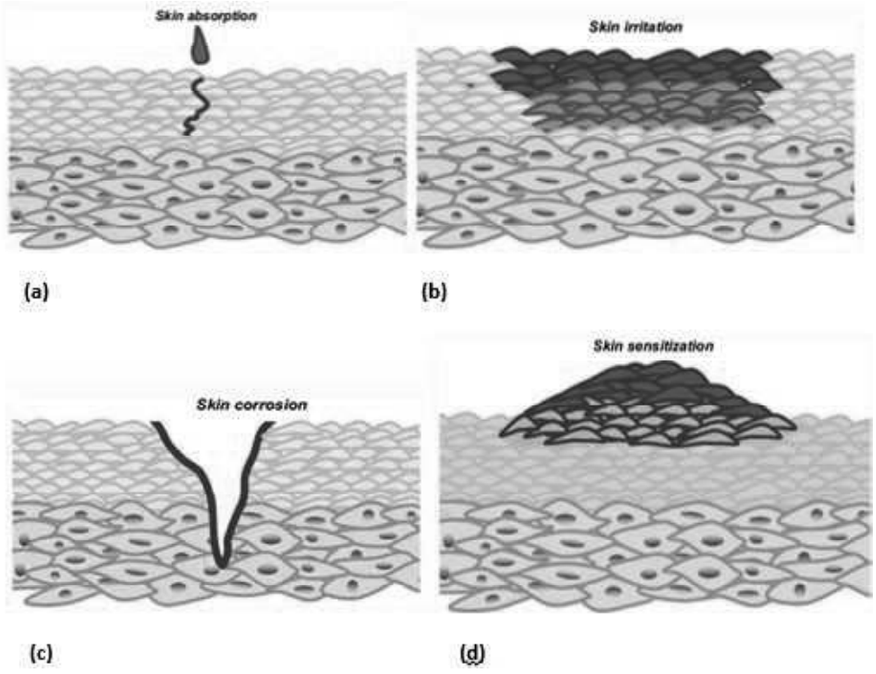
(xii) Skin genotoxicity.

In the skin irritation test, 0.5g of a test substance is applied to the surface of an animal's skin. During the observation period (14 days), signs such as erythema and edema are assessed. Some alternative in vitro testing methods are available that can be used in place of the Draize eye irritancy test. At the end of the study, the animals are sacrificed and pathological changes are evaluated. The eye irritation

NOTES

test and skin irritation test are very important for topical preparations. Dermal and ophthalmic preparations can be tested using Draize tests. The Draize eye irritancy test and the Draize skin irritancy test are used to measure the harmfulness of chemicals and pharmaceutical substances in rabbits and guinea pigs. In the eye irritation test, 0.5ml of a test substance is administered to an animal's eyes, and the animal is restrained for 4h. Redness, swelling, discharge, ulceration, hemorrhage, and blindness are assessed and monitored for 14 days.

Skin sensitization tests are carried out using the guinea pig as a model. Skin sensitization is assessed using the Draize test, open epicutaneous test, optimization test, split adjuvant test, Guinea Pig Maximization Test (GPMT), Buehler test, and Murine Local Lymph Node Assay (LLNA). The LLNA method is used as an alternative to the guinea pig Draize test, and it is widely accepted that this method meets regulatory requirements. In the LLNA test, the test substance is applied on the surface of the ears of a mouse for three consecutive days, and the proliferation of lymphocytes in the draining lymph node is measured at the end.

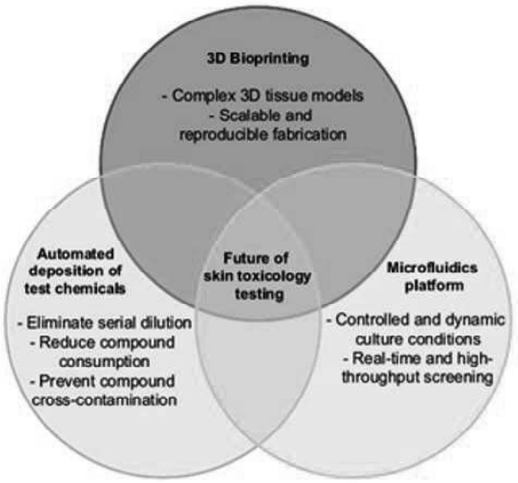


Different Toxico-Pathological Effect on Skin and Subcutaneous Structures

A paradigm shift in the testing models has occurred over the past few years; the implementation of non-animal testing strategy has spurred the development of numerous human-based three-dimensional (3D) in vitro testing models. Notably, the use of 3D bio printing technology provides a highly-automated and advanced manufacturing platform that enables the simultaneous and highly-specific deposition of multiple types of human skin cells and biomaterials with high throughput rates and reproducibility, which is lacking in conventional skin tissue engineering approaches. This facilitates the fabrication of highly-complex human-based 3D skin tissue models with additional types of cells and biomaterials to improve the homology to native skin and enhance the tissue functionalities. Furthermore, the integration of bio printed skin constructs within microfluidics platform enables the

NOTES

incorporation of more physiologically relevant tissue maturation conditions (controlled medium flow, and supplementation of important growth factors) to achieve more biomimetic 3D skin tissue models and also facilitates real-time monitoring and high throughput screening. Dermal (Skin) irritation test skin is frequently exposed to cosmetic products and it should not cause skin irritation and skin corrosion.



Paradigm Shift in the Skin or Subcutaneous Testing Models

4.5.2 Subcutaneous Tissue Specific Technique

Toxicity test uses bio organisms instead of testing components and compounds to detect toxicity in water samples. The main advantage of toxicity test is the fact that it is not necessary to deploy this test on many available pollutants. Base of deploying toxicity test is when special biological species are exposed to toxic compounds in a sample of water; there would be a measurable biological response for each of them. In rodents, gross lesions and all scheduled tissues from the animals in the control and high dose groups should be microscopically examined. When effects are observed, histological examination is extended to other dose groups, until a dose level is examined at which no effects are observed. Any animals found dead or terminated early in the study must also be examined histologically. Properly conducted histological examination is a powerful means of assessing toxicity. As with other toxicological parameters, adaptation or tolerance may alter the responses observed over time. The rat transcutaneous electrical resistance test is another alternative test for subcutaneous corrosively. In this procedure, test materials are applied for 2 to 24 hrs. To the epidermal surface of skin discs taken from young rats. Corrosive materials are identified by their ability to produce a loss of integrity to normal stratum corneum, measured by the reduction in the transcutaneous electrical resistance of the layers of the skin to an applied current (5kΩ). Corrosive materials would damage the integrity of the stratum corneum and reduce the electrical resistance of the skin to transmission of current from one side to the opposite. The OECD tiered testing strategy for evaluating dermal corrosion and irritation allows for the use of validated and accepted in vitro methods.

NOTES

Cutaneous adverse drug or chemical reactions in patients are not common. Among hospitalized patients, the incidence of adverse drug reactions concerning the skin ranges from 1% to 3%; however, the actual prevalence is much higher, as many mild forms of cutaneous adverse reactions are not reported. We are constantly exposed to external stimuli, such as chemical and environmental substances, resulting in various skin symptoms.. In preclinical studies, cutaneous toxicity is rarely encountered, except in cutaneous application, intradermal administration, and subcutaneous administration. Cutaneous toxicity primarily involves either a direct local inflammatory reaction to the drug without involvement of an immunological mechanism or an indirect inflammatory reaction associated with a systemic manifestation. In cutaneous application studies, both epidermis and skin appendages are important factors in transdermal drug absorption. Experimental animals such as guinea pigs, monkeys, and swine exhibit similar absorption characteristics to humans. The extent of transdermal drug absorption differs according to skin location. Sites in order of favorable absorption, due to the skin thickness, are the abdomen, forehead, palms, and soles of feet. Microsomal enzymes in keratinocytes are capable of metabolizing topically applied chemicals, thus rendering them inactive or active. Dimethylbenz(a)anthracene (DMBA) becomes a potent skin carcinogen after metabolic activation by keratinocytes.

Cutaneous toxicity can be classified according to the mechanism of onset into the following: (1) contact dermatitis, i.e., damage resulting from contact of the skin with a drug (irritant dermatitis, allergic contact dermatitis, and chemical burns); (2) Photosensitivity, caused by the combined effect of a chemical substance and ultraviolet light (phototoxic dermatitis and photoallergic contact dermatitis); (3) Contact urticaria; (4) Chemical-induced acne; (5) Pigmentary disturbance; (6) Drug rash; (7) Hair disturbance; (8) Nail disturbance; and (9) Tumor-induced.

Cutaneous toxicity can also be classified according to the route of exposure, i.e., either due to systemic effects or local irritation of the skin (local toxicity).

Classification and characteristics of cutaneous toxicological pathology.

Classification	Type	Definition and characteristics
A. Classification according to the route of exposure to the drug		
1. Cutaneous toxicity	Local toxicity	Due to systemic effect local irritation of skin
B. Classification according to the mechanism of onset		
1. Contact dermatitis	Irritant dermatitis	Skin inflammation occurring as a result of direct contact of the skin with a drug, without involvement of an immune mechanism
	Allergic dermatitis	Skin inflammation upon re-exposure to a drug that had been previously administered and bound as a hapten to a protein in the skin to become immunogenic (type IV allergic reaction)
2. Photosensitivity	Phototoxic dermatitis	A condition caused by a drug with covalent binding as a result of a photochemical reaction with ultraviolet light
	Photo-allergic dermatitis	Skin inflammation upon re-exposure to a previously administered drug that absorbed ultraviolet light and was transformed to act as a hapten to bind with a protein in the skin to become immunogenic (type IV allergic reaction)
3. Contact Urticaria		Acute erythema with involvement of histamine release from mast cells (increased vascular permeability), occurring soon after contact with the drug

4. Chemical Acne		Inflammation of hair follicles due to excessive keratin and sebum in hair follicles
5. Pigmentary Disturbance	Hyperpigmentation	A condition occurring in association with increased melanin production due to activation of melanocytes, hemosiderin deposition due to hemorrhage, or deposition of the drug itself
	Hypopigmentation	A condition occurring in association with loss of melanin or selective damage to melanocytes
6. Drug Rash (Cutaneous Reaction)	Toxic epidermal necrolysis, oculomucocutaneous syndrome	The mechanism remains unknown, although an allergic reaction has been speculated. Reported for greater than 1100 drugs, including sulfa drugs
7. Hair Disturbance	Alopecia	A condition due to drugs with an androgenic effect acting on hair follicles to shorten the hair cycle, or drugs with an antimitotic effect inducing atrophy of hair follicles and prolongation of the resting phase of the hair cycle
	Hypertrichosis	A condition due to prolongation of the anagen phase of hair follicles induced by certain immune-suppressants, anti-hypertensives (minoxidil), or drugs for benign prostatic hyperplasia (finasteride)
8. Nail Disturbance	Nail Transverse Ridges, Onycholysis, Discoloration	A condition arising from damage to the nail matrix cells due to drugs with an antimitotic effect or deposition of the drugs themselves

