CALICUT UNIVERSITY

FIRST SEMESTER

FOUR-YEAR UNDER GRADUATE PROGRAMME (CU-FYUGP)

BASICS IN CELLULAR PHYSIOLOGY

FYUGP PSYCHOLOGY-MINOR

PREPARED BY

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DEPARTMENT OF PSYCHOLOGY

CPA COLLEGE OF GLOBAL STUDIES, PUTHANATHANI

Group name: Human Physiology - 1

Course code	PSG1MN101				
Course title	Basics in cellular physiology				
Type of course	Minor				
Semester	I				
Academic level	100-199				
Course details	Credit	Lecture per week	Tutorial per week	Practical per week	Total hours
	4	3		2	75
Pre requisites	+2/ VHSC or the following online courses. 1. https://www.coursera.org/learn/physiology 2. https://learn.utoronto.ca/programs-courses/courses/2159-basic-human-physiology 3. https://www.ivyroses.com/Revise/AnatomyPhysiology/index.php 4. https://www.medicalnewstoday.com/articles/organs-in-the-body#organ-systems 5. https://www.cartercenter.org/resources/pdfs/health/ephti/library/lecture notes/health science students/physiologypti.pdf https://www.classcentral.com/classroom/youtube-anatomy-physiology-45834/60c82bd43739c				
Course objectives	The course aims to students delve into topics such as cell biology, Mendelian inheritance, genetic disorders, and microscopy, gaining both theoretical knowledge and practical skills essential for further studies or careers in biology-related fields.				

MODULE 1: CYTOLOGY (15 hr)

Unit 1: Cellular organization (10 hr) -Cell theory, cell principle; Cell structure, plasma membrane (fluid mosaic model), Structure and function of cell organelles (Mitochondria, ribosome, ER, Golgi bodies, Lysosomes, cytoskeleton and interphase nucleus); Cell inclusions-brief description of the structure of carbohydrates, lipids and proteins; Unicellularity to multicellularity, differentiation. Brief mention of spatial and temporal control of gene activity: Tissues- brief description of major types.

Unit 2: . Cell division (5 hr)- Cell cycle: G1, S, G2 and M phases, Checkpoints Go Phase; Mitosis; Description of all stages and significance; Meiosis. Description of all stages and significance.

MODULE 2: GENES AND CHROMOSOMES (12 hr)

Unit 1: DNA, the genetic material (5 hr): Structure of DNA, DNA replication- Semiconservative method, Okazaki fragments, leading strand, Lagging strand, the role of enzymes in DNA replication
Unit 2: Concept of a gene (3 hr) - Classical and modern concept, genetic code, introns, exons.

Unit 3: Morphology of chromosomes (4 hr): Size, shape, karyotype, ideogram, kinds of chromosomes; Linkage and crossing over, sex-linked chromosomes

MODULE 3: ELEMENTS OF HEREDITY AND VARIATION (12 hr)

Unit 1: Mendelian principles (5 hr): Mendel's work and laws of inheritance (monohybrid cross, dihybrid cross, test cross). Brief explanation of terms-alleles, homozygosity, heterozygosity, genotype, phenotype.
Unit 2: Non Mendelian inheritance patterns (7 hr): Brief description of other patterns of inheritance and genotype expression-incomplete dominance, co-dominance, multiple alleles, epistasis, pleiotropy.

MODULE: 4 MUTATIONS AND GENETIC DISORDERS (6 hr)

Unit 1: Mutations (3 hr): Gene Mutation-Kinds of mutation, classification (Somatic, gametic, point, spontaneous, induced, dominant, recessive and silent mutations). Gene mutation disorders - albinism, phenylketonuria, alkaptonuria, galactosemia, brachydactyly.
Unit 2: Chromosomal anomalies (3 hr): Autosomal anomalies - Down's syndrome, Edward's syndrome, Cri du chat syndrome. Sex chromosomal anomalies - Klinefelter's syndrome and Turner's syndrome.

MODULE 5: PRACTICALS (1 CREDIT, 30 hr) MANDATORY EXPERIMENTS

1. 1 Operation and maintenance of Microscopes (Simple and Compound)
2. Demonstration and identification of different tissues using charts.
3. Study of Mitosis and Meosis using suitable charts.
4. Experiments on monohybrid and dihybrid cross (Mendelian inheritance).

