

**NEXT IAS**

# GENERAL SCIENCE

---

**CIVIL SERVICES  
EXAMINATION 2025**

*Published by*





**MADE EASY Publications Pvt. Ltd.**

Corporate Office: 44-A/4, Kalu Sarai  
(Near Hauz Khas Metro Station), New Delhi-110016  
Contact: 011-45124660, 8860378007  
E-mail: infomep@madeeasy.in  
Visit us at: [www.madeeasypublications.org](http://www.madeeasypublications.org)

**General Science**

© Copyright, by MADE EASY Publications Pvt. Ltd.

All rights are reserved. No part of this publication may be reproduced, stored in or introduced into a retrieval system, or transmitted in any form or by any means (electronic, mechanical, photo-copying, recording or otherwise), without the prior written permission of the above mentioned publisher of this book.

First Edition: 2017

Second Edition: 2018

Third Edition: 2019

Revised & Updated: 2020

Fourth Edition: 2021

Fifth Edition: 2022

Sixth Edition: 2023

**Seventh Edition: Nov. 2023**

# Contents

## General Science

### UNIT – I: BIOLOGY

#### Chapter - 1

##### Diversity World ..... 2

1.1	Classification .....	2
1.2	Kingdom Classification .....	3
1.3	Kingdom Plantae .....	3
	Algae .....	4
	Bryophytes .....	4
	Pteridophytes.....	4
	Gymnosperms .....	4
	Angiosperms .....	4

#### Chapter - 2

##### Cell, Building Block, Genetics..... 5

2.1	Cell .....	5
2.2	Cell Theory.....	5
2.3	Types of Cells .....	5
2.4	Structure of Cell .....	6
2.5	Various Cell Organelles .....	6
	Cell Organelles .....	6
	Plasma Membrane or Cell Membrane.....	6
	Cell Wall.....	6
	Cytoplasm.....	6
	Nucleus.....	7
	Chromosomes.....	7
	Vacuoles .....	7
	Endoplasmic Reticulum (ER) .....	8
	Golgi Apparatus or Golgi Complex.....	8
	Lysosomes.....	8
	Mitochondria.....	8
	Plastids .....	9
2.6	Differences between Plant Cell and Animal Cell.....	10

#### Chapter - 3

##### Biomolecules ..... 11

3.1	Biomolecule .....	11
-----	-------------------	----

3.2	Carbohydrates .....	11
	Monosaccharides .....	11
	Oligosaccharides.....	12
	Polysaccharides .....	12
3.3	Proteins, Amino Acids, Enzymes .....	12
	Proteins.....	12
3.4	Fats, Healthy Fats and Unhealthy Fats .....	13
	Fats/Triglycerides.....	13
	Lipid.....	13
	Fatty Acid.....	13
	Saturated Fat .....	13
	Unsaturated Fat .....	13
	Healthy Fats.....	14
	Unhealthy Fats – Saturated Fat and Trans Fat .....	14
	Adipose Tissue .....	15
3.5	Nucleic Acids, DNA and RNA.....	15
3.6	Micronutrients – Vitamins and Minerals.....	16
3.7	Vitamins .....	16
	Fat Soluble Vitamins .....	17
	Water Soluble Vitamins .....	17
3.8	Minerals .....	17
	Five Important Micronutrients .....	17
3.9	Dietary Fibers .....	18

#### Chapter - 4

##### Cell Cycle and Cell Division ..... 19

4.1	Cell Cycle and Cell Division.....	19
4.2	Cell Cycle in Prokaryotes.....	19
4.3	Cell Cycle in Eukaryotes .....	19
	Significance of Mitosis .....	20
4.4	Meiosis.....	20
	Significance of Meiosis .....	21
	Difference between Mitosis and Meiosis.....	21

#### Chapter - 5

##### Genetics ..... 23

5.1	Genetics .....	23
-----	----------------	----

5.2	Inheritance – Mendel's Laws of Inheritance .....	23
	Mendel's Experiments on Inheritance .....	23
	Factors – Genes.....	23
	Pair of Alleles – Homozygous and Heterozygous .....	24
	Dominant and Recessive Factor .....	24
	Mendel Conducted Monohybrid and Dihybrid Cross Between Plants to Give Mendel's Laws of Inheritance.....	25
5.3	Mendel's Laws of Inheritance .....	25
	First Law or Law of Dominance.....	26
	Second Law or Law of Segregation .....	26
5.4.	Inheritance of Two Genes – Dihybrid Cross.....	27
	Law of Independent Assortment.....	27
5.5	Chromosomal Theory of Inheritance .....	27
5.6	Sex Determination, Genetic Disorders.....	27
	Sex Determination.....	27
	Sex Determination in Humans.....	28
5.7	Genetic Disorders.....	28
	Pedigree Analysis .....	28
	Genetic Disorders.....	29
	Mendelian Disorders.....	29
	Sickle-Cell Anaemia.....	29
	Thalassemia .....	29
	Chromosomal Disorders .....	29

## Chapter - 6

<b>Origin and Evolution of Life on Earth.....</b>		<b>32</b>
6.1	Origin of Life on Earth.....	32
6.2	Evolution of Life on Earth .....	32
	Biological Evolution.....	33
	A Brief Account of Evolution .....	33
	Origin and Evolution of Man.....	34
	Important Tissues .....	37

## Chapter - 7

<b>Human Physiology .....</b>	<b>37</b>
7.1 Human Digestive System.....	37
Alimentary Canal .....	37
Buccal Cavity or Oral Cavity – Teeth, Tongue, Saliva...	37
Teeth .....	37
Saliva .....	38
Tongue.....	38
Foodpipe/Oesophagus .....	38

