# M.Sc. Zoology Semester 1 Assignment (2025-2027)

## M. R. M. College, Darbhanga - Department of Zoology

## CC-1: Evolutionary Significance of Respiratory Pigments in Different Phylogenetic Groups

### Introduction

Respiratory pigments are metalloprotein molecules that facilitate oxygen transport in body fluids. Their evolution represents a crucial adaptation enabling organisms to colonize diverse habitats and achieve larger body sizes. The distribution and characteristics of these pigments across phylogenetic groups reveal important evolutionary trends.

### Types of Respiratory Pigments and Their Distribution

**1. Hemoglobin (Iron-based)**

**Distribution:** Vertebrates, some annelids, some molluscs, some arthropods, and certain nematodes

**Structure:** Consists of heme group (iron-porphyrin complex) bound to globin protein

**Evolutionary Significance:**

- Most widespread and efficient respiratory pigment
- High oxygen-binding capacity with cooperative binding (sigmoidal dissociation curve)
- Evolved independently multiple times (convergent evolution)
- In vertebrates, shows progressive complexity from monomeric forms in cyclostomes to tetrameric forms in mammals
- Different globin gene families arose through gene duplication events
- Enables high metabolic rates and active lifestyles

**2. Hemocyanin (Copper-based)**

**Distribution:** Molluscs (except bivalves) and arthropods (especially crustaceans and arachnids)

**Structure:** Contains two copper atoms per functional unit; directly dissolved in hemolymph

**Evolutionary Significance:**

- Appears to have evolved independently in molluscs and arthropods
- More efficient at high pH and low temperatures
- Large molecular size limits diffusion but provides stability
- Enables survival in cold, oxygen-poor aquatic environments
- In arthropods, supported the evolution of large body sizes in ancient high-oxygen atmospheres

**3. Hemerythrin (Iron-based, non-heme)**

**Distribution:** Some marine invertebrates (sipunculids, priapulids, brachiopods, some annelids)

**Structure:** Contains binuclear iron center; octameric structure

**Evolutionary Significance:**

- Limited distribution suggests restricted ecological advantages
- May represent an evolutionary "experiment" that was outcompeted
- Functions adequately in low-activity sedentary organisms
- Reflects adaptation to specific marine niches

**4. Chlorocruorin (Iron-based)**

**Distribution:** Certain families of polychaete annelids

**Structure:** Similar to hemoglobin but with modified porphyrin ring

**Evolutionary Significance:**

- Derived from hemoglobin through mutation
- Green color due to altered porphyrin structure
- Functions similarly to hemoglobin but with lower oxygen affinity
- Represents evolutionary modification within annelid lineage

## Evolutionary Trends and Adaptive Significance

### Transition from Water to Land

The evolution of respiratory pigments facilitated terrestrial colonization. Hemoglobin's high efficiency enabled vertebrates to develop lungs and maintain aerobic metabolism on land. The Bohr effect (pH-dependent oxygen release) evolved as an adaptation to varying metabolic demands.

### Body Size and Metabolic Rate

More efficient respiratory pigments (particularly hemoglobin) enabled the evolution of larger body sizes and higher metabolic rates. The correlation between oxygen-carrying capacity and maximum body size is evident across phylogenetic groups.

#### Environmental Adaptations

- **Temperature:** Hemocyanin performs better in cold-water environments
- **Oxygen availability:** Different pigments show varying affinities adapted to habitat oxygen levels
- **pH variation:** Respiratory pigments evolved sensitivity to $CO_2$ and pH for efficient oxygen delivery

#### Molecular Evolution

- Gene duplication events produced diverse globin families (myoglobin, hemoglobin, neuroglobin, cytoglobin)
- Amino acid substitutions fine-tuned oxygen affinity for specific physiological needs
- Fetal hemoglobin evolution enabled efficient placental oxygen transfer in mammals

### Convergent Evolution

The independent evolution of similar respiratory pigments in distantly related groups demonstrates convergent evolution driven by similar selective pressures. Hemoglobin evolved independently at least 8-10 times, indicating its fundamental importance for aerobic life.

### Conclusion

Respiratory pigments represent key evolutionary innovations that enabled diversification and colonization of varied ecological niches. Their distribution patterns, structural diversity, and functional properties reflect the evolutionary history and ecological adaptations of different phylogenetic groups.