Of the remaining experiments any 4 can be selected by the Institution from the following list. Two experiments other than the listed should be selected by the Supervising teacher and introduced to the students.

Virtual Labs (Suggestive sites)

5. Study of different types of tissues using permanent slides.
6. Determination of human blood group using ABD antisera.
1. Demonstration of Meiosis using grasshopper testes.
8. Study on models of DNA and RNA structure.
9. Study of normal human karyotype (Male & Female).
10. Study of autosomal anomalies (Down's, Edward's and Cri du-chat syndrome).
11. Study of sex chromosomal anomalies (Klinefelter's & Turner's syndrome).
12. Simple Mendelian traits in humans and its inheritance (Pedigree analysis).

References

1. Vijayakumaran Nair & Jayaprakash, Cell Biology, Genetics, Molecular Biology, Academia, Thiruvananthapuram.
2. Guptha, P.K., Cell and Molecular Biology, Rastogi Publications, Meerat.
3. Dewitt-Saunders, Biology of the cell.
4. Strickberger W.M-Mac Millon, Genetics.
5. Gerald Karp, Cell and Molecular Biology: Concept and Experiments.
6. Roothwell, Human Genetics, Prentice Hall.
7. Lodish; Verk; et.al; Molecular Cell Biology, W.H. Freemann publishers.
8. Verma, P. S. and Agarwal, V. K., Cell Biology, Genetics, Molecular Biology, and Ecology, S. Chand and Co. New Delhi.
9. De Robertis EDP and De Robertis EMF., Cell and molecular biology. 7th Edition Saunders International Edition.

MODULE 1: CYTOLOGY

Unit 1: Cellular Organization (10 hr)

1.1 Cell Theory & Cell Principle

- **Cell Theory** (Schleiden & Schwann, 1839; later contributions by Virchow) states that:
    1. All living organisms are composed of cells.
    2. The cell is the basic unit of life.
    3. All cells arise from pre-existing cells.
- **Modern Cell Principle** expands on this by including:
    - Genetic information is passed from cell to cell.
    - Cells maintain homeostasis.
    - Energy flow occurs within cells.

1.2 Cell Structure

Plasma Membrane (Fluid Mosaic Model)

- Proposed by **Singer and Nicolson (1972)**.
- **Structure:**
    - **Phospholipid bilayer** (hydrophilic heads & hydrophobic tails).
    - **Proteins**: Integral (embedded) and Peripheral (surface).
    - **Carbohydrates**: Glycolipids & Glycoproteins (cell recognition).
    - **Cholesterol**: Provides stability and fluidity.
- **Functions:**
    - Selective permeability.

- Communication & signaling.
- Transport (diffusion, osmosis, active transport).

1.3 Cell Organelles: Structure & Function

Organelle	Structure	Function
Mitochondria	Double membrane, inner folded into cristae	ATP production (powerhouse of the cell)
Ribosome	No membrane, made of rRNA & proteins	Protein synthesis
Endoplasmic Reticulum (ER)	Network of membranes; Rough ER (with ribosomes), Smooth ER (without ribosomes)	Rough ER: Protein synthesis; Smooth ER: Lipid synthesis, detoxification
Golgi Bodies	Flattened sacs (cisternae)	Modifies, packages, and transports proteins & lipids
Lysosome	Single membrane, contains digestive enzymes	Intracellular digestion, waste removal
Cytoskeleton	Microfilaments, Microtubules, Intermediate filaments	Shape, support, intracellular transport
Interphase Nucleus	Nuclear envelope, nucleoplasm, chromatin, nucleolus	Genetic material storage, transcription

1.4 Cell Inclusions

- **Carbohydrates**: Provide energy (e.g., glycogen, starch).
- **Lipids**: Energy storage, membrane formation (e.g., triglycerides, phospholipids).
- **Proteins**: Enzymes, structural components, signaling (e.g., hemoglobin, insulin).

1.5 Unicellularity to Multicellularity & Differentiation

- **Unicellular organisms** (e.g., Amoeba, Paramecium) perform all life processes within a single cell.
- **Multicellular organisms** have specialized cells forming tissues and organs.
- **Cell differentiation**: The process by which cells develop specialized functions.

1.6 Spatial & Temporal Control of Gene Activity

- **Spatial control**: Certain genes are activated in specific cell locations (e.g., muscle genes in muscle cells).
- **Temporal control**: Genes are turned on/off at different developmental stages (e.g., hemoglobin production in fetal vs. adult life).