4.5.3 Pulmonary System Specific Technique

Properly conducted histological examination is a powerful means of assessing toxicity. Due to the potentially long exposure periods, permeability and sensitive nature of airway regions, the tissues spanning the nasal and oropharynx to the deep lung are exceptionally susceptible to insult and damage by toxicants. Manifestations can range from asymptomatic or mild up regulation of immune mediators/cytokines and decreased cellular function to fulminant disease states (such as asthma, COPD and fibrosis) to complete system failure. As a result, knowledge of how the body responds to an inhaled material is critical toxicological information. Acute inhalation toxicity testing is performed for aerosol-like preparations. Rats are the most preferred animal species. The animals are acclimatized to laboratory conditions (temperature preferably 22°C ± 2°C). They are maintained in an air flow of 12–15 air changes per hour with adequate oxygen (19%/h). The animal is exposed to the test substance for a minimum of 4 hour, and then it is monitored for 14 days. Food is withheld during the exposure period, and water may be withheld under certain conditions. During the observation period, the animal is observed for tremors, convulsions, salivation, diarrhea, lethargy, sleep, and coma. Mortality during the exposure and observation period is noted. Dead animals are examined for histological and pathological changes. At the end of the study, the animals are sacrificed, and pathological changes are evaluated. Thus the acute inhalation toxicity is the total of adverse effects caused by a test chemical following a single, uninterrupted exposure of non-fasted healthy young adult animals by inhalation over a short period of time (less than 24 hours) to an adequately generated and characterized test chemical atmosphere. The total of adverse effects is best described by cumulative mortality. The following should be considered when choosing an inhalation chamber:

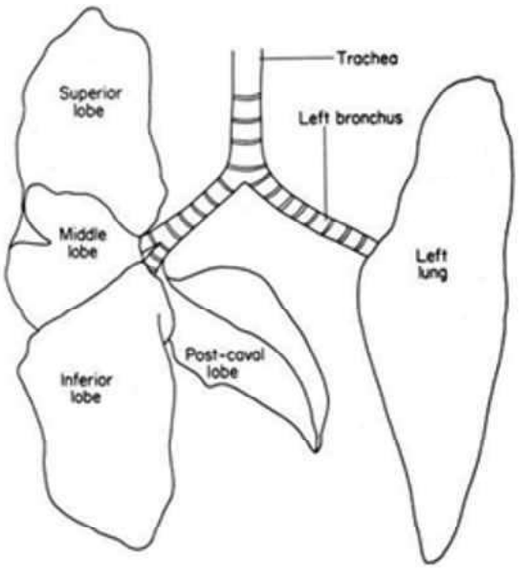
(1) Reactivity of test chemical with humidity and/or ammonia.

(2) Temporal stability of test atmosphere (e.g., minimization of particle growth and coagulation/aggregation).

(3) Prevention of re-breathing of test atmospheres.

(4) Measurements and/or collection of biological specimens during the course of exposure.

NOTES



Schematic Presentation of Respiratory System

The preferred mode of exposure is nose-only (which term includes head-only, nose-only, or snout-only) for the following reasons:

(a) Exposure and/or uptake by any other route than inhalation (oral route via preening or dermal route) are minimized, especially when testing aerosols.

(b) Technician exposure from handling exposed animals is minimized.

(c) A minimum of test chemical is needed due to low chamber volume.

(d) High concentrations (e.g., limit concentrations) are readily achieved.

(e) The instability of test chemicals (e.g., reactivity with excreta or humidity) and test atmosphere in-homogeneity are of minimal concern.

(f) The time required to attain inhalation chamber equilibration (t 95) is negligible relative to the duration of exposure and therefore not an issue.

(g) Adding or removing animal restraining tubes during exposure to a fixed steady state chamber concentration allows for multiple exposure durations in one single test (the C × t protocol, utilizing the same exposure concentrations for multiple exposure durations).

(h) The exposure of individual animals can be interrupted at any time during the course of exposure to avoid undue suffering of animals.

NOTES

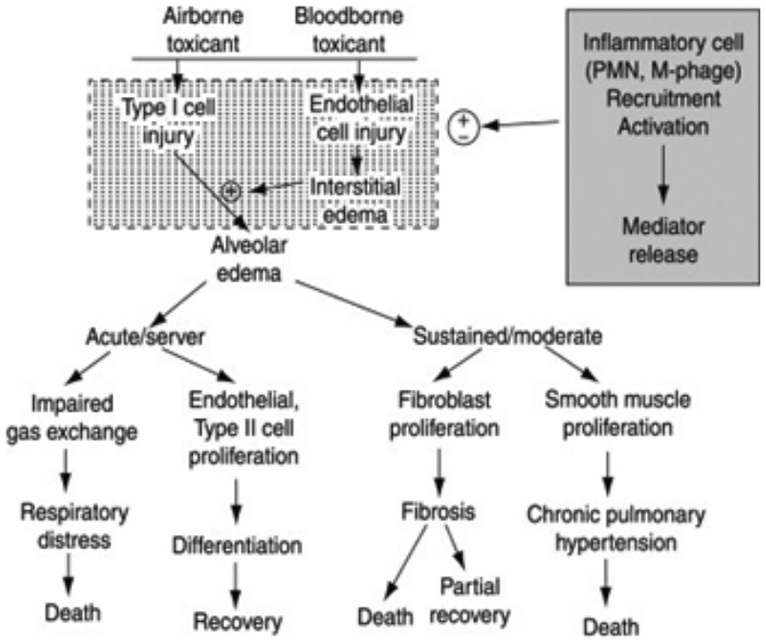
(i) Animals are readily accessible for specific physiological measurements (e.g., respiratory function, body temperature) or the collection of blood, if applicable.

(j) The pre-conditioning of air prior to entering the inhalation chamber (e.g., in order to eliminate ubiquitous environmental constituents such as ozone, nitrogen oxides, hydrocarbons, and particulates, or to allow testing under defined humidity or gas conditions) is technically less demanding with nose-only chambers than with larger whole-body inhalation chambers.

During nose-only exposure Technique, animals are exposed to the test chemical while in restraining tubes. The restraining tubes should not impose undue physical, thermal, or immobilization stress on the animals. Restraint may affect physiological endpoints such as body temperature (hyperthermia) and/or respiratory minute volume. Urine and faeces should escape from the restrainer during the course of exposure.

During whole-body exposure technique animals should be tested with inhalation equipment designed to sustain a dynamic airflow of at least 10 air changes per hour. Higher airflow rates may be useful to meet specific requirements imposed by the test chemical. An oxygen concentration of at least 19%, a carbon dioxide concentration not exceeding 1%, and an evenly distributed exposure atmosphere should be ensured. Where concerns might apply, these gas levels should be measured in the vicinity of the animals' breathing zone. All animals should be individually housed to preclude them from breathing through the fur of their cage mates, thus reducing their aerosol exposure. To ensure stability of a chamber atmosphere, the total volume of the test animals should not exceed 5% of the chamber volume. Maintenance of slight negative pressure inside the chamber will prevent leakage of test chemical into the surrounding area. Food and drinking water should be accessible for exposures exceeding 8 hours. Due to the testing of very low concentrations and the higher number of animals per chamber (relative to acute studies) possible interferences/interactions of the test article with excreta/ ammonia/exhaled air, etc., needs to be considered.

Lung burden measurements performed in the course of repeated exposure studies in rats, provide a metric of retained dose and may be helpful in understanding the toxicity of poorly soluble particles. However, each retained lung burden may have a different kinetic history due to burden-specific changes in clearance. The dosage-effect relationships can usually be described by cumulative frequency distributions, mathematically represented by sigmoid curves. For each substance, a dosage (concentration)-effect relationship is examined which is assumed to be characteristic for a specific effect and species. In order to quantify this relationship, the term 'Median Lethal Concentration' (LC50) was suggested as a measure of acute inhalation toxicity.



Pulmonary Cellular Response against Blood borne and Airborne Toxicants

4.5.4 Digestive System Specific Technique

Chronic toxicity studies are conducted with a test compound that was administered over more than 90 days in experimental animals and observed periodically. A chronic toxicology study provides inferences about the long-term effect of a test substance in animals, and it may be extrapolated to the human safety of the test substance. The report on chronic oral toxicity is essential for new drug entities. There should be little individual variation between the animals, and the allowable weight variation range is ±20%. During the study period, the animals are observed for normal physiological functions, behavioral variations and alterations in biochemical parameters. At the end of the study, tissues are collected from all parts of the animal and subjected to histological analyses. During carcinogenicity testing, the tests are carried out over the greater portion of an animal's lifespan. During and after exposure to test substances, the experimental animals are observed for signs of toxicity and development of tumors. If these are not found, a test may be terminated after 18 months in the case of mice and hamsters and after 24 months with rats. If the animals are healthy, hematological analysis is performed after the 12 months and the 18 months, respectively, and the study is terminated. The animals are sacrificed, and gross pathological changes are noted and histo-pathological studies are carried out on all the tissues.

The food allergy attention has been given to the types of food products that can produce an allergic response, few studies have addressed whether contaminants in the diet may affect food allergy. The normal response to ingested proteins is a state of non-reactivity known as oral tolerance, which likely protects most individuals from developing food allergies. Since IgE is the immunoglobulin subclass most

NOTES

susceptible to suppression by oral tolerance, substances that modify IgE responses may contribute to a failure of oral tolerance. Food allergy currently affects 6–8% of children under the age of 4 and 1–4% of adults, and the consequences of allergic reactions to food can be severe or even fatal. An understanding of the mechanisms underlying oral tolerance and how these mechanisms may be modified by chemical exposures will be important not only for understanding the pathogenesis of food allergy, but also to evaluate the risk for the potential of increased hypersensitivity responses to foodstuffs due to chemicals present in the diet. Exposure to low or minimal amounts of a food allergen that would not be of significance to the general population could potentially be hazardous to individuals with a food allergy. Hence, determination of a 'safe' or tolerable level of exposure to an allergen is critical to the subpopulation of those individuals with an allergic sensitivity to it.

Metabolic disorders describe those conditions where adverse reactions result from a genetic deficiency in the ability to metabolize some component of the consumed food. Common examples of metabolic food disorders include lactose intolerance, a deficiency of β-galactosidase, and favism, a deficiency of erythrocyte glucose-6-phospahte dehydrogenase. Individuals with lactose intolerance are unable to digest lactose and experience adverse gastrointestinal effects associated with bacterial metabolism of lactose in the colon. Favism is acute hemolytic anemia resulting from oxidative damage to erythrocytes following the consumption of fava beans containing vicine and convicine.

Interactions that may occur between chemicals in food, including food additives and residues of veterinary drugs, and the bacterial flora of the gastrointestinal tract should be considered in terms of the effects of the gut microflora on the chemical and the effects of the chemical on the gut microflora. Because the gut microflora is important in the metabolic fate and toxicological activity of some chemicals, the safety assessment should consider the possibility that the chemical in food may affect the host microflora and thereby modify the host response to the chemical in food. The gut microflora may influence the outcome of toxicity tests in a number of ways, reflecting their importance in relation to the nutritional status of the host animal, the metabolism of xenobiotics prior to absorption, and the hydrolysis of biliary conjugation products. While hepatic metabolism of foreign compounds is predominantly by oxidation and conjugation reactions, the gut bacteria perform largely reductive and hydrolytic reactions, some of which appear to be unique to the gut flora. Typical reactions include: (1) The hydrolysis of glycosides (including glucuronide conjugates), amides, sulfates and sulphamates, (2) The reduction of double bonds and functional groups, and (3) The removal of functional groups such as phenol and carboxylic acid moieties.

4.5.5 Urinogenital Tract Specific Technique

Urine analyses consist of determining the volume of urine produced, specific gravity, pH, glucose and protein. In addition, microscopic evaluation for sediment and presence of blood/blood cells is typically done. These analyses are usually conducted during the last week of the study. Analysis of urine, and faeces if indicated,

may provide important information relating to changes in normal excretory functions caused by the test substance. The test compound is administered to both male and female animals. Administration is for the duration of one complete spermatogenic cycle in male animals and for two complete estrous cycles for female animals. Rodents are preferred for the one-generation reproduction toxicity testing. After the completion of the specified duration of drug administration, the animals are allowed to mate. The test compound is administered to the female animals during the period of pregnancy and nursing. The sperms of male animals are collected, and the sperm morphology and motility are analyzed. During the study period, the animals are observed for signs of toxicity. Parturition, the number of offspring and their sexes are recorded. The number of dead and live pups are noted, and live pups are weighed in the morning and evening each day during the first 4 days. After the termination of the study, the animals and pups are sacrificed and subjected to a histo-pathological examination.