## CC-2: Vesicular Transport (Diagrammatic Description)

### Overview of Vesicular Transport

Vesicular transport is the cellular mechanism for moving large molecules, particles, and fluid across membranes through membrane-bound vesicles. This process is essential for maintaining cellular compartmentalization and communication.

### Types of Vesicular Transport

#### A. ENDOCYTOSIS (Into the Cell)

#### 1. Phagocytosis ("Cell Eating")

- Large particles (>0.5 µm) engulfed
- Forms phagosome
- Common in: macrophages, neutrophils, amoebas

- Process: Particle binding → pseudopod extension → phagosome formation → fusion with lysosome

**2. Pinocytosis ("Cell Drinking")**

- Uptake of fluids and small solutes
- Forms small vesicles (≈100 nm)
- Constitutive process in most cells
- Non-specific uptake mechanism

**3. Receptor-Mediated Endocytosis**

- Highly specific and efficient
- Involves clathrin-coated pits
- Key proteins: clathrin, adaptor proteins, dynamin
- Examples: LDL uptake, transferrin uptake, viral entry
- Process: Ligand binding → clathrin coat assembly → pit invagination → dynamin-mediated scission → vesicle uncoating

**4. Caveolae-Mediated Endocytosis**

- Small flask-shaped invaginations (50-80 nm)
- Contains caveolin proteins
- Important in: signal transduction, lipid regulation

**B. EXOCYTOSIS (Out of the Cell)**

**1. Constitutive Exocytosis**

- Continuous, unregulated process
- Delivers membrane proteins and lipids
- Secretes extracellular matrix components

**2. Regulated Exocytosis**

- Triggered by specific signals ($Ca^{2+}$, hormones)
- Secretory vesicles stored until signal received
- Examples: neurotransmitter release, hormone secretion, enzyme secretion

**Key Steps in Regulated Exocytosis:**

- Vesicle budding from trans-Golgi network
- Transport to plasma membrane
- Docking at target site
- Priming for fusion

- $Ca^{2+}$-triggered fusion
- Content release
- Membrane retrieval/recycling

#### C. TRANSCYTOSIS

- Vesicles move material across the cell
- Important in: endothelial cells, epithelial cells
- Combines endocytosis and exocytosis

## Molecular Machinery of Vesicular Transport

#### 1. Coat Proteins

- **Clathrin:** Endocytosis from plasma membrane, TGN to endosomes
- **COPI:** Retrograde transport (Golgi to ER, intra-Golgi)
- **COPII:** Anterograde transport (ER to Golgi)

#### 2. SNAREs (Soluble NSF Attachment Protein Receptors)

- v-SNAREs on vesicle membrane
- t-SNAREs on target membrane
- Form coiled-coil complex for membrane fusion
- Specificity ensures correct targeting

#### 3. Rab GTPases

- Small GTP-binding proteins
- Regulate vesicle formation, movement, and fusion
- Over 60 different Rabs in mammals
- Provide spatial and temporal specificity

#### 4. Tethering Factors

- Initial capture of vesicles at target membrane
- Examples: golgins, exocyst complex

#### 5. Motor Proteins

- Kinesins and dyneins (microtubule-based)
- Myosins (actin-based)
- Provide directional movement

## Diagram Reference

For detailed diagrams of vesicular transport mechanisms, refer to:

- **Molecular Biology of the Cell** (Alberts et al., 6th Edition) - Chapter 13, Figures 13-5, 13-10, 13-38, 13-45
- **Cell and Molecular Biology** (Lodish et al., 8th Edition) - Chapter 14
- Online resource: NCBI Bookshelf - Cell Biology textbooks (free access)

**Key diagrams to include:**

1. Overview of endocytosis types with cellular membrane cross-sections
2. Receptor-mediated endocytosis showing clathrin-coated pit formation
3. SNARE-mediated membrane fusion mechanism
4. Coat protein structures (COPII, COPI, Clathrin)
5. Regulated exocytosis at neuronal synapse

# CC-3: Organization of Eukaryotic Chromosome (Diagrammatic Description)

## Hierarchical Levels of Chromosome Organization

Eukaryotic chromosomes exhibit multiple levels of structural organization that allow approximately 2 meters of DNA to be packaged into a nucleus of about 10 µm diameter, while maintaining accessibility for transcription and replication.