1.7 Tissues (Brief Description of Major Types)

1. **Epithelial Tissue**: Covers body surfaces & lines cavities (e.g., skin, gut lining).
2. **Connective Tissue**: Supports & connects (e.g., bone, blood, cartilage).
3. **Muscle Tissue**: Movement (e.g., skeletal, cardiac, smooth muscle).
4. **Nervous Tissue**: Communication (e.g., brain, spinal cord, nerves).

Unit 2: Cell Division (5 hr)

2.1 Cell Cycle

- **Phases**:
    1. **G1 Phase**: Growth & preparation for DNA replication.
    2. **S Phase**: DNA replication.
    3. **G2 Phase**: Preparation for mitosis.
    4. **M Phase (Mitosis)**: Nuclear division.
- **Checkpoints**: Ensure DNA integrity & proper cell division.
- **G0 Phase**: Resting phase (cells exit the cycle).

2.2 Mitosis (Equational Division)

- **Purpose**: Growth, repair, asexual reproduction.
- **Stages**:
    1. **Prophase**: Chromosomes condense, spindle forms.
    2. **Metaphase**: Chromosomes align at the equator.
    3. **Anaphase**: Sister chromatids separate.
    4. **Telophase**: Nuclear envelope reforms, cytokinesis begins.
- **Significance**: Produces genetically identical daughter cells.

2.3 Meiosis (Reductional Division)

- **Purpose**: Formation of gametes (sperm & egg).
- **Stages**:
  Meiosis I
    1. **Prophase I**: Homologous chromosomes pair, crossing over occurs.
    2. **Metaphase I**: Chromosomes align in homologous pairs.
    3. **Anaphase I**: Homologous chromosomes separate.
    4. **Telophase I**: Two haploid cells form.

  Meiosis II (Similar to mitosis)

    5. **Prophase II**: Chromosomes condense.
    6. **Metaphase II**: Chromosomes align at the equator.
    7. **Anaphase II**: Sister chromatids separate.
    8. **Telophase II**: Four haploid gametes are formed.

- **Significance**:
  - Maintains chromosome number across generations.
  - Introduces genetic variation (crossing over, independent assortment).

Summary of Differences Between Mitosis & Meiosis

Feature	Mitosis	Meiosis
Number of Divisions	1	2
Number of Daughter Cells	2	4
Chromosome Number	Diploid (2n)	Haploid (n)
Genetic Variation	No	Yes (crossing over)
Function	Growth, repair	Gamete formation

MODULE 2: GENES AND CHROMOSOMES

Unit 1: DNA – The Genetic Material (5 hr)

1.1 Structure of DNA

- Discovered by **James Watson & Francis Crick (1953)** based on **Rosalind Franklin's X-ray diffraction data**.
- **Double Helix Model**:
  - Two **antiparallel strands** (5' → 3' and 3' → 5').
  - **Sugar-phosphate backbone** (deoxyribose + phosphate).
  - **Nitrogenous bases**: Adenine (A) pairs with Thymine (T), Cytosine (C) pairs with Guanine (G) via **hydrogen bonds**.
  - **Base pairing rule**: A=T (2 bonds), C≡G (3 bonds).
  - Helix stabilized by **hydrogen bonds** & **hydrophobic interactions**.

1.2 DNA Replication (Semiconservative Method)

- **Proposed by Meselson & Stahl (1958)**.
- **Semiconservative replication**: Each new DNA molecule has **one old strand & one new strand**.

Process of DNA Replication

1. **Initiation**:
   - **Helicase** unwinds DNA, breaking hydrogen bonds.
   - **Topoisomerase** prevents supercoiling.
   - **Single-strand binding proteins (SSBs)** stabilize open strands.
2. **Elongation**:
   - **Leading strand**: Synthesized continuously **(5' → 3')** by **DNA Polymerase III**.

- **Lagging strand**: Synthesized discontinuously in **Okazaki fragments**, joined by **DNA Ligase**.
- **Primase** adds RNA primers to initiate synthesis.

3. **Termination**:
   - **DNA Polymerase I** replaces RNA primers with DNA.
   - **DNA Ligase** seals gaps.

Unit 2: Concept of a Gene (3 hr)

2.1 Classical vs. Modern Concept of a Gene

- **Classical Concept**: A gene is a unit of inheritance responsible for a trait (**Mendel**).
- **Modern Concept**: A gene is a sequence of DNA that codes for a functional protein or RNA.