During two-generation reproduction toxicity studies both male and female rodents are administered the test substance. The duration of administration extends to one complete spermatogenic cycle for males and two complete estrous cycles for females. After the administration period, the animals are intertwined (parental mating), after which the female animals are separated. Sperms are collected from male animals, and the sperm morphology and motility are analyzed. The test substance is administered continuously to pregnant female animals, which are monitored regularly for mortality and signs of toxicity. After parturition, nursing rats are administered the test drug, and the mortality of the pups (F1 generation) is observed. From the F1 generation, one male and one female animal are selected. The same procedure is repeated to get the F2 generation offspring. F1 off springs are not allowed to mate until they have attained full sexual maturity, and pairs without a pregnancy are evaluated for infertility. Necropsies and histological examinations are carried out. At the end of the study, the animals are sacrificed and gross pathological and histological examinations are carried out on all the animals.

The toxicokinetics helps study the metabolism and excretion pattern of xenobiotics. In toxicological testing, pharmacokinetic studies are usually carried out in rodents, rabbits, dogs, nonhuman primates and swine using many routes of administration. Blood samples are collected at various time points to analyze pharmacokinetic data such as the area under the curve, drug distribution ratio, Cmax, tmax, and other pharmacokinetic parameters. Toxicokinetic studies may be performed using in vitro cell lines also.

Check Your Progress 4.5

15. What do you understand by toxicological pathology?
16. What are metabolic disorder?
17. What is Favism?
18. How is urine analyses done?

4.6 TOXICANTS OF PUBLIC HEALTH HAZARDS

NOTES

Although chemical substances are widely used in almost all economic sectors, their utilization is much higher in some specific areas. Data collected from Member States show that chemical use is more pronounced in agriculture and industry, mainly manufacturing, mining and petroleum oil refining. The chemicals mostly utilized by the agricultural sector are pesticides and fertilizers. Insecticides such as DDT are also reported to be common in the health sector for the control of many vector-borne diseases such as malaria and typhus. Other sectors that were reported to be significant users of chemicals included construction, transport, power generation and tourism. The public health impact of a chemical is determined by an assessment process that aims to provide a consensus scientific description of the risks resulting from exposure to the chemical. In order to identify chemicals that are of major public health concern, certain epidemiological factors need to be taken into account. These factors include the substance's prevalence, toxicity, adverse public health impacts and tendency to spread. Using the self-assessment questionnaire, Member States identified the sectors that were the main users of chemicals and listed the chemicals that were most used having public hazards impact. Among the many chemicals listed by Member States, the following were identified as being of major public health concern by the World Health Organization (WHO): Heavy metals (mercury, lead, cadmium and arsenic), Cyanide, Air pollutants and automobile emissions (carbon monoxide, nitrogen dioxide, sulfur dioxide, etc.), Benzene (polycyclic aromatic hydrocarbons, PAHs), Asbestos POPs (dioxins, furans and polychlorinated-biphenyls, PCBs), Hazardous pesticides (organophosphates and organochlorines), Fluoride, Fertilizers, Environmental mutagens, Food additives, Radioactive toxicants, etc. Exposure to the chemicals or groups of chemicals listed above may result in acute or chronic health effects.

4.6.1 Heavy Metals

The term heavy metal is loosely defined, as no consensus on its definition exists in the literature. Many definitions have been proposed, some based on substance density, others on atomic number or atomic weight and some others on chemical properties or features of toxicity. From a public health point of view, the term heavy metal usually refers to a metal or semi-metal that has the potential to cause human or environmental toxicity. These may include lead, mercury, cadmium, cobalt, nickel, iron, thallium, bismuth and arsenic. Based on 'Member States Reports' and the literature review, the main threat to human health from heavy metals is from exposure to mercury, lead, cadmium and arsenic. These metals have been studied extensively and their effects on human health are reviewed regularly by WHO. Heavy metals are generally considered to be especially toxic to humans and animals, and exposure to them even at low concentrations is associated with diverse health effects including but not limited to neurotoxicity and carcinogenicity.

Mercury is a heavy metal that exists in the environment in three chemical forms; elemental or metallic mercury, inorganic mercury compounds and organic

NOTES

mercury compounds. In high enough doses, all these forms can produce toxic effects. Humans are exposed to mercury by various means. The most common route for exposure to elemental mercury is through the lungs, as the metal volatizes at room temperature. The vapor irritates the lungs, affects the kidneys, easily penetrates the blood-brain barrier and is neurotoxic. Children are vulnerable to the toxic effects of mercury, particularly during the early stages of brain development. Exposure to methyl mercury, an organic form of mercury, occurs mainly by ingestion of contaminated fish. Methyl mercury is the most toxic form of mercury. The best known cases of severe methyl mercury poisoning are of the industrial release of methyl mercury in Minamata Bay, Japan, in 1956 and of the treatment of wheat with a methyl mercury fungicide in Iraq in 1971. In each of these cases hundreds of people died and thousands were affected in other ways and many left with permanent health consequences.

Lead is a naturally occurring toxic metal found in the earth's crust. Its widespread use has resulted in extensive environmental contamination, human exposure and significant public health problems in many parts of the world. Lead is one of the most dangerous chemicals to children and developing fetus. Neurodevelopment impairment is its most critical effect. The risk of exposure to lead is especially high among young children because of their tendency to pick up particles from the ground and put them in their mouths, and due to higher levels of absorption of ingested lead compared to adults. Lead exposure in childhood is associated with lowering Intelligence Quotient (IQ) scores and aggressive and violent behavior. Lead accumulates in the skeleton, and is passed from a mother's bones during pregnancy and lactation to foetuses and breast-fed infants. Exposure of pregnant women to high levels of lead can cause miscarriage,

Cadmium is an extremely toxic metal that has no known valuable function in the body and is considered more toxic than lead or mercury. Cadmium toxicity contributes to a large array of health conditions including heart disease, cancer and diabetes. The toxic effects of cadmium result primarily from inhalation of cadmium oxide fumes or dust. Cadmium oxide fumes are a pulmonary irritant. Acute exposure to cadmium mainly affects the lungs, resulting in conditions such as pulmonary irritation. Chronic inhalation of, or oral exposure to cadmium leads to a build-up of the chemical in the kidneys that can cause organ dysfunction. Cadmium also concentrates in the liver and other organs. Maternal exposure to cadmium is associated with low birth weight and an increase in the likelihood of a spontaneous abortion. An association between cadmium exposure from inhalation of the chemical in occupational settings and an increased risk of lung cancer has been reported in human studies. Many of the toxic effects of cadmium, including renal dysfunction, neurological damage, arteriosclerosis and birth defects stem from cadmium replacement of zinc in sensitive enzyme binding sites.

Arsenic is highly toxic in its inorganic form. It is rarely found as a free element in the natural environment, it exists more commonly as a component of sulphur containing ores in which it occurs as metal arsenides. Arsenic exposure induces cardiovascular diseases, developmental abnormalities, neurological and neurobehavioural disorders, diabetes, hearing loss and haematological disorders. Long-term consumption of arsenic-contaminated water leads to serious health

NOTES

effects often referred to as arsenicosis. The features of arsenicosis manifest after several years of exposure, initially as skin lesions, which then progress into localized gangrene and eventually into cancers of the skin, lung, bladder or kidneys. Potential sources of exposure Arsenic is widely distributed in natural bodies of water and is often associated with particular geological sources, but in some locations anthropogenic inputs such as arsenical insecticides and combustion of fossil fuels can be extremely important sources of additional arsenic. Human beings may be exposed to arsenic from many sources including air, water, soil and food. Smoking tobacco is also an important source of exposure to the natural inorganic arsenic in tobacco because tobacco plants take up arsenic present in the soil. However, the greatest threat to public health from arsenic originates from contaminated groundwater, which may be a result of natural geochemical processes or anthropogenic pollution. Drinking water: Arsenic concentrations in drinking water above accepted standards have been reported in many countries on all continents, and should therefore be regarded as a global public health issue.

Fluoride has both beneficial and detrimental effects on human health. The beneficial effects are limited to levels of about 1 mg/l in potable water levels at which fluoride reportedly improves skeletal and dental health. Nonetheless, as far as acute exposure is concerned, fluoride is more toxic than lead but slightly less toxic than arsenic. High or low fluoride levels in drinking water are associated with adverse health effects. The prevalence of dental caries is inversely related to the concentration of fluoride in drinking water, while a dose response relationship exists between the concentration of fluoride in drinking-water and the prevalence of dental fluorosis. In terms of general health, skeletal fluorosis and bone fractures are the adverse health effects most commonly reported by communities whose drinking water and food are excessively high in fluoride. Moreover, exposure to high levels of fluoride has also recently been associated with neurological damage in children. Potential sources of exposure Excessive fluoride intake usually results from consumption of groundwater naturally rich in fluoride or crops that take up fluoride that have been irrigated with such water.

Cyanide is acutely toxic to humans. Liquid or gaseous hydrogen cyanide and alkali salts of cyanide can enter the body by inhalation, ingestion or absorption through the eyes and skin. The toxicity of cyanide to humans is dependent on the nature of exposure. Inhaled salts of cyanide are readily dissolved and absorbed upon contact with the moist mucous membranes. Symptoms and signs of cyanide poisoning usually occur less than one minute after cyanide inhalation and within a few minutes after ingestion. Early manifestations of cyanide toxicity include anxiety, headache, giddiness and mydriasis, and as hypoxia progresses, gradually lower levels of consciousness, seizures and coma will occur. Potential sources of exposure to cyanide has two main sources; food plants naturally rich in cyanide and contamination of air, soil and water with cyanide associated with industrial activities, principally mining.

Food source: Cyanogenic glycosides occur in many food plants such as cassava, lima beans and the seeds of some fruits such as peaches. Because of this, ingestion of large amounts of cassava and lima beans can be fatal if they are eaten raw or are not prepared correctly. The cassava plant is by far the most important

source of cyanide in human food. Cassava toxicity is reduced a great deal by peeling, washing in running water to remove the cyanogen, and then cooking or fermenting it to inactivate the enzymes and to volatilize the cyanide.

NOTES

Industry: Cyanide is used in various occupational settings including certain metal-mining processes, gold extraction, metal cleaning, electroplating, metallurgy, some types of pesticide application, tanning, photography and photoengraving, and dying and pharmaceutical processes. During this process, Hydrogen Cyanide (HCN) gas, which is extremely poisonous, is produced and released into the environment and caused extensive occupational health problems.

4.6.2 Air Pollutants and Automobile Emissions

Air pollution is a major environmental health problem affecting both developed and developing countries. Air pollution encompasses both indoor and outdoor air quality. Indoor air pollution usually results from the burning of wood, coal or paraffin for space heating, cooking and lighting purposes. Outdoor air pollution is largely a consequence of fossil fuel combustion for transport and electricity generation, industrial non-fossil fuel emissions and other human activities. Air pollutants may be grouped into four categories: (a) Gaseous pollutants such as sulphur dioxide, carbon monoxide and ozone (b) Persistent organic pollutants such as dioxins and furans (c) Heavy metals such as lead, mercury and arsenic (d) Particulate matter of various sizes, e.g. PM 2.5 and PM 10.

