Chapter 4

Genetic Diversity

Genetic diversity includes various genes. **Genes** composed of DNA are the building blocks that decide the development of an organism and its abilities. This diversity can differ by allele, entire gene, or unit larger than genes, such as chromosomal structure. Genetic diversity can be measured at various levels, including population, species, community, and biome, and is important at each level. The **diversity at the genetic level** is the raw material for adaptation and evolution. More genetic diversity in a species means a greater ability for some individuals to adapt to environmental changes.

Less diversity leads to uniformity, which is a long-term problem. Modern agricultural practices employ **monocultures** and large cultures of genetically identical plants. This offers an advantage when it comes to growing and harvesting crops but becomes a problem when a disease attacks the field, as every plant in the field is susceptible. Monocultures cannot effectively deal with changing conditions. Genetic diversity increases with environmental variability. If the environment often changes, different genes have advantages at various times and places. In this circumstance, genetic diversity stays high because many genes stay in the population at any given time. If the environment does not change, a small number of genes with advantages in an unaltered environment would spread at the cost of other factors, causing a drop in genetic diversity.

An increase in **species diversity** affects genetic diversity at various levels. When there are many species, the genetic diversity at that level is greater than that of a few species. Genetic diversity within each species can decrease if the vast number of species creates so much competition that each species must be highly specialised, such as eating a single type of food. Specialisation leads to little genetic diversity within the species.

In communities, this can increase species diversity. The extent of this increase depends on both the number of species and how closely related the species are. Closely related species have a similar genetic makeup and do not contribute much to genetic diversity, rather than more remotely related species. Genes, the functional part of the DNA store, carry an assemblage of variations in inherited biological information from parent to offspring.

Inherited genetic differences exist within living organisms. Living organisms have a "history" of genes from their ancestry line, making individual organisms of the same species different from one another. There are no exact duplicates of any (naturally created) living organisms. All the living organisms were reproduced. If an entire species cannot reproduce, it will ultimately become extinct. Genetic diversity allows species to adapt to changing environments, including new pests, diseases, and climatic conditions.

Conservation of genetic resources can be traced back to the 1910s. The origin of interest of agriculturalists in domesticated crops and the use of wild relatives of crops in breeding programmes dates back to the same year. By 1924, Russian botanist Nikolai I. Vavilov founded the All-Union Institute of Applied Botany and New Crops. Before World War II, the institute sponsored 180 collection trips in 65 countries. By 1940, it held approximately 200 thousand accessions of wheat, cotton, potato, legumes, vegetables, and other crops. The number and size of crop gene banks have continued to grow dramatically ever since. Presently, we depend on a small proportion of existing plant diversity. Approximately 2,50,000 species of land plants are currently available. Of those about 60,000 are believed to have human food value. Over the course of recorded human history, about 3,000 people have been used by one or more cultures as sources of foodstuffs (about 1% of the total) and approximately 150 plants have been commercially cultivated. In 1974, only seven plants including wheat, rice, corn, potato, barley, and sweet potato out of 30 major cultivated crops were harvested more than 100 million tons. Wheat, rice, and corn account for over two-thirds of the world's total grain crop.

Many minor crops like *Lupinus mutabilis*, relatives of sword bean, *Canavalia plagiosperma, C. regalis,* and African yeheb nut; *Cordeauxia edulis* are in danger of economic extinction. A similar pattern was seen in domesticated animals. Out of more than 3000 breeds of donkeys, cattle horses, pigs, sheep, and water buffalo, over 1000 are at risk of extinction. Concern about narrow-base species and narrow-base diversity within the species on which human welfare depends led to the formation of the **International Board for Plant Genetic Resources (IBPGR)** within the framework of the **Consultative Group on International Agricultural Research (CGIAR)** to promote the collection, conservation documentation evaluation, and use of crop plant genetic resources.

Intra-specific genetic diversity stands for the range of heritable differences in a trait or set of traits among individuals within a species and includes diversity among individuals within populations and variation among different populations. The term is synonymous with **genetic variation** or **genetic variance**. Genetic diversity, as a trait of populations and species, not of individuals, includes variations in the genetic determinants of eye colour, growth rate, and disease resistance within and among populations. Similar variations can be assessed for specific stretches of DNA using molecular markers.

Genetic diversity is shaped bypass population processes. This affects the sustainability of species and populations. Physical, chemical, and biological environments are constantly changing over short- and long-term scales to which species must adapt or face extinction.

The ability of a species to adapt to altered environments is directly related to its genetic diversity available for natural selection. For two populations under similar environmental pressures, populations with greater genetic diversity for fitness traits are expected to adapt more quickly. Maintenance of genetic diversity, as a key to the long-term survival of most species, is a central paradigm of **conservation genetics** *(Soule, 1987)*. The main forces that decide the present genetic diversity within a species are mutation, migration, selection, and genetic drift.

4.1 Concept of Genetic Diversity

Nature's knowledge lies in the knowledge of the DNA of living cells *(Meadows, 1990)*. The observed variations in the living world are due to variations in the sequences of the four base pairs of DNA and their interactions with the environment. The pool of genetic diversity of a species exists at three levels: Genetic diversity within individuals, often referred to as **heterozygosity**; genetic diversity between individuals within a population; and genetic variation between populations. Genetic diversity is the heritable variation within and between populations. New genetic variations are produced in individuals of a species through **genetic or chromosomal mutations**.

Recombination contributes to genetic diversity in sexually reproducing organisms. Genetic diversity enables the occurrence of natural evolutionary changes to take place. The rate of such changes is proportional to the available genetic diversity. Conservation of species diversity depends on the degree of genetic diversity within each species *(Woodruff, 2001)*. As genes can result in a competitive advantage, genetic diversity at the individual and population levels ultimately decides the ability of the species to survive and adapt to environmental conditions. This measure of fitness is fundamental to the natural selection and evolution process. Thus, higher genetic diversity offers more opportunities for survival, and vice versa *(Cockburn, 1992)*. The degree of genetic diversity, referred to as gene flow, is kept when populations of a species interact over time and space.

When practical populations become isolated for long periods, adaptations to local conditions result in speciation *(Primack, 1993)* which contributes to an overall increase in species diversity. When only small populations are involved, isolation can reduce genetic and species diversity. In such cases, diminished gene flow and an increased likelihood of **inbreeding** may lead to a reduction in the overall fitness of the population and an eventual risk of extinction. This reveals the mechanisms underlying the theory of island biogeography and the potential legacy of **habitat fragmentation**. Genetic diversity is essentially a source of survival and future evolution of the species. Extinct in the wild, a single tree is growing in the botanic garden cum orchidarium of the Botanical Survey of India at Yercaud, Salem, Tamil Nadu, India (Table 4.1).

The environment exerts its effects at the genetic level by regulating the transcription of a specific gene. Out of 10^9 genes in the world biota (105 are found in higher organisms), not a single gene duplicates the contribution of others. Genes controlling fundamental processes such as photosynthesis and respiration are highly conserved across different taxa and show slight variation *(Groombridge, 1992)*. The genetic diversity of microorganisms is

Table 4.1: Some taxa extinct in the wild but conserved in botanic gardens (data from IUCN/WCMC and Michael Maunder, in Prance, 1997)

Taxon	Country
Anthurium leuconeurum	Mexico
Arctostaphylos uva-ursi spp.	USA
Bromus verticillatus	UK
Calandrinia feltonii	Falkland Island
Ceratozamia hildae	Central America
Commidendrum rotundifolium	St Helena
Cosmos atrosanguineus	Mexico
Erica verticillata	South Africa
Encephalartos woodii	South Africa
Franklinia alatamaha	USA
Graptopetalum bellus	Mexico
Helichrysum selaginoides	Tasmania
Lysimachia minoricensis	Minorea
Opuntia lindheimeri	Mexico
Paphiopedilum delenatii	Vietnam
Sophora toromiro	Easter Island
Tecophilaea cyanocrocus	Chile
Trochetiopsis erythroxylon	St Helena
Tulipa sprengeri	Turkey
Dombeya acutangula	Rodriguez
D. mauritiana	Mauritius
Vernonia shevaroyensis	S India

higher than that of microorganisms because the former originated first and has existed on Earth for a longer time. Of the 95 phyla of living organisms, 52 belonged to microorganisms, excluding viruses. A total of 159 mutant lines of *Chlamydomonas reinhardtii* and more than 3,000 mutants of *Neurospora crassa (Woese et al. 1990)* exemplify the genetic diversity of microbes. Most genetic variability within species over a single generation occurs because of the shuffling of homologous chromosomes, crossing over, and fusion of gametes during sexual reproduction.

Mutations are rare and occur once in 10^5–10^6 genes per generation. Evolution stops without mutation, although mutation does not occur in anticipation of environmental demand. This causes structural and functional changes in organisms. Environmental conditions decide whether such changes are beneficial, harmful, or neutral in the present and future. When a single species population invades a number of new habitats and evolves owing to differing environmental pressures, many new species would evolve in a relatively brief period through adaptive radiation. This is due to superior adaptation in species that enables the displacement of less-adapted species from a variety of habitats. Natural selection favours the spread of **mutations**. It cannot directly detect an organism's genotype but rather acts on phenotypes.

Mutation, **migration, selection, and drift,** individually and collectively, alter allele frequencies, bring about evolutionary divergence and cause the formation of species depending on ecological diversity. Wild relatives (weedy crop relatives) and species contribute substantially to the expansion of the genetic basis of cultivated taxa. Hence, they are invariably used to breed and improve the latter *(Prescott-Allen and Prescott-Allen, 1990)*. Wild relatives often have genes that are unavailable to domesticated plants. These genes confer resistance to diseases, pests, and other environmental stresses. Such resistance genes have been acquired by wild relatives through their long period of **co-evolution** with microbes/pests and have survived for a long time in stressed environments. Many resistance genes control specific resistance. Wild relatives of cultivated plants form part of the **primary, secondary, and tertiary gene pools** *(Harlan and de Wet, 1971)*. These gene pools are called the genetic resource profiles of crop species *(Smartt, 1990)*.

Primary gene pools (GP1) represent the true biological species, including all its cultivated (cultigens), wild, and weedy forms; hybrids among these forms are fertile, and gene transfer to the crop is simple, direct, and poses no problem. Most primary gene pools show at least 80% genetic similarity with crop species. Secondary gene pools stand for a species group that can be artificially hybridized with the crop, but gene transfer may not be easy. If produced, hybrids are usually weak or partially sterile. Secondary gene pools showed approximately 60% similarity to crop species.

Tertiary gene pools (GP3) include all species that can be crossed with crop species but with some difficulty (Table 4.2). These gene pools showed approximately 40% closeness to the cultivated species. There is also a quaternary gene pool, and its constituents are incompatible with related species *(Krishnamurthy, 2018)*.

Table 4.2: Genetic resource profiles of crop species (Smartt, 1990)

Harlan and de Wet Category	Constituents	Order of recourse and accessibility to breeders
GP1—Primary gene pool	a. Cultigen b. Weedy form c. Wild prototype	1st order 2nd order
GP2—Secondary gene pool	Cross-compatible species Producing + fertile hybrids	3rd order
GP3—Tertiary gene pool	a. Cross-compatible species Producing viable but sterile hybrids b. Cross-compatible species Producing non-viable hybrids	4th order 5th order
Quaternary gene pool	Incompatible related species	6th order

4.2 Genetic Drift

Chance events mostly alter allele frequencies in a small population than in a large population due to genetic drift. *Audesirk and Audesirk (1999)* noted two important points about genetic drift:

1. Genetic drift tends to reduce the genetic variability within a small population.
2. Genetic drift tends to increase genetic variability between populations.

Two special cases of genetic drift are the population bottlenecks and founder effects. In population bottlenecks, a population reduces to the extent that only a few individuals are available to contribute genes for future generations. The **population bottleneck** was recorded in the case of the Northern elephant seal and cheetah. The **founder effect** occurs when isolated colonies are found by a small number of organisms, as illustrated in the human Ellis-van Creveld syndrome. Approximately 200 members of the Amish religion migrated from Switzerland to Pennsylvania between 1720 and 1770. Since then, Pennsylvania Amish has moved to Lancaster and has remained reproductively isolated from non-Amish Americans. By 1964, the population had increased to approximately 8000. The allele frequency for Ellis-van

Creveld of approximately 0.07, compared with a frequency of loss of 0.001 in the general population, was recorded in the same year. One couple who immigrated in 1744 was reported to carry this allele. Inbreeding among the Amish passed the allele along with their descendants.

Isolated populations lose a percentage of their original variation over time, approximately at a rate of ½N per generation, where, N is the number of individuals in the population. Thus, if N = 500, then ½N = 1/1000 = 0.001 or 0.1% genetic variation is lost per generation; if N = 50, then ½N = 1/100 = 0.01 or 1% genetic variation is lost per generation *(Stiling, 2004)*. Thus, a population of 500 individuals will retain 99.9% of its genetic variation in a generation, whereas a population of 50 individuals will retain 99.0%. After 20 generations, a population of 500 will keep over 98% of its original variation, whereas a population of 50 will retain only 81.79%. This effect became more severe as the population size decreased. A population of 500 individuals is necessary to reduce the effects of genetic drift. Thus, the **"50/500" rule** has entered conservation theory literature as a magic number (*Simberloff, 1998*).

4.3 Use of Genetic Resources

The need to avoid genetic uniformity over an extended period is clear from examples of agricultural pathogens such as corn leaf blight, wheat rust, and potato blight. Genetic resources are used to increase agricultural production. The yield of many crops increased dramatically between 1930 and 1980. The production of rice, barley, soybeans, wheat cotton, and sugarcane has doubled, that of tomatoes has tripled, and that of corn, potatoes, and sorghum has quadrupled. Plant breeders' use of genetic diversity accounts for at least half of this doubling. Maintaining agricultural productivity requires the constant input of new genetic material to overcome crop losses due to pests. Resistance to at least 32 major tomato diseases has been discovered in the wild relatives of cultivated tomatoes. Genes that promote resistance to 16 of these have been bred, allowing tomato production in areas where they could not otherwise have grown. Insect resistance, tolerance to temperature extremes, salinity tolerance, drought tolerance, and tolerance to waterlogging are among the traits expressed in wild relatives that may be useful in breeding commercial tomatoes.

4.4 Conservation of Genetic Resources

There are two major alternatives for the conservation of genetic resources: ***in situ*** and ***ex situ***. *In situ* conservation refers to the conservation of genetic resources in wild populations and land recesses and is often associated with traditional subsistence agriculture. If the focus is only on agricultural varieties, the approach is only partially effective because traditional crop varieties, although much more diverse than elite varieties, are themselves much less diverse than wild populations and wild relatives. An attractive approach is to combine nature reserves focussed on the protection of wild races and relatives with traditional agricultural practices. *Ex situ* conservation refers to the conservation of off-site genetic resources in the gene bank, often in long-term storage as seeds. Seeds of many important tropical species are recalcitrant, that is, difficult or impossible to store for extended periods. Several crops are propagated clonally.

4.5 Landscapes to Gene

Half of the world's mangrove forests are destroyed by coastal development or pond construction to grow shrimp *(Chua et al. 1987)*. Many mangrove forests are rapidly disappearing owing to the uncontrolled and explosive growth of industrial shrimp aquaculture. Mangrove areas in the Philippines declined from 4,50,000 ha in 1920 to 1,32,500 ha in 1990. Half of the mangroves lost in 1952–1987 were converted into brackish water fish and shrimp ponds *(Primavera, 1995b)* which resulted in habitat loss of wild juvenile shrimps, ecosystem health deterioration, and alteration of way of life in coastal communities. Approximately 20 years ago, industries began to realise ocean potential for farming purposes.

The "Blue" revolution started making oceans an area for harvesting and gradually expanded involving developing nations around the world. The unregulated growth of the coastal **shrimp aquaculture** industry has been stimulated by financial institutions to thrive in the global market. Shrimp aquaculture has increased rapidly, providing jobs for people and accounting for roughly one-fourth of shrimp sales. A genetic concern that needs to be addressed is the indiscriminate use of chemicals in aquaculture facilities.

Mortalities and morphological deformities in shrimp larvae due to the widespread use of chemicals, such as oxytetracycline, nitrofurans, and chloramphenicol, have been reported *(Primavera, 1993b)*. Pathogenic bacteria that cause luminous vibriosis in shrimp are resistant to antibiotics. The prevalence of infectious diseases in shrimp larvae suggests drug resistance to pathogens following the rampant use of antibiotics in Philippine hatcheries in the 1980s *(Baticados and Paclibare, 1992)*. The evolution of antibiotic resistance in bacteria is genetically decided *(Brown, 1989)*. The indiscriminate use of chemicals and therapeutics in the shrimp industry has probably weakened the shrimp's immune system and, so, its ability to respond to a pathogenic attack.

4.6 Heavy Metals, PCBs, and PAHs

The intensification of aquaculture has made the use of chemicals and biological products inevitable. The use of chemicals in marine shrimp culture has intensified. In most countries, these products are readily available in the local markets as disinfectants, antimicrobials, soil and water conditioners, plankton growth promoters, organic matter decomposers, feed supplements, and pesticides. Chemotherapy is commonly used to treat diseases in fish. However, in the Philippines, this is widely practised in the shrimp culture. Polychlorinated biphenyls are manufactured by the rapid chlorination of biphenyl, which is commonly used in electric insulators and the rubber and paper industries as plasticisers. These are stable pollutants that are stored in adipose tissues and have highly toxic effects on the immune system. They atrophy lymphoid tissues and suppress immunity. **Immunosuppressants** were found using the following chemicals:

Heavy metals: Lead, cadmium, nickel, chromium, methyl mercury, and arsenic.

Pesticides: DDT, dieldrin, methyl parathion, chlordane, hexa-chlorobenzene.

Halogenated hydrocarbons like PCBs, polybrominated biphenyls, TCDD, trichloroethylene, and chloroform, as well as polycyclic aromatic hydrocarbons (PAHs) such as benzo [a] pyrene, methylcholanthrene, and benzene, are found in metals like nickel, beryllium, and platinum. These substances can cause various clinical symptoms, including allergies, and many PAHs are carcinogenic. Common sources of these pollutants in marine and freshwater environments include fossil fuel spills, domestic and industrial waste discharges, atmospheric deposition, and runoff. There is a direct correlation between PAH concentrations in river water and the level of industrialisation and human activity in nearby watersheds. Rivers in heavily industrialised regions may contain 1–5 ppb of total PAH, while unpolluted river water, groundwater, or seawater typically contains less than 0.1 ppb. PAHs also bioaccumulate in aquatic organisms, affecting water, sediments, and the food chain.

4.7 Shrimp Aquaculture and Genetic Diversity

The danger posed by shrimp aquaculture to the genetic diversity of wild stocks is through the accidental or intentional release of potentially inbreed shrimp from culture systems. Selection practices in shrimp hatcheries tend to decrease the genetic diversity of the cultured stocks. If a large number of cultured or genetically modified shrimp escape or are released, their interbreeding with wild *P. monodon* may set up hybrid populations that could displace native shrimp or otherwise significantly alter natural ecosystems in undesirable ways *(Goldburg and Triplett, 1997)*. Even so-called "**successful acclimatisation**" often has unfavourable ecological consequences for native populations because natives are forced out through competition for food and spawning sites or affected by the spread of infections and lethal diseases to which they are not immune *(Kirpichnikov, 1992)*.

The introduction of exotic species and gene pool alternation by **interbreeding** of cultured and wild stocks has been considered biological pollution that is potentially irreversible with ecosystem-wide repercussions *(Weston, 1991)*. Exotic species have been introduced to the Philippines *(Primavera, 2000)*, and a significant reduction in genetic diversity has been found in cultured shrimp populations. Genetic differentiation patterns in wild shrimp are positively associated with mangrove status and shrimp culture systems in the surrounding area near the collection sites. Both mangrove loss and the intensification of shrimp culture systems influence the genetic composition of wild penaeid populations. In the short-term, the massive conversion of mangrove forests into shrimp ponds may increase shrimp production. In the long-run, the fitness of wild populations will suffer from a loss of genetic diversity and increased disease susceptibility.

4.8 Genetically Modified Shrimp

Since it evolved from selective breeding of animals and plants, transgenic plants have been increasingly used. Some promote the advancement of genetically modified organisms and others are completely against it. The overall intention of transgenic plants is to improve and refine the genetic structure of animals and plants. The latest genetic modifications have been in fish aquaculture, where salmon have been changed to grow faster and bigger. This increase in fish production or in the case of any increase in animals consumed by humans as dietary staples may have some benefits. However, in the United States, the FDA has not approved any genetically modified animal or plant products to be consumed by humans. The possible benefits of **transgenic science** are that it can help feed developing or third-world countries. Modified animal products can be used to carry vaccines, which can help the immune system by increasing **disease resistance**. However, there are many disadvantages to using genetically modified animals. GMOs are a contradiction of Mother Nature.

By genetically transforming animals, we are messing with the natural balance. A slight alteration can affect the entire environment. A GMO placed in the environment will tip over the ecological balance. This can happen by creating competition between modified and wild populations, tainting gene pools by mixing wild populations with GMOs, and affecting natural species diversification after the introduction of GMOs. This mystery may have too many dangers. The public is concerned with the rights that animals lose once they are modified. Treatment of these animals may be unjust, as outcomes cannot always be understood until after the study, and the animals may be very uncomfortable. Ethically, it bothers many people for the reasons mentioned above. However, the effects on public safety and health have not been fully researched. Economically, this may cause problems for farmers who may have to pay higher prices to use genetically modified animals.