2.2 Genetic Code

- **Triplet Code**: Three nucleotides (codon) code for one amino acid.
- **Characteristics**:
  - **Universal**: Same in all organisms.
  - **Degenerate**: Multiple codons can code for the same amino acid.
  - **Non-overlapping**: Read in triplets.
  - **Start Codon**: AUG (Methionine).
  - **Stop Codons**: UAA, UAG, UGA.

2.3 Introns & Exons

- **Introns**: Non-coding sequences, removed during RNA splicing.
- **Exons**: Coding sequences, expressed as proteins

Unit 3: Morphology of Chromosomes (4 hr)

3.1 Size & Shape of Chromosomes

- **Size**: Varies from organism to organism.
- **Shape**: Thread-like during interphase, condensed during mitosis.

3.2 Karyotype & Ideogram

- **Karyotype**: Ordered display of chromosomes (e.g., **human karyotype: 46 chromosomes**).
- **Ideogram**: A schematic representation of chromosomes showing banding patterns.

3.3 Types of Chromosomes (Based on Centromere Position)

Type	Centromere Position	Example
Metacentric	Center	Human Chromosome 1
Submetacentric	Slightly off-center	Human Chromosome 4
Acrocentric	Near one end	Human Chromosome 13
Telocentric	At the end	Not found in humans (common in rodents)

3.4 Linkage & Crossing Over

- **Linkage**: Genes located on the **same chromosome** are inherited together.
- **Crossing Over**: Exchange of genetic material between homologous chromosomes during **Prophase I of Meiosis**.
- **Significance**: Increases genetic variation.

3.5 Sex-Linked Chromosomes

- **Sex Chromosomes**: X & Y determine gender.
- **X-linked traits**: More common in males (e.g., Hemophilia, Color Blindness).
- **Y-linked traits**: Only in males (e.g., Male pattern baldness).

Topic	Key Points
DNA Structure	Double helix, A=T, C≡G
DNA Replication	Semiconservative, leading vs. lagging strand
Gene Concept	Classical vs. Modern, Genetic Code
Introns & Exons	Introns (non-coding), Exons (coding)
Chromosomes	Karyotype, Ideogram, Types
Linkage & Crossing Over	Inheritance patterns, genetic variation
Sex Chromosomes	X-linked, Y-linked traits

MODULE 3: ELEMENTS OF HEREDITY AND VARIATION

Unit 1: Mendelian Principles (5 hr)

1.1 Gregor Mendel's Work & Laws of Inheritance

- **Gregor Mendel (1865)**: Conducted experiments on **pea plants (Pisum sativum)** and formulated the principles of inheritance.

1.1.1 Mendel's Laws

1. **Law of Segregation** (1st Law)
   - Each individual has **two alleles** for a gene, which separate during gamete formation.
   - **Example:** Monohybrid cross (Tall × Short pea plants).
2. **Law of Independent Assortment** (2nd Law)
   - Alleles of different genes assort independently during gamete formation.
   - **Example:** Dihybrid cross (Yellow round × Green wrinkled peas).

1.2 Mendelian Crosses

1.2.1 Monohybrid Cross

- Cross involving **one trait** (e.g., Tall vs. Short plants).
- **Genotypic ratio:** 1:2:1 (**TT:Tt:tt**)
- **Phenotypic ratio:** 3:1 (**Tall:Short**)

1.2.2 Dihybrid Cross

- Cross involving **two traits** (e.g., Seed shape & color).

- **Phenotypic ratio: 9:3:3:1**
- **Example: Yellow Round × Green Wrinkled** peas.

1.2.3 Test Cross

- Crossing an unknown genotype with a **homozygous recessive**.
- Used to determine if an organism is **homozygous dominant or heterozygous**.

1.3 Important Genetic Terms

Term	Definition
Allele	Alternative forms of a gene (e.g., T or t).
Homozygosity	Having two identical alleles (TT or tt).
Heterozygosity	Having two different alleles (Tt).
Genotype	Genetic makeup (e.g., TT, Tt, tt).
Phenotype	Observable trait (e.g., Tall or Short).

Unit 2: Non-Mendelian Inheritance Patterns (7 hr)

2.1 Incomplete Dominance

- Neither allele is completely dominant, resulting in a **blended phenotype**.
- **Example: Snapdragon flowers**
  - **Red (RR) × White (rr) → Pink (Rr)**
- **Phenotypic ratio:** 1:2:1 (Red:Pink:White).

2.2 Co-Dominance

- Both alleles are **expressed simultaneously** without blending.
- **Example: AB Blood Group**
  - **A (IA) × B (IB) → AB Blood Type (IAIB)**.

2.3 Multiple Alleles

- More than two alleles for a single gene in a population.
- **Example: ABO Blood Group System**
  - **IA, IB, and i** alleles determine blood type.

2.4 Epistasis

- One gene **masks the expression** of another gene.
- **Example:** Coat color in **Labrador retrievers**

- **B (black) is dominant to b (brown), but E (pigment deposition) is required.**
- **ee results in yellow labs, regardless of B/b allele.**

2.5 Pleiotropy

- A single gene affects **multiple traits**.
- **Example: Marfan Syndrome** (mutation in the **FBN1 gene**)
  - **Affects eyes, heart, and skeletal system.**

Summary of Non-Mendelian Inheritance

Pattern	Key Feature	Example
Incomplete Dominance	Blended phenotype	Snapdragon flowers
Co-Dominance	Both alleles expressed	AB Blood Type
Multiple Alleles	More than two alleles for a trait	ABO Blood Group
Epistasis	One gene controls another	Labrador coat color
Pleiotropy	One gene affects multiple traits	Marfan Syndrome

MODULE 4: MUTATIONS AND GENETIC DISORDERS

Unit 1: Mutations (3 hr)

1.1 Definition of Mutation

- A **mutation** is a **permanent change in the DNA sequence** of a gene or chromosome.
- Can be **heritable** (if in gametes) or **non-heritable** (if in somatic cells).

1.2 Kinds & Classification of Mutations

Based on Location

Type	Description
Somatic Mutation	Occurs in body cells, **not inherited**.
Gametic Mutation	Occurs in reproductive cells, **passed to offspring**.

Based on Cause

Type	Description
Spontaneous Mutation	Occurs naturally due to errors in DNA replication.
Induced Mutation	Caused by environmental agents (e.g., radiation, chemicals).

Based on Effect

Type	Description
Point Mutation	Change in a single nucleotide (e.g., sickle cell anemia).
Silent Mutation	No change in protein function.

Dominant Mutation	Expressed even in heterozygous state.
Recessive Mutation	Expressed only in homozygous state.

1.3 Gene Mutation Disorders

Disorder	Cause	Symptoms
Albinism	Mutation in **TYR gene** (affects melanin production).	Lack of skin, hair, and eye pigmentation.
Phenylketonuria (PKU)	Mutation in **PAH gene** (affects phenylalanine metabolism).	Intellectual disability, seizures, light skin.
Alkaptonuria	Mutation in **HGD gene** (affects homogentisic acid breakdown).	Dark urine, joint issues.
Galactosemia	Mutation in **GALT gene** (affects galactose metabolism).	Liver damage, cataracts, brain damage.
Brachydactyly	Mutation in **HOXD13 gene**.	Short fingers/toes.

Unit 2: Chromosomal Anomalies (3 hr)

2.1 Autosomal Anomalies

- Caused by **numerical or structural changes** in autosomes.

Disorder	Cause	Symptoms
Down's Syndrome (Trisomy 21)	Extra chromosome 21 (47, +21).	Intellectual disability, short stature, heart defects.
Edward's Syndrome (Trisomy 18)	Extra chromosome 18 (47, +18).	Severe developmental delay, clenched fists.
Cri du Chat Syndrome	Deletion in **chromosome 5p**.	Cat-like cry, small head, intellectual disability.

2.2 Sex Chromosomal Anomalies

- Caused by **abnormal numbers of sex chromosomes (X/Y)**.

Disorder	Cause	Symptoms
Klinefelter's Syndrome (XXY)	Extra X chromosome in males (47, XXY).	Tall, infertility, reduced muscle mass.
Turner's Syndrome (XO)	Missing X chromosome in females (45, XO).	Short stature, infertility, webbed neck.

Summary

Topic	Key Points

Mutations	Changes in DNA sequence, classified by location, cause, and effect.
Gene Mutation Disorders	Albinism, PKU, Alkaptonuria, Galactosemia, Brachydactyly.
Chromosomal Anomalies	Down's, Edward's, Cri du Chat, Klinefelter's, Turner's Syndromes.