Public Health Impact: The public health impact of exposure to air pollutants is too complex to determine because there are many sources of pollutants and their individual effects vary. Exposure to air pollutants, particularly from combustion of solid fuels used in households, has been implicated with varying degrees of evidence as a causal agent in a number of diseases in developing countries including acute respiratory infection, otitis media, Chronic Obstructive Pulmonary Disease (COPD), lung cancer, asthma, nasopharyngeal and laryngeal cancer, tuberculosis, perinatal conditions and low birth weight, and eye diseases such as cataracts and blindness. Exposure to air pollution causes an estimated 4.5% of the global burden of disease.

Inhalation is the primary route of exposure, but airborne pollutants may also be deposited on soil, plants and in water, which serve as indirect exposure routes. **Solid Fuels**: Solid fuels are the main source of indoor air pollution. Nearly 3 billion people worldwide and a great majority of households in developing countries rely on solid fuels such as wood, dung, crop residues, coal and charcoal for cooking and other household energy needs and have little or no access to modern fuels. Incomplete combustion of solid fuels in inefficient, poorly vented combustion devices such as open fires and traditional stoves results in much of the fuel energy being emitted as potentially toxic pollutants, including particles of varying sizes, carbon monoxide, nitrogen dioxide, volatile and semi-volatile organic compounds such as formaldehyde and benzo[a]pyrene, methylene chloride, and dioxins. Land transport has emerged as a major source of outdoor air pollution in many parts worldwide. With population growth and rapid urbanization, land transport has increased tremendously but without adequate controls or inspection procedures for automobile exhaust gases. Quantitative data on the impact of automobile

NOTES

emissions on outdoor air quality is limited because air quality studies are not routinely conducted.

Human exposure to benzene has been associated with a range of acute and long-term adverse health effects and diseases. Acute exposure to benzene may cause narcosis, headache, dizziness, drowsiness, confusion, tremors, irritation and loss of consciousness. Use of alcohol enhances the toxic effect of benzene. Chronic exposure to benzene has been reported to result in bone marrow depression, aplasia and leukemia, cardiac abnormalities, myocardial ischemia, and cancers of the lung, brain and stomach. Benzene can also cause excessive bleeding and can affect the immune system, increasing the risk of infection. Long term exposure to benzene has also been associated with reproductive disorders in women. Exposure to benzene can occur from occupational or domestic activities because of the widespread use of benzene-containing petroleum products such as motor fuels and solvents and studies indicate that benzene occurs in higher concentrations in poorer quality gasoline. Benzene is found in the air due to emissions from coal and oil burning, benzene waste and storage operations, motor vehicle exhaust, and gasoline evaporation at service stations. Tobacco smoke also is a significant source of benzene in the air, particularly indoors. Benzene is highly volatile, and exposure to it occurs mostly through inhalation. Automobile mechanics and petrol station attendants are at a special risk mainly because they lack proper guidance on and adherence to safety procedures.

Asbestos is a group of minerals with thin microscopic fibers. Two types of asbestos fibers exist: serpentine and amphibole. The serpentine type has just one member, chrysotile (white asbestos), while the amphibole type has five members: amosite (brown), crocidolite (blue), anthophyllite, tremolite and actinolite. Amphibole asbestos fibers are needle-like in appearance and have been determined to be the most dangerous asbestos to which human beings can be exposed. Inhalation of these fibers is the main route of exposure to asbestos. Significant exposure to any type of asbestos, including chrysotile, will increase the risk of lung cancer, mesothelioma and non-malignant lung and pleural disorders, including asbestosis, pleural plaques, pleural thickening and pleural effusions. Cigarette smoke is known to interact synergistically with asbestos to increase the risk of lung cancer. Asbestos-related diseases have a long latency period and can take between 10 to 40 years to appear after exposure. The use of asbestos is banned in many industrialized countries. The occupational activities can be a significant source of exposure to asbestos, such as asbestos mining, treatment of raw asbestos (milling), production of asbestos-containing products, transportation of asbestos, and repairs or demolition of buildings constructed with asbestos materials.

4.6.3 Persistent Organic Pollutants

Persistent Organic Pollutants (POPs) are a group of toxic chemicals that adversely affect human health and the environment. Because they can be transported by wind and water, most POPs can and do affect people and wildlife that are located far from where substances are initially used and released. POPs persist for long periods in the environment and can accumulate in and pass from one species to another through the food chain. To address the global concern about POPs, a

number of treaties and non-binding legal agreements have been signed at international and regional levels, the most significant one of which is the Stockholm Convention. That convention initially targeted a group of 12 chemicals, the so-called dirty dozen: that were of primary public health and environmental concern. Of these, dioxins, furans and PCBs, which are industrial chemicals, are considered the most hazardous to humans, while the other nine: aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene, mirex and toxaphene – which are used as pesticides, have varying degrees of toxicity. Dioxins, furans and dioxin-like PCBs are the names of families of chemicals that have similar toxicity and shared chemical characteristics. The most toxic member of the dioxin group is 2,3,7,8 tetrachlorodibenzo-p-dioxin or TCDD. Exposure to dioxins, furans and PCBs has been associated with adverse health effects including birth defects, inability to maintain a pregnancy, decreased fertility, reduced sperm count, endometriosis, diabetes, learning disabilities, immune system suppression, lung problems, skin disorders, lowered testosterone levels and cancer. Dioxins and furans are by-products of a range of chemical, manufacturing and combustion processes. These include production of certain pesticides, dyes and pigments, PVC plastic, and metal; paper pulp bleaching; incineration of municipal and hospital waste and sewage sludge; diesel-engine exhaust; accidental fires and explosions involving chlorine-containing materials; and wood combustion. In the past PCBs were manufactured as insulator fluids in heat-exchangers and transformers, as hydraulic fluids, and as additives for paints, oils, window caulking and floor tiles. Incineration is believed to be a main method by which dioxins and furans are produced.

4.6.4 Pesticides

The term pesticide is a composite term that covers all chemicals used to kill or control pests in different environments such as the home and various forms of agriculture. These include herbicides, insecticides, fungicides, nematocides and rodenticides (vertebrate poisons). According to the United States' Environmental Protection Agency (EPA), 60% of herbicides, 90% of fungicides and 30% of insecticides are known to be carcinogenic. The pesticides are used to increase the production of food, cotton fiber and tobacco and to control many vector-borne diseases such as malaria and typhus. However, many of these pesticides are extremely dangerous and exposure to them can result in adverse health problems. According to a joint report from the Food and Agriculture Organization (FAO) and UNEP, approximately 30% of pesticides marketed in developing countries do not conform to international standards, contain active ingredients exceeding toxic thresholds, and do not exclude other toxic substances. A large proportion of pesticides still in use particularly organo-chlorines and organophosphates have been extensively evaluated toxicologically for a range of adverse effects and are known to induce a series of acute and chronic effects even at very low exposure levels. A toxic effect common in them all is neurotoxicity. According to WHO, an estimated 1–5 million cases of pesticide poisoning occur every year among agricultural workers and result in 20000 fatalities, most of these are in developing countries. Some of the most commonly used hazardous pesticides that are said to be currently in use include aldicarb, chlordane, DDT, dieldrin, endrin, heptachlor,

NOTES

hexachlorobenzene, mirex, toxaphene, carbofuran, cyfluthrin, dichlorvos, methomyl, parathion, methamidophos, alphacypermethrin, deltamethrin, endosulfan, etc. Typically, human exposure to pesticides used in agriculture is highest among farm workers, pesticide appliers and those who live adjacent to heavily treated agricultural land. In addition to being frequently exposed to a wide array of pesticides, farm workers and pesticide appliers are likely to be exposed to high doses by multiple routes. Misuse of highly toxic pesticides, a lack of attention to safety precautions, poor spraying techniques and inadequate personal protection during pesticide use are some of the main reasons for the high incidence of pesticide intoxication observed. Indiscriminate use of pesticides represents one of the main environmental and public health problems globally, contributing to soil contamination, water pollution, destruction of useful organisms and development of pesticide resistance in pests, and consequently leading to harmful effects on the health of both farmers and food consumers. The typical pesticides detected in soil, water and crops include organochlorines such as DDT, endosulfan and lindane. For example, hazardous pesticides including DDT and its breakdown products endosulfan I and II, endosulfan sulfate and profenofos were detected in the soil samples collected from various agro farming sources. Similarly, residues from six banned or restricted chemical pesticides – DDT, endosulfan, lindane, aldrin, dieldrin and endrin – were reported in food samples as well. Humans are substantially exposed to DDT and DDE through indoor spraying. Such exposure may result in a range of health effects, including reduced fertility, genital birth defects, breast cancer, diabetes and damage to the developing foetus's brain. DDE is known to also block male hormone activity. DDT is one of the 12 original POPs banned under the Stockholm Convention, but its use in the control of malaria and other vector-borne diseases has been granted a "health-related exemption" by the Parties to the POPs treaty until cost-effective substitutes for malaria control are found since cessation of DDT use caused catastrophic epidemics of malaria in several parts of the world.

4.6.5 Plant and Animal Toxins

Different portions of a plant may contain different concentrations of chemicals. Some chemicals made by plants can be lethal. For example, taxon, used in chemotherapy to kill cancer cells, is produced by a species of the yew plant. Animal toxins can result from venomous or poisonous animal releases. Venomous animals are usually defined as those that are capable of producing a poison in a highly developed gland or group of cells, and can deliver that toxin through biting or stinging. Poisonous animals are generally regarded as those whose tissues, either in part or in their whole, are toxic. For examples, venomous animals, such as snakes, spiders, etc., and poisonous animals, such as puffer fish, or oysters, which may be toxic to some individuals.

4.6.6 Environmental Health Hazards

There are a range of environmental health hazards that affect our wellbeing. Hazards can be grouped together to improve understanding and action planning. The actions that you need to carry out to protect the health of your community depend on

knowing how these hazards can affect us all. In this study session, you will learn about the types and categories of environmental health hazards, the routes of exposure and the ways of preventing and controlling these hazards. It is worth pausing here to clarify the difference between hazard and risk. A **hazard** is something which is known to cause harm, that is, a source of danger to health. **Risk** is the likelihood or probability of the hazard occurring and the magnitude of the resulting effects. For example, if you climb a ladder you know there is a chance you could fall off and be injured, although it is unlikely. The ladder is the hazard and the chance of injury is the risk you take by climbing the ladder. For example, the production of cow dung cake to be used for fuel is a common practice. Fresh dung supports the breeding of flies. Dung cake is usually prepared near to the house. Young flies need food and move from the dung to the food that is found in the house. The flies pick up pathogenic organisms from the dung and transfer them to fresh food that is ready for consumption. A child eats the contaminated food and gets diarrhoea in a few days. The conditions or the situation of producing dung cake close to the house is hazardous (or dangerous) because it facilitates the breeding of flies near to fresh food in the house. The infected food is the hazard that damages the child's health. In this example, the hazard arises because of the infectious agent (the pathogenic organisms) and the process or condition (the preparation of cow dung cake close to the house). The risk of getting an infection is very high if someone consumes food that is contaminated with an infectious agent.