## Level 1: DNA Double Helix (2 nm diameter)

- Basic Watson-Crick double helix structure
- Right-handed B-form DNA
- 10 base pairs per helical turn
- 3.4 Å rise per base pair
- Antiparallel strands with complementary base pairing

## Level 2: Nucleosome (11 nm "Beads-on-a-String")

**Nucleosome Core Particle:**

- 147 base pairs of DNA wrapped 1.65 turns around histone octamer
- Histone octamer composition: $(H2A\text{-}H2B\text{-}H3\text{-}H4)_2$
- Left-handed superhelical wrapping
- Histone fold domains mediate histone-histone interactions
- N-terminal histone tails extend outward (subject to post-translational modifications)

**Linker DNA:**

- 20-80 base pairs between nucleosomes (varies by organism and cell type)
- Binds H1/H5 linker histone
- Creates "beads-on-a-string" appearance in electron microscopy

**Chromatin Compaction:** DNA length reduced by factor of ~7

## Level 3: 30 nm Chromatin Fiber

**Structure:**

- Nucleosomes fold into higher-order structure
- H1 histone critical for formation
- Two proposed models:
  - **Solenoid model:** Continuous helical structure (6 nucleosomes per turn)
  - **Zigzag model:** Nucleosomes form zigzag ribbon that folds

**Chromatin Compaction:** DNA length reduced by factor of ~40-50

**Dynamic Structure:**

- Not uniformly present throughout genome
- More pronounced in heterochromatin
- Can be disrupted for transcription/replication

## Level 4: Higher-Order Loops (300 nm)

**Loop Domains:**

- 30 nm fiber forms loops of 50-200 kb
- Anchored at bases to nuclear scaffold/matrix
- Loop bases contain Scaffold/Matrix Attachment Regions (S/MARs or MARs)
- AT-rich sequences facilitate protein binding

**Loop Organization:**

- Functionally related genes often in same loop
- Regulatory elements within loops coordinate gene expression
- Provides additional level of gene regulation

**Chromatin Compaction:** DNA length reduced by factor of ~1000

## Level 5: Condensed Chromatin (700 nm)

**Characteristics:**

- Further coiling and folding of loops
- Requires condensin protein complexes
- Begins in early prophase of mitosis
- Creates rosette-like structures

## Level 6: Metaphase Chromosome (1400 nm)

**Maximum Condensation:**

- Achieved during metaphase of mitosis
- Total DNA compaction: ~10,000-fold
- Visible under light microscopy
- Characteristic X-shaped appearance (after DNA replication)

**Structural Components:**

- **Sister chromatids:** Two identical DNA molecules held together
- **Centromere:** Constricted region for kinetochore attachment
  - Contains repetitive DNA sequences
  - Binds centromere-specific histone variant CENP-A
  - Kinetochore protein complex assembles here
- **Telomeres:** Chromosome ends with repetitive sequences (TTAGGG in vertebrates)
  - Protect against degradation
  - Prevent fusion with other chromosomes
- **Chromosome arms:** p (short) and q (long) arms

## Special Chromosomal Regions

**Euchromatin:**

- Loosely packed, transcriptionally active
- Light staining in microscopy
- Rich in genes
- Acetylated histones

**Heterochromatin:**

- Densely packed, transcriptionally inactive
- Dark staining
- Gene-poor regions
- Methylated histones and DNA

**Types of Heterochromatin:**

- **Constitutive:** Permanently condensed (centromeres, telomeres)
- **Facultative:** Can decondense (e.g., inactive X chromosome - Barr body)

## Proteins Involved in Chromosome Organization

**Histone Proteins:**

- H2A, H2B, H3, H4 (core histones)
- H1/H5 (linker histones)
- Histone variants (CENP-A, H2A.Z, H3.3)

**Non-Histone Chromosomal Proteins:**

- **Condensins:** SMC proteins for chromosome condensation
- **Cohesins:** Hold sister chromatids together
- **Topoisomerases:** Resolve DNA tangles and supercoiling
- **HMG proteins:** Architectural chromatin proteins
- **Scaffold proteins:** Form chromosomal scaffold

## Functional Significance

**Gene Regulation:**

- Chromatin structure controls gene accessibility
- Histone modifications create "histone code"
- Chromatin remodeling complexes alter nucleosome positioning

**DNA Replication:**

- Must balance compaction with accessibility
- Replication fork progression requires chromatin disruption and reassembly