	Stomach.....	38
	Small Intestine .....	39
	Large Intestine .....	39
	Digestive Glands .....	39
	Salivary Glands.....	39
	Liver.....	39
	Pancreas.....	40
7.2	Respiratory System.....	41
	Human Respiratory System .....	41
7.3	Body Fluids and Circulation.....	42
	Formed Elements.....	42
	Lymph (Tissue Fluid).....	42
	Blood Groups.....	43
	Circulatory System.....	43
	Human Circulatory System .....	43
	Cardiac Cycle.....	43
7.4	Excretory System, Kidney, Urine Formation .....	44
	Excretory Products and Their Elimination .....	44
	Human Excretory System.....	44
	Role of other Organs in Excretion .....	45
7.5	Locomotion and Movement .....	45
	Muscular and Skeletal System.....	45
	Muscular System – Muscle Types.....	46
	Skeletal System .....	46
7.6	Human Neural System, Human Brain .....	47
	Neural Control and Coordination .....	47
	Human Neural System .....	47
	Human Brain.....	48
	Human Eye (sensory organ which helps in coordination).....	49
7.7	Chemical Coordination and Integration .....	50
	Endocrine Glands and Hormones.....	50
	Pituitary Gland .....	50
	Hypothalamus.....	50
	Pineal Gland .....	51
	Thyroid Gland.....	51
	Parathyroid Gland.....	52
	Thymus .....	52
	Adrenal Gland.....	52
	Pancreas.....	53
	Testis.....	53
	Ovary.....	53
	Hormones of Heart, Kidney and Gastrointestinal Tract .....	53
7.8	Human Reproductive System .....	54
	Male Reproductive System .....	54
	Female Reproductive System .....	55

Pregnancy and Embryonic Development .....	56
Parturition and Lactation .....	56

## Chapter - 8

<b>Health and Disease.....</b>	<b>57</b>
8.1 Classification of Disease causing organisms.....	57
8.2 Diseases Caused by Microorganisms .....	57
Types of Acquired Immune Response .....	63

## Chapter - 9

<b>Plant Morphology .....</b>	<b>65</b>
9.1 Morphology of Flowering Plants.....	65
The Root System.....	65
The Stem System.....	67
The Leaf System .....	67
The Flower System.....	68
9.2 Anatomy of Flowering Plants.....	68
Epidermal Tissue System .....	69
The Ground Tissue System .....	69
The Vascular Tissue System .....	70
Monocotyledons (Monocots) and Dicotyledons (Dicots) .....	70

## Chapter - 10

<b>Plant Physiology.....</b>	<b>72</b>
10.1 Transport in Plants .....	72
10.2 Mineral Nutrition.....	74
Essential Mineral Elements .....	74
10.3 Photosynthesis In Higher Plants .....	75
Location of Photosynthesis .....	75
Types of Pigments Involved in Photosynthesis .....	75
Light and Dark Reactions .....	76
C3 Pathway and C4 Pathway.....	77
Photorespiration.....	78
Factors Affecting Photosynthesis.....	78
10.4 Plant Growth Regulators/Plant Hormones.....	79
Plant Hormones .....	79

## UNIT – II: PHYSICS

## Chapter - 11

<b>Units and Measurements.....</b>	<b>83</b>
11.1 Physical Quantities .....	83
11.2 Units .....	83

Fundamental or Base Units.....	83
Supplementary Units .....	83

## Chapter - 12

<b>Force and Laws of Motion .....</b>	<b>86</b>
12.1 Force.....	86
12.2 Fundamental or Basic Forces in Nature.....	86
12.3 Motion .....	87
12.3 Force and Motion Relation .....	88
12.4 Newton's Laws of Motion .....	88
Newton's First Law of Motion .....	88
Newton's Third Law of Motion .....	89
12.5 Common Forces in Mechanics .....	89
12.6 Circular Motion Forces.....	90
Centripetal Force .....	90
Centrifugal Force .....	90
Coriolis Force.....	90

## Chapter - 13

<b>Gravitation.....</b>	<b>92</b>
13.1 Gravitation .....	92
13.2 Universal Law of Gravitation (Newton's Law) .....	92
Acceleration Due to Gravity (g) .....	92
Relation Between 'G' and 'g' (Acceleration Due to Gravity) .....	92
Variations of g .....	92
Some Major Applications of Gravitational Force and Gravity .....	94
Kepler's Laws of Planetary Motion .....	94
Orbital Velocity.....	94
Escape Velocity / Escape Speed / second cosmic velocity .....	95

## Chapter - 14

<b>Work, Energy and Power .....</b>	<b>96</b>
14.1 Work.....	96
14.2 Energy .....	96
14.3 States of Energy .....	96
14.4 Kinetic Energy .....	96
14.5 Potential Energy .....	97
Mechanical Energy .....	97
14.6 Work-Energy Theorem .....	97
14.7 Transformation of Energy .....	97

14.8	Law of Conservation of Energy .....	97
14.9	Einstein's Mass-Energy Equivalence .....	98
14.10	Power.....	98

## Chapter - 15

### Mechanical Properties of Fluids ..... 99

15.1	Thrust and Pressure .....	99
15.2	Density .....	99
15.3	Relative Density .....	99
15.4	Fluid Properties and Laws Associated with them .....	99
	Pressure of Fluid .....	99
	Pascal's Law .....	100
	Buoyancy and Buoyant Force.....	100
	Archimedes Principle (Physical Law of Buoyancy).....	101
	Surface Tension .....	101
	Surface Energy .....	103
	Angle of Contact.....	103
	Capillary Rise.....	103

## Chapter - 16

### Heat, Temperature and Thermodynamics..... 106

16.1	Heat .....	106
16.2	Temperature.....	106
16.3	Humidity.....	106
	Absolute Humidity.....	106
	Relative Humidity .....	106
16.4	Specific Heat Capacity .....	106
16.5	Latent Heat .....	107
16.6	Heat Transfer .....	107
	Conduction .....	107
	Convection.....	108
	Radiation.....	108
16.7	Thermodynamics .....	109
	Laws of Thermodynamics.....	109

## Chapter - 17

### Wave Motion and Sound..... 111

17.1	Types of Waves.....	111
17.2	Types of Mechanical Waves .....	111
	Longitudinal Waves.....	111
	Transverse Waves.....	111

	Electromagnetic waves or Non-mechanical waves.....	112
--	--	-----

17.3	Terms Related to Waves .....	112
	Sound Waves .....	112
	Characteristics of Sound .....	113
	Speed of Sound in Different Media .....	113
	Reflection of Sound.....	114
	Range of Hearing and Types of Sounds .....	114
17.4	Applications of Ultrasound.....	115
17.5	Beats .....	116
17.6	Doppler Effect in Sound.....	116
17.7	Electromagnetic Waves (EM Waves) .....	116
17.8	Electromagnetic Spectrum .....	117

## Chapter - 18

### Optics ..... 119

18.1	Properties of Light .....	119
18.2	Reflection of Light.....	119
	Laws of reflection.....	119
	Mirror .....	119
	Plane Mirror .....	119
	Spherical Mirrors.....	120
	Uses of Mirrors.....	120
18.3	Scattering of Light .....	121
18.4	Refraction .....	121
	Total Internal Reflection.....	122
	Refraction by Spherical Lenses .....	123
	Convex or Converging Lens .....	123
	Image Formation by Lenses .....	124
	Uses of Lens .....	124
18.5	Dispersion of Light.....	125
18.6	Diffraction of Light.....	126
18.7	Doppler Effect in Light.....	127

## Chapter - 19

### Electrostatics and Current Electricity ..... 128

19.1	Electric Charge .....	128
	Types of Charges.....	128
	Properties of Electric Charges .....	128
19.2	Coulomb's Law .....	129
19.3	Electric Field .....	129
	Electric Field of hollow conductor .....	129
19.4	Different Types of Conductivity .....	129
	Conductors .....	129

Insulators .....	130
Semiconductors .....	130
Superconductors .....	130
<b>19.5 Electric Current .....</b>	<b>131</b>
Types of Electric Current .....	131
Ohm's Law .....	131
Resistance .....	132
Heating Effects of Electric Current .....	133
<b>19.6 Electric Cell .....</b>	<b>133</b>

## Chapter - 20

<b>Magnetism .....</b>	<b>135</b>
20.1 Magnet .....	135
20.2 Magnetic Field .....	135
Magnetic Properties of Materials .....	136
Permanent Magnets and Electromagnets .....	136
Earth's Magnetism .....	137

## UNIT - III: CHEMISTRY

### Chapter - 21

<b>Matter and Its States .....</b>	<b>140</b>
21.1 Physical Nature of Matter .....	140
21.2 States of Matter .....	140
Two More States of Matter .....	140

### Chapter - 22

<b>Structure of Atom .....</b>	<b>143</b>
22.1 Dalton's Atomic Theory .....	143
22.2 Sub-atomic Particles .....	143
Fundamental Particles .....	143
Non-Fundamental Particles .....	144
22.3 Atomic Models .....	144
Thomson Model of Atom .....	144
Rutherford's Model of Atom .....	145
Bohr's Model of an Atom .....	145
Bohr Bury Scheme .....	146
Valency .....	146

### Chapter - 23

<b>Classification of Elements .....</b>	<b>148</b>
23.1 Classification of Elements and Periodicity in Properties .....	148

23.2 Periodic Classification .....	148
23.3 Mendeleev's Periodic Table .....	148
23.4 Modern Periodic Table .....	149
Characteristics of Modern Periodic Table .....	149
23.5 Trends in the Modern Periodic Table .....	151

## Chapter - 24

<b>Bonding and Chemical Reactions .....</b>	<b>153</b>
24.1 Chemical Bond .....	153
24.2 Kossel-Lewis Approach to Chemical Bonding .....	153
24.3 Electronic Theory of Chemical Bonding (Octet Rule) .....	153
Types of Bonding .....	153
Ionic Bond .....	153
Covalent Bond .....	153
Coordinate Bond/Dative Bond .....	154
Hydrogen Bonding .....	154
Van der Waal's Forces .....	155
24.4 Chemical Reactions .....	155
Some Important Types of Chemical Reactions .....	155

## Chapter - 25

<b>Chemistry in Everyday Life .....</b>	<b>158</b>
25.1 Drugs .....	158
Classification of Drugs on the Basis of Therapeutic Action .....	158
25.2 Chemicals in Food .....	159
Artificial Sweetening Agents .....	159
Food Preservatives .....	159
Colloidal Solutions and Emulsions .....	159
Cleansing Agents .....	161
25.3 Polymers .....	163
Plastics .....	163
Polythene .....	164
Teflon .....	165
Polyvinyl Chloride (PVC) .....	165
Bakelite .....	165
Melamine .....	165
Synthetic Fibres .....	165
Rubber .....	166
25.4 Acids, Bases, Salts and pH .....	166
Uses of Acids in Everyday Life .....	167
Uses of Bases in Everyday Life .....	167
Uses of Salts in Everyday Life .....	168
Importance of pH in Everyday Life .....	168

25.5	Some Important Fuels and their Uses.....	168
	Coal .....	169
	Petroleum.....	170
	Natural Gas.....	170
	Liquified Petroleum Gas (LPG) .....	171
	Bio gas or Gobar gas .....	171
	Water Gas or Syngas .....	171
	Petrol.....	171
	Diesel.....	172
	Brent Crude Oil .....	172

Cell and Battery .....	172
Different Types of Batteries.....	173
Sodium Ion Battery .....	175
Fuel Cell technology .....	175

## Chapter - 26

### Miscellaneous ..... 178

26.1	What Are Colligative Properties?.....	179
	Colligative Properties Examples .....	179
	Different Types of Colligative Properties of Solution...	179







# Unit

## Biology

1. Diversity World .....	2
2. Cell, Building Block, Genetics .....	5
3. Biomolecules .....	11
4. Cell Cycle and Cell Division .....	19
5. Genetics.....	23
6. Origin and Evolution of Life on Earth .....	32
7. Human Physiology .....	37
8. Health and Disease .....	57
9. Plant Morphology .....	65
10. Plant Physiology .....	72

# CHAPTER

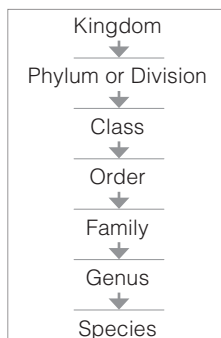
# 1

# DIVERSITY WORLD

## 1.1 Classification

Scientists have estimated that there are around 8.7 million species of plants and animals in existence out of which nearly 1.2 million species have already been identified and described so far.

This number is so huge that it is extremely difficult to study each and every single species separately. Thus, species were grouped into convenient categories based on some easily observable characters. This process is known as classification. Based on characteristics, all living organisms can be classified into different taxa. This process of classification is taxonomy



**Figure:** Taxonomic categories showing hierarchial arrangement in descending order

- **Species:** It comprises *related organisms* that share *common characteristics* and are *capable of interbreeding*.