Categories of Environmental Health Hazards

Hazards are generally categorized as follows: Physical hazards, Biological hazards, Chemical hazards, Cultural/practice-related hazards, and Social hazards

a. **Physical Hazards:** Physical hazards are those substances or conditions that threaten our physical safety. Fires, explosive materials, temperature (hot or cold), noise, radiation, spills on floors and unguarded machines are some examples of physical hazards. Physical hazards also include ergonomic hazards which occur when the type of work, body position and working conditions put strain on your body. The harm these hazards cause muscle fatigue or tiredness, but long-term exposure can result in serious long-term injuries of the musculoskeletal system. Ergonomic hazards also exist among farmers, for example while manually ploughing and cleaning the weeds in farmland.

b. **Biological Hazards:** Biological hazards are organisms, or by-products from an organism, that are harmful or potentially harmful to human beings. They include pathogenic bacteria, viruses and parasites, and also toxins (poisons) that are produced by organisms. Biological hazards are the cause of the majority of human diseases. For example, bacteria cause cholera, tuberculosis, leprosy, relapsing fever and many diarrhoeal diseases; viruses are responsible for hepatitis 'B' and 'C', HIV, measles and polio; and there are many diseases caused by parasites. A parasite is any organism that lives on or in another organism, called the host, and causes damage, ill health or even death to the host. Some human parasites are external and live on the skin and hair, for

NOTES

example, mites that cause scabies. Internal parasites, living inside the body, include protozoa and helminthes. Protozoan parasites are single-celled organisms that enter the body either by ingestion or via the bite of an infected insect. Malaria, sleeping sickness and leishmaniasis are examples of diseases caused by protozoan parasites introduced by insect bites; amoebic dysentery and giardiasis result from drinking or eating contaminated water or food. Helminths are parasitic worms that live inside the body. Several helminths have complicated life cycles involving humans and other animals as secondary hosts. They have different routes of entry into the human body depending on the type of worm including ingestion with food or water, the faeco-oral route, insect bites and penetration through the skin. 'Helminth' is the general term used to describe several different types of parasitic worm. There are three main groups: tapeworms, roundworms and flukes. Tapeworms may be ingested with food, especially under-cooked meat, or with water or soil contaminated with faeces. Roundworms, also called nematodes, are responsible for many different diseases including Ascariasis, Dracunculiasis (Guinea Worm), Filariasis, Hookworm, Onchocerciasis (River Blindness), Trichinosis and Trichuriasis (whipworm). A type of fluke is the cause of schistosomiasis, also known as bilharzia. People become infected with schistosomiasis, not through food, but by standing or swimming in water that contains the immature form of the fluke; these are released into the water from the snail secondary host. The fluke gets into the water and the snail from the excreta of infected people.

c. **Chemical Hazards:** Chemical hazards are present when a person is exposed to a harmful chemical at home or at work. The chemicals can be in the form of gases, solids or liquids. Exposure to chemicals could cause acute health effects (an immediate or rapid onset) if taken in large quantities in a single dose; and chronic health effects (long-term effects on health) if taken in small doses over an extended time. Detergents (powdered soap, bleaching powder), drugs (veterinary and human) and pesticides (DDT, Malathion, diazinon, zinc phosphide, warfarin) are chemical hazards that are commonly found in rural households. Farmers, young children (under 5 years) and household animals are vulnerable to chemical exposure, but it is always possible that anyone might come into contact with the chemical during preparation, spraying, use or storage. A person is exposed to chemicals through various ways: through inhaling the vapors, gases or dusts; through skin contact with solvents, acids and alkalis; and through ingestion of unknown chemicals with food and water.

d. **Cultural/Practice-Related Hazards:** Culture is the knowledge, belief, art, law, morals, customs and habits that are acquired by people as members of society. It is also the common ways of life and set of thoughts and feelings shared by the members of a society. Just as there are cultural practices that are good for health, such as breast feeding a child, there are also cultural practices that adversely affect health and these can be considered to be cultural hazards. There are practices that are widely accepted and found hazards for health; for example, the belief that evil spirits are the source of

diseases, practices of storing drinking water uncovered, open defecation and not hand washing before meals and after latrine use.

e. **Social Hazards:** Poverty and illiteracy are examples of social hazards. We know that poor and uneducated people get sick more frequently, compared to wealthier and more educated people. Alcoholism, obesity, smoking and drug abuse are also social hazards that affect our health. A person with such habits is, over time, degraded, not respected by society, physically and mentally dissatisfied, and ultimately is likely to suffer with chronic illnesses such as lung and cardio-vascular diseases.

Principles of Hazard Management

The plan how to manage environmental hazards is a big question for mills or industries. Involvement in hazard management requires following certain steps, which are outlined below.

a. **Establish the Context and Identify the Hazard:** These are the first steps. You have learned that a hazard is something that is harmful to our health. A description of the categories of hazards is given in Section 2.2 above. You should identify the type of the hazard in as much detail as you can. You should also describe the exposure conditions and try to answer the following questions: What is the source of the hazard? Who is exposed? What are the pathways or activities that expose a person? What part of the environment is involved in the transfer of the hazard to humans?

b. **Hazard/Risk Analysis and Evaluation:** Here you would analyze the risk and evaluate the potential of the hazard to cause damage to health. This step needs a deeper appraisal in collaboration with the environmental health worker. The evaluation may require appropriate design, sampling and laboratory investigation.

c. **Communicate and Consult:** When the hazards and risks have been determined, advice can be communicated on the interventions or control measures that are needed to control the hazard. There can also be consultations with relevant people and organizations.

d. **Treat The Hazard/Risk:** The interventions or control measures are carried out by the person or people responsible for the hazard or risk.

e. **Monitoring and Reviewing:** The implementation of interventions or control measures for the hazard must be followed up in order to determine whether they are successful. Correction measures can be applied if there is any failure. Identifying appropriate indicators for monitoring is critical and must be done formally.

f. **Record Keeping:** Keeping records and reports on hazard management is always important. These records must contain the type of hazard, exposures and what control measures were taken.

4.6.7 Food Additives

Food additives are substances which are added to food which either improve the flavor, texture, color or chemical preservatives, taste, appearance or function as

NOTES

processing aid. Food additives as non- nutritive substances added intentionally to food, generally in small quantities, to improve its appearance, flavor, texture or storage properties. A broad definition of 'food additive' is any substance the intended use of which results, directly or indirectly, in it's becoming a component of or otherwise affecting the characteristic of any food, and which is safe under the condition of its use.

Need For Food Additives

a. Additives provide protection against food spoilage during storage transportation, distribution or processing. Also, with the present degree of urbanization, it would be impossible to maintain food distribution without the processing.

b. A number of factors have led to the demand for foods with built- in preparation of 'Convenience' Foods. The 'Convenience Food Revolution' would not have been possible without food additives.

c. Many of these chemical additives can be manufactured so that foods can be fortified or enriched. Potassium iodide, for instance, added to common salt can eliminate goiter, enriched rice or bread with B-complex vitamins can eliminate pellagra, and adding vitamin D to cow milk prevents rickets.

d. Many foods, particularly those with high moisture contents, do not keep well. All foods are subjected to microbial attack. Fats or oily foods become rancid, particularly when exposed to humid air. The conversation of the quality of foods against agents causing such deterioration of food requires the addition of preservatives. Additives are also used to color foods, add flavor, impart firmness, and retard or hasten chemical reaction in food.

e. The use of food additives is to maintain the nutritional quality of food, to enhance stability with resulting reduction in waste, to make food more attractive, and to provide efficient aids in processing, packaging and transport.

Classification of Food Additives

Over 3,000 different chemical compounds are used as food additives. They are categorized into different groups. A few types of additives are indicated below.

1. **Anti-oxidants:** An anti-oxidant is a substance added to fats and fat-containing substances to retard oxidation and thereby prolong their wholesomeness, palatability, and, sometimes, keeping time. An anti-oxidant should not contribute an objectionable odor, flavor, or color, to the fat or to the food in which it is present. It should be effective in low concentrations, and be fat soluble. Some anti-oxidants used in foods are butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), propyl gallate (PG), and teriarybutyl hydroquinone (TBHQ), which are all phenolic substances. 'The Joint FAO/WHO Expert Committee on Food Additives' has recently considered the 'Acceptable Daily Intakes (ADls)' of BHA and BHT and set them at 0-0.5 mg/kg body weight for BHA and 0-0.3 mg/kg body weight for BHT. Naturally occurring substances that act as anti-oxidants are tocopherols but they are rarely used as additives because they are more expensive than synthetic anti-oxidants.

NOTES

2. **Chelating Agents:** Chelating agents are not anti-oxidants. They serve as scavengers of metals which catalyze oxidation. Recommended usage levels for citric acid typically vary between 0.1 and 0.3 % with the appropriate anti-oxidant at levels ranging between 100 and 200 ppm) EDTA is a chelating agent permitted for use in the food industry as a chemical preservative. Calcium disodium EDTA and disodium EDTA have been approved for use as food additives by the United States Food and Drug Administration.
3. **Colouring Agents:** These include color stabilizers, colour fixatives, colour fixatives, colour retention agents, etc. They consist of synthetic colours, synthesized colours that also occur naturally, and other colours from natural sources. Even though colours add nothing to the nutritive value of foods, without certain colours most consumers will not buy or eat some foods. Thus, colours are frequently added to restore the natural ones lost in food processing or to give the preparations the natural colour we expect. A number of natural food colours extracted from seeds, flowers, insects, and foods, are also used as food additives. One of the best known and most widespread red pigment is bixin, derived from the seed coat of *Bixa orellana*, the lipstick pod plant of South American origin. Bixin is not considered to be carcinogenic. Saffron has both flavouring and colouring properties and has been used for colouring foods. Turmeric is a spice that gives the characteristic colour of curries and some meat products and salad dressings. A natural red colour, cochineal (or carnum) obtained by extraction from the female insect (Coccus cacti), grape skin extract, and caramel, the brown colour obtained from burnt sugar, are some natural colours that are used as food additives.
4. **Curing Agents:** These are additives to preserve (cure) meats, give them desirable colour and flavor, discourage growth of micro-organisms, and prevent toxin formation. Sodium nitrite has been used for centuries as a preservative and colour stabilizer in meat and fish products. The nitrite, when added to meat, gets converted to nitric oxide, which combines with myoglobin to form nitric oxide myoglobin (nitrosyl myoglobin), which is a heat-stable pigment. The curing also contributes flavor to the meat. In addition, nitrite curing inhibits the growth of Clostridium and Streptococcus, and also lowers the temperature required to kill *Clostridium botulinum*.
5. **Emulsifiers:** Emulsifiers are a group of substances used to obtain a stable mixture of liquids that otherwise would not or would separate quickly. They also stabilize gas-in-liquid and gas –in-solid mixtures. They are widely used in dairy and confectionery products to disperse tiny globules of an oil or fatty liquid in water. Emulsifying agents are also added to margarine, salad dressings, and shortenings. Peanut butter contains up to 10 per cent emulsifiers.
6. **Flavours and Flavour Enhancers:** Flavouring additives are the ingredients, both naturally occurring and added, which give the characteristic flavor to almost all the foods in our diet. Flavour enhancers are not flavours themselves but they amplify the flavours of other substance through a synergistic effect. Flavour and flavor enhancers constitute the largest class of food additives. Natural flavor are substances, such as spices, herbs, roots, essences, and

NOTES

essential oils, have been used in the past as flavor additives. Natural food flavours are now replaced by synthetic flavor materials, like esters, aldehydes, ketones, alcohols, and ethers. These substances are easily synthesized and can be easily substituted for natural ones. Typical of the synthetic flavor additives are amyl acetate for banana, methyl anthranilate for grapes, ethyl butyrate for pineapple, etc. One of the best known, most widely used and somewhat controversial flavor enhancers is Monosodium Glutamate (MSG), the sodium salt of the naturally occurring amino acid glutamic acid. This is added to over 10,000 different processed foods including Chinese and Japanese cooking for centuries. MSG is generally recognized as safe. However, it was reported some time back that MSG injected to young mice resulted in brain damage. Also, some individuals experience symptoms often comparable to those of heart attack, when served with food containing large amounts of MSG.

