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TPSC EXAMINATION

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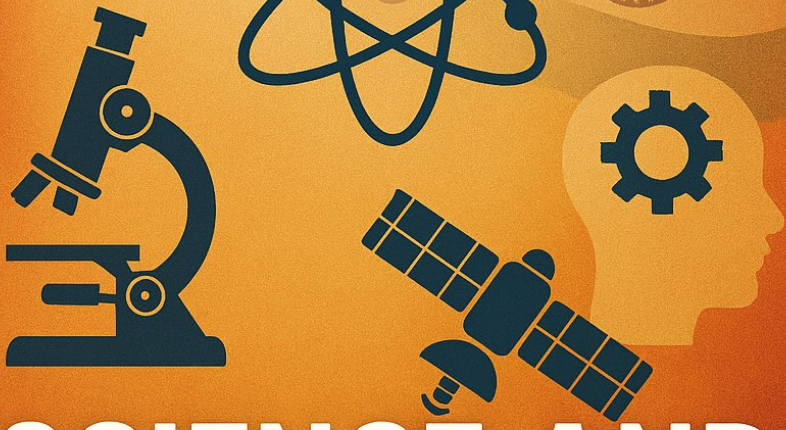

SCIENCE AND TECHNOLOGY

Section 1: Cell – Ideal Structure, Types with Examples and Functions

1.1 Introduction

- The **cell** is defined as the **structural, functional, and hereditary unit of life**.
- The word *cell* (Latin: *cella* = small room) was first used by **Robert Hooke in 1665** when he observed cork slices under a primitive microscope.
- The **cell theory** was proposed by **Matthias Schleiden (plants, 1838)** and **Theodor Schwann (animals, 1839)**, later refined by **Rudolf Virchow (1855)** who stated *"Omnis cellula e cellula"* (every cell arises from a pre-existing cell).
- Modern cell theory adds that cells contain genetic material (DNA), metabolism occurs inside cells, and all energy flow happens within cells.

1.2 Types of Cells

*(A) **Prokaryotic Cells***

- Found in **Bacteria and Archaea**.
- Features:
    - Nucleoid region (no true nucleus).
    - **70S ribosomes** (30S + 50S subunits).
    - Cell wall (bacteria = peptidoglycan; archaea = pseudopeptidoglycan).
    - Reproduce by **binary fission**.
    - Example: *Escherichia coli*, *Streptococcus pneumoniae*.

*(B) **Eukaryotic Cells***

- Found in Protists, Fungi, Plants, and Animals.
- Features:
    - True nucleus surrounded by double membrane.
    - **80S ribosomes** (40S + 60S subunits), except mitochondria/chloroplasts which have 70S.
    - Membrane-bound organelles.
    - Reproduce by mitosis or meiosis.
    - Example: Human cheek cell, Onion epidermal cell.

1.3 Structure of a Generalized Eukaryotic Cell

- **Plasma membrane**: Phospholipid bilayer (Fluid Mosaic Model, Singer & Nicolson, 1972). Semi-permeable. Functions in transport, recognition, signaling.
- **Cytoplasm**: Contains cytosol and organelles.
- **Nucleus**: Double membrane with pores. Contains chromatin (DNA + histone proteins). Nucleolus synthesizes ribosomal RNA.
- **Mitochondria**: Double membrane, inner folds (cristae). Site of aerobic respiration. Contain own DNA and ribosomes. ATP generated by oxidative phosphorylation.
- **Chloroplasts**: (in plants) Site of photosynthesis. Thylakoids arranged into grana. Chlorophyll pigments absorb light. Own DNA.
- **Endoplasmic Reticulum (ER)**:
    - Rough ER: ribosomes attached, synthesizes proteins.
    - Smooth ER: lipid synthesis, detoxification, calcium storage.
- **Golgi apparatus**: Modifies, packages proteins, forms secretory vesicles and lysosomes.
- **Lysosomes**: Contain hydrolytic enzymes, responsible for digestion and autophagy. Called *suicidal bags of cell*.
- **Peroxisomes**: Contain catalase and oxidases; break down fatty acids and detoxify H_2O_2.
- **Cytoskeleton**: Microtubules (tubulin), Microfilaments (actin), Intermediate filaments. Provides support, intracellular transport, motility.
- **Centrioles**: Found in animal cells; 9×3 arrangement of microtubules. Role in spindle formation.
- **Vacuole**: Large central vacuole in plants for storage and turgor pressure.
- **Cilia and Flagella**: Provide motility; eukaryotic cilia/flagella have a 9+2 microtubule arrangement.

1.4 Cell Division

- **Mitosis**: Somatic cell division. Produces two diploid identical daughter cells.

- **Meiosis**: Reduction division. Produces four haploid gametes. Introduces genetic variation by crossing over (Prophase I).

Section 2: Human Nutrition

2.1 Classification of Nutrients

Nutrients are classified into:

1. **Macronutrients** (required in large amounts – carbohydrates, proteins, fats, water).
2. **Micronutrients** (required in small amounts – vitamins, minerals).

2.2 Macronutrients

*(A) **Carbohydrates***

- Main source of energy (1g = 4 kcal).
- Composed of C, H, O in ratio ~1:2:1.
- Types:
    - Monosaccharides: Glucose, Fructose, Galactose.
    - Disaccharides: Sucrose (glucose + fructose), Lactose (glucose + galactose), Maltose (glucose + glucose).
    - Polysaccharides: Starch, Glycogen, Cellulose.
- Sources: cereals, pulses, potato, fruits.
- Deficiency: ketosis, fatigue.

*(B) **Proteins***

- 1g = 4 kcal.
- Made of amino acids linked by peptide bonds.
- 20 amino acids → 9 essential (cannot be synthesized, e.g., Lysine, Methionine, Valine, Leucine, Isoleucine, Threonine, Tryptophan, Histidine, Phenylalanine).
- Functions: structural (keratin, collagen), enzymatic, hormones, antibodies.

- Sources: pulses, meat, eggs, fish, soybeans, milk.
- Deficiency:
    - **Kwashiorkor**: protein deficiency → edema, enlarged liver, lethargy.
    - **Marasmus**: protein + calorie deficiency → wasting, weakness.

(C) ***Fats (Lipids)***

- 1g = 9 kcal (most energy-dense nutrient).
- Composed of glycerol + fatty acids.
- Saturated fatty acids (butter, ghee) vs Unsaturated (mustard oil, sunflower oil).
- Essential fatty acids: **Linoleic acid, Alpha-linolenic acid, Arachidonic acid**.
- Functions: energy storage, insulation, absorption of fat-soluble vitamins (A, D, E, K).
- Excess: obesity, atherosclerosis, cardiovascular disease.

(D) ***Water***

- Constitutes ~60–70% of human body.
- Functions: solvent, thermoregulation, transport of nutrients, excretion.
- Requirement: 2–3 litres/day (varies).

2.3 Micronutrients – Vitamins

Fat-Soluble Vitamins

1. **Vitamin A (Retinol)**
    - Sources: carrots, spinach, liver, milk, butter.
    - Functions: vision (retinal component of rhodopsin), epithelial tissue maintenance.
    - Deficiency: Night blindness (Nyctalopia), Xerophthalmia, Keratomalacia.
2. **Vitamin D (Calciferol)**
    - Forms: D_2 (Ergocalciferol), D_3 (Cholecalciferol).
    - Synthesized in skin under UV-B light.
    - Sources: fish liver oil, egg yolk, fortified milk.
    - Functions: calcium and phosphorus metabolism, bone health.
    - Deficiency: Rickets (children), Osteomalacia (adults).
3. **Vitamin E (Tocopherol)**

- Sources: vegetable oils, nuts, seeds.
- Functions: antioxidant, protects cell membranes from oxidative damage.
- Deficiency: hemolytic anemia, neurological disorders.

4. **Vitamin K (Phylloquinone, Menaquinone)**
    - Sources: leafy greens, intestinal bacteria.
    - Function: synthesis of clotting factors II, VII, IX, X.
    - Deficiency: bleeding disorders, delayed clotting.

Water-Soluble Vitamins

1. **Vitamin B1 (Thiamine)**
    - Coenzyme: Thiamine pyrophosphate.
    - Sources: cereals, pulses, pork.
    - Deficiency: Beri-Beri (wet – cardiac; dry – neurological), Wernicke's encephalopathy.
2. **Vitamin B2 (Riboflavin)**
    - Coenzymes: FAD, FMN.
    - Sources: milk, eggs, green vegetables.
    - Deficiency: Cheilosis, Glossitis, Corneal vascularization.
3. **Vitamin B3 (Niacin / Nicotinic acid)**
    - Coenzymes: NAD, NADP.
    - Sources: groundnuts, meat, cereals.
    - Deficiency: Pellagra (Dermatitis, Diarrhoea, Dementia).
4. **Vitamin B5 (Pantothenic acid)**
    - Component of Coenzyme A.
    - Sources: eggs, meat, whole grains.
    - Deficiency: rare; fatigue, burning feet syndrome.
5. **Vitamin B6 (Pyridoxine, Pyridoxal, Pyridoxamine)**
    - Coenzyme: Pyridoxal phosphate.
    - Sources: meat, cereals, banana.
    - Deficiency: microcytic anemia, irritability, seizures.
6. **Vitamin B7 (Biotin)**

- Sources: nuts, soy, egg yolk (raw egg white contains avidin which binds biotin).
- Deficiency: dermatitis, alopecia, neurological symptoms.

7. **Vitamin B9 (Folic Acid)**
   - Coenzyme in nucleotide synthesis.
   - Sources: green leafy vegetables, pulses.
   - Deficiency: megaloblastic anemia, neural tube defects in fetus.
8. **Vitamin B12 (Cobalamin)**
   - Contains cobalt atom.
   - Sources: animal foods (meat, fish, eggs, milk).
   - Deficiency: pernicious anemia, neuropathy.
9. **Vitamin C (Ascorbic acid)**
   - Strong reducing agent.
   - Sources: citrus fruits, guava, amla.
   - Functions: collagen synthesis, antioxidant, iron absorption.
   - Deficiency: scurvy (bleeding gums, poor wound healing).

2.4 Minerals

- **Calcium (Ca)**: bones, clotting, muscle contraction. Deficiency → rickets, osteoporosis.
- **Phosphorus (P)**: bone and teeth, ATP, nucleic acids.
- **Iron (Fe)**: hemoglobin, cytochromes. Deficiency → microcytic hypochromic anemia.
- **Iodine (I)**: thyroid hormone synthesis. Deficiency → goiter, cretinism.
- **Zinc (Zn)**: enzyme cofactor, wound healing. Deficiency → growth retardation, hypogonadism.
- **Selenium (Se)**: antioxidant (glutathione peroxidase). Deficiency → Keshan disease.

2.5 Balanced Diet

- Should provide ~55–65% carbs, 10–15% protein, 20–30% fat.
- Indian Council of Medical Research (ICMR) – Recommended Dietary Allowance (RDA) varies by age, sex, and activity.

Section 3: Plant Nutrients and Improvement of Food Production

3.1 Introduction

Plants, like all living organisms, require nutrients for **growth, development, reproduction, and resistance to diseases**. Unlike animals, plants synthesize their own food through photosynthesis, but they need a **constant supply of mineral nutrients** from the soil, water, and air. Agricultural science has shown that deficiency or excess of particular nutrients affects not only plant health but also **crop yield and food security**. Understanding plant nutrition is therefore central to **increasing food production**, which is a core goal of national agricultural policies.

The subject also has a **direct link with India's Green Revolution, agricultural sustainability, and biotechnology**, making it a highly important topic for civil service exams.

3.2 Classification of Plant Nutrients

Nutrients are classified on the basis of **quantity required** and **biological function**.

(A) Macronutrients

These are required in large amounts (>1 mg/g dry matter).

1. **Primary Macronutrients**
    - **Nitrogen (N):**
        - Present in amino acids, nucleic acids, chlorophyll, ATP.
        - Deficiency → chlorosis (yellowing of older leaves), stunted growth.
        - Supplied by: Urea $(NH_2)_2CO$, Ammonium sulfate $(NH_4)_2SO_4$, Nitrate salts.

- **Phosphorus (P):**
    - Component of nucleic acids, ATP, phospholipids.
    - Deficiency → stunted roots, purpling of leaves.
    - Supplied by: Diammonium Phosphate (DAP) $(NH_4)_2HPO_4$, Superphosphate.
- **Potassium (K):**
    - Regulates osmosis, enzyme activation, stomatal function.
    - Deficiency → leaf edge necrosis ("scorching"), weak stems.
    - Supplied by: Muriate of Potash (MOP = KCl).

2. **Secondary Macronutrients**
    - **Calcium (Ca):** cell wall stability (calcium pectate), root growth.
    - **Magnesium (Mg):** central atom of chlorophyll, enzyme cofactor.
    - **Sulphur (S):** component of cysteine, methionine (amino acids), vitamins (Biotin, Thiamine).

(B) **Micronutrients**

Required in very small amounts (<100 ppm in plant tissue).

- **Iron (Fe):** chlorophyll synthesis (though not part of molecule). Deficiency → interveinal chlorosis in young leaves.
- **Manganese (Mn):** activates enzymes of photosynthesis. Deficiency → mottled leaves.
- **Zinc (Zn):** auxin synthesis, enzyme activation. Deficiency → "little leaf disease" in rice.
- **Copper (Cu):** component of plastocyanin in photosynthesis. Deficiency → die-back of shoots.
- **Boron (B):** essential for cell wall formation, pollen tube growth. Deficiency → death of shoot tip.
- **Molybdenum (Mo):** cofactor of nitrogenase, nitrate reductase (N metabolism). Deficiency → "whiptail" in cauliflower.
- **Chlorine (Cl):** required for photosynthesis (water-splitting step).
- **Nickel (Ni):** essential for urease enzyme.

3.3 Fertilizers

(A) Chemical Fertilizers

1. **Nitrogenous Fertilizers**
    - Urea: $(NH_2)_2CO$, 46% N.
    - Ammonium sulfate: $(NH_4)_2SO_4$, 21% N + 24% S.
    - Calcium ammonium nitrate (CAN): 25–28% N.
2. **Phosphatic Fertilizers**
    - Diammonium phosphate (DAP): 18% N, 46% P_2O_5.
    - Single superphosphate (SSP): 16–20% P_2O_5.
3. **Potassic Fertilizers**
    - Muriate of potash (MOP, KCl): 60% K_2O.
    - Sulphate of potash (K_2SO_4): 50% K_2O.
4. **Complex Fertilizers**
    - Contain more than one nutrient, e.g., NPK mixtures.

Problem: Excessive use leads to **soil salinity, groundwater pollution (nitrates), eutrophication**, and micronutrient imbalance.

(B) Organic Fertilizers

- Farmyard manure (FYM).
- Green manures (Sesbania, Crotalaria).
- Compost, bio-compost.
- Vermicompost (earthworm-based).

(C) Biofertilizers

Biofertilizers are **living microorganisms** which increase nutrient availability.

1. **Nitrogen-fixing bacteria**
    - *Rhizobium* (symbiotic with legumes).
    - *Azotobacter*, *Azospirillum* (free-living).
2. **Cyanobacteria (BGA)**

- *Anabaena*, *Nostoc* – fix nitrogen in rice fields.

3. **Mycorrhizal fungi**
    - Symbiosis with roots; enhance phosphorus absorption.
4. **Phosphate-Solubilizing Bacteria (PSB)**
    - *Pseudomonas striata*, *Bacillus megaterium*.

Advantages: Cost-effective, eco-friendly, improve soil fertility.

3.4 Vermicompost

- Made by decomposition of organic matter using earthworms (*Eisenia fetida*, *Eudrilus eugeniae*).
- Rich in humus, plant growth regulators, and enzymes.
- Improves soil aeration, water holding, and microbial activity.

3.5 Integrated Nutrient Management (INM)

- Combination of **chemical fertilizers, organic manures, and biofertilizers**.
- Objective: sustain soil health and productivity.
- Example: Partial substitution of urea with FYM + PSB in paddy fields improves yield and maintains fertility.

3.6 Increasing Food Production

(A) High-Yielding Varieties (HYVs)

- Introduced during India's Green Revolution (1960s).
- Examples:
    - Wheat: *Kalyan Sona*, *Sonalika*.
    - Rice: *IR-8*, *Jaya*, *Swarna*.

(B) Hybrid Seeds

- Cross between two genetically distinct lines → hybrid vigor (heterosis).
- Used in maize, sorghum, cotton, vegetables.

(C) Irrigation Practices

- Canal irrigation, tube wells, drip irrigation, sprinkler irrigation.
- Micro-irrigation conserves water and increases efficiency.

(D) Pest & Weed Control

- Integrated Pest Management (IPM): biocontrol agents + minimal pesticides.
- Examples: *Trichogramma* wasps (control sugarcane borer), neem extracts.

3.7 Biotechnology in Agriculture

(A) Genetically Modified Crops

- **Bt Cotton:** Gene from *Bacillus thuringiensis* (Cry protein) inserted to resist bollworm.
- **Golden Rice:** Enriched with β-carotene (provitamin A).
- **Flavr-Savr Tomato:** Delayed ripening by antisense RNA.
- Benefits: higher yield, pest resistance, improved nutrition.
- Concerns: biosafety, gene flow, resistance development, ethical debates.

(B) Tissue Culture & Micropropagation

- Produces disease-free, uniform plants.
- Example: Banana, Orchid propagation.

(C) Molecular Breeding

- Marker-Assisted Selection (MAS) speeds up breeding of disease-resistant varieties.

3.8 Sustainable Agriculture

- Crop rotation and mixed cropping to maintain soil health.
- Organic farming to reduce chemical load.
- Conservation tillage and mulching to improve soil structure.
- Precision farming using sensors, drones, GIS for resource optimization.

3.9 National Programs and Policies (India)

- **National Food Security Mission (NFSM)** – enhance production of rice, wheat, pulses.
- **Rashtriya Krishi Vikas Yojana (RKVY)** – holistic agricultural development.
- **Pradhan Mantri Krishi Sinchai Yojana (PMKSY)** – irrigation efficiency.
- **Soil Health Card Scheme** – personalized fertilizer recommendations.

3.10 Conclusion

Plant nutrition and food production improvement are **foundations of India's agricultural policy**. Sustainable nutrient management, combined with biotechnology and irrigation efficiency, is key to meeting future food demands while protecting soil and environment.

Section 4: Blood Grouping, Rh Typing, and Hazards of Blood Transfusion

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4.1 Introduction

Blood is a **connective tissue** composed of plasma and formed elements (RBCs, WBCs, platelets). For transfusion, **compatibility between donor and recipient blood** is essential. Mismatches can cause **life-threatening reactions** due to the presence of **antigen–antibody interactions**. Understanding blood group systems is thus critical both in medicine and in public health.

4.2 ABO Blood Group System

- Discovered by **Karl Landsteiner in 1900**.
- Based on the presence/absence of **two antigens (A, B)** on the surface of red blood cells (RBCs) and **naturally occurring antibodies (agglutinins)** in plasma.

Types:

1. **Group A**: Antigen A on RBCs, antibody anti-B in plasma.
2. **Group B**: Antigen B on RBCs, antibody anti-A in plasma.
3. **Group AB**: Antigens A and B on RBCs, no antibodies in plasma. Known as **universal recipient**.
4. **Group O**: No antigens, antibodies anti-A and anti-B in plasma. Known as **universal donor**.

Genetic Basis:

- Controlled by **ABO gene on chromosome 9**.
- Three alleles: **IA, IB, i**.
- IA and IB are codominant, i is recessive.
- Genotypes:
    - IAIA or IAi → Blood group A.
    - IBIB or IBi → Blood group B.
    - IAIB → Blood group AB.
    - ii → Blood group O.

4.3 Rh Factor

- Discovered by Landsteiner and Wiener (1940) in **Rhesus monkeys**, hence the name.
- Based on the presence or absence of **Rh(D) antigen** on RBCs.
- Rh-positive (Rh^+): D antigen present.
- Rh-negative (Rh^-): D antigen absent.

Medical Importance:

- Most Rh^+ individuals (≈85% in India).

- If Rh^- individual receives Rh^+ blood, immune system produces **anti-D antibodies**.
- In subsequent exposures, severe hemolytic reaction occurs.

4.4 Hemolytic Disease of the Newborn (Erythroblastosis Fetalis)

- Occurs when **Rh^- mother carries an Rh^+ fetus**.
- During first pregnancy, small exposure sensitizes mother's immune system.
- In subsequent pregnancies, **maternal anti-D antibodies cross placenta**, attacking fetal RBCs → anemia, jaundice, hepatosplenomegaly, even stillbirth.

Prevention:

- **Anti-D immunoglobulin (Rho(D) Ig)** given to Rh^- mothers within 72 hours of delivery or abortion.

4.5 Blood Transfusion – Principles

1. **Blood typing** must be done (ABO + Rh).
2. **Cross-matching** between donor and recipient samples:
    - Major crossmatch: Recipient serum × donor RBCs.
    - Minor crossmatch: Donor serum × recipient RBCs.
3. Screening for infectious agents: HIV, HBV, HCV, Syphilis, Malaria.
4. Blood is stored in blood banks with anticoagulants (CPDA solution).

4.6 Hazards of Mismatched Transfusion

1. **Acute Hemolytic Transfusion Reaction**
    - Due to ABO mismatch.
    - Symptoms: fever, chills, chest pain, hypotension, hemoglobinuria.
    - Can lead to acute kidney failure, shock, death.
2. **Febrile Non-Hemolytic Reaction**
    - Caused by recipient antibodies against donor WBCs/cytokines.

3. **Allergic/Anaphylactic Reaction**
    - Due to plasma proteins.
    - Symptoms: urticaria, wheezing, bronchospasm.
4. **Transfusion-Transmitted Infections (TTIs)**
    - Despite screening, risks remain (HIV, HBV, malaria).
5. **Iron Overload**
    - In repeated transfusions (e.g., thalassemia patients).
6. **Graft vs Host Disease (GVHD)**
    - Donor lymphocytes attack recipient tissues; occurs in immunocompromised.

4.7 Blood Donation in India

- Voluntary donation is encouraged under **National Blood Policy (2002)**.
- Blood Components:
    - Packed RBCs, Platelet concentrate, Fresh frozen plasma, Cryoprecipitate.
- Benefits: One donation can save multiple lives through component therapy.

4.8 Modern Advances

- **Leukoreduced blood products** – removal of WBCs to reduce reactions.
- **Irradiated blood** – prevent GVHD in immunosuppressed.
- **Synthetic blood substitutes (Hemoglobin-based oxygen carriers, perfluorocarbons)** – under research.

4.9 Conclusion

- Blood grouping and Rh typing are crucial in transfusion medicine.
- Errors can lead to fatal consequences.
- Modern immunohematology and stringent screening have made transfusions much safer.

- Knowledge of this topic is indispensable for **public health, emergency medicine, and civil services aspirants**.

5.8 Conclusion

Health and hygiene are **cornerstones of development**. Communicable diseases remain a challenge in India, but lifestyle-related disorders are also rising. Preventive strategies like **vaccination, sanitation, awareness, and lifestyle modification** are the way forward.

Section 5: Health and Hygiene

5.1 Introduction

Health is defined by the **WHO (1948)** as *"a state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity."* Hygiene refers to the **science and practice of maintaining cleanliness and preventing disease** through safe habits, sanitation, and preventive care.

India, being a populous country with varied climates, faces a **double burden of disease** — both **communicable (infectious)** and **non-communicable (lifestyle-related)** illnesses. Understanding their causes, prevention, and management is essential for both **public administration** and **personal health awareness**.

5.2 Classification of Diseases

(A) **Communicable Diseases**

- Caused by **pathogens** (bacteria, viruses, protozoa, helminths, fungi).
- Spread via direct contact, vectors, food, water, or air.
- Preventable by vaccination, sanitation, and hygiene.

(B) Non-Communicable Diseases (NCDs)

- Result of lifestyle, environment, genetics.
- Chronic in nature (diabetes, hypertension, cancer).
- Account for **60% of deaths in India** (WHO 2022).

5.3 Communicable Diseases – Causes, Symptoms, Prevention

1. Bacterial Diseases

- **Tuberculosis (TB)**
    - Agent: *Mycobacterium tuberculosis*.
    - Transmission: airborne droplets.
    - Symptoms: cough >2 weeks, blood in sputum, weight loss, fever.
    - Treatment: Anti-TB regimen (Rifampicin, Isoniazid, Pyrazinamide, Ethambutol).
    - Prevention: BCG vaccine, early detection.
- **Cholera**
    - Agent: *Vibrio cholerae*.
    - Symptoms: severe watery diarrhoea ("rice water stool"), dehydration.
    - Prevention: safe water, sanitation, Oral Cholera Vaccine (OCV).
- **Typhoid**
    - Agent: *Salmonella typhi*.
    - Spread: contaminated food/water.
    - Symptoms: prolonged fever, rose spots on abdomen.
    - Prevention: Typhoid Vi-polysaccharide vaccine, hand hygiene.

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2. Viral Diseases

- **HIV/AIDS**
    - Virus: Human Immunodeficiency Virus (retrovirus).
    - Attacks **$CD4^+$ T-cells**, weakens immunity.
    - Spread: unsafe sex, infected needles, blood transfusion, mother-to-child.

- Treatment: ART (antiretroviral therapy) lifelong.
- Prevention: safe practices, screening, awareness.

- **Influenza (Flu, including H1N1 "Swine Flu")**
  - Seasonal epidemic disease.
  - Spread: droplets, fomites.
  - Prevention: annual flu vaccines.
- **Dengue & Chikungunya**
  - Virus: Flavivirus (dengue), Alphavirus (chikungunya).
  - Vector: *Aedes aegypti* mosquito (day-biting).
  - Symptoms: high fever, severe joint pain, rash, bleeding (in dengue).
  - Prevention: vector control, elimination of stagnant water, mosquito nets.
- **Japanese Encephalitis (JE)**
  - Virus: Flavivirus.
  - Vector: *Culex* mosquito.
  - Prevention: JE vaccination in endemic areas.

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3. Protozoan Diseases

- **Malaria**
  - Agent: *Plasmodium falciparum, vivax, malariae, ovale*.
  - Vector: *Anopheles* mosquito.
  - Symptoms: intermittent fever with chills, anemia, splenomegaly.
  - Prevention: insecticide-treated nets, ACT (Artemisinin-based Combination Therapy).
- **Amoebiasis**
  - Agent: *Entamoeba histolytica*.
  - Spread: contaminated food/water.
  - Symptoms: dysentery with blood/mucus.
  - Prevention: sanitation, safe drinking water.

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4. Helminthic Diseases

- **Ascariasis (Roundworm)**: *Ascaris lumbricoides* → intestinal obstruction.

- **Filariasis**: *Wuchereria bancrofti* → elephantiasis (lymphatic swelling).
- Control: Mass Drug Administration (MDA) with **DEC + Albendazole**.

5.4 Non-Communicable Diseases (NCDs)

1. **Diabetes Mellitus (Type 2 common)**
    - Cause: insulin resistance.
    - Complications: nephropathy, retinopathy, neuropathy.
    - Prevention: exercise, diet, metformin.
2. **Hypertension**
    - Risk factor for heart disease, stroke, kidney failure.
    - Control: low salt diet, antihypertensive drugs.
3. **Coronary Artery Disease (CAD)**
    - Atherosclerosis → angina, heart attack.
    - Lifestyle modification + statins.
4. **Cancer**
    - Uncontrolled cell proliferation.
    - Common in India: oral (tobacco-related), breast, cervix, lung.
    - Prevention: tobacco control, screening (Pap smear, mammography).
5. **Chronic Obstructive Pulmonary Disease (COPD)**
    - Strongly linked to smoking, air pollution.
6. **Osteoporosis & Arthritis**
    - Bone density loss; common in elderly women.

5.5 Health and Hygiene Practices

- **Personal Hygiene**: handwashing, dental care, safe food, menstrual hygiene.
- **Environmental Hygiene**: waste disposal, clean water, sanitation.
- **Occupational Hygiene**: workplace safety, protective gear.
- **Community Hygiene**: vector control, vaccination drives.

5.6 Substance Abuse and Social Health

- **Tobacco**
    - Contains nicotine, carcinogens.
    - Causes oral cancer, lung cancer, COPD, CVDs.
    - Controlled under COTPA 2003, taxation, pictorial warnings.
- **Alcohol**
    - Chronic use → liver cirrhosis, pancreatitis, accidents.
    - Social impact: family breakdown, violence.
- **Drugs**
    - Opioids, stimulants, sedatives.
    - Cause dependence, overdose, crime.
    - Controlled by NDPS Act (1985).

5.7 Preventive Health Measures in India

- **Swachh Bharat Mission (2014):** Clean toilets, sanitation.
- **Pulse Polio Immunization:** India polio-free since 2014.
- **National AIDS Control Programme (NACP).**
- **Revised National TB Control Programme (RNTCP → NTEP).**
- **National Vector Borne Disease Control Programme (NVBDCP).**
- **Ayushman Bharat & Health and Wellness Centres** for NCD screening.

5.8 Conclusion

Health and hygiene are **cornerstones of development**. Communicable diseases remain a challenge in India, but lifestyle-related disorders are also rising. Preventive strategies like **vaccination, sanitation, awareness, and lifestyle modification** are the way forward.

Section 6: Immunity and Vaccination

6.1 Introduction

Immunity is the **ability of the body to resist infections and toxins** through defense mechanisms. The human immune system is highly evolved, consisting of **barriers, specialized cells, and molecules** that work in coordination. Vaccination is one of the most successful public health interventions, preventing millions of deaths annually by inducing protective immunity against specific diseases.

6.2 Types of Immunity

(A) Innate Immunity (Natural/Non-specific)

- Present from birth.
- Provides immediate defense, not specific to a particular pathogen.
- Components:
    - **Physical barriers**: skin, mucous membranes.
    - **Physiological barriers**: stomach acid, tears (lysozyme), saliva.
    - **Cellular defenses**: phagocytes (neutrophils, macrophages), natural killer (NK) cells.
    - **Humoral factors**: complement proteins, interferons.

(B) Adaptive Immunity (Acquired/Specific)

- Develops after exposure to a pathogen or vaccination.
- **Specific, has memory, and stronger response upon re-exposure.**
- Types:
    a. **Humoral Immunity**
        - Mediated by **B lymphocytes**.
        - Plasma cells produce **antibodies (immunoglobulins)** against antigens.
    b. **Cell-mediated Immunity**
        - Mediated by **T lymphocytes**.
        - Helper T cells ($CD4^+$), Cytotoxic T cells ($CD8^+$).

(C) Active and Passive Immunity

- **Active Immunity**: develops after infection or vaccination. Long-lasting.
- **Passive Immunity**: transfer of ready-made antibodies (e.g., mother to child via placenta/colostrum, injection of antiserum). Temporary.

6.3 Antibodies (Immunoglobulins)

Antibodies are **glycoproteins** secreted by plasma cells. They bind to antigens and neutralize them.

- **IgG**: most abundant; crosses placenta (fetal protection).
- **IgA**: found in mucosal secretions, breast milk.
- **IgM**: first antibody produced in primary response.
- **IgE**: involved in allergic reactions, defense against helminths.
- **IgD**: role in B cell activation.

6.4 Vaccination – Principles

- Introduces an antigen in safe form to stimulate immune memory without causing disease.
- Basis: **memory B and T cells** respond rapidly on future exposure.
- Provides **herd immunity** — when a majority is immunized, the spread of infection reduces, protecting even unvaccinated individuals.

6.5 Types of Vaccines (with Examples)

1. **Live Attenuated Vaccines**
    - Contain weakened forms of pathogens.
    - Examples: BCG (tuberculosis), OPV (oral polio vaccine), MMR (measles, mumps, rubella), Varicella.
    - Advantages: strong, long-lasting immunity.
    - Limitations: not for immunocompromised.
2. **Inactivated (Killed) Vaccines**
    - Pathogen killed by heat/chemicals.

- Examples: IPV (inactivated polio vaccine), Hepatitis A, Rabies.
- Need booster doses.

3. **Toxoid Vaccines**
    - Contain inactivated toxins.
    - Examples: Diphtheria, Tetanus.
4. **Subunit/Recombinant Vaccines**
    - Only parts of pathogen (antigens).
    - Examples: Hepatitis B (recombinant surface antigen), HPV vaccine.
5. **Conjugate Vaccines**
    - Polysaccharide antigen linked to a protein to improve immune response in infants.
    - Examples: Hib (Haemophilus influenzae type b), Pneumococcal (PCV), Meningococcal.
6. **DNA/RNA Vaccines (Modern)**
    - Genetic material encoding antigen is delivered.
    - Examples: COVID-19 mRNA vaccines (Pfizer-BioNTech, Moderna).
7. **Vector-based Vaccines**
    - Harmless viral/bacterial vectors carry antigen genes.
    - Example: Oxford-AstraZeneca COVID-19 vaccine (ChAdOx1).

6.6 National Immunization Schedule (India)

The **Universal Immunization Programme (UIP)** is one of the largest in the world.

- **At Birth**: BCG, OPV-0, Hepatitis B-0.
- **6, 10, 14 weeks**: Pentavalent (DPT + Hep B + Hib), OPV, IPV, Rotavirus, PCV.
- **9–12 months**: Measles-Rubella (MR-1), JE in endemic areas.
- **16–24 months**: DPT booster-1, OPV booster, MR-2, Vitamin A.
- **5–6 years**: DPT booster-2.
- **10 & 16 years**: Td (Tetanus-diphtheria).
- **Pregnant women**: Td doses.

6.7 Cold Chain in Vaccination

- Vaccines are sensitive to heat/freezing.
- Maintained at 2–8 °C until administration.
- Equipment: Ice-lined refrigerators, cold boxes, vaccine carriers.
- Managed by **National Cold Chain Management Information System (NCCMIS)**.

6.8 Modern Vaccine Developments

- **DNA and mRNA vaccines**: allow faster development, used in COVID-19.
- **Edible vaccines**: under research (antigens expressed in plants like banana, potato).
- **Therapeutic vaccines**: target cancers (e.g., HPV vaccine preventing cervical cancer).
- **Nanoparticle-based vaccines**: enhance antigen delivery.

6.9 Challenges in Immunization

- Vaccine hesitancy due to misinformation.
- Cold chain maintenance in remote areas.
- Emergence of new variants (e.g., COVID).
- Need for booster doses and universal coverage.

6.10 Conclusion

Immunity is the natural defense of the body, and vaccination harnesses it for preventive health. With India's vast population, a robust immunization programme is crucial. Modern advancements in biotechnology will further revolutionize preventive medicine.

Section 7: National Health Mission (NHM) – Key Health Programmes

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7.1 Introduction

India, with its **1.4+ billion population**, faces unique public health challenges: maternal and infant mortality, communicable diseases like TB and malaria, emerging non-communicable diseases, and regional health inequities. To address these systematically, the **Government of India launched the National Rural Health Mission (NRHM) in 2005**, which was later **extended in 2013 as the National Health Mission (NHM)** to cover both rural and urban populations.

NHM today is a **flagship umbrella programme** designed to provide **universal, equitable, and affordable health care** to all citizens, with particular attention to **vulnerable populations**.

7.2 Structure of NHM

NHM consists of two sub-missions:

1. **National Rural Health Mission (NRHM)** – launched in 2005 to strengthen rural health care.
2. **National Urban Health Mission (NUHM)** – launched in 2013 for urban poor, slums, and migrant populations.

Focus areas:

- Strengthening public health infrastructure.
- Human resource development (ASHA, ANM, medical officers).
- Maternal and child health.
- Communicable disease control.
- Preventive and promotive health, including NCDs.

7.3 Key Components of NHM

(A) Accredited Social Health Activist (ASHA)

- **ASHA workers** are female community health volunteers (1 per 1000 population in rural areas).
- Roles:
    - Health awareness and mobilization.
    - Escorting women for institutional delivery.
    - Distribution of contraceptives, ORS, zinc tablets.
    - Home-based newborn care (HBNC).
- Incentive-based remuneration (not salaried).

(B) Janani Suraksha Yojana (JSY)

- Launched in 2005 under NRHM.
- Objective: reduce maternal and neonatal mortality by promoting **institutional deliveries**.
- Provides **cash incentives** to pregnant women for delivering in government/empanelled hospitals.
- Differential support for **low-performing vs high-performing states**.

(C) Janani Shishu Suraksha Karyakram (JSSK)

- Launched in 2011.
- Entitlements:
    - Free and cashless delivery (including caesarean).
    - Free drugs, diagnostics, blood, diet during stay.
    - Free transport: home → facility, facility → home, and between facilities.
    - Benefits extended to **sick newborns (up to 1 year)**.

(D) RMNCH+A Approach

- Introduced in 2013 under NHM.

- **Reproductive, Maternal, Newborn, Child and Adolescent Health (RMNCH+A)** approach emphasizes **continuum of care**.
- Key interventions:
    - Antenatal care, safe delivery, postnatal care.
    - Family planning services.
    - Immunization.
    - Adolescent health education (ARSH programme).

(E) LaQshya Programme

- Launched in 2017.
- Objective: improve **quality of care in labour rooms and maternity operation theatres**.
- Emphasizes **respectful maternity care**.
- Implemented at high case-load facilities like district hospitals, FRUs (First Referral Units).

(F) Kayakalp Programme

- Launched in 2015.
- Recognizes and rewards public health facilities that maintain **high standards of sanitation and hygiene**.
- Promotes Swachh Bharat Abhiyan in hospitals.

(G) Home-Based Care Programmes

- **Home-Based Newborn Care (HBNC):**
    - ASHA visits households up to 42 days after birth.
    - Focus: exclusive breastfeeding, thermal care, early detection of illness.
- **Home-Based Young Child Care (HBYC):**
    - For children up to 15 months.
    - Nutrition counseling, growth monitoring.

(H) Free Drugs & Free Diagnostics Initiative

- To reduce out-of-pocket expenditure on health.
- Provides free essential medicines and diagnostic tests at government hospitals.

(I) Emergency Response & Transport

- **Dial 108/102 ambulance services**.
- Provides free transport for pregnant women, accident victims, emergency cases.

7.4 Urban Health Initiatives (NUHM)

- Focus on urban slums, homeless, migrant workers.
- Establishment of **Urban Primary Health Centres (UPHCs)**.
- Outreach through **Urban ASHAs and Mahila Arogya Samitis**.

7.5 Integration with Ayushman Bharat

Although Ayushman Bharat (2018) is administratively separate, its **Health and Wellness Centres (HWCs)** are closely linked with NHM.

- **HWCs**: expanded primary health care including NCD screening, mental health, geriatric care.
- **PM-JAY (Pradhan Mantri Jan Arogya Yojana):** secondary and tertiary care hospitalization insurance.

7.6 Disease Control Programmes under NHM

- **National TB Elimination Programme (NTEP):** goal of TB-free India by 2025.
- **National Vector Borne Disease Control Programme (NVBDCP):** malaria, dengue, chikungunya, JE, kala-azar, filariasis.
- **National Leprosy Eradication Programme (NLEP).**
- **National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases and Stroke (NPCDCS).**

7.7 Achievements of NHM

- Increase in **institutional deliveries** (>80% as per NFHS-5).
- Decline in **Maternal Mortality Ratio (MMR)** to 97 (2018–20, SRS).
- Decline in **Infant Mortality Rate (IMR)** to 27 (2019, SRS).
- Immunization coverage significantly improved under **Mission Indradhanush**.

7.8 Challenges

- Uneven progress across states.
- Human resource shortages in rural areas.
- Inadequate infrastructure in many primary health centres.
- Rising burden of non-communicable diseases.
- Vaccine hesitancy and misinformation.

7.9 Conclusion

The **National Health Mission** has transformed India's health system, especially in maternal and child health. With continued investment, strengthening of infrastructure, and integration of digital health, NHM can help India achieve **Universal Health Coverage (UHC)** and the **Sustainable Development Goals (SDGs)** by 2030.

Section 8: Biotechnology and Biomedical Engineering

8.1 Introduction

Biotechnology is defined as the **application of biological organisms, systems, and processes for the development of products and technologies for human welfare**. It integrates **biology with technology**, using principles of molecular biology, microbiology, genetics, and engineering. Biomedical engineering, on the

other hand, applies **engineering and technological principles to medicine and health care**, leading to diagnostic tools, imaging techniques, and therapeutic devices.

Both are **high-priority subjects** in civil service exams because of their **applications in agriculture, medicine, industry, and environment**.

8.2 Agricultural Biotechnology

(A) **Biofertilizers**

- Biofertilizers are **living microorganisms** that improve nutrient availability to plants.
- Examples:
    - *Rhizobium* → symbiotic N_2 fixation in legumes.
    - *Azotobacter*, *Azospirillum* → free-living N_2 fixers.
    - Blue-Green Algae (BGA: *Anabaena*, *Nostoc*) in paddy fields.
    - Phosphate-Solubilizing Bacteria (PSB: *Pseudomonas striata*).
    - Mycorrhizal fungi → enhance phosphorus absorption.

Advantages:

- Cost-effective.
- Reduces dependence on chemical fertilizers.
- Improves soil fertility and sustainability.

(B) **Vermicompost**

- Produced by decomposition of organic waste using earthworms (*Eisenia fetida*).
- Rich in humus, plant hormones (auxins, gibberellins), and enzymes.
- Improves soil structure, aeration, and water retention.

(C) **Genetically Modified (GM) Crops**

- DNA technology is used to insert desired genes into crops.
- Examples:

- **Bt Cotton**: gene from *Bacillus thuringiensis* produces Cry protein toxic to bollworm.
- **Golden Rice**: engineered to produce β-carotene (Vitamin A precursor).
- **Flavr Savr Tomato**: delayed ripening by antisense RNA.
- **Bt Brinjal**: resistant to fruit and shoot borer (field-tested in India).

Benefits:

- Pest resistance.
- Enhanced nutritional value.
- Reduced pesticide usage.
- Increased yield.

Concerns:

- Biosafety risks (gene transfer to wild species).
- Allergic/toxic effects.
- Ethical issues and farmer dependency on seed companies.

(D) **Transgenic Animals**

Animals whose genome is altered by inserting foreign DNA.

- Applications:
  - **Pharming**: producing pharmaceuticals (e.g., transgenic goats producing antithrombin in milk).
  - **Disease models**: transgenic mice used in cancer and Alzheimer's research.
  - **Organ transplantation**: research on pigs as potential donors (xenotransplantation).

(E) **DNA Fingerprinting**

- Technique to identify individuals based on **unique DNA patterns**.
- Uses **Short Tandem Repeats (STRs)** or **Variable Number Tandem Repeats (VNTRs)**.
- Applications:

- Forensic identification (crime cases, paternity disputes).
- Wildlife conservation (tracking illegal poaching).
- Anthropological studies.

- In India, **Centre for DNA Fingerprinting and Diagnostics (CDFD), Hyderabad** is a premier institute.

(F) Nanotechnology in Agriculture

- Nanoparticles used in smart delivery of fertilizers/pesticides.
- Nano-sensors for soil moisture, nutrient analysis.
- Potential for **precision farming**.

8.3 Medical Biotechnology

(A) Recombinant DNA Technology

- Used for producing therapeutic proteins.
- Examples:
  - **Insulin (Humulin)** produced using *E. coli*.
  - **Human Growth Hormone**.
  - **Interferons** for viral diseases.

(B) Vaccines & Therapeutics

- Recombinant vector vaccines (Hepatitis B, HPV).
- Monoclonal antibodies for cancer therapy.
- Gene therapy (under trial for hemophilia, muscular dystrophy).

(C) Stem Cell Technology

- **Totipotent, pluripotent, multipotent stem cells**.
- Applications: regenerative medicine (spinal cord injuries, Parkinson's, burns).
- Ethical concerns in embryonic stem cell use.

(D) **CRISPR-Cas9 Technology**

- A gene-editing tool allowing **precise modification of DNA**.
- Applications: correcting genetic disorders, developing disease-resistant crops.
- Ethical debates: "designer babies," gene manipulation limits.

(E) **Nanomedicine**

- Nanoparticles for targeted drug delivery (e.g., liposomes, polymeric nanoparticles).
- Nano-diagnostics (quantum dots, biosensors).
- Photothermal therapy for cancer using gold nanoparticles.

8.4 Biomedical Engineering

Biomedical engineering bridges **technology with medicine**, creating devices and techniques to improve health.

(A) **Medical Imaging Techniques**

1. **X-ray Radiography**
    - Uses ionizing radiation.
    - Best for bone fractures, chest imaging.
2. **CT Scan (Computed Tomography)**
    - Cross-sectional images using X-rays + computer processing.
    - Useful in trauma, tumors, lung/chest conditions.
3. **MRI (Magnetic Resonance Imaging)**
    - Based on nuclear magnetic resonance of hydrogen atoms.
    - Excellent for soft tissue, brain, spine imaging.
4. **Ultrasound (USG)**
    - Uses high-frequency sound waves.
    - Safe for pregnancy scans, abdominal imaging, Doppler studies.
5. **PET Scan (Positron Emission Tomography)**
    - Uses positron-emitting tracers (FDG).

- Functional imaging in oncology, cardiology, neurology.

(B) **Diagnostic and Laboratory Techniques**

1. **ELISA (Enzyme-Linked Immunosorbent Assay)**
   - Detects antigen/antibody in patient samples.
   - Used for HIV, Hepatitis, Dengue (NS1 antigen).
2. **PCR (Polymerase Chain Reaction)**
   - Amplifies DNA sequences.
   - Used for COVID-19 detection, genetic testing.
3. **Western Blotting**
   - Identifies proteins.
4. **Electrocardiogram (ECG/EKG)**
   - Records electrical activity of heart.
5. **Electroencephalogram (EEG)**
   - Measures brain electrical activity.
6. **Electromyography (EMG)**
   - Records electrical signals from muscles.

(C) **Biomedical Devices**

- **Pacemaker**: maintains heartbeat in arrhythmias.
- **Dialysis machine**: removes waste in kidney failure.
- **Ventilators**: life-support during respiratory failure.
- **Artificial joints and prosthetics**: restore mobility.

(D) **Recent Advances**

- **Wearable devices**: fitness trackers, glucose monitors.
- **Telemedicine & AI diagnostics**: remote consultations, computer-aided imaging.
- **Robotic surgery**: precision and minimal invasion.

8.5 Ethical, Legal, and Social Issues

- GMO and GM crops: food safety debates.
- Cloning and stem cells: ethical dilemmas.
- DNA databases: privacy concerns.
- AI in health: accountability and regulation.

8.6 Conclusion

Biotechnology and biomedical engineering have **revolutionized agriculture and medicine**. From increasing crop yield and developing GM crops to advanced diagnostic imaging and life-saving devices, these technologies are central to **India's health, food security, and economic development**. Future progress must balance **innovation with ethics and sustainability**.

Section 9: Physics Fundamentals

9.1 Introduction

Physics is the study of matter, energy, and their interactions. For civil service exams, questions are generally asked from **basic principles of mechanics, heat, light, sound, electricity, electromagnetism, and atomic physics**, with applications in daily life, environment, and technology. This section covers the **core concepts** that frequently appear in UPSC and state civil service prelims.

9.2 Force and Laws of Motion

Newton's Laws of Motion

1. **First Law (Law of Inertia):** A body remains at rest or in uniform motion unless acted upon by an external force.
    - Example: A passenger jerks forward when a bus suddenly stops.
2. **Second Law:** Force is proportional to the rate of change of momentum.
    - Formula: **F = ma**.

    - Example: Greater force is needed to accelerate a heavier object.
3. **Third Law:** Every action has an equal and opposite reaction.
    - Example: Rocket propulsion.

Friction

- Opposes relative motion between surfaces.
- Types: static, kinetic, rolling.
- Coefficient of friction (μ) depends on surface nature.
- Applications: brakes, shoes, tires.

Circular Motion

- Centripetal force = mv^2/r.
- Examples: satellites orbiting Earth, banked roads.

Gravitation

- Newton's Law: $F = Gm_1m_2/r^2$.
- Acceleration due to gravