An Introduction to Biology

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Chapter 1: Introduction to Biology

In its broadest sense, biology is the study of living things. It can be also called as the science of life from its objective standpoint. All living things or living organisms are studied under this division of science. It pays attention and study on the things related to living organisms such as organization of life, their functions, patterns and order of organisms, growth and development of living organisms and so on. Living things have variety of shapes, forms and functions, and biologists study life in many different ways from the cell at the smallest and ecosystems at large. Due to that, biology has variety of branches and divisions such as evolutionary biology, cellular biology, genetics, growth and developmental biology and so on.

Properties of Life

What then do we mean by life? How is the order of living things? Although there is no exact definition of life in general, most of the living things share certain key characteristics. These are,

1. **Cellular organization.** All living organisms consist of one or more cells. The cell is the basic unit of life. Each one of them carries the basic activities of living. Little more explanations shall be seen in chapter 2.

2. **Order.** All living things are highly ordered. Your body is composed of many different kinds of cells. Each containing may complex molecular structures.

3. **Sensitivity.** Any organisms are capable of responding to signals and stimuli from its surroundings. Plants grow toward a source of light, and your pupils dilate when you walk into a dark room.

4. **Growth, development and reproduction.** Any organisms are capable of growing and reproducing, and they all possess genes or hereditary molecules that are passed to their offspring.

5. **Energy utilization.** All organisms take in energy and use it to perform many kinds of work. Every muscle in your body is powered with energy you obtain from the food you eat.

6. **Evolutionary adaptation.** All organisms interact with other organisms and the environment in ways that influence survival, and as a consequence, organisms evolve adaptations to their environments.

7. **Homeostasis.** All organisms maintain relatively constant internal conditions, different from their environment, a process called homeostasis.

These properties are characteristics of all living organisms, and on that basis, we shall have to examine whether things are living or not. More details are given below.

Hierarchical Organisation.

Is the world of living things in disorder without being organized? As it isn't, any living things do seem to have hierarchical organization. Any living thing falls under a hierarchical level. The representation of level in order to have easier picture of the sense of hierarchy is called hierarchy of life. Hierarchy of life can have variety of level. In general, there is atom at the lowest level to ecology at the highest level, and so, in a nutshell, there are ten levels. If we were to consider in one go from lowest to highest, atom at the lowest, above is the cell, on it is tissue, then organ, then organ system, then organism or person, on it is, population, then community, and ecology at the highest. In fig.(1), the earlier ones are the parts or the composition of later ones and later ones are formed out of the composition of earlier ones. For example, two or more atoms are joined together to form a molecule, and certain molecules are assembled into cell, certain cells are assembled to form tissue and likewise to the later ones. This organization is called hierarchical organization of life. Each level is considered an organization.

The Cellular Level. At the cellular level, atoms, the fundamental elements of matter, are joined together into clusters called molecules. Complex biological molecules are assembled into tiny structures called organelles, part of cells, which are assembled together to form cells. Nucleus and mitochondria are the basis of organelles. As mentioned above, the cell is the basic unit of life and many organisms are composed of single cells in the world. Bacteria are single cells, for example. All animals and plants, as well as most fungi and algae, are multicellular-composed of more than one cell. More descriptions can be learnt from cell and gene chapter.

The Organismal Level. Cells are organized into three levels of organization. The most basic level is that of the tissues, which are groups of similar cells that act as a functional unit such as muscle tissues and blood tissues. Tissues, in turn, are grouped into organs, which are body structures composed of several different tissues grouped together in a structural and functional unit such as heart and brain. Your brain is an important organ composed of zillions of nerve cells and a variety of connective tissues. At the third level of organization, organs are grouped into organ systems. The nervous system, for example, consists of sensory organs, the brain and spinal cord.

The Populational Level. Individual organisms are organized into several hierarchical levels within the living world. The most basic of these is the population, which is a group of organisms of the same species living in the same place such as human population and fish population. All the populations of a particular kind of organism together form a species, its members similar in appearance and able to interbreed. At a higher level of biological organization, a biological community consists of all the populations of the different species living together in one place. At the highest tier of biological organization, a biological community and the physical habitat within which it lives together constitute an ecological system, or ecosystem.

Emergent Properties

Many new properties emerge at the higher level of living hierarchy as we climb up the level from lower to higher level. These are called emergent properties. For example, we can see the properties and energy in a cell that has been formed from the aggregates of so many molecules, which are not present in single molecule. For example, there are properties in molecule such as protein that are not present in atoms that comprised it. That is, if we take a simple example of diamond and coal that are composed of same carbon molecule and even though they are formed differently and yet they have so much difference in terms of their properties and characteristics. We can know from the hierarchy nature of life from the emergent property of life. Note: Hierarchical Organisation and emergent property are the two most important theories in biology. So, you are asked to heed upon these.

5 Core Themes in all of biology.

Organisation of Life. The Cell Theory

As it was stated earlier, all organisms are composed of cells, life's basic units. Despite having huge d
ifferences in sizes and shapes of all the living organisms from the tiniest living organisms of a single-celled organisms to the largest 10 kilometers-squard size fungi, Armillaria Ostoyae, are consist of cells. This conclusion forms the basis of what has come to be known as the cell theory. The cell theory, one of the basic ideas in biology, is the foundation for understanding the reproduction and growth of all organisms. The cell theory gives two important conclusions. Firstly, it concluded that all living organisms consist of cells and secondly, all cells come from earlier cells. Description of the discovery of cell follows later.

Continuity of life: The Molecular Basis of Inheritance

Even the simplest cell that cannot be seen by naked eye is incredibly complex-more intricate than a computer. Cells have many different types of shapes, basis and functions and so what specifies a particular cell is encoded inside a nucleus of cell called gene. Gene specifies work, shapes, functions and energy of cells. Genes are formed aside DNA. DNA is a long, cable-like molecule, two long chains of building blocks, called nucleotides, wound around each other. Winding around each other like the rails of spiral staircase, the two strands of DNA make a double helix.

The continuity of life from one generation to the next-heredity - depends upon the faithful copying of a cell's DNA into daughter cells. So, DNA is a basic unit of molecule of heredity characteristics.

The Correlation of structure and function.

Structure and function are correlated at all levels of biological organization. This theme is a guide to the anatomy of life at its many structural levels, from molecules to organisms. Analyzing a biological structure gives us clues about what it does and how it works. Conversely, knowing the function of a structure provides insight about its construction.

We can see the correlation of structure and shape of bird's wings and their functions clearly. The aerodynamically efficient shape of a bird's wing, chest muscle for flight efficacy, the width of chest bones to build up the muscles, air bags in the skeleton to lighten up the weight of body helps in the flight of a bird.

Diversity of Life: Evolutionary Change

The nature of diversity is a hallmark of life. Biologists have identified and named about 1.5 million species, including over 260,000 plants, almost 50,000 vertebrates (animals with backbones), and more than 750,000 insects. Thousands of newly identified species are added to the list each year. Estimates of the total diversity of life range from about 5 million to over 100 million species.

Biologists divide life's great diversity into three great groups, called domains: Bacteria, Archaea, and Eukarya. The domains Bacteria and Archaea are composed of prokaryotes (single-celled organisms with little internal structure), while domain Eukarya is made up of eukaryotes, organisms composed of a complexly organized cell or multiple complex cells. However, Archaea seem more closely related to Eukarya than to Bacteria. Within the Eukarya are four main groups called kingdoms. Kingdom Animalia includes human being; all plants are included in Kingdom Plantae. Kingdoms are also categorized into phylum, phylum to class, class to order, order to family, family to genus, genus to species. These are 8 great classification of life. If we ask about how do such diverse life forms of living organism form? All biologists unanimously claim it to happen through the evolution.

Unity of Life: Evolutionary Conservation

Biologists believe that all living things have descended from some simple cellular creature that arose about 2.5 billion years ago. Some of the characteristics of that earliest organism have been preserved in all things alive today. The storage of hereditary information in DNA, for example, is common to all living things. Also, all eukaryotes possess a nucleus that contains chromosomes. The retention of these conserved characteristics in a long line of descent usually reflects a fundamental role in the biology of the organism, one not easily changed once adopted.

These five properties are the core themes in biology that are visible and we have to analyse any biological theories with respect to these themes.

Debating Questions/Discussions

Review Questions

1. What are the seven important properties of life?

2. Identify each 10 hierarchy of life.

3. What is the basic building block of life? Why is it so?

4. How do we understand by the emergent property? Explain with an example.

5. Identify five core themes that form the basis for all of biology.

6. Hierarchy of life and Core themes are very important while studying biology. Why?

Chapter 2: Evolutionary Theory/ Theory of Evolution

Generally speaking, Biology is a diverse and has many sub-categories yet this introductory book is a preliminary textbook and thereby it will present an essential account of biology chapters in year 2 through to year 6. That is, the theory of evolution, cell and gene theory, growth and reproduction theory and immune system. The brief historical events at the first place and secondly, the general meaning.

Brief historical context for Evolutionary Theory.

A number of classical Greek philosophers believed in the gradual evolution of life. But the philosophers who influenced Western culture most, Plato and his student Aristotle, held opinions that opposed any concept of evolution in which species are permanent, are perfect, and do not evolve. In Judeo-Christian culture, the Old Testament account of creation fortified the idea that species were individually designed and permanent. In the 1700s, biology in Europe and America was dominated by natural theology, a philosophy dedicated to discovering the Creator's plan by studying nature. Natural theologians saw the adaptations of organisms as evidence that the Creator had designed each and every species for a particular purpose. A major objective of natural theology was to classify species in order to reveal the steps of the scale of life that God had created.

In 18th century, Carolus Linnaeus, a Swedish physician and botanist, sought to discover order in the diversity of life "for the greater glory of God". Linnaeus was the founder of taxonomy, the branch of biology concerned with naming and classifying the diverse forms of life. He developed the two-part, or binomial, system of naming organisms according to genus and species that is still used today. In addition, Linnaeus adopted a system for grouping similar species into a hierarchy of increasingly general categories. For example, similar species are grouped in the same genus, similar genera (plural of genus) are grouped in the same family, and so on. To Linnaeus, clustering similar species together implied no evolutionary kinship, but a century later his taxonomic system would become a focal point in Darwin's arguments for evolution.

In the early part of 19th century and late 18th century, natural scientists have started studying fossils. Fossils are remains or impressions of a prehistoric organism preserved in petrified form or as a mold or cast in rock. There were many opinions and arguments on the geological formation and how life evolved on it by relying on fossils.

Paleontology, the study of fossils, was largely developed by French anatomist Georges Cuvier. Realizing that the history of life is recorded in strata containing fossils, he documented the succession f fossil species in the Paris Basin. He noted that each stratum is characterized by unique group of fossil species, and that the deeper (old) the stratum, the more dissimilar the flora (plant life) and fauna (animal life) are from modern life. Cuvier even recognized that extinction had been a common occurrence in the history of life. From stratum to stratum, new species appear and others disappear. Yet Cuvier was a staunch opponent to the evolutionists of his day. Instead, he advocated catastrophism, speculating that each boundary between strata corresponded in time to a catastrophe, such as flood or drought that had destroyed many of the species living there at that time. He proposed that these periodic catastrophes were usually confined to local geographical regions, and that the ravaged region, such as mountain sliding to form ground and bulging of planes forming mountain, was repopulated by species immigrating from other areas.

The leading geologist of Darwin's era, a Scot, named Charles Lyell had criticized the theory of gradualism. He incorporated Hutton's gradualism into a theory known as uniformitarianism. The term refers to Lyell's idea that geological processes have not changed throughout Earth's history. Thus, for example, the forces that build mountains and erode mountains and the rates at which these forces operate are the same today as in the past. Darwin was strongly influenced by two conclusions that followed directly from the observations of Hutton and Lyell. First, if geological change results from slow, continuous actions rather than sudden events, then Earth must be very old, certainly much older than the 6000 years assigned by many theologians on the basis of biblical inference. Second, very slow and subtle processes persisting over a long period of time can cause substantial change. Darwin was not the first to apply the principle of gradualism to biological evolution, however.

Toward the end of the 18th century, several naturalists suggested that life had evolved along with the evolution of Earth. But only one of Darwin's predecessors developed a comprehensive model that attempted to explain how life evolves: Jean Baptiste Lamarck. Lamarck published his theory of evolution in 1809, the year Darwin was born. He agreed that living organisms on Earth evolved from much simpler nature toward greater complexity and he proposed to explain specific adaptations evolve. It incorporated two ideas that were popular during Lamarck's era. The first was use and disuse, the idea that those parts of the body used extensively to cope with the environment become larger and stronger while those that are not used deteriorate. Among the examples Lamarck cited were a blacksmith developing a bigger bicep in the arm that wields the hammer and a giraffe stretching its neck to reach leaves on high branches. The second idea Lamarck adopted was called the inheritance of acquired characteristics. In this concept of heredity, the modifications an organism acquires during its lifetime can be passed along to its offspring. The long neck of the giraffe, Lamarck reasoned, evolved gradually as the cumulative product of a great many generations of ancestors stretching ever higher. There is, however, no evidence that acquired characteristics can be inherited.

Not only had Charles Darwin (1809-1882) established firmly the evolutionary theory but also showed clearly how the evolution occurs and therefore transformed it into an essential claim of biology. Even as a boy he had a consuming interest in nature. Darwin was 22 years old when he sailed for five years from Great Britain aboard HMS Beagle in December 1831 across the seas on his voyage to different continents and islands of the world. During this long voyage, Darwin had the chance to observe and study in detail a wide variety of birds, plants, flowers, fossils, etc., on those regions of the world. During this long voyage, he found the evidence to change the fundamental claims of evolution.

Soon after returning, Darwin started reassessing all the information and evidence that he had observed during the voyage of the Beagle and finally came up with the idea that the existential diversity of life on earth happened from evolution and by means of natural selection. That is, evolution of living organisms occurs by means of natural selection and natural selection itself occurs through organisms' adaptation to its environment. It occurred to him that a new species could arise from an ancestral form by the gradual accumulation of adaptations to a different environment. Darwin developed his famous ideas of evolution and compiled with extensive evidence to publish the book titled The Origin of Species in 1859. After the publication of the book, it spread wide and open and became a manifesto of biology.

Descent with Modification

Secondly, in order to talk about general meaning of evolution, there are five things to talk about. These are, descent with modifications, variation, natural selection, adaptation and origin of species.

Darwin perceived unity in life, with all organisms related through descent from some unknown prototype that lived in the remote past. As the descendants of that inaugural organism spilled into various habitats over millions of years, they accumulated diverse modifications, or adaptations, that fit them to specific ways of life. Such descent of external phenotypic characteristics and internal genetic variation unto descendants is called descent with modification. This is the core idea of Darwin's view on the nature of life and comprised the views of the descent of genetic based ancestry characteristics onto descendants.

If asked, can it be possible to pass on all the characteristics of ancestors to descendants, which is not as genetic based characteristics cannot be passed down. For example, in human being, colour of eyes and skin, blood type, baldness and so forth are transferable characteristics. Most of the characteristics that have been acquired through learning and other factors in this life are not transferrable such as big arms of blacksmith and degeneration of organs due to concussion.

Transferrable characteristics are passed down from parent to offspring through DNA, a gene-holding molecule. More details will come up in chapter 3. So, because of the changes in the transferrable characteristics due to causes and conditions, new characteristics are passed onto descendants and gradually spread across the population of that organism, and thereby evolution takes place in the population of that organism.

Variation

Secondly, variation refers to differences that are visible in the population. When we pay attention to our surrounding environment, we can see so many different variations among population such as differences in skin colour, facial structure, body height and so on in human population, different characteristics in same species of domestic animals and different types of colour and size in same species of flowers. Visible characteristics are given the term dominant gene and that characteristic based genes are referred to as genetic composition. We can predict the differences in genetic composition the population from the differences in dominant gene of population and differences in dominant gene emerge from the differences occurring in the genetic composition. There happens change in genetic composition of the population with time and spread across the population and when it brings change in the nature of population, it is considered that evolution has happened in the population.

And then if we asked by depending on what has the variation occurred? We can say that it occurred from the changes in genetic composition, gene alteration from mating and also from the gene flow, gene flow from one population to another due to the migration between populations. More details will come up in the second year chapters. Variation is one important cause of the happening of evolution and that evolution will not occur if there are no diverse variations in the population.

And if we are asked about the way evolution occurred in population with such variation, the way of happening of this evolution is called natural selection that is explained below.

Natural Selection

Thirdly, there are three ways by which we can say about natural selection and these are: general meaning, examples of its occurring and types.

At first, the meaning or definition. The organisms that have characteristics that let them adapt better to the environment than rest of the same species have better chance of survival and reproduction thereby having more descendants and due to that have chance of prolonging the advantageous genetic composition onto future generations. In this way, the genes of the organisms with advantageous traits are preserved and passed onto descendants. This is called Natural Selection.

One popular empirical example of natural selection is that during the industrial revolution, lot of factories were running in so many places producing smokes from the burning of coal. Nearby forests were turned black by the smokes. There were two different kinds of moth, white and black. Because of the darkening of trees and branches from the black smokes, it gave favourable conditions for the survival of black moth relative to white moth and thereby can survive longer and advantageous in terms of reproduction. Due to the similar colour of moths and tree branches, birds cannot see and so it's easy to escape from the danger. And because it's easier to see white moths on black branches, they became prey to birds. Gradually, the empirical evidence of the transformation of earlier population of mixed moths to black population is one of the simplest and most popular examples of natural selection.

Secondly, if we were to show how natural selection would occur through example, such as there are few factors for natural selection to occur in the population of beetles.

First condition is that of variation in traits. For example, there are many different kinds of physical colour for beetles such as green and brown, and white and black traits in population of moths.

Second condition is that of the differences in the hereditary reproduction. Not only can the population not expand limitlessly but also can it extend the full use of the ability for hereditary reproduction and therefore there emerges differences in the hereditary reproduction in the population of organisms. In this example, because of the visibility of green beetles, they became prey to the birds and so the ability for the hereditary reproduction is comparatively less than the brown beetles.

Third condition. Traits have genetically inherited nature. For example, brown beetles reproduce brown offspring and green beetles reproduce green offspring because these characteristics have genetic basis.

Consequently, organisms with traits that give them an advantage over their competitors are more likely to pass on their traits to the next generation than those with traits that do not confer an advantage thereby spreading within the population. The whole organisms in the population turn into the population with such traits. And if there are variations in traits within the population and that there are variations in the reproduction of each organism of the population, traits having genetically inherited nature, then consequently it follows that evolution occurs through the means of natural selection.

Thirdly when we talk about different types of natural selection, there is directional selection, disruptive selection, stabilizing selection, sexual selection, artificial selection and so forth. When we ask about the consequences of evolution by means of the mechanism of natural selection, generally speaking, although evolution do influence the features and behavior of organisms, the most visible consequences are the organism's behavioral adaptation and physical adaptation. Therefore, we will discuss little bit about adaption.

Adaptation

Fourthly, there are three things in order to talk about adaptation, the nature of adaptation, and mechanism of adaptation and consequences of adaptation.

Firstly, adaptation is the process that makes the organisms better suited to their habitat.

Secondly, Adaptedness is the state of being adapted: the degree to which an organism is able to live and reproduce in a given set of habitats. Organisms have to compete for suitable conditions to survive and reproduce and in undergoing such processes, organisms having traits that adapt to the environment are being naturally selected and pass onto next generation.

Thirdly the regarding consequences of adaptation, adaptation enables or enhances the probability of that organism surviving and reproducing. And if the organism lacks adaptive traits then their survival and reproduction weakens. Therefore, adaptation helps increasing the population quantity.

The Origin of Life

Sixth thing regarding the origin of life, in general, scientists popularly claim that the universe formed about 13.7 billion years ago and Earth formed about 4.5 billion years ago. Scientists cannot recognise the exact dateline of the origin of life and neither have they found the standard evidence. According to the claim, when the earth started forming, all the inner and outer parts are made up of fire and gradually the temperature started dropping.

Earth is situated at a suitable distance from Sun and many factors such as huge water bodies have conditioned for life to form on it and developed continuously. Planets Mercury and Venus are too close to Sun and Planets Mars and Jupiter are too far from Sun and so pose challenges to form life on these planets.

Carbon is the necessary atom for all organisms and it is estimated that it has conditioned the origin of diverse forms of life in the early part on earth. One of the primary origins of carbon is from the vapours from volcanic eruption. Carbon and hydrogen, oxygen, nitrogen are joined together to form an important form of chemical called amino acid, the building block of protein.

Since amino acid is the building block of protein, it is also the basis of early forms of life. Enzymes and catalyst made up of proteins become inevitable for organisms to carry on their different bodily functions. Generally, it is a phenomenon of organisms to develop from simplest to more complex state. For example, it is like even though organisms originated from very small size and number yet gradually expanded and become diverse in nature.

What is clear for us is that an organism that depends on other cell cannot be considered as the origin of life. This is because one has to depend on other organism in order to survive and reproduce and so it cannot be claim as origin from the state of earlier life form. However virus and other organisms that are dependent on other cell can be regarded as formed after the start of the evolution of living things.

We have to consider something physical as living thing on this earth when it takes nutrients from others and starts breathing and that is to consider from the formation of amino acid through chemical reaction in the oceans and lakes on the planet dating back to 3 billion years. But some scholars say that life originated from other exo-planet and not from this earth.

Some researchers have found the evidence of the formation of RNA molecule through chemical reactions in the early stage of the world. And some researchers estimate that life has to be considered from the point of conception of reproduction ability to a combination of chemical substances. At present, so many scientists conduct different kinds of experiment in laboratory to obtain new understanding on the formation of life from the beginning and strive to make the type of chemical substances or things to generate similar substances or things.

Seed Questions/Debating questions.

Review questions

1 What is Evolution?
2 What relation is there between living things according to Evolution?
3 How does gene influence evolution?
4 What are the three conditions of natural selection?
5 Does evolution prove the existence of creator or negates it?
6 What evidence can you bring forth in claiming the theory of evolution?
7 How does natural selection happens?
8 Why is it that while one species of organism gets extinct, the other survives?
9 How would fish species remain when organisms living in water evolve into both land and water animals in the process of evolution?
10 Do human evolve from monkeys?
11 How do you differentiate if its organism or not?
12 How does the origin of life started on the planet?
13 How do we know the situation happened millions of years ago that no one has seen?
14 How can one species of organism change into another form?
15 Does evolution happen spontaneously and continuously? If yes, how do we know?
16 What basic challenges do scientists face in claiming the origin of life?

Chapter 3: Cells and Genes

Secondly, in order to talk about cells and genes, there are two theories, cellular and genetic. For the first part, we shall talk about nature of cells, types, nature of organelles and function, and cell cloning.

Discovery of Cell

The cell was first discovered by a British scientist Robert Hooke in 1665 while observing a multitude of tiny pores on very thin slices of bottle cork through compound microscope and he named "cells", meaning 'a small room' like monks lived in. (With regard to the nature of cells, translators use the term thraphung.)

But he was unable to observe and find details of those pores such as the nature, structure and function of those pores. (Fig. 6) More details of cell theory started developing from 1830s. German botanist Matthais Schleiden understood that all plants are composed of cells and German veterinary Theodor Schwann discovered that all organisms are made up of cells. Due to these findings, biology started developing gradually.

Nature of Cell

Cell is the basic unit of living organisms that are aggregates of all the essential characteristics of life yet it is not the basic unit of things because cell itself is made up of diverse molecules and atoms. Cells have characteristics of life such that they can reproduce offspring, respond to change in environment, breathing in and out, transformation of intake of nutrients from outside into energy, waste disposal, homeostasis, growth and reproduction. From the standpoint of cellular theory, all cells arise only by division of a previously existing cell and all living organisms are composed of basic unit of cell.

Types of Cell

Secondly, there are two different types of cell, prokaryote and eukaryote.

Firstly, prokaryotes are comparatively smaller in shape than eukaryotes and less complex and simple. It does not have nucleus, have less number of chromosomes and unicellular. (Fig.7)

Prokaryotes are of two main groups: archaebacteria and bacteria. Bacteria are amongst the earliest organisms on the earth and they takes birth and grow on land, sea and ponds, salt water and acid soup. They have three different shapes such as spherical, rod shaped and spiral. (Fig. 8) Archaebacteria live in the environment such as hot volcanoes, salt water and deoxygenated swamp. Archaebacteria are recognized as living things only around 1990.

Secondly, eukaryotes are composed of membrane covering nucleus and aggregate of different kinds of organelles. There are two kinds: Plant cell and animal cell. Plant cells are those cells that compose plant leaf, root, flower and stem while animal cells are those that compose all the inside of physical body such as skeleton, muscles, blood, skin, nerves and so on.

Plant cell and animal cell have differences such that former has cell wall and chlorophyll while later do not have those. Former are rectangular while later are spherical although the differences in shape is not the primary difference. Former depend on Sun light to generate its nutrient to survive while later it cannot function in that manner but draws nutrients by depending on other living organisms. For example, human body cells cannot make up glucose and so have to take up the nutrients from food items such as wheat, barley and beans and others. (Fig. 9)

Organelles and their functions

In general, we cannot see from our naked eyes the body cells as its too small yet they are not something which is not composed of something rather they are composed of subtle things. They are called organelles of cell. Each organelle has its separate shapes and functions. Few important organelles amongst are: Gene embedded nucleus, energy producing mitochondria; waste breaking lysosome, and protein synthesizer cytoskeleton.

Nucleus is centered in a cell and there lie chromosomes, DNA, genes and so on. These are formed step by step as DNA is formed from the aggregates of genes and these are spiraled to form chromosomes and they function in encoding most of the cells and body messages. When cells perform protein synthesis, messenger RNA performs transcription of information in the DNA that is in nucleus and then carries the information and messages onto protein-making RNA through the pores of nucleus. This process is called transcription. Then RNA synthesizes protein according to the information carried on by the messenger. This process is called translation. (Fig.10)

Unlike other organelles of cell, mitochondria have uncommon DNA and gene and so it can perform transcription and reproduce by itself. And although eukaryotes only have mitochondria and not the prokaryotes, the later can equally produce energy. Both the parent cells have mitochondria yet we receive it from mother. This organelle is highly important that most of the energy need for our body is generated by it. Like digestive system, this organelle carries nutrients to cell and break up into pieces to change it into energy form. These energies are used in our body such as we need energy to work during day time, walking, thinking, breathing in and out during sleep in the night time and so forth. There are three stages of processes in producing energy and that it produces 36 energies in total, i.e., in the 1^{st} stage – 4 energy molecules ADP, at 2^{nd} stage-6 ADP and in the 3^{rd} stage-24 ADP. That is why it is also called storehouse of cell.

Lysosomes are situated in the outer fluid of cell and membrane-bound tiny vesicles. Lysosomes are located in a part of cell called Golgi apparatus that contains acid. They enter inside the stomach of bacteria and viruses entering from outside the cell that are harmful to cell and kill them by releasing acid. Likewise, acids in the lysosomes help in digestion of nutrients such as proteins and fats. Lysosomes break down those mitochondria that become worn-out and useless and make up new storehouse of cell.

All the living cells have thousands of cytoskeleton and their main function is to make protein and when cells are in need of protein, mRNA in nucleus carries information about what type of protein to synthesize from nucleus to cytoskeleton that lies outside the nucleus. There are two parts of cytoskeleton, small and large, such that smaller one reads information carried on by messenger and larger part synthesize proteins from amino acids transferred by the tRNA through continuous chain of amino acids based on information carried by messenger. Above-mentioned cell organelles are just the representation of organelles and that there are so many other organelles that you can learn from other books.

Cell Division or Cell Duplication

Cell Division has two types, 1. Mitosis and 2. Meiosis. Mitosis involves restoration of damaged cells during infection on bodies through the production of body cells. That is to say that Nucleus and chromosomes of a diploid cell gets separated into two parts at the beginning. Then that cell divides into two cells and forms two new cells. This process is called mitosis. At this stage, replicated and replicating cells have same number of chromosomes. Diploid refers to the chromosomal pair.

Meiosis occurs in the sexually reproducing organisms. Cell division process involves production of four cells of any of reproduction cells or gamete from the diploid cell. There are two processes called the first phase and the second phase of meiosis. In the first phase, two new cells are formed. Their chromosomal numbers are the same as the initial chromosomal numbers of the diploid cell. In the second phase, the two new cells again undergo division to form four new cells at the end. In male, the news cells formed from meiosis are sperms and egg in female. (Fig.12) Initially, these cells are formed from diploid cells and yet they have half the number of chromosomes than the diploid cells. The main factor behind the formation of two new cells in mitosis and four new cells in meiosis is that the two chromatids of the part of chromosome do not undergo division during mitosis while the two chromatids of the part of the chromosome does undergo division during meiosis. More details are shown in the second book of the introductory to biology.

Genetic Theory

Secondly, in order to talk about gene, we have to talk about Mendel and his idea of gene, chromosome theory, DNA theory and gene.

As mentioned in the second chapter, one of the main properties of life is the ability to reproduce. However, organisms have to arise from same type. For example, pine tree will only grow from pine tree and rhinoceros will only be born from rhinoceros. And again, the offspring are more similar to their parents than far off same species organisms. As shown in chapter 2, the nature of passing of traits from one generation to another generation is called descent with modification. Although many similar traits are passed down from parent to offspring yet there can be so much differences from all round from their parent. This is called variation. The inheritance nature and variation are known to human for thousands of years earlier and that they are used in producing heredity of animals and plants. But the mechanism of these two have been started to understand from the development of genetics in the 20th century.

Mendelian Gene Theory

Mendel brought an experimental and quantitative approach to genetics and also had he established the basic principes of heredity. He was born in 1822 to a German family in Austria. (Fig 14) He studied philosophy, science and mathematics in school and later became a monk in a Christian monastery. He studied mathematics and plant biology and other studies at University of Vienna. In around 1857, Mendel began breeding garden peas in the abbey garden at the monastery in order to study on inheritance. Mendel chose to work with peas because they are available in many varieties. For example, one variety has purple flowers, while a contrasting variety has white flowers. Geneticists use the term character for a heritable feature, such as flower color, that varies among individuals. Each variant for a character, such as purple or whit color for flowers, is called a trait.

Review Questions

1 What is the smallest form amongst the living things? How many different types are there?
2 Who has discovered the cell first and how? How much does it influence the development of Biology?
3 Are cells living? If it is, what are the properties that shall have to meet for it to be living?
4 What are the two broadly categorized cells? What are their main differences?
5 Identify four main organelles that composed cell?
6 What are the two cell division processes? Write a briefing on their differences?
7 What is the main claim of Mendel’s view of gene?
8 In the experiment carried out by Mendel, what is the fruit seen in the first offspring of cross-fertilization of maroon and white flower?
9 How many cells are there in human body? How many chromosomes are there in sperm and egg (zygote)?

10 Who is the first person to describe the structure of DNA correctly?

Chapter 4: The Theory of Development, Growth, and Reproduction

The explanation of the theory of development is divided into ten categories:

1. Identifying the nature of growth, reproduction and developmental biology

The science of development is the study of any living organism, and how it is produced, develops, and then reproduces. The modern understanding of the science of development identifies all of the activities, which arise under the control of genes, including the development and differentiation of the cell, the formation of tissues and organs, and the processes of reproduction and maturing.

2. The sperm and the ovary

Here we are going to discuss the formation and the development of the human body. However, to understand this concept we should generate some questions in our minds as to how the fertilization of one small egg by a sperm results in the very complex structure that is the human body. What are the methods that guide and regulate this process? What are the factors that help to form the organ system of the body?

The DNA in the cell nuclei is the chief controller that changes the nature and function of any cell; and it is like a library storing all of the aforementioned information. Thus, to access and use the stored information, the cell requires proteins. The proteins undertake all of the functions of cells. In that case, which protein undertakes what function at the external and internal of the cells?

The other questions that naturally arise relate to how and where the sperm and eggs are produced in the male and female body. Figure 18 shows the production of an egg in the female gonads and sperm in male testes. Firstly, the eggs develop beyond the primary oocyte stage in the womb when females reach 12 years of age. Figure 19 shows that under the control of genes, the pituitary gland (part of the amygdala of the brain) releases two hormones directly into the bloodstream to the gonads. These chemical signals are catalysts for the reaction leading to the maturation of the egg cell in the gonad. At birth, females have about 400,000 egg cells that are ready to mature in response to the appropriate hormone signaling. Once females have matured, they will experience monthly menstrual cycles consisting of the maturation of the egg cell and its degradation.

Similarly, the male human body undergoes formation of sperm in the testes. The male reproductive system includes the testes, urethra, vas deferens, prostate gland, seminal vesicle, and penis. About 200 million sperm cells are generated by the testes each day.

As aforementioned, genes control the pituitary gland, which is part of amygdala of the brain and releases hormones directly into the bloodstream. These hormones are the catalysts that stimulate the generation of sperm. The hormones also help to mature immature sperm, and carry them into the epididymis for nutrition and storage.

3. The formation of the embryo in the womb

Spermatogonia reach the female reproductive organ (མོ་དབང་)and fuse with the egg within 12 to 44 hours. Each ejaculation releases about 300 million spermatogonia, which survive in the female reproductive system for 4-5 days. There are only several hundred of these that actually reach the female egg, and the [acidic] environment of the embryo kills most of them. Only one among the several hundred sperms that reach the egg can enter inside of female egg. To enter the the sperm must perforate the thin wall of the female egg. The acrosome (top part of sperm) releases acid to perforate the wall, which also immediately renders the wall of female egg impermeable to other sperm.

The fertilized egg cell that results from the union of a female egg with a male sperm is called a zygote. After forming a zygote, the single cell divides into two smaller cells each containing the same genetic information. At this stage, the zygote is called a morula and travels through the ventricle. The morula then continues to divide into multiple cells until it becomes a trophoblast and surrounds the embryoblast developing internally on one side.

Liquid creates a space between the two different cells, and the three parts compose a blastocyst. The complete organ system of the fetus will develop from the inner cells to the outer cells, becoming a thin layer covering the fetus in the womb. The inner cells, now known as embryonic stem cells which can differentiate into any cell type, are then ready and may travel to the surface of the organs or tissues.

4. Cell Division

Special activity is necessary for the development of the embryo cells into various states; this process is called cellular differentiation (the process by which a cell changes from one cell type to another.) In the process of cellular differentiation, the initial cell type specializes into another cell type, and each cell has a specific function. For instance, the embryo cells will gradually differentiate into blood cells, organ cells, skin cells and so on. The collection of one cell type will form a specific tissue and different tissues form a specific organ. This process allows the fetus' organ structure to adapt quickly and efficiently, therefore if there is a problem with cellular differentiation then there is the potential for disability.

What controls the cells gradual growth? How does one type of cell develop into another type of cell? How do different cells form different tissues, and how do these form different organs? When the cells are in contact with one another, the genes in the cells activate and then produce different proteins. These different proteins are conditioned for developing different cells. The growth factor proteins (of the cell) do signal transduction, signaling to the surrounding cells, and transcription factors proteins (of the cell) transcribe specific genes from specific proteins. Proteins interfere with the intracellular and extracellular functions of the cell while completing their own functions.

There are many levels of embryo development and in the beginning of gastrulation the outer surface cells move around to adjust the structure and order of the embryo. During this structuring and ordering known as embryogenesis, three important layers form: endoderm, mesoderm, and ectoderm. Of these three layers, the endoderm forms the innermost layer from which the internal organs develop such as the five nonvisceral organs of the human body (heart, lungs, liver, spleen and kidney) and the six visceral organs (stomach, colon, intestine, bile, urinary bladder, and gonads). The ectoderm generates the outer layer of the embryo and produces tissues of the epidermis, aids in the formation of neurons within the brain, and constructs melanocytes. The mesoderm germ layer forms in the embryos of triploblastic animals and is a substantial component for the development of the muscle system, skeletal system, and circulatory system.

5. Cell signaling in multicellular organisms

The conception of a baby in the mother's womb begins with a single cell, which can only differentiate with the help of signaling. The differentiation process also occurs due to interactions between the cells. If the cell relies on cell signaling for differentiation, what steps lead to cell signaling? The signal comes from the environment the cell exists in or may come from other surrounding cells. The reaction that leads to signal transduction allows the signal to be carried through the cell membrane (cell wall; only found in plant cells) and then amplified.

Some chemical signals, whether they have a receptor or not, enter inside the cell by breaking through the cell membrane. The majority of signals signal receptors on the outer surface of cells. Signal receptor proteins' most important function is for intracellular and extracellular communication. Even if there is a disturbance of signal transmitters extracellularly, the receptor proteins only bind their specific chemical signal carriers and not others.

Once these signals enter the cell, they continue to travel from protein to protein. The ultimate destination of the signal depends on the signal's entity. Some signals enter the nucleus from the inside of the cell, some exit the nucleus, and some travel to specific parts of the cell membrane. When the signal travels from one protein to another, the previous protein changes the following proteins and so forth; this is called the signaling pathway (cascade).

There are different types of signaling pathways, some of which spread into many different directions signaling many places in the inner cell. The signal can increase as it travels from one protein to another, or it can decrease during cell division; either way, the signal generates a huge reaction. After the signals reach their ultimate destination, they change the behavior of the cell. However, the behavior changes all depend on which proteins interfere and participate in the process of signal transduction.

6. Reproduction: a study model

Biologists are studying the development of human beings on numerous models. The animals that are simple and most accessible to study are mice, bees, frogs, chickens, water insects and so on. During the development in the womb of these animals, biologists carefully examine the functions of proteins and genes.

Furthermore, biologists observe the influence of these functions on the organ system through gene changes, regulation, and movement. Depending on these models, the biologists explain the protein and gene activities during human development.

7. Changes in the womb at each week

The process of the embryo formation in the mother's womb and the developmental stages are referred to as embryogenesis. After five weeks, the embryo begins to form a brain, spinal cord, and heart. Other organ systems related to the stomach and small intestine also begin to develop. During the sixth and seventh week, limb bones form and the brain further develops by dividing into five parts. Some of these parts begin to show nerve formation and begin to form tissues that generate the eyes, ears, vertebra, and other bones. The heart further develops and begins to beat. The blood begins to circulate in the main blood vessels of the fetus. During the eighth week, the limb extremities (fingers and toes) lengthen and show as protruding shapes, and the lungs begin to form. During the ninth week, hair nerve cells begin to form, limbs become more prominent, and some important organs begin to develop. During the tenth week, the eyelids and outer ears start to appear. By the end of tenth week of development, the initial embryonic period ends.

Between the eleventh and fourteenth week of development, the facial details form and limbs lengthen. The development of reproductive system begins as well as the formation of red blood cells in the lungs. During this time, the baby's head alone composes half the weight of the whole body. From that point until the twenty-eighth week of development, the baby's eyes will remain closed. Between the fifteenth to eighteenth weeks of development, the skin remains transparent and hair begins to grow on the head. The mouth is able to move to suck and inhale, and fluids are produced (or released) by the liver and gallbladder. Muscular tissues are formed and bones become stronger. The baby begins to move. From the nineteenth week, the baby is able to hear sound.

During the twenty-second week the head develops a layer of fine hair, eyelashes, and eyelids. At the fingertips, the nails begin to develop. As the fetus develops muscles, there is an increase in movement and the mother can feel the fetus' movements. The rapid heartbeat of the fetus can be heard with a stethoscope. Between the twenty third to twenty fifth weeks, the bone marrow starts generating blood stem cells. Although the lower parts of the lungs appear, the fetus cannot breath due to the incompletion of its air pathways. During the twenty-sixth week of development, there is the completion of growth of the eyebrows, eyelashes, all parts of the eyes, palms and soles, and (diaphragm containing the lungs).

During the twenty-seventh to thirtieth weeks of development, there is rapid development of the brain and nervous system that controls the activities of the body. From that point onwards the eyes are able to open and close, and respiratory system further develops. Between the thirty-first and thirty-third weeks, fatty tissue (?) develops in the lungs and the breathing process begins although the lung development is incomplete. Although the skeletal formation is complete, the fetus is soft and flexible. The fetus' body begins to store iron, calcium, and phosphate.

During the thirty-eighth week of development, the fetus become fatter as it gradually loses its hairs. Between the thirty-ninth and forty-second weeks, only the upper parts of the hands and shoulders retain their hair while the rest of the body sheds its hair. In contrast, the hair on top of the fetus' head becomes thicker, and its nails lengthen. In accordance with the mother's body, the baby is born between the forty-second and forty-fourth week.

8. The menstrual cycle and fetus development

The average period of a menstrual cycle is twenty-eight days but varies depending on the female body. Depending on the female body, a middle-aged woman would have a menstrual cycle of twenty-one to thirty-five days while a teenage woman can have a menstrual cycle of twenty-one to forty-five days. The first day a female loses menstrual blood is considered the beginning of the menstrual cycle. Then, the ovarian follicle (a place for oocyte development) starts to develop. At the end of the menstrual cycle, there is a decline of catalysts leading to oocyte development. Menstruation ends after five days and because of the catalyst enzymes some follicle growth occurs in the ovary during menstrual period. Oocytes are then activated in the ovarian follicle. Normally, there is a continuous development or growth of the ovarian follicle for the seven or eight days following the end of menstrual bleeding. After fourteen days, one of the many ovarian follicles becomes significantly larger and further develops. At this point, the embryonic layer thickens and readies itself for embryogenesis. The embryonic layer is filled with blood and vitamins.

On the fourteenth day of embryonic development, with the help of catalysts or enzymes, the developed eggs are released from the gonads, rupture the follicle, and enter fallopian tube. The process of rupturing and release is called ovulation. For a few days after ovulation, the egg travels and if the egg meets and fuses with a sperm then it will continue to travel until it binds the surface of the uterus. It is possible to become pregnant through sexual contact between the eleventh to eighteenth day of the menstrual period. If the female egg does not meet a sperm cell, then ovulation gradually ends on the twenty-fifth day. When an egg is released and does not meet a sperm cell, then the egg will disintegrate and descend through the fallopian tube.

9. The benefits of a multicellular cell

As discussed earlier, any organism has unicellular or multicellular cells. There are significantly more unicellular organisms than multicellular organisms. Therefore, multicellular organisms have a division of labor rendering them more effective in their function. A variety of multicellular organisms evolved due to this characteristic. What are the benefits of being multicellular organisms?

The cells of multicellular organisms demonstrate division of labor and responsibility. Each cell has its unique specialized responsibility, and if there is a deficiency of any cell then there is no way to complete its work. Each cell completes its function, and cannot take on the function of another. For example, the nucleus will not complete the function of the membrane and the membrane will not complete the function of the nucleus.

Why are there different functions for different kinds of cells? All the cells have to complete their unique activity so as to form specific tissues. For instance, the cells which develop into lung tissue cannot develop into other organ tissues such as heart or brain tissue. Different tissue cells create different shapes and structures depending to their function. Therefore, different cells have different responsibilities and are trained for specific functions.

We can understand that the reason for having different shapes and sizes is to complete different functions and responsibilities. For example, neurons are tiny and long for they help transmit messages to all parts of the body. Skin cells are flat and tightly connected because they help to defend the body from foreign invasions. Many activities are needed for the completion of whole body system, and the collection of similar cells can function as a specialized cell.

As mentioned earlier stem cells can irreversibly change into specific cells under the influence of chemical signals. Once it becomes a specialized cell, it can begin to develop into each organ. Why are cells with the same kind of DNA able to differentiate into cells with different characteristics? Although the DNA of the cells is the same, due to the different expression or activation of genes the cells express different characteristics. According to the timing and what function must be completed, the same genes of cells may be expressed differently.

If we think of our own bodies- skin, bones, blood, and muscles- all around our body there are different cells. These different cells sum to a total of over 3 trillion cells in our bodies, and all these cells arise from a single cell. With different functions of different kinds of cells, aggregations of cells form tissues and the assembly of many tissues leads to the formation of organs. Each organ completes a unique task, and to complete the whole task the organ works with other organs to form an organ system. The complete function of the body comes from the cooperation of all the organ system's function.

All living beings have tissues and cells to live continuously. If we take the example of the human being, many organ systems form with the function to allow the body to live life continuously. All the organs are engaged in their unique functions and actively complete their role. For example, the function of the nervous system is to receive signals from all parts of the body and to carry them to the brain. The brain will understand the signals and respond accordingly. The blood circulatory system is an organ system that permits blood to circulate and transports oxygen and nutrients to different parts of the body while also carrying waste collected from different parts of the body to the kidney. Also, the integumentary system or immune system acts as a barrier to protect the body against disease and maintain the welfare of the body. The reproductive system ensures that humans are able to procreate. Any activity, from the movement of a thumb to the jumping into the air was conditioned by the muscular system. All of these body systems complete their unique tasks, and therefore allow for the continued survival of human beings.

10. Two mutational processes of genes

The other concept that must be explained is that faulty genotype during embryogenesis may lead to an abnormal fetus (for example a fetus with two heads, incomplete limbs, twins sharing one body, chest limbs, or deafness and blindness from birth. There are so many conditions; what are the causative agents and how do they arise? To know the answer, we need to understand the theory of gene mutation. A gene mutation is a mutation that occurs in the DNA sequence that comprises the gene. Gene mutations can be classified in two major categories:

Hereditary mutations are inherited from a parent and are present throughout a person's life in virtually every cell in the body. These mutations are also called germline mutations because they are present in the parent's egg or sperm cells, which are also called germ cells. This germline mutation is present for the whole life in all cells of the child's body.

Acquired (or somatic) mutations occur at some time during a person's life and are present only in certain cells, not in every cell in the body. These changes can be caused by environmental factors such as ultraviolet radiation from the sun, or can occur if a mistake is made as DNA copies itself during cell division. Acquired mutations in somatic cells (cells other than sperm and egg cells) cannot be passed on to the next generation. This type of mutation occurs in a single cell early in embryonic development.

Mutations cause a deformation of the proteins, which leads to a change in cell function resulting in an abnormal or defective body. For example, flies (bees?) may have three different types of mutations before and after the embryonic development. When a deletion mutation occurs, there is the danger of losing part of the body. When a point or missense mutation occurs, then there is controlled fault. When a frameshift mutation occurs, each part of the inside of section of body.

Chapter 5: The Immune System

Introduction

All living organisms, especially animals, have to protect themselves from external, harmful viruses and germs. Moreover, unhealthy body cells need resistance for there is the possibility of them becoming infectious. In the process of development there are three different layers of defense. The first layer of defense is the skin, membranes, and different kinds of secretions. The second layer of defense are the white blood cells, the proteins that defend small cell organisms and respond to inflammation. These are two unspecific defenses because they defend without differentiating the germs. The second layer of defense is activated by chemical signals; phagocytes and proteins that defend small cell organisms both attack the germs that have survived the first layer of defense. Increased inflammation in the body is a sign of the engagement of the second layered defense.

The third layer of defense is an innate defense of the immune system. The immune system is a network of cell tissues and organs that work together to defend the body against attacks by foreign invaders. These are primarily microbes (germs)-tiny, infection-causing organisms such as bacteria, viruses, parasites and fungi. This defense is a specific defense because it produce different kinds of antidotes depending upon various cause of infections. The immune system is amazingly complex. It can recognize and remember millions of different enemies, and it can produce secretions and cells to match up with and wipe out each one of them.

The key to a healthy immune system is its remarkable ability to distinguish between the body's own cells (self) and foreign cells (non-self).The body's immune defenses normally coexist peacefully with cells that carry distinctive self-marker molecules. But when immune defenders encounter cells or organisms carrying markers that say foreign, they quickly launch an attack. Anything that can trigger this immune response is called an antigen. An antigen can be a microbe such as a virus, or even a part of microbe. Tissues or cells from another person (except an identical twin) also carry nonself markers and act as antigens. This explain why tissue transplant may be rejected. In an abnormal situations, the immune system can mistake self for nonself and launch an attack against the body's own cells or tissues. The result is called an autoimmune disease. Some forms of arthritis and diabetes are autoimmune diseases.

The Structure of the Immune System

The organs of the immune system are positioned throughout the body. They are called lymphoid organs because they are home to lymphocytes, small white blood cells that are the key players in the immune system. Bone marrow, the soft tissue in the hollow center of bones, is the ultimate source of all blood cells, including white blood cells destined to become immune cells. The thymus is an organ that lies behind the breastbone; lymphocytes known as T lymphocytes, or just T cells, mature in the thymus.

Lymphocytes can travel throughout the body using the blood vessels. The cells can also travel through a system of lymphatic vessels that closely parallels the body's veins and arteries. Cells and fluids are exchanged between blood and lymphatic vessels, enabling the lymphatic system to monitor the body for invading microbes. The lymphatic vessels carry lymph, a clear fluid that bathes the body's tissues. Small, bean-shaped lymph nodes are laced along the lymphatic vessels, with clusters in the neck, armpits, abdomen, and groin. Each lymph node contains specialized compartments where immune cells congregate, and where they can encounter antigens.

Immune cells and foreign particles enter the lymph nodes via incoming lymphatic vessels or the lymph nodes' tiny blood vessels. All lymphocytes exit lymph nodes through outgoing lymphatic vessels. Once in the bloodstream, they are transported to tissues throughout the body. They patrol everywhere for foreign antigens, then gradually drift back into the lymphatic system, to begin the cycle all over again.

The spleen is a flattened organ at the upper left of the abdomen. Like the lymph nodes, the spleen contains specialized compartments where immune cells gather and work, and serves as a meeting ground where immune defenses confront antigens.

Immune Cells and Their Products

The immune system stockpiles a huge arsenal of cells, not only lymphocytes but also cell-devouring phagocytes and their relatives. Some immune cells take on all comers, while others are trained on highly specific targets. To work effectively, most immune cells need the cooperation of their comrades. Sometimes immune cells communicate by direct physical contact, sometimes by releasing chemical messengers.

The immune system stores just a few of each kind of the different cells needed to recognize millions of possible enemies. When an antigen appears, those few matching cells multiply into a full-scale army. After their job is done, they fade away, leaving sentries behind to watch for future attacks.

All immune cells begin as immature stem cells in the bone marrow. They respond to different cytokines and other signals to grow into specific immune cell types, such as T cells, B cells, or phagocytes.

B Lymphocytes

B cells and T cells are the main types of lymphocytes. B cells work chiefly by secreting substances called *antibodies* into the body's fluids. Antibodies ambush antigens circulating the bloodstream. They are powerless, however, to penetrate cells. The job of attacking target cells—either cells that have been infected by viruses or cells that have been distorted by cancer—is left to T cells or other immune cells. (Figure 22)

Each B cell is programmed to make one specific antibody. For example, one B cell will make an antibody that blocks a virus that causes the common cold, while another produces an antibody that attacks a bacterium that causes pneumonia. When a B cell encounters its triggering antigen, it gives rise to many large cells known as plasma cells. Every plasma cell is essentially a factory for producing an antibody. Each of the plasma cells descended from a given B cell manufactures millions of identical antibody molecules and pours them into the bloodstream.

An antigen matches an antibody much as a key matches a lock. Some match exactly; others fit more like a skeleton key. But whenever antigen and antibody interlock, the antibody marks the antigen for destruction.

T Cells

Unlike B cells, T cells do not recognize free-floating antigens. Rather, their surfaces contain specialized antibody-like receptors that see fragments of antigens on the surfaces of infected or cancerous cells. T cells contribute to immune defenses in two major ways: some direct and regulate immune responses; others directly attack infected or cancerous cells. Helper T cells, or Th cells, coordinate immune responses by communicating with other cells. Some stimulate nearby B cells to produce antibody, others call in microbe-gobbling cells called phagocytes,still others activate other T cells.

Killer T cells (also called cytotoxic T lymphocytes or CTLs) perform a different function. These cells directly attack other cells carrying certain foreign or abnormal molecules on their surfaces. CTLs are especially useful for attacking viruses because viruses often hide from other parts of the immune system while they grow inside infected cells. CTLs recognize small fragments of these viruses peeking out from the cell membrane and launch an attack to kill the cell.

Natural killer (NK) cells are another kind of lethal white cell, or lymphocyte. Like killer T cells, NK cells are armed with granules filled with potent chemicals. Unlike killer T, NK cells have potential to recognize and attacks many types of foreign cells. Both kinds of killer cells slay on contact. The deadly assassins bind to their targets, aim their weapons, and then deliver a lethal burst of chemicals.

Phagocytes and Their Relatives

Phagocytes are large white cells that can swallow and digest microbes and other foreign particles. Monocytes are phagocytes that circulate in the blood. When monocytes migrate into tissues, they develop into macrophages. Specialized types of macrophages can be found in many organs, including lungs, kidneys, brain, and liver. Macrophages play many roles. As scavengers, they rid the body of worn-out cells and other debris. They display bits of foreign antigen in a way that draws the attention of matching lymphocytes. And they churn out an amazing variety of powerful chemical signals, known as monokines, which are vital to the immune responses. (Figure 23).

Granulocytes are another kind of immune cell. They contain granules filled with potent chemicals, which allow the granulocytes to destroy microorganisms. Some of these chemicals, such as histamine, also contribute to inflammation and allergy.

One type of granulocyte, the neutrophil, is also a phagocyte; it uses its prepackaged chemicals to break down the microbes it ingests. Eosinophils and basophils are granulocytes that degranulate, spraying their chemicals onto harmful cells or microbes nearby.

Platelets, too, contain granules. In addition to promoting blood clotting and wound repair, platelets activate some of the immune defenses.

Cytokines

Components of the immune system communicate with one another by exchanging chemical messengers called cytokines. These proteins are secreted by cells and act on other cells to coordinate an appropriate immune response. For instance, cytokines help to produce T cells by the immune system and also turns certain immune cells on and off. These chemically attract specific cell types and help to call other immune cells to the damaged site.

Immunity: Natural and Acquired

Long ago, physicians realized that people who had recovered from the plague would never get it again—they had acquired immunity. This is because some of the activated T and B cells become memory cells. The next time an individual meets up with the same antigen, the immune system is set to demolish it. Immunity can be strong or weak, short-lived or long-lasting, depending on the type of antigen, the amount of antigen, and the route by which it enters the body. Immunity can also be influenced by inherited genes. When faced with the same antigen, some individuals will respond forcefully, others feebly, and some not at all.An immune response can be sparked not only by infection but also by immunization with vaccines. Vaccines contain microorganisms—or parts of microorganisms—that have been treated so they can provoke an immune response but not full-blown disease. Immunity can also be transferred from one individual to another by injections of serum rich in antibodies against a particular microbe (antiserum). For example, immune serum is sometimes given to protect travelers to countries where hepatitis A is widespread. Such passive immunity typically lasts only a few weeks or months.

Infants are born with weak immune responses but are protected for the first few months of life by antibodies received from their mothers before birth. Babies who are nursed can also receive some antibodies from breast milk that help to protect their digestive tracts.

Disorders of the Immune System

Immune system also have disorder sometimes like other system of the body. We will discuss some from many types of disorders.

Allergic Diseases

The most common types of allergic diseases occur when the immune system responds to a false alarm. In an allergic person, a normally harmless material such as grass pollen or house dust is mistaken for a threat and attacked. Allergies such as pollen allergy are related to the antibody known as IgE. Like other antibodies, each IgE antibody is specific; one acts against oak pollen, another against ragweed.

Autoimmune Diseases

Sometimes the immune system's recognition apparatus breaks down, and the body begins to manufacture T cells and antibodies directed against its own cells and organs. Misguided T cells and *autoantibodies*, as they are known, contribute to many diseases. For instance, T cells that attack pancreas cells contribute to diabetes, while an autoantibody known as rheumatoid factor is common in people with rheumatoid arthritis. People with systemic lupus erythematosus (SLE) have antibodies to many types of their own cells and cell components.

No one knows exactly what causes an autoimmune disease, but multiple factors are likely to be involved. These include elements in the environment, such as viruses, certain drugs, and sunlight, all of which may damage or alter normal body cells. Hormones are suspected of playing a role, since most autoimmune diseases are far more common in women than in men.

Immunodeficiency Disorders

When the immune system is missing one or more of its components, the result is an immunodeficiency disorder. Immunodeficiency disorders can be inherited, acquired through infection, or produced unintentionally by drugs such as those used to treat people with cancer or those who have received transplants. Temporary immune deficiencies can develop in the wake of common virus infections, including influenza, infectious mononucleosis, and measles. Immune responses can also be depressed by blood transfusions, surgery, malnutrition, smoking, and stress.

Some children are born with poorly functioning immune systems. Some have flaws in the B cell system and cannot produce antibodies. Others, whose thymus is either missing or small and abnormal, lack T cells. Very rarely, infants are born lacking all of the major immune defenses.

AIDS is an immunodeficiency disorder caused by a virus (HIV) that infects immune cells. HIV can destroy or disable vital T cells, paving the way for a variety of immunologic shortcomings. HIV also can hide out for long periods in immune cells. As the immune defenses falter, a person with AIDS falls prey to unusual, often life-threatening infections and rare cancers.

Cancers of the Immune System

The cells of the immune system, like other cells, can grow uncontrollably, resulting in cancer. Leukemias are caused by the proliferation of white blood cells, or leukocytes. The uncontrolled growth of antibody-producing plasma cells can lead to multiple myeloma.

Therefore, the immune system is an important and indispensable system for our body. Scientists have learned much about the immune system but certain areas remain unknown and scientists continue to focus their studies on these areas. New technologies for identifying individual immune cells are now aiding scientists to quickly determine which targets trigger immune responses. Improvements in microscopy are permitting the first-ever observations of B cells, T cells, and other cells as they interact within lymph nodes and other body tissues. The combination of new technology and expanded genetic information will undoubtedly teach us even more about how the body protects itself from disease.