7. **Flour Improvers:** These are bleaching and maturing agents; usually, they both bleach and 'mature' the flour. These are important in the flour milling and bread-baking industries. Freshly milled flour has a yellowish tint and yields a weak dough that produces poor bread. Both the colour and baking properties improve by storing the flour for several months before making bread. Chemical agents used as flour improvers are oxidizing agents, which may participate in bleaching only, in both bleaching and dough improvement, or in dough improvement only. The agent that is used only for flour bleaching is Benzoyl Peroxide ($(C6H5CO)_2O_2$). Materials used both for bleaching and improving are chlorine gas, (Cl2); Chlorine Dioxide, (ClO_2); Nitrosyl Chloride, (NOCI); and Nitrogen Di and Tetra Oxides, (NO_2 and N_2O_4). Oxidizing agents used only for dough improvement are potassium bromate, ($KBrO_3$); potassium iodate, (KIO_3); Calcium iodate, [$Ca(IO_3)_2$]; and calcium peroxide, (CaO_2).

8. **Humectants:** Humectants are moisture retention agents. Their functions in foods include control of viscosity and texture, bulking, retention of moisture, reduction of water activity, control of crystallization, and improvement or retention of softness. They also help improve the rehydration of dehydrated food and solubilization of flavor compounds. Polyhydroxy alcohols are water soluble, hygroscopic materials which exhibit moderate viscosities at high concentrations in water and are used as humectants in foods. Some of them are propylene glycol ($CH_3.CHOH.CH_2OH$), glycerol, and sorbitol and mannitol [$CH_2OH\ (CHOH)_4\ CH_2OH$]. Polyhydric alcohols are sugar derivatives and most of them, except propylene glycol, occur naturally.

9. **Anti-Caking Agents:** Anti-caking agents help prevent particles from adhering to each other and turning into a solid chunk during damp weather. They help free flowing of salt and other powders.

10. **Leavening Agents:** Leavening agents produce light fluffy baked goods. Originally, yeast was used almost exclusively to leaven baked products. It is still an important leavening agent in bread making. When yeast is used, ammonium salts are added to dough to provide a ready source of nitrogen for yeast growth. Phosphate salts (sodium phosphate, calcium phosphate) are added to aid in control of pH.

NOTES

11. **Nutrient Supplements:** Nutrient supplements restore values lost in processing or storage, or ensure higher nutritional value than what nature may have provided. When foods are processed, there may be loss of some nutrients and additives may be added to restore the original value. For example, to produce white flour, wheat is milled in such a way as to remove the brown coloured part of the grain, which is rich in vitamins and minerals. To restore the nutritive value, thiamine, nicotinic acid, iron and calcium, are added to the flour. Similarly, vitamin C is added to canned citrus fruits to make up the loss of the vitamin during processing.
12. **Non-Nutritive Sweeteners:** In many ways, sucrose is an ideal sweetener; it is colourless, soluble in water, and has a 'pure' taste, not mixed with overtones of bitterness or saltiness. But it is rich in calories. Diabetics and overweight, who must restrict their intake of sugar, must have an alternative to sucrose. Thus, synthetic non- nutritive sweeteners, having less than two per cent of the calorific value of sucrose, for equivalent unit of sweetening capacity came into use. The first synthetic sweetening agent used was saccharin (sodium ortho benzene sulphonamide), which is about 300 times sweeter than sucrose in concentrations up to the equivalent of a 10 % sucrose solution. Acesulfame potassium is used in baked goods, chewing gum, gelatin desserts, and soft drinks. It is about 200 times sweeter than sugar. Aspartame is used in 'Diet' foods, including soft drinks, drink mixes, gelatin desserts, and low calorie frozen desserts and is 180 times sweeter than sucrose.
13. **pH Control Agents:** These include acids, alkalis and buffers. They not only control the pH of foods but also affect a number of food properties such as flavor, texture, and cooking qualities.
14. **Preservatives:** Preservative is defined as any substance which is capable of inhibiting, retarding, or arresting, the growth of micro-organisms, of any deterioration of food due to micro-organisms, or of masking the evidence of any such deterioration. It is estimated that nearly 1/5 of the world's food is lost by microbial spoilage. Chemical preservatives interfere with the cell membrane of micro-organisms, their enzymes, or their genetic mechanisms. The compounds used as preservatives include natural preservatives, such as sugar, salt, acids, etc, as well as synthetic preservatives.
15. **Stabilizers and Thickeners:** These compounds function to improve and stabilize the texture of foods, inhibit crystallization (sugar, ice), stabilize emulsions and foams, reduce the stickiness of icings on baked products, and encapsulate flavours. Substances used as stabilizers and thickeners are polysaccharides, such as gum Arabic, guar gum, carrageenan, agar-agar, alginic acids, starch and its derivatives, carboxy methylcellulose and pectin. Gelatin is one non-carbohydrate material used extensively for this purpose. Stabilizers and thickeners are hydrophilic and are dispersed in solution as colloids. These swell in hot or even cold water and help thicken food. Gravies, pie fillings, cake toppings, chocolate milk drinks, jellies, puddings and salad dressings, are some among the many foods that contain stabilizers and thickeners.
16. **Other Additives:** There are a number of food additives that provide functions other than those indicated above. Clarifying agents like bentonite,

NOTES

gelatins, synthetic resins (polyamides and poly vinyl pyrrolidone) are used to remove haziness or sediments and oxidative deterioration products in fruit juices, beers and wines. Enzymes are added to bring about desirable changes; rennin for producing curd and cheese, papain for tenderizing meat, and pectinase for clarifying beverages. Firming agents like aluminium sulphates and calcium slats are used t keep the tissues of fruits and vegetables crisp. Freezing agents like liquid nitrogen and dichloro fluoro methane, which are extremely volatile and rapidly evaporate at ordinary temperatures, are used to chill foods. Solvents like alcohol, propylene glycol and glycerine are used to dissolve suspended flavours, colours, and many other ingredients. Packing gases, such as inert gases, are added to packets of instant foods to prevent oxidative and many other changes.

17. **Unintentional Additives:** The unintentional incorporation of chemicals into food is as widespread as intentional addition and may present health hazards. The sources of contamination are radioactive fall-out, thousands of chemicals used in agricultural production, animal food additives, and accidental contaminants during food processing.

    a. **Radio-Active Fallout:** Radio-active fallout through nuclear explosions is a serious modern problem. Nuclear explosions inject into the atmosphere considerable amounts of smaller particles called fission products. These contain unstable atoms, called radio-isotopes, which spontaneously break down emitting radiations and particles that are highly injurious to living tissues. The fission products finally reach the ground through rain, snow or wind. This is known as fall-out. The fall-out matter reaches man directly in drinking water, fruits and vegetables, or indirectly through animals, which eat contaminated feed or graze on contaminated pastures.

    b. **Agricultural Contaminants:** Chemicals in the form of insecticides, fungicides, herbicides (in general biocides), growth promoting substances, and pollutants etc., are extensively used in large numbers in agricultural production. Without them much food would be lost. Commercial production of some crops would be impossible if chemicals are not used. It is estimated that 23 percent of the commercial cabbage crop and 37 percent of the potato crop would be lost if chemicals were not used. Small quantities of chemical residues often remain in such crops. The residues of the pesticide DDT, has been observed in small amounts in soil, water, vegetables and animal tissues in all parts of the world. From these sources, the pesticide residues reach man. The widespread use of this chemical as an insecticide has contaminated even the air we breathe. The presence of pesticide and other residues in food is a serious international problem, WHO has attempted to control the extent of contamination by prescribing the limits for the amount of many pesticides that may be present in foods. Some countries have banned the use of chemicals like DDT.

    c. **Animal Food Additives:** They are also used as plant and animal additives. In some countries (particularly USA), about 80 per cent of

animal feed it treated with small quantities of antibiotics for enhancing growth, improved feed utilization, and the checking of intestinal flora of animals. This has helped to produce less expensive meat and poultry. In all the cases where antibiotics have been used, residues may remain in meat. As already indicated, the presence of antibiotics in foods may result in the development of strains resistant to antibiotic drugs. The synthetic female hormone, diethylstilbestrol (DES), is used on chicken, cattle, and sheep as implants and as a daily additive to the feed. Residues of DES when present in food are potential cancer hazards.

Safety of a Food Additive

The limit should be established with due importance to following factors:

a. The estimated level of consumption of the food product by the consume world for which the additive is proposed.

b. Finding out minimum levels which would produce significant deviation from physiological behavior.

c. An adequate margin of safety to reduce any hazard to a minimum.

d. Legal control over the use of food additives. This can be accomplished only when a list of permitted additives exists with specified safe levels and toxic levels.

e. Stringent labeling on foods, i.e., declaring the usage of additives in food and their quantities.

f. Employing trained food inspectors, food control laboratories and reliable analytical methods are of utmost important for regulation / control over usage of food additives.

Factors Affecting Toxicity or Safety of Toxicants

a. Exogenous Factors: Examples: Nature of the compound, Dose of the compound, Frequency of exposure, Route of exposure, and Dietary factors.

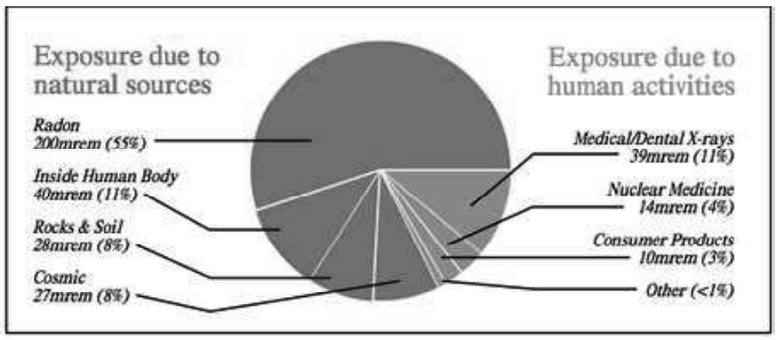
b. Endogenous Factors: Examples: Binding of toxicants to plasma proteins and tissues, and excretory process (Urinary excretion, and biliary excretion).

c. Dosage: Examples: Lethal Dose (LD_{50}), Toxicity in terms tumor dose (TD_{50}), Virtually Safe Dose, and No Effect Dose (NED).

4.6.8 Radiation and Radioactive Materials

Radiation is the release and propagation of energy in space or through a material medium in the form of waves, the transfer of heat or light by waves of energy, or the stream of particles from a nuclear reactor. Radiation is a fairly general term that can be used to describe the transfer of energy through space away from a source. There are many types of radiation. Ionizing radiation is generated through nuclear reactions and can be very harmful to human health. Nuclear reactions can be naturally occurring, or artificial. There are three basic types of radiation. These include alpha, beta, and gamma radiation. Each radiation source is unique in the type of radiation it emits, and its risk to humans.

NOTES



Where does radiation come from?

Sources of Radioactive Material and Radiation

Figure 4.7 gives a breakdown of the many sources that can expose humans to radiation. Four major groups from which humans receive doses of radiation include Radon, sources inside the human body, rocks and soil, and the sun. These are all natural sources. Other sources of radiation include medical diagnostic tools, nuclear medicine, and consumer products.

a. **Natural sources:** Radon is a chemical element. Its atomic number is 86. It lies within the noble gas column on the periodic table, which means it is inert and nonreactive. Radium is, however, radioactive. Radon occurs as an intermediate decay product from uranium or thorium as they decay to lead. The half life of radon is about 3.8 days. This means that it takes about 3.8 days for half of the radon available to decay. 3.8 days after this, 1/4 will be left, another half life and an 1/8 will be left and so on. Radon emits alpha particles, and is therefore ionizing radiation, and dangerous to human health.

   Some of the elements that make up the human body have radioactive isotopes that can add to the amount of radiation you are exposed to while decaying inside your body. Carbon and potassium are two of these elements. C14 has a half life of over 5,000 years while potassium has a half life of about 1.25 billion years. Potassium accounts for the majority of the radiation inside your body. There are three naturally occurring isotopes of potassium. K39, K40, and K41. K40 decays to Ar40 by electron capture or positron emission (Beta decay)

   Rocks and soil is also a good source of Radon, Uranium and Thorium. Some parts of the world naturally have higher concentrations of these elements in soils than others. It is important to remember that this is not from any kind of human contamination. Just like oxygen, nitrogen, carbon or hydrogen, Uranium and thorium are elements that were present in the nebular cloud that eventually formed the solar system and our earth. They were present in trace amounts compared to other elements, but none the less present. The visible light the sun is also emitting radiation from all areas of the electromagnetic spectrum from radio waves to gamma rays. The higher end of this spectrum (X-ray to gamma) is dangerous radiation to human health. This is why you can get a sunburn, UV light is a form of ionizing radiation, and can burn your skin. Most of the harmful radiation sent our way by the sun is reflected back into space by our protective atmosphere, but some of

this radiation gets through and accounts for a large amount of the radiation you experience every day.

b. **Man made sources:** Diagnostic radiation is a term used to describe the non-invasive procedures used to diagnose disease that rely upon radiation to produce images of internal structures. Some of the procedures that use diagnostic radiation include CT scans, MRI, mammography, radiography, and ultrasound. While the radiation involved in these scans can cause cancer, it is important to weight the benefits and risks to make an informed decision. When the risk of cancer s small compared to the condition potentially being diagnosed, the procedure is very worth the risk. Certain treatments of disease also use radiation. The treatment of cancer using certain types of radiation can be highly effective. Radiation can be targeted to mostly effect cancer cells while only delivering a small dose of radiation to other tissues that the radiation must pass through to get to the cancer tissue.

Antiques, building products, smoke detectors, fertilizers, tobacco products and many other products that we use and are exposed to every day may contain small amounts of radioactive materials. This does not account for a large radiation dose compared to the other sources that we have talked about, but it is significant enough to mention.

4.6.9 Fertilizers

Fertilizers both have definite propose associated with their use. Fertilizers are the chemicals tend to increase yields, and thus make a significant difference in food production, particularly in countries that struggle periodically with famines. On the other hand, these can cause water pollution when erosion carries the chemicals off of farms along with eroded soils after each rainfall. There is also concern by some authorities that fertilizers pose a risk, not only to non-target animal and plant species, but to humans as well.

Positive Effects of Fertilizers

There is no doubt that fertilizers increase yields of crops around the world. Use of modern fertilizers exploded after World War II. New, ammonia-based fertilizers also fed the process of specialization that was occurring in agriculture. Farmers rotated crops less, which led more quickly to soil exhaustion. Norman Borlaug, the father of the 1960s Green Revolution, which vastly expanded food production and helped stave off world hunger, has argued that modern farming, including the use of fertilizers and herbicides, could 'double or triple food production' in Africa. Increased yields also reduce the need for conversion of wild lands to agriculture, contributing to the conservation of biodiversity.

Negative Effects of Fertilizers

The downside of fertilizers is that some portion inevitably washes into waterways along with eroded sediments. This nonpoint source runoff occurs nationwide, and the nitrogen fertilizer finds its way into rivers, lakes and the ocean where it causes eutrophication and "dead zones" that kill aquatic life. Eutrophication is a process whereby nitrogen feeds an algal bloom, but when the short-lived algae die, decomposing bacteria then consume most of the available oxygen, suffocating aquatic life. Additionally, use of artificial fertilizers in place of animal or "green"

manure—cover crops plowed into the soil—eventually can deplete soils of organic matter, making them lose their ability to hold water and more subject to erosion.

Environmental Mutagenesis

NOTES

The Environmental Mutagenesis and Genomics Society (EMGS) is a scientific society for the promotion of critical scientific knowledge and research into the causes and consequences of damage to the genome and epigenome in order to inform and support national and international efforts to ensure a healthy, sustainable environment for future generations. The society promotes scientific research into the causes of DNA damage and repair and the relevance of these to disease. It also promotes the application and communication of this knowledge, especially through education, to help protect human health and the environment. Mutagen agents may increase the genetic load of human populations by inducing heritable diseases and cancer. The most effective way of protection is prevention: detection of the mutagenic agents and the regulation of their use. The harm occurred can be visualized by mutational monitoring and epidemiology. The harmful effects of the induced mutations may be reduced to a level accepted by the society with suitable approach and methods. The role of physicians is especially important to fulfill this task.

The environmental mutagens, such as polycyclic aromatic hydrocarbons (PAH) and heterocyclic amines are known to bind to nucleotides, resulting in the formation of DNA adducts. Some DNA adducts are fixed as mutations through replication of DNA. Mutagenicity testing is used to assess submicroscopic changes in the base sequence of DNA, chromosomal aberrations, and structural aberrations in DNA including duplications, insertions, inversions, and translocations. Certain types of mutations result in carcinogenesis (alteration in proto-oncogenes of tumor suppressor gene mutation), and so the determination of the mutagenicity is essential in the drug development process. In vitro testing is carried out in two or three different bacteria and mammalian cells to cover the end points of gene mutations, clastogenicity, and aneuploidy. The test generally includes a bacterial reverse mutation assay. The choice of an additional test depends on the chemical structure/ class of the substance. In vivo mutagenicity which is dose dependent is used to determine the case-by-case basis risk assessment of the test substances. Mutagenicity studies with transgenic animals are more appropriate assay techniques to determine the toxicity of a test substance.

Check Your Progress

19. Why lead is considered as one of the most dangerous chemicals to children?
20. What are asbestos?
21. What is the difference between risk and hazard?
22. Which are the various categories of environmental health hazards?
23. Define anti-oxidant?
24. What do you understand by the term radiation?

4.7 ANSWERS TO 'CHECK YOUR PROGRESS'

NOTES

1. Genetic toxicity assessment is the evaluation of agents for their ability to induce any of three general types of changes (mutations) in the genetic material (DNA); gene, chromosomal and genomic.
2. The word **biomarker** is short for biological marker, a term that refers to a measurable event occurring in a biological system, such as the human body. This event is then interpreted as a reflection, or marker, of a more general state of the organism or of life expectancy.
3. In each tissue and organ a certain percentage of cells is specialized for phagocytic activity, engulfing micro-organisms, particles, colloid particles, and so on. This system is called the Reticuloendothelial System (RES).
4. Bone is a highly specialized tissue consisting by volume of 54% minerals and 38% organic matrix. The mineral matrix of bone is hydroxyapatite, Ca10 (PO4)6 (OH) 2, in which the ratio of 'Ca' to 'P' is about 1.5 to 1.
5. Metabolic bones are active bones in which processes of resorption and new bone formation, or remodeling of existing bone, are very extensive.
6. The objective of occupational and environmental toxicology is to improve the prevention or substantial limitation of health effects of exposure to hazardous agents in the general and occupational environments.
7. Critical effect is a defined point in the relationship between dose and effect in the individual, the point at which an adverse effect occurs in cellular function of the critical organ. The critical effect has been defined as 'The first adverse effect which appears when the threshold (critical) concentration or dose is reached in the critical organ'.
8. The hazard identification and dose-response assessment steps are primarily based on a number of different tests where animals are exposed to the chemical or test substance. These tests are called toxicity tests.
9. Substances that interact with the hormonal systems of humans and/or wildlife, and thereby disrupt normal biological functions are called endocrine disruptors
10. Genetic toxicity tests are used to identify gene mutations, chromosome changes, and alterations in the DNA sequencing. These tests are usually conducted in various species including whole animals, plants, micro-organisms, and mammalian cells.
11. An autopsy is an examination of a dead body to determine cause of death, the effects or indications of disease or, in some cases, to identity the dead person.
12. Clinical or pathological autopsies are performed to diagnose a particular disease or for research purposes. They aim to determine, clarify, or confirm medical diagnoses that remained unknown or unclear prior to the patient's death.

NOTES

13. Autolysis is process of self-digestion where the body's enzymes contained within cells begin to go into a post death meltdown. The process can be speeded up by extreme heat and likewise slowed down by extreme cold.
14. The autopsy findings can be utilized to educate physicians, nurses, residents, and students, thereby contributing to an improved quality of care. Many of the benefits of the autopsy are experienced by society as a whole. The autopsy aids in the evaluation of new diagnostic tests, the assessment of new therapeutic interventions (drugs, devices, surgical techniques), and the investigation of environmental and occupational diseases.
15. Toxicological pathology integrates the disciplines of pathology and toxicology most often in an experimental setting. Pathologists study the nature of disease (pathophysiology), evaluating changes produced in cells, tissues, organs, or body fluids in response to a 'challenge,' whether it is metabolic, infectious, neoplastic, immune-mediated, physical, or toxic in origin.
16. Metabolic disorders describe those conditions where adverse reactions result from a genetic deficiency in the ability to metabolize some component of the consumed food.
17. Favism is acute hemolytic anemia resulting from oxidative damage to erythrocytes following the consumption of fava beans containing vicine and convicine.
18. Urine analyses consist of determining the volume of urine produced, specific gravity, pH, glucose and protein. In addition, microscopic evaluation for sediment and presence of blood/blood cells is typically done.
19. . Lead exposure in childhood is associated with lowering Intelligence Quotient (IQ) scores and aggressive and violent behavior. Neurodevelopment impairment is its most critical effect.
20. Asbestos is a group of minerals with thin microscopic fibers. Two types of asbestos fibers exist: serpentine and amphibole. The serpentine type has just one member, chrysotile (white asbestos), while the amphibole type has five members: amosite (brown), crocidolite (blue), anthophyllite, tremolite and actinolite. Amphibole asbestos fibers are needle-like in appearance and have been determined to be the most dangerous asbestos to which human beings can be exposed.
21. A hazard is something which is known to cause harm, that is, a source of danger to health and risk is the likelihood or probability of the hazard occurring and the magnitude of the resulting effects.
22. Hazards are generally categorized as Physical hazards, Biological hazards, Chemical hazards, Cultural/practice-related hazards, and Social hazards
23. An anti-oxidant is a substance added to fats and fat-containing substances to retard oxidation and thereby prolong their wholesomeness, palatability, and, sometimes, keeping time.
24. Radiation is the release and propagation of energy in space or through a material medium in the form of waves, the transfer of heat or light by waves of energy, or the stream of particles from a nuclear reactor.