**DNA Repair:**

- Chromatin must be locally relaxed for repair machinery access
- Histone modifications signal DNA damage

## Diagram Reference

For detailed diagrams of eukaryotic chromosome organization, refer to:

- **Molecular Biology of the Cell** (Alberts et al., 6th Edition) - Chapter 4, Figures 4-24 through 4-33
- **Lehninger Principles of Biochemistry** (Nelson & Cox, 7th Edition) - Chapter 24

- **Genetics: Analysis of Genes and Genomes** (Hartl & Jones, 9th Edition) - Chapter 6

**Key diagrams to include:**

1. Hierarchical levels from DNA double helix to metaphase chromosome
2. Nucleosome structure showing histone octamer and DNA wrapping
3. 30 nm fiber formation (both solenoid and zigzag models)
4. Loop domain organization with scaffold attachment
5. Metaphase chromosome with labeled centromere, telomeres, and sister chromatids
6. Comparison of euchromatin and heterochromatin

# CC-4: Pedigree for Autosomal Dominant Trait, Sex-Limited to Males, Excluding Y-Linkage

## Understanding the Requirements

**Autosomal Dominant:**

- Trait controlled by a dominant allele on an autosome (non-sex chromosome)
- Only one copy of the allele needed to express the trait
- Can be inherited from either parent
- Does not skip generations (typically)

**Sex-Limited to Males:**

- Trait only expressed in males, not females
- Females can carry and transmit the allele but don't express the phenotype
- Due to hormonal or anatomical differences, not chromosomal location
- Examples: male-pattern baldness, precocious puberty in males

**Excluding Y-Linkage:**

- Must show father-to-daughter transmission of the allele (silent in daughters)
- Must show affected males with unaffected fathers (inherited through mother)
- Y-linkage would only show father-to-son transmission

## Key Features to Demonstrate

1. **Affected males have at least one affected parent** (dominant inheritance)
2. **Affected fathers can have unaffected sons** (not all sons affected, rules out Y-linkage)
3. **Affected males can have affected maternal grandfathers** (maternal transmission)

4. **Unaffected males can have affected sons if mother is a carrier** (autosomal)
5. **No females express the trait** (sex-limited)
6. **Carrier females (heterozygous) don't show the phenotype**

## Pedigree Symbols

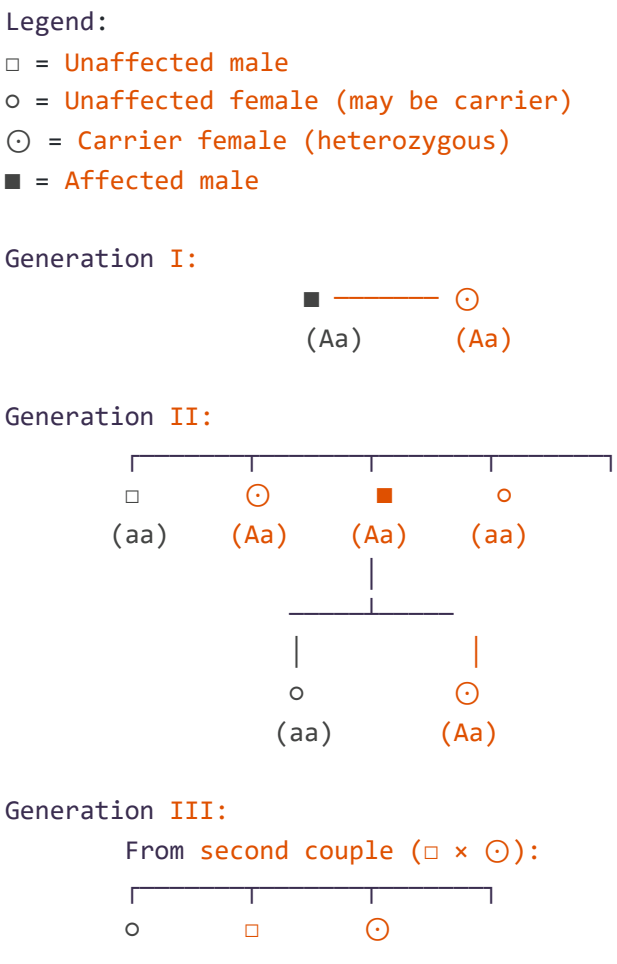
### Standard Symbols:

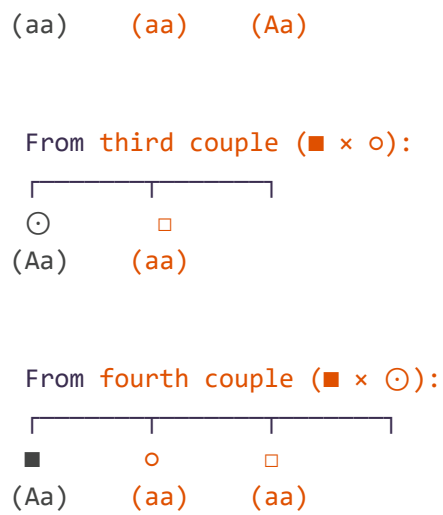
- □ = Unaffected male
- ○ = Unaffected female
- ■ = Affected male
- ● = Affected female (not applicable here)
- □ with dot in center = Carrier male (not applicable for dominant traits)
- ○ with dot in center = Carrier female (heterozygous)

### Relationships:

- Horizontal line between symbols = Mating
- Vertical line down from horizontal = Offspring
- Siblings connected by horizontal line above them

## Example Pedigree






## Genotype Explanation

Let's use "A" for the dominant allele and "a" for the recessive allele.

**Possible Genotypes:**

- Males: AA (affected), Aa (affected), aa (unaffected)
- Females: AA (carrier, no phenotype), Aa (carrier, no phenotype), aa (no allele, no phenotype)

## Analysis of the Pedigree

**Evidence for Autosomal Dominant:**

1. Affected individuals in multiple generations without skipping
2. Both males and females can transmit the trait
3. Approximately 50% of offspring from affected × carrier matings are affected

**Evidence for Sex-Limited Expression:**

1. Only males show the trait phenotype
2. Females with the dominant allele (carriers) do not express the trait
3. Carrier females can have affected sons

**Evidence Against Y-Linkage:**

1. Affected male (Generation I) has unaffected son (Generation II)
2. Affected male (Generation II) has daughter who is a carrier (can only happen with autosomal inheritance)
3. Affected males can arise from unaffected fathers (maternal transmission)
4. Not all sons of affected fathers are affected

## Diagram Reference

For proper pedigree construction and additional examples, refer to:

- **Human Genetics: Concepts and Applications** (Lewis, 12th Edition) - Chapter 4
- **Genetics: From Genes to Genomes** (Hartwell et al., 6th Edition) - Chapter 2
- Online: National Human Genome Research Institute - Talking Glossary of Genetic Terms

**Your hand-drawn or digital pedigree should include:**

1. At least three generations
2. Clear symbols showing affected males, unaffected males, carrier females, and unaffected females
3. Labels indicating genotypes where informative
4. A legend explaining symbols used
5. Evidence of:
    - Father-to-daughter transmission (showing autosomal, not Y-linked)
    - Mother-to-son transmission
    - Unaffected males with affected sons (mother is carrier)
    - No affected females (sex-limited)

# AECC 1: Importance of Swachh Bharat Abhiyan

## Introduction

Swachh Bharat Abhiyan (Clean India Mission) is a nationwide cleanliness campaign launched by the Government of India on October 2, 2014, commemorating Mahatma Gandhi's 145th birth anniversary. This ambitious program aimed to achieve a "Clean India" by October 2, 2019, Gandhi's 150th birth anniversary. The mission represents one of the largest cleanliness drives in the world, encompassing both rural (Swachh Bharat Abhiyan - Gramin) and urban (Swachh Bharat Abhiyan - Urban) components.

## Objectives of Swachh Bharat Abhiyan

1. Elimination of open defecation
2. Eradication of manual scavenging
3. Modern and scientific municipal solid waste management
4. Behavioral change regarding healthy sanitation practices
5. Generation of awareness about sanitation and its linkage with public health
6. Capacity augmentation for urban local bodies
7. Creation of an enabling environment for private sector participation

## Public Health Importance

**Prevention of Diseases:** The mission addresses critical public health challenges. Poor sanitation and open defecation lead to numerous waterborne diseases including cholera, typhoid, hepatitis A, diarrhea, and dysentery. These diseases disproportionately affect children, with diarrheal diseases being a leading cause of child mortality in India. By improving sanitation infrastructure and promoting hygiene practices, the campaign directly reduces disease burden and mortality rates.

**Nutritional Impact:** Poor sanitation contributes to environmental enteropathy and chronic intestinal infections, which impair nutrient absorption and lead to stunting and malnutrition in children. The Swachh Bharat Abhiyan, by addressing these sanitation issues, indirectly contributes to improved nutritional outcomes and child development.

**Maternal and Women's Health:** Lack of toilet facilities poses significant challenges for women's health, dignity, and safety. Women without access to private toilets face risks of assault, particularly when relieving themselves in open areas during early morning or late evening hours. The construction of household and community toilets directly addresses these safety and dignity concerns.

## Environmental Significance

**Water Quality Protection:** Open defecation and improper waste disposal contaminate groundwater and surface water sources, making water unsafe for drinking and other uses. The mission's focus on toilet construction and proper waste management protects water resources from fecal contamination, ensuring safer drinking water for communities.

**Solid Waste Management:** The campaign promotes scientific waste management practices including source segregation, recycling, and composting. This reduces environmental pollution, decreases the burden on landfills, and converts waste into resources, supporting circular economy principles.

**Reduction of Soil Contamination:** Proper sanitation prevents soil contamination from human waste, maintaining soil health for agriculture and reducing the spread of soil-transmitted helminths and other parasites.

## Socio-Economic Impact

**Economic Productivity:** Poor sanitation results in significant economic losses through healthcare costs, lost productivity due to illness, and premature deaths. Studies estimate that inadequate sanitation costs India approximately 6.4% of GDP. By improving sanitation, the Swachh Bharat Abhiyan contributes to economic development and productivity gains.

**Tourism and Investment:** Cleanliness and sanitation infrastructure are crucial for tourism development. The campaign has enhanced India's image as a tourist destination and improved the experience of both domestic and international visitors. Clean cities and towns attract investment and support economic growth.

**Employment Generation:** The mission has created employment opportunities in construction, waste management, and maintenance of sanitation facilities. It has also promoted entrepreneurship in waste recycling and sanitation-related services.

## Social and Cultural Transformation

**Dignity and Social Equity:** Access to toilets is a matter of basic human dignity. The campaign addresses social inequities by ensuring that marginalized communities, including Dalits who have historically been forced into manual scavenging, have access to proper sanitation facilities and alternative livelihoods.

**Women's Empowerment:** Toilet construction has had profound impacts on women's lives. It has improved school attendance for girls (who often drop out after reaching puberty due to lack of toilet facilities), enhanced women's participation in the workforce, and reduced their vulnerability to violence.

**Behavioral Change:** Beyond infrastructure, the campaign focuses on changing mindsets and behaviors regarding cleanliness and sanitation. Through extensive awareness campaigns, community mobilization, and participation of celebrities and influencers, it has initiated a cultural shift toward valuing cleanliness as a collective responsibility.

## Educational and Awareness Impact

**School Sanitation:** The mission prioritized construction of separate toilets for girls and boys in schools. This intervention has demonstrably improved school enrollment and retention rates, particularly for girls, directly supporting educational outcomes.

**Mass Movement:** By involving citizens, schools, colleges, corporations, and media, Swachh Bharat Abhiyan has become a mass movement. It has fostered civic consciousness and community participation in maintaining cleanliness, creating sustainable behavioral changes.

**Health Education:** The campaign integrates health education with sanitation infrastructure development, teaching communities about disease transmission, hygiene practices, and the importance of handwashing, safe water handling, and menstrual hygiene management.

## Achievements and Progress

**Infrastructure Development:**

- Construction of over 110 million toilets across rural and urban India
- Declaration of numerous districts, blocks, and villages as Open Defecation Free (ODF)
- Significant reduction in open defecation rates from approximately 550 million people (2014) to substantial decline

**Waste Management:**

- Improved solid waste management in urban areas with increased processing capacity
- Promotion of waste segregation at source in households and institutions
- Development of waste-to-energy and waste-to-compost facilities

**Behavioral Change:**

- Measurable shifts in sanitation behaviors and practices
- Increased community ownership and maintenance of sanitation facilities
- Growing social stigma against open defecation

## Challenges and Areas for Improvement

**Sustainability:** Ensuring continued functionality and maintenance of constructed toilets remains a challenge. Some facilities become non-functional due to lack of water supply, poor maintenance, or absence of waste disposal systems.

**Water Availability:** Toilet functionality depends on adequate water supply, which remains a challenge in water-scarce regions. Integrated approaches linking sanitation with water supply are essential.

**Behavior Change Sustainability:** While significant progress has been made, sustaining behavioral changes requires continued awareness efforts, particularly in regions with deeply rooted cultural practices.

**Waste Management Infrastructure:** Urban India still faces challenges in comprehensive waste management, including collection, transportation, processing, and disposal. Scaling up infrastructure and technology remains necessary.

**Manual Scavenging Elimination:** Despite legal prohibition and rehabilitation programs, manual scavenging persists in some areas, requiring stronger enforcement and comprehensive rehabilitation.

## Connection to Sustainable Development Goals (SDGs)

Swachh Bharat Abhiyan directly contributes to multiple United Nations Sustainable Development Goals:

- **SDG 6:** Clean Water and Sanitation
- **SDG 3:** Good Health and Well-being
- **SDG 4:** Quality Education
- **SDG 5:** Gender Equality
- **SDG 11:** Sustainable Cities and Communities
- **SDG 12:** Responsible Consumption and Production

## Conclusion

Swachh Bharat Abhiyan represents a transformative national initiative addressing fundamental aspects of public health, environmental sustainability, social equity, and economic development. Its importance extends beyond mere infrastructure development to encompass behavioral change, cultural transformation, and holistic societal improvement.

The campaign has demonstrated that large-scale sanitation improvements are achievable through political will, community participation, and integrated approaches. While challenges remain in ensuring sustainability and universal coverage, the mission has laid a strong foundation for a cleaner, healthier, and more dignified India.

As future professionals in zoology and biological sciences, understanding initiatives like Swachh Bharat Abhiyan is crucial because environmental health directly impacts biodiversity, ecosystem functioning, and wildlife conservation. Clean water bodies, reduced pollution, and proper waste management support healthy ecosystems that sustain both human and wildlife populations. The principles of this mission align with ecological sustainability and remind us that human health and environmental health are inseparably linked.

The continued success of Swachh Bharat Abhiyan requires sustained commitment from all stakeholders—government, communities, NGOs, private sector, and individuals. It serves as a model for how nations can mobilize resources and people toward achieving fundamental improvements in quality of life and environmental stewardship.

## References and Recommended Reading

### For CC-1 (Respiratory Pigments):


1. Schmidt-Nielsen, K. (1997). Animal Physiology: Adaptation and Environment. Cambridge University Press.
2. Hill, R.W., Wyse, G.A., & Anderson, M. (2016). Animal Physiology. Sinauer Associates.
3. Mangum, C.P. (1985). Oxygen transport in invertebrates. American Journal of Physiology.


### For CC-2 (Vesicular Transport):


1. Alberts, B. et al. (2022). Molecular Biology of the Cell (7th ed.). Garland Science.
2. Lodish, H. et al. (2021). Molecular Cell Biology (9th ed.). W.H. Freeman.
3. Online: NCBI Bookshelf - "Cell Biology" sections on membrane trafficking


### For CC-3 (Chromosome Organization):


1. Alberts, B. et al. (2022). Molecular Biology of the Cell (7th ed.). Garland Science.
2. Hartl, D.L. & Ruvolo, M. (2021). Genetics: Analysis of Genes and Genomes (9th ed.). Jones & Bartlett.
3. Luger, K. et al. (1997). Crystal structure of the nucleosome core particle. Nature.


### For CC-4 (Pedigree):


1. Lewis, R. (2020). Human Genetics: Concepts and Applications (13th ed.). McGraw-Hill.

2. Nussbaum, R.L. et al. (2015). Thompson & Thompson Genetics in Medicine (8th ed.). Elsevier.

## For AECC-1 (Swachh Bharat Abhiyan):

1. Government of India. Swachh Bharat Mission official website: swachhbharatmission.gov.in
2. WHO & UNICEF reports on Water, Sanitation and Hygiene (WASH) in India
3. Ministry of Jal Shakti reports and publications

**Submission Reminder:** January 16, 2026

**Note:** For diagrams (CC-2, CC-3, CC-4), please refer to the mentioned textbooks or create detailed, labeled diagrams based on standard representations in these references. Hand-drawn or digitally created diagrams are both acceptable, but ensure they are clearly labeled and scientifically accurate.