4.9 Genetic Diversity in India

In India, NBPGR has a collection of over 1,59,080 varieties and 1,07,018 germplasm. Agrobiodiversity is mostly in the custody of farming communities/tribes. Genetic diversity is concentrated in the Western Ghats, northeastern Himalayas, southern plateau, central India, and northwestern Himalayas. Wild relatives of wheat and barley are found in the Western and Northern eastern Himalayas, while a major centre of wild rice is eastern Peninsular India. India has the best water buffaloes, including *Murrah, Surti, Nili-Ravi, Jaffarabadi,* and *Mehsana*. Common breeds of sheep are Kashmir, *Chokla, Magra, Kali, Gaddi,* and *Bakarwal*. The breeds of Merino and Suffolk sheep were imported for better wool production. Milk goat breeds, such as *Saanen, Alpore, Nubian,* and *Toggenburg*, have been introduced. Livestock contributes at least 20,000 million rupees annually to the national economy.

Poultry alone contributes approximately ₹ 9,000 million. Almost all world fowls trace their origins to India's red jungle fowls. Ducks are approximately 10 per cent of all poultry in India. *Aseel*, *Kadaknath*, and short-legged Nicobari fowl breeds have been found in India. Of approximately 20,000 species of fish genetic resources worldwide, nearly 11% have been reported in India *(MoEF, 2001)*. In India, 49 indigenous major and minor crops have been reported, including 5 cereals and minor millets, 4 pulses, 1 oilseed, 9 vegetables, 5 tuber crops, 11 fruits, 5 spices, 1 sugar-yielding plant, and 7 fibre crops. India is the centre of origin of 30,000–50,000 varieties of cultivated plants, including rice, pigeon pea, mango, okra, and bamboo. Crops such as rice, sugarcane, *Asiatic vignas*, jute, mango, citrus, banana, millet, and several medicinal, aromatic, and ornamental crops first grew in India and then spread throughout the world. India ranks 6th among the centres of diversity and the origin of agrobiodiversity *(Khoshoo, 1998)*. Of the 329 million hectares of land in India, approximately 142 million are cultivated. Of India's net national product of ₹ 17,32,000 million, agriculture contributes approximately 33%. A marked increase in crop productivity is due to genetic manipulation, fertilizer use, and pest control methods. Two to three crops are grown on the same land because of good irrigation and the use of short-duration growth plants. Rice accounts for approximately 80% of the cultivated land. Wheat, the most important Rabi crop, has shown an increase in yield per hectare during the last few years. The total production of pulses was 12 million tonnes in 1986–1987 compared to 11 million tons in 1954–1955. The main pulses are *arhar*, and the soya bean is now widely grown. Other important crops are oilseeds, sugar crops, fibre crops, potatoes, other tuber crops, and plantation crops such as tea, coffee, cocoa, rubber coconut, cardamom, and black pepper.

India produces approximately 15 million tons of fruit from 2 million hectares and 9 million tons of vegetables per year from 1 million hectares *(MoEF, 2002)*. Domesticated livestock and poultry in India include 27 cattle, 8 buffalo, over 42 sheep, 20 goats, 7 camels, 8 horse breeds, and a few types of pigs. The total livestock population consists of 185 million cattle, 97 million goats, 61 million buffaloes, 45 million sheep, 1 million horses and ponies, 1 million camels, and about 1 million other livestock, in addition to 156 million poultry, fowls, ducks, and turkeys for providing about 1 million tonnes of meat, 40 million tonnes of milk, 39 million kilograms of wool, and 13 million eggs. Cow dung was used for biogas and manure production. Livestock is used in rural transportation and agriculture. Milch breed cattle include the *Gir, Red Sindhi, Deoni* and *Sahiwal* and draught breed cattle are *Nagari, Malvi, Kenkatha, Khillari, Hallikar, Amrit Mahal, Ponwar,* and *Siri*. The dual-purpose cattle are *Rewati, Kankrej, Ojgol,* and *Danji.* Humped zebu cattle originating in India and humpless cattle are believed to have been domesticated in India during the Harappan period *(Rana, 2013)*.

Short Answer Questions

1. Define genetic diversity.
2. Define gene.
3. What do you understand by intraspecific genetic diversity?
4. Define mutation.
5. Define heterozygosity.
6. What do you understand by speciation?
7. What is the primary gene pool?
8. What is secondary gene pool?
9. What is the tertiary gene pool?
10. Define genetic drift.
11. Mention the name of two heavy metals.
12. What is the full form of DDT?
13. What do you understand by GMO?

Long Answer Questions

1. Write an account of the gene.
2. Give an account of shrimp aquaculture on genetic diversity.
3. Give an account of landscape to gene.
4. Give an account of genetic drift.
5. Give the concept of genetic diversity.