4.8 SUMMARY

NOTES

- Toxicology is 'the study of the adverse effects of chemical, physical, or biological agents on living organisms and the ecosystem'.
- Toxicological methods are also widely used by industry in product development, to provide information useful in the design of specific molecules or product formulations.
- Genetic toxicology has become an integral part of the overall risk assessment process and has gained in stature in recent times as a reliable predictor for carcinogenic activity.
- The word biomarker is short for biological marker, a term that refers to a measurable event occurring in a biological system, such as the human body.
- There are also societal issues that relate to public health and safety, as well as increasing public concern about the use of animals for product safety testing.
- The duration of retention in a compartment is expressed by the biological half-life.
- The priority objective of occupational and environmental toxicology is to improve the prevention or substantial limitation of health effects of exposure to hazardous agents in the general and occupational environments.
- According to WHO (1989), the critical effect has been defined as 'The first adverse effect which appears when the threshold (critical) concentration or dose is reached in the critical organ'.
- The hazard identification and dose-response assessment steps are primarily based on a number of different tests where animals are exposed to the chemical or test substance.
- Toxicity assays can be conducted using models developed with primary cells, cell lines, stem cells, 3-dimensional cultured cells, excised tissues, or cultured organs.
- The study and characterization of chemicals and other agents for toxic properties is often undertaken on the basis of specific organs and organ systems.
- The effects of a test substance on the central nervous system can be studied through neurotoxicity studies.
- Embryo-toxicity can be studied using both *in vivo* and *in vitro* methods.
- Genetic toxicity tests are used to identify gene mutations, chromosome changes, and alterations in the DNA sequencing.
- Target organ toxicology studies are usually undertaken on the basis of information indicating the potential for specific toxic effects of a substance.
- The cell of in vitro tests that is used as part of this tier-testing strategy depends upon the needs of the particular industry

NOTES

- An autopsy is an examination of a dead body to determine cause of death, the effects or indications of disease or, in some cases, to identity the dead person.
- An autopsy may be restricted to a specific organ or region of the body for cause of death, legal purposes, and for education and research as well.
- An autopsy is performed when there are suspicious circumstances surrounding someone's death; or when no signs of natural causes can be located.
- Pathology is the study of disease, particularly the structural and functional changes in tissues and organs.
- Toxicological pathology integrates the disciplines of pathology and toxicology most often in an experimental setting.
- The main species of animal used in the pharmaceutical industry are rats, mice, dogs, non-human primates, mini pigs and rabbits.
- Toxicity testing of new compounds is essential for drug development process.
- Properly conducted histological examination is a powerful means of assessing toxicity.
- Properly conducted histological examination is a powerful means of assessing toxicity.
- During whole-body exposure technique animals should be tested with inhalation equipment designed to sustain a dynamic airflow of at least 10 air changes per hour.
- Metabolic disorders describe those conditions where adverse reactions result from a genetic deficiency in the ability to metabolize some component of the consumed food
- The chemicals mostly utilized by the agricultural sector are pesticides and fertilizers.
- The public health impact of a chemical is determined by an assessment process that aims to provide a consensus scientific description of the risks resulting from exposure to the chemical.
- From a public health point of view, the term heavy metal usually refers to a metal or semi-metal that has the potential to cause human or environmental toxicity.
- Mercury is a heavy metal that exists in the environment in three chemical forms; elemental or metallic mercury, inorganic mercury compounds and organic mercury compounds.
- Lead is a naturally occurring toxic metal found in the earth's crust. Its widespread use has resulted in extensive environmental contamination, human exposure and significant public health problems in many parts of the world.
- Cyanide is acutely toxic to humans. The toxicity of cyanide to humans is dependent on the nature of exposure.
- Air pollution is a major environmental health problem affecting both developed and developing countries.

NOTES

- Asbestos is a group of minerals with thin microscopic fibers.
- Persistent Organic Pollutants (POPs) are a group of toxic chemicals that adversely affect human health and the environment.
- The term pesticide is a composite term that covers all chemicals used to kill or control pests in different environments such as the home and various forms of agriculture.
- Different portions of a plant may contain different concentrations of chemicals.
- A hazard is something which is known to cause harm, that is, a source of danger to health.
- Physical hazards are those substances or conditions that threaten our physical safety. Fires, explosive materials, temperature (hot or cold), noise, radiation, spills on floors and unguarded machines.
- Biological hazards are organisms, or by-products from an organism, that are harmful or potentially harmful to human beings.
- Chemical hazards are present when a person is exposed to a harmful chemical at home or at work.
- Food additives are substances which are added to food which either improve the flavor, texture, color or chemical preservatives, taste, appearance or function as processing aid.
- An anti-oxidant is a substance added to fats and fat-containing substances to retard oxidation and thereby prolong their wholesomeness, palatability, and, sometimes, keeping time.
- A number of natural food colours extracted from seeds, flowers, insects, and foods, are also used as food additives.
- One of the best known, most widely used and somewhat controversial flavor enhancers is Monosodium Glutamate (MSG), the sodium salt of the naturally occurring amino acid glutamic acid.
- The first synthetic sweetening agent used was saccharin (sodium ortho benzene sulphonamide), which is about 300 times sweeter than sucrose.
- Chemical preservatives interfere with the cell membrane of micro-organisms, their enzymes, or their genetic mechanisms.
- Substances used as stabilizers and thickeners are polysaccharides, such as gum Arabic, guar gum, carrageenan, agar-agar, alginic acids, starch and its derivatives, carboxy methylcellulose and pectin.
- Radio-active fallout through nuclear explosions is a serious modern problem.
- Radiation is the release and propagation of energy in space or through a material medium in the form of waves, the transfer of heat or light by waves of energy, or the stream of particles from a nuclear reactor.
- Four major groups from which humans receive doses of radiation include Radon, sources inside the human body, rocks and soil, and the sun.
- Rocks and soil is also a good source of Radon, Uranium and Thorium.

NOTES

- Diagnostic radiation is a term used to describe the non-invasive procedures used to diagnose disease that rely upon radiation to produce images of internal structures.
- Antiques, building products, smoke detectors, fertilizers, tobacco products and many other products that we use and are exposed to every day may contain small amounts of radioactive materials.
- The downside of fertilizers is that some portion inevitably washes into waterways along with eroded sediments.
- The Environmental Mutagenesis and Genomics Society (EMGS) is a scientific society for the promotion of critical scientific knowledge and research into the causes and consequences of damage to the genome and epigenome in order to inform and support national and international efforts to ensure a healthy, sustainable environment for future generations.

4.9 KEY TERMS

- **Toxicology:** Toxicology is 'the study of the adverse effects of chemical, physical, or biological agents on living organisms and the ecosystem'.
- **Reticuloendothelial system (RES):** In each tissue and organ a certain percentage of cells is specialized for phagocytic activity, engulfing micro-organisms, particles, colloid particles, and so on. This system is called the Reticuloendothelial System (RES), comprising fixed cells as well as moving cells (phagocytes).
- **Critical organ:** That particular organ which first attains the critical concentration of metal under specified circumstances of exposure and for a given population.
- **Forensic pathologists:** Forensic pathologists are physicians trained in the study of diseases and abnormalities.
- **Autopsy**: Autopsy (also known as a post-mortem examination or necropsy) is the examination of the body of a dead person and is performed primarily to determine the cause of death.
- **Pathology**: Pathology is the study of disease, particularly the structural and functional changes in tissues and organs.
- **Heavy metals:** From a public health point of view, the term heavy metal usually refers to a metal or semi-metal that has the potential to cause human or environmental toxicity.
- **Asbestos:** Asbestos is a group of minerals with thin microscopic fibers.
- **Persistent Organic Pollutants (POPs):** Persistent Organic Pollutants (POPs) are a group of toxic chemicals that adversely affect human health and the environment.
- **Pesticide**: The term pesticide is a composite term that covers all chemicals used to kill or control pests in different environments such as the home and various forms of agriculture.

NOTES

- **Physical hazards:** Physical hazards are those substances or conditions that threaten our physical safety.
- **Biological hazards:** Biological hazards are organisms, or by-products from an organism, that are harmful or potentially harmful to human beings.
- **Chemical hazards:** Chemical hazards are present when a person is exposed to a harmful chemical at home or at work.
- **Culture:** Culture is the knowledge, belief, art, law, morals, customs and habits that are acquired by people as members of society.
- **Food additives:** Food additives are substances which are added to food which either improve the flavor, texture, color or chemical preservatives, taste, appearance or function as processing aid.
- **Anti-oxidants:** An anti-oxidant is a substance added to fats and fat-containing substances to retard oxidation and thereby prolong their wholesomeness, palatability, and, sometimes, keeping time.
- **Colouring agents**: Colouring agents include color stabilizers, colour fixatives, colour fixatives, colour retention agents, etc.
- **Curing agents:** These are additives to preserve (cure) meats, give them desirable colour and flavor, discourage growth of micro-organisms, and prevent toxin formation.
- **Emulsifiers:** Emulsifiers are a group of substances used to obtain a stable mixture of liquids that otherwise would not or would separate quickly.
- **Humectants:** Humectants are moisture retention agents. Their functions in foods include control of viscosity and texture, bulking, retention of moisture, reduction of water activity, control of crystallization, and improvement or retention of softness.
- **Preservatives**: Preservative is defined as any substance which is capable of inhibiting, retarding, or arresting, the growth of micro-organisms, of any deterioration of food due to micro-organisms, or of masking the evidence of any such deterioration.
- **Fertilizers:** Fertilizers are the chemicals tend to increase yields, and thus make a significant difference in food production, particularly in countries that struggle periodically with famines.

4.10 SELF-ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions

1. What are the major categories of methods currently used for identifying human cancer risks?
2. How the biomarkers are used in toxicological studies in occupational health?
3. Which components are important for the intracellular distribution of toxicants in the cells of various tissues?

NOTES

4. What are osteotropic toxicants?
5. What do you understand by osteotropic elements?
6. How incorporation of toxicants into bone occurs?
7. What do you understand by term critical organ concentration?
8. Define dermal penetration.
9. What do you understand by reproductive and developmental toxicity?
10. What are the difficulties associated with designing target organ toxicity tests?
11. What are virtual or medical imaging autopsies?
12. What are the challenges faced by a physician during autopsy?
13. What is the difference between autolysis and putrefaction?
14. Why toxicity testing of new compounds is essential for drug development process?
15. How the cutaneous toxicity can be classified according to the mechanism of onset?
16. Name the main species of animal used in the pharmaceutical industry for testing.
17. Which epidemiological factors are considered to identify chemicals that are of major public health concern?
18. Write the name of chemicals identified as being of major public health concern by the World Health Organization (WHO).
19. What is the impact of exposure to air pollutants on public health?
20. Define Persistent Organic Pollutants (POPs) and their effects on humans.
21. What are flour improvers? Why they are added in flour?
22. What is Radio-active fallout? Why it is serious modern day problem?
23. Which are the various sources of radioactive material and radiation?

Long-Answer Questions

1. Describe the importance of toxicology.
2. Analyze the process of accumulation of toxicant inside the cell.
3. Discuss the factors that can influence the elimination rate of toxicants and their metabolites from the body.
4. Briefly elaborate on critical organs and critical effects of toxicants.
5. Explain the non-animal methods for producing toxicological data.
6. Give a detail note on autopsy, its requirement, procedures and types of autopsy.
7. Briefly describe the pulmonary system specific technique.
8. Explain various heavy metals as public health hazard, their effect on human health and common route for exposure.
9. What is a pesticide? Give an account on the various pesticides and their ill effects.

10. Elaborate on principles of hazard management in detail.
11. Write a short note on environmental mutagenesis.
12. What are food additives? Discuss various types of food additives. Also mention the safety measures and toxicity of various food additives.

NOTES

4.11 FURTHER READING

Sinclair, Anthony R. E., John M. Fryxell and Graeme Caughley. 2009. *Wildlife Ecology, Conservation and Management.* New Jersey: Wiley.

Gupta, Tapashi. 2017. *Ecology, Wild Life Conservation and Management.* Guwahati (Assam): Eastern Book House.

Murphy, Chloe. 2020. *Wildlife Conservation and Management: Principles and Practices.* US: Syrawood Publishing House.

Newman, Michael C. 2013. *Quantitative Ecotoxicology*, 2nd Edition. UK: Taylor & Francis.

Walker C.H., R.M. Sibly, S.P. Hopkin, and D.B. Peakall. 2012. *Principles of Ecotoxicology*. 4th Edition, UK: Taylor & Francis.

Sparling, Donald W. 2017. *Basics of Ecotoxicology.* US: CRC Press.

Connell, Des W., Paul Lam, Bruce Richardson, and Rudolf Wu. 2009. *Introduction to Ecotoxicology.* US: Blackwell Publishing.