- **Genus:** Genus comprises a group of *related species* which has *more characters in common in comparison to species of other genera*
- **Family:** It has a group of related genera with still a *smaller number of similarities* as *compared to genus and species*
- **Order:** It is the assemblage of families which exhibit a few similar characters. The similar characters are less in number as compared to different genera included in a family
- **Class:** This category includes related orders. For example, order Primata comprising monkey, gorilla and gibbon is placed in class Mammalia along with order Carnivora that includes animals like tiger, cat and dog.
- **Phylum/Division:** Classes comprising animals like fishes, amphibians, reptiles, birds along with mammals constitute the next higher category called Phylum. In case of plants, classes with a few similar characters are assigned to a higher category called Division
- **Kingdom:** All animals belonging to various phyla are assigned to the highest category called Kingdom Animalia in the classification system of animals. The Kingdom Plantae, on the other hand, is distinct, and comprises all plants from various divisions.

Common	Biological	Genus	Family	Order	Class	Phylum/ Division
Man	Homo sapiens	Homo	Hominidae	Primates	Mammalia	Chordata
Housefly	Musca domestica	Musca	Muscidae	Diptera	Insecta	Arthropoda
Mango	Mangifera indica	Mangifera	Anacardiaceae	Sapindales	Dictoyledonae	Angiospermae
Wheat	Triticum aestivum	Triticum	Poaceae	Poales	Monocyledonae	Angiospermae

## 1.2 Kingdom Classification

- Initially **Linnaeus** proposed two kingdom classification i.e., *plantae* and *animaliae* in his book *systema naturae*.
- After various evolutions, **R.H. Whittaker** (1969) proposed a *Five Kingdom Classification*.
- The kingdoms defined by him were named Monera, Protista, Fungi, Plantae and Animalia.

- The main **criteria for classification** used by him included *cell structure, body organisation, mode of nutrition, reproduction and phylogenetic relationships*.
- In the five kingdom classification of Whittaker there is **no mention of lichens and some acellular organisms like viruses, viroids (infectious agent) and prions (infectious agent)**.

**Table:** Kingdom Classification and characteristics

Five Kingdoms					
Characters	Monera	Protista	Fungi	Plantae	Animalia
<b>Cell type</b>	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	<b>Eukaryotic</b>
<b>Cell wall</b>	Noncellulosic (Polysaccharide + amino acid)	Present in some	Present with chitin	Present (cellulose)	Absent
<b>Nuclear membrane</b>	Absent	Present	Present	Present	Present
<b>Body organisation</b>	Cellular	Cellular	Multicellular/ loose tissue	Tissue/organ	Tissue/organ/ organ system
<b>Mode of nutrition</b>	Autotrophic (chemosynthetic and photosynthetic) and Heterotrophic (saprophytic/parasitic)	Autotrophic (Photosynthetic) and Heterotrophic	Heterotrophic* (Saprophytic/ Parasitic)	Autotrophic** (Photosynthetic)	Heterotrophic (Holozoic/ Saprophytic etc.)
<b>Examples</b>	Bacteria are the sole members of the Kingdom Monera	Members of Protista are primarily aquatic. Dinoflagellates, Euglenoids, Slime moulds and Protozoans come under this	Mushroom, Mucor etc.	All plants except fungi and members of Monera and Protista having cell walls	Almost all animals except protozoan

\* **Heterotrophic:** Heterotrophic nutrition is a mode of nutrition in which organisms depend upon other organisms for food to survive. They can't make their own food like Green plants. Heterotrophic organisms have to take in all the organic substances they need to survive.

\*\* **Autotrophic:** Autotrophic nutrition is a process where an organism prepares its own food from a simple inorganic material like water, mineral salts and carbon dioxide in the presence of sunlight."

**Monera:** It includes all prokaryotic organism like bacteria, cyanobacteria and archaeobacteria. Filamentous bacteria also come under this kingdom. All organism of this kingdom are microscopic.

**Protista:** This includes unicellular forms like Amoeba that are usually found in aquatic habitats. On the basis of mode of nutrition they are autotrophic, parasitic and saprophytic. Diatoms, flagellates and protozoa come under this kingdom.

\*Euglena have both *heterotrophic* and *autotrophic* mode of nutrition. So, it is placed between plant and animal.

**Fungi:** This kingdom includes non-green plants. It has saprophytic nutrition grow on dead and decaying organic matter. The cell wall is composed of chitin.

**Example:** Mushroom, mucor, etc.

**Plantae:** This kingdom includes all plants except algae, diatoms, fungi and member of monera and protista.

**Animalia:** Almost all animal comes under this kingdom except protozoans.

## 1.3 Kingdom Plantae

- Plantae includes algae, bryophytes, pteridophytes, gymnosperms and angiosperms



## Algae

- Algae are *chlorophyll-bearing*, simple, thalloid, autotrophic and *largely aquatic* (both fresh water and marine) organisms.

## Bryophytes

- The word bryophyte is the collective term for *mosses, hornworts and liverworts*.
- They are *spore-producing*, rather than seed-producing, plants and they *are all without flowers*.

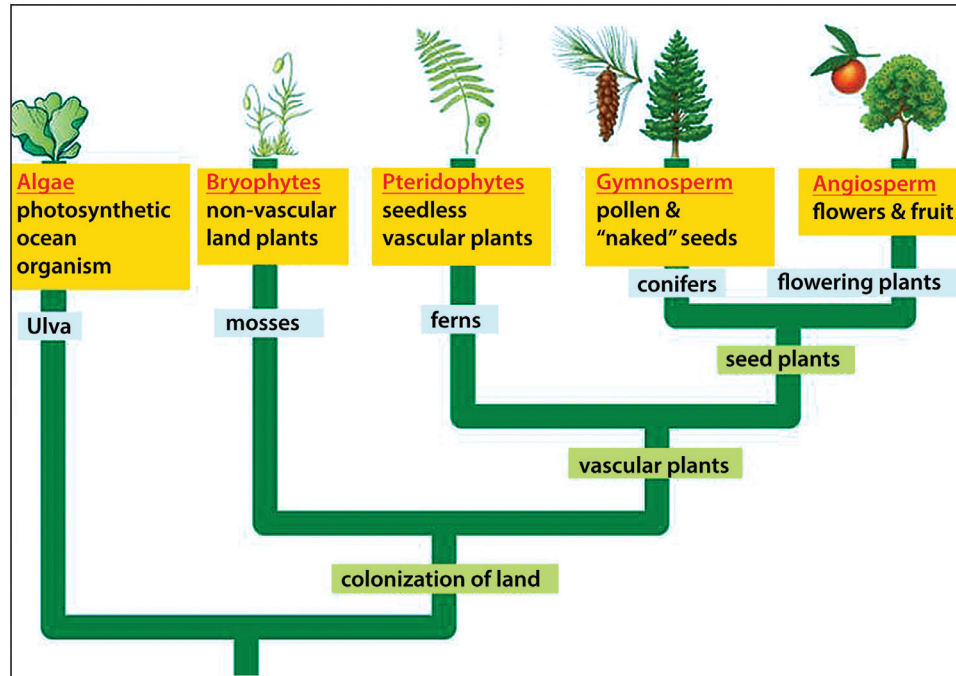


Figure: Evolution of plants from algae to angiosperms

- They are also called **amphibians of the plant kingdom** because these plants can *live in soil* but are dependent on *water for sexual reproduction*.

## Pteridophytes

- These include *horsetails* and *ferns*
- Evolutionarily, they are the **first terrestrial plants to possess vascular tissues** – xylem and phloem.

**Xylem** tissue transports water and nutrients from the roots to different parts of the plant, and also plays a role in structural support in the stem.

**Phloem** tissue transports organic compounds from the site of photosynthesis to other parts of the plant.

- They are also *spore-producing*, rather than seed-producing, plants and they are **all without flowers**.

## Gymnosperms

These include medium-sized trees or tall trees and shrubs

These are *vascular plants* in which the *ovules are not enclosed by any ovary wall* and remain exposed and thus have naked seeds.

**Examples:** conifers, pines, firs, cycads etc.

## Angiosperms

Angiosperms are plants that *produce flowers* and bear their *seeds in fruits*.

They are the largest and most diverse group within the kingdom Plantae.

**Examples:** lilies, orchids, grasses, peas, roses, sunflower, apple, mango etc.

■■■■



## TRY SOME QUESTIONS

- Which one of the following sets of elements was primarily responsible for the origin of life on the Earth ? [CSE Prelims : 2012]  
 (a) Hydrogen, Oxygen, Sodium  
 (b) Carbon, Hydrogen, Nitrogen

- Oxygen, Calcium, Phosphorus
- Carbon, Hydrogen, Potassium

Ans. (b)

# CHAPTER 2

# CELL, BUILDING BLOCK, GENETICS

## 2.1 Cell

Cell is the fundamental structural and *functional unit of all living organisms*. It is the basic unit of life that makes an organism living. All organisms are composed of cells. Some are composed of a single cell and are called unicellular organisms while others, like us, composed of many cells, are called multicellular organisms.

**Anton Von Leeuwenhoek** first saw and described a live cell and is called the *father of microbiology*. Later, **Robert Hooke** discovered and coined the term cell in 1668. Then, **Robert Brown** discovered the cell nucleus in 1831.

## 2.2 Cell Theory

- **Schleiden** and **Schwann** together formulated the cell theory which was refined by **Rudolf Virchow**.

- Cell theory states that –
  - ♦ All living organisms are composed of cells and products of cells.
  - ♦ All cells arise from pre-existing cells.

## 2.3 Types of Cells

- Based on the structure and functions, cells are broadly classified **as Prokaryotic cell and Eukaryotic cell**.
- **Prokaryotes** are simple, small cells, **whereas eukaryotic cells** are complex, large structured.
- **Prokaryotic cells do not have a well-defined nucleus** but DNA molecule is located in the cell, termed as nucleoid, **whereas eukaryotic cells** have a well-defined nucleus, where genetic material is stored. Prokaryotic cells usually do not have Organelles, but if present any, they are not membrane bound. Eukaryotic Cells possess organelles which are membrane bound and have specific function.

**Table:** Difference between Prokaryotic and Eukaryotic Cells

Basis for Comparison	Prokaryotic Cells	Eukaryotic Cells
<b>Organelles</b>	Usually not present. But if present any, they are not membrane bound.	Organelles are membrane bound and are specific in function.
<b>Size</b>	0.5-3um (Small)	2-100um (large)
<b>Kind of Cell</b>	Single-cell (Less complex)	Multicellular (More complex)
<b>Cell Wall</b>	Cell wall present	Usually cell wall absent, if present (only in plant cells and fungus)
<b>Presence of Nucleus</b>	Well-defined nucleus is <b>absent</b> , rather 'nucleoid' is present which is an open region containing DNA.	A well-defined nucleus is present enclosed within nuclear membrane.
<b>Shape of DNA</b>	Circular, double-stranded DNA.	Linear, double-stranded DNA.
<b>No. of chromosomes</b>	Only one chromosome present	More than one chromosome present.
<b>Cell Divison</b>	By Binary Fission or Budding	By Mitosis and meiosis
<b>Examples</b>	Archaeabacteria, Bacteria	Plants and Animals.

## 2.4 Structure of Cell

- A typical cell consists of **three parts/cell organelles**:
  - ♦ **Cell membrane**: It is the *outermost covering of the cell* that separates the contents of the cell from its external environment.
  - ♦ **Nucleus**: *Eukaryotic* have membrane bound nuclei whereas *prokaryotic cells lack a membrane bound nucleus*
  - ♦ **Cytoplasm**: It is the jellylike semi-fluid substance present between the cell membrane and the nucleus.
- However, within the cytoplasm **the eukaryotic cells have other membrane bound** distinct structures **called organelles** like the endoplasmic reticulum (ER), the golgi complex, lysosomes, mitochondria, microbodies and vacuoles.
  - ♦ **The prokaryotic cells lack** such membrane bound organelles.
- An organelle** is a subcellular structure that has one or more specific jobs to perform in the cell, much like an organ does in the body.

- The plasma membrane is *flexible* and is made up of organic molecules called **lipids and proteins**.
- Plasma membrane is a **living thin selectively permeable membrane** [The plasma membrane is porous and allows the movement of substances or materials both inward and outward].

### Cell Wall

- It is the rigid **nonliving permeable** wall that surrounds the plasma membrane of the plant cells. Cell wall is *absent in animals*.
- It is a rigid outer covering and lies outside the plasma membrane.
- The plant cell wall is mainly composed of **cellulose**. Cellulose is a complex substance and provides structural strength to plants.
- It provides a structural framework to support plant growth and acts as the first line of defense when the plant encounters pathogens.
- It thus renders **mechanical strength** and maintains the **shape and expansion** of the cell.
- It regulates the intercellular transport and provide a semi-permeable surface for molecules to pass in and out of the cell.

## 2.5 Various Cell Organelles

### Cell Organelles

#### Plasma Membrane or Cell Membrane

- Plasma membrane is the outermost covering of the cell that separates the contents of the cell from its external environment. In plant cells it is found within cell wall.

### Cytoplasm

- It is the jellylike semi-fluid substance present *between the cell membrane and the nucleus*.
- It is mainly composed of water, salts, and proteins.
- It is the main arena of cellular activities in both the plant and animal cells.

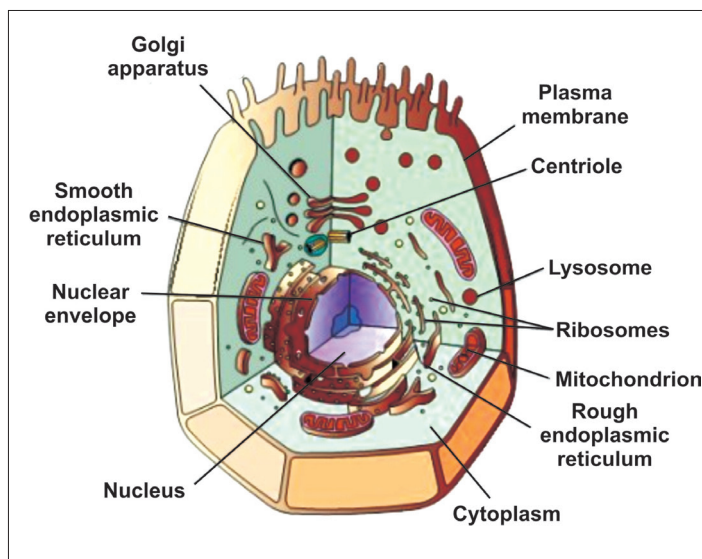


Figure: Animal Cell

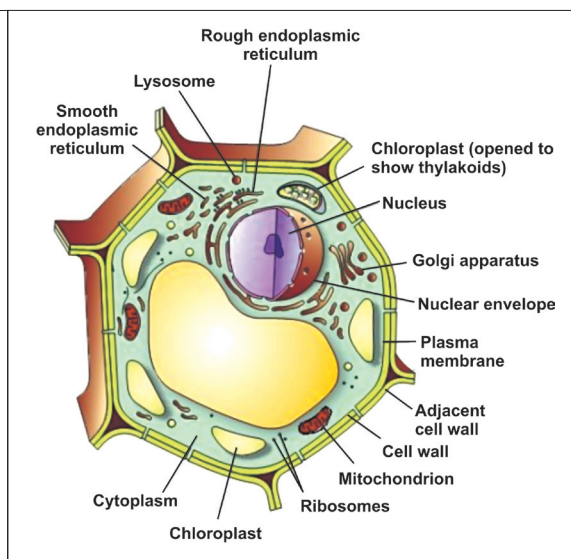


Figure: Plant Cell

- Various chemical reactions occur in it to keep the cell in the 'living state'. The entire content of a living cell is known as **protoplasm** [*cytoplasm + nucleus*]. It includes the cytoplasm and the nucleus. Protoplasm is called the living substance of the cell.
- All of the organelles in eukaryotic cells, such as the nucleus, endoplasmic reticulum, and mitochondria, are located in the cytoplasm.

#### Difference between Cytoplasm and Protoplasm

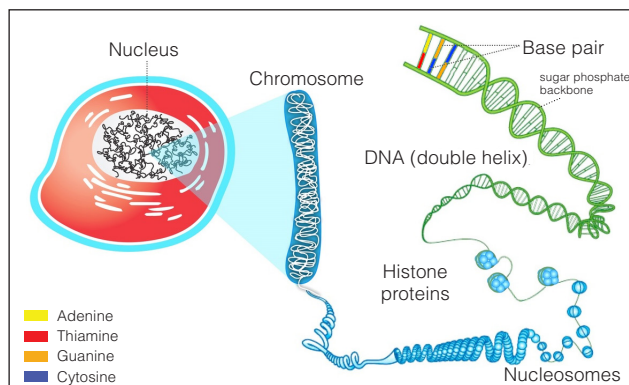
- The protoplasm is bounded by a cell membrane from all sides. While Cytoplasm is surrounding the nucleus in a cell.
- The cytoplasm contains organelles, Cytosol, enzymes, proteins Whereas, the Protoplasm contains Cytoplasm and nucleus.
- The cytoplasm is composed of water, salt, and protein whereas the Protoplasm is composed of liquids, carbohydrates, proteins, and a nucleus.

### Nucleus

- The nucleus is a highly specialized organelle that serves as the information processing and *administrative center of the cell*.
- This organelle has **two major functions**:
  - ♦ It **stores** the cell's hereditary material, or **DNA**, and
  - ♦ It **coordinates the cell's activities**, which include growth, intermediary metabolism, protein synthesis, and reproduction (cell division).
- Only the cells of advanced organisms, known as eukaryotes, have a nucleus.
- **The nucleolus**: It is a *membrane-less organelle within the nucleus that manufactures Ribosomal RNA*. These RNA's are then transferred to outside the cells to make Ribosomes (cell's protein-producing structures).
- **The nucleoid (meaning nucleus-like)**: It is an *irregularly-shaped* region within the cell of a *prokaryote* that contains all or most of the *genetic material*.
  - ♦ This term is given as in prokaryotes, there is poorly defined nucleus due to absence of nuclear membrane.

### Chromosomes

- In the nucleus of each cell, the DNA molecule is packaged into thread-like structures called chromosomes.
- Chromosomes contain information for inheritance of features from parents to next generation in the form of DNA (deoxyribo nucleic acid).
- Chromosomes are composed of DNA and DNA is wrapped around Proteins called histones.
- When the cell is not dividing chromosomes are not visible in the cell's nucleus. However DNA is present as part of chromatin material. Chromatin material is visible as entangled mass of thread like structures.
- Whenever the cell is about to divide, the chromatin material gets organised into chromosomes which are then visible as rod shaped structures.
- Different organisms have different numbers of chromosomes.



**Figure:** Depiction of chromosomes and DNA

- Humans have 23 pairs of chromosomes--22 pairs of numbered chromosomes, called autosomes, and one pair of sex chromosomes, X and Y called allosomes.
- Each parent contributes one chromosome to each pair so that offspring get half of their chromosomes from their mother and half from their father.
- A **chromatid** is one of two identical halves of a replicated chromosome.
- A centromere is a constricted region of a chromosome that separates it into a short arm (p) and a long arm (q).
- A telomere is the end of a chromosome.

### Vacuoles

- Empty structure in the cytoplasm is called vacuole. It could be single and big as in an onion cell (plant cell). Cheek cells (animal cells) have smaller vacuoles.



- *Large vacuoles* are common in *plant cells*. Vacuoles in animal cells are much smaller. Many substances of importance in the life of the plant cell are stored in vacuoles. These include amino acids, sugars, various organic acids and some proteins.
- Vacuoles are **storage sacs** and in *plant cells vacuoles are full of cell sap* and provide turgidity [swollen and distended or congested] and rigidity to the cell.
- In single celled organisms like amoeba, the food vacuole contains the food items that the amoeba has consumed.
- In some unicellular organisms, specialized vacuoles also play important roles in expelling excess water and some wastes from the cell

### Endoplasmic Reticulum (ER)

- The endoplasmic reticulum (ER) is a large *network of membrane bound tubes and sheets*. It looks like long tubules or round or long bags (vesicles).
- It *contains ribosomes*, which are the sites of protein manufacture.
- The manufactured proteins are then sent to various places in the cell depending on need, using the ER.
- It also helps in the *manufacture of fat molecules, or lipids*, important for cell function.
- It can also play a crucial role in *detoxifying* many *poisons and drugs*.

### Golgi Apparatus or Golgi Complex

- The golgi apparatus consists of a system of *membrane bound vesicles* arranged approximately parallel to each other in stacks called cisterns.
- These *membranes* often *have connections* with the *membranes of ER* and therefore constitute another portion of a complex cellular membrane system.
- The material synthesized near the ER is packaged and dispatched to various targets inside and outside the cell through the golgi apparatus.
- Its **functions** include the *storage, modification and packaging of products in vesicles*.
- In some cases, complex sugars may be made from simple sugars in the golgi apparatus.
- The golgi apparatus is also involved in the *formation of lysosomes*.

### Lysosomes

- Lysosomes are a kind of *waste disposal system of the cell*.
- Lysosomes help to keep the cell clean by *digesting any foreign material as well as worn out cell organelles*.
- Foreign materials entering the cell, such as bacteria or food, as well as old organelles end up in the lysosomes, which break them up into small pieces. Lysosomes are able to do this because they *contain powerful digestive enzymes* capable of breaking down all organic material.
- *Lysosomes are also known as the 'suicidal bags' of a cell*. During the disturbance in cellular metabolism, for example, *when the cell gets damaged, lysosomes may burst and the enzymes digest their own cell*.

### Mitochondria

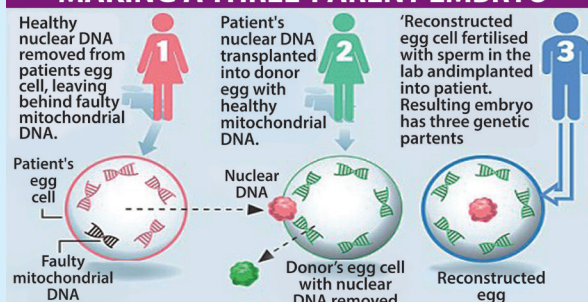
- Mitochondria are known as the **powerhouse of the cell**.
- The energy required for various chemical activities needed for life is released by mitochondria in the form of ATP (Adenosine Triphosphate) molecules. **(It is an analogy that if Mitochondria is the Power Plant. ATP is the Electricity).**
- ATP is known as the energy currency of the cell.
- The body uses energy stored in ATP for making new chemical compounds and for mechanical work.
- Mitochondria are strange organelles in the sense that they *have their own DNA and ribosomes*. Therefore, mitochondria are able to make *some of their own proteins* [ribosomes prepare proteins].
- Mitochondria are found in the cells of nearly every eukaryotic organism, including plants and animals. Cells that require a lot of energy, such as muscle cells, can contain hundreds or thousands of mitochondria. A few types of cells, such as *red blood cells, lack mitochondria entirely*.
- Mitochondrial diseases are chronic (long-term), genetic, often inherited disorders that occur when mitochondria fail to produce enough energy for the body to function properly.  
e.g., *Leigh's Syndrome*, a *mitochondrial disorder* that causes severe *neurodegeneration*.  
As these diseases can not be treated, *mitochondrial transfer* is done to *prevent* its *inheritance in the foetus*.



## Mitochondrial Transfer

Mitochondrial transfer works by replacing the damaged mitochondria in the mother's egg with healthy mitochondria from another woman's donor egg. Thus, it is called **3 parent baby** as a small fraction comes from the mitochondria of the donor egg or third parent in addition to the majority of the child's DNA is from his parents.

### MAKING A THREE-PARENT EMBRYO

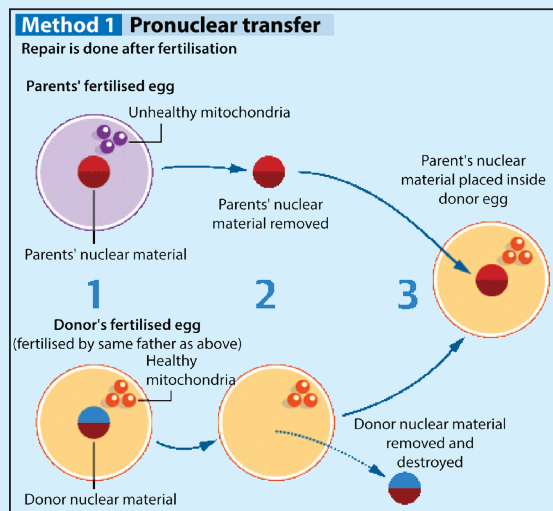


Mitochondrial transfer is of two types – Pronuclear transfer and Spindle transfer.

**Pronucleus** is the nucleus of a sperm or an egg cell during the process of fertilization. **Spindle fibers** are protein structures that form during cell division and divide the genetic material in a cell.

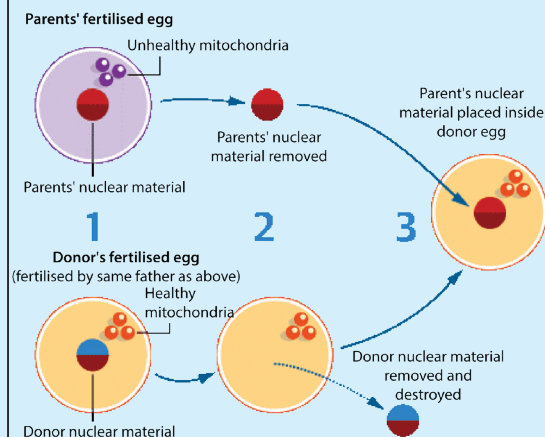
In **pronuclear transfer**, the mother's egg is first fertilized with the sperm which produces a zygote. The pronuclei of the egg and sperm are then removed from the zygote and inserted into a donor egg that has been fertilized and has had its own nucleus removed. The zygote derived from the donor egg is then implanted into the mother's uterus.

In **maternal spindle transfer**, the technique is similar to pronuclear transfer but it uses unfertilized eggs instead of the fertilized zygote used in Pronuclear Transfer.



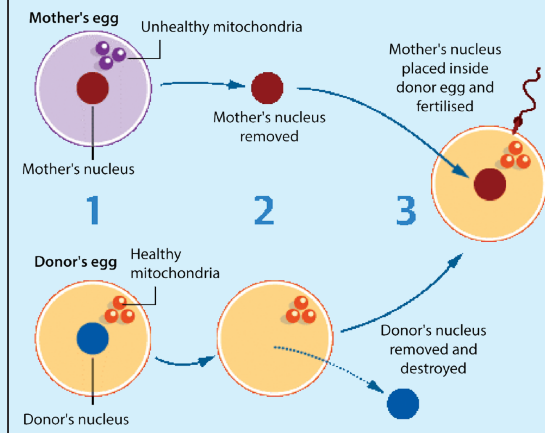
### Method 1 Pronuclear transfer

Repair is done after fertilisation



### Method 2 Maternal spindle transfer

Repair is done before fertilisation



The major issue in these techniques is that it makes genetic modifications to an embryo that will pass down to all future generations. That raises the risk of unforeseen complications affecting generations to come.

## Plastids

- Plastids are *double membrane bound organelles* involved in the *synthesis and storage of food*, and are commonly found within the cells of photosynthetic organisms, like *plants*
- These are several small colored bodies scattered in the cytoplasm of the leaf cells. They are *present only in plant cells*.
- There are **three types** of plastids
  - Chromoplasts (coloured plastids)
  - Leucoplasts (white or colourless plastids)
  - Chloroplast (green)
- Chloroplasts:** They are *green colored* plastids due to the *presence of chlorophyll*. They are involved in the process of photosynthesis.

- **Chromoplasts:** They are *carotenoid accumulating plastids* and contribute to the bright red, orange, and yellow colors to many fruits.
  - ♦ It thus *attracts animals* to *act as seed dispersers*.
  - ♦ They originate as chloroplasts and transit into chromoplasts.
- **Leucoplasts:** They are *colorless* plastids found in endosperm, tubers, roots and other non-photosynthetic tissues of plants.
  - ♦ They are primarily organelles in which *materials such as starch, oils and protein granules are stored*.
- Plastids are similar to mitochondria in external structure. Like the mitochondria, plastids also have *their own DNA and ribosomes*.
- Most of these plastid types can interconvert upon environmentally induced changes in plant and tissue development.

During these interconversions' nucleoids change in morphology, size and location within the organelle.

## 2.6 Differences between Plant Cell and Animal Cell

- **Both plant and animal cells are eukaryotic**, so they contain membrane-bound organelles like the nucleus and mitochondria.
  - ♦ **Structures that are common** to plant and animal cells are the cell membrane, nucleus, mitochondria, and vacuoles.
- However, there are some major structural differences between the cells of plants and animals.

**Table:** comparison of Plant Cell vs. Animal Cell

Basis for Comparison	Plant Cell	Animal Cell
<b>Cell wall</b>	<b>The cell wall</b> surrounds the <b>cell membrane</b> .	Animal cells simply have a cell membrane, <b>but no cell wall</b> .
<b>Mitochondria and Chloroplasts</b>	Both animal and plant cells have mitochondria, <b>but only plant cells have chloroplasts</b> .	<b>Only Mitochondria</b> is present.
<b>Centrosome and Centrioles</b>	These are absent in plant cells.	These are present in animal cells. (Centrosome is the region present adjacent the nucleus and in cytoplasm which contain centrioles.)
<b>Vacuoles</b>	It contains a large singular vacuole	It has many smaller vacuoles
<b>Shape</b>	It has square or rectangular shape	It has an irregular or round shape.

■■■■



### TRY SOME QUESTIONS

1. **A plant cell wall is mainly composed of**  
 (a) Protein (b) Cellulose  
 (c) Lipid (d) Starch

**Ans.** (b)

2. **The cell is not applied for**  
 (a) Algae (b) Bacteria  
 (c) Virus (d) Fungi

**Ans.** (c)

3. **The Major difference between the human cheek cells and onion peel cells is \_\_\_\_\_?**  
 (a) Presence of mitochondria in onion peel  
 (b) Absence of plasma membrane in cheek cells  
 (c) Cell wall presence in onion peel cells  
 (d) Absence of endoplasmic reticulum in cheek cells

**Ans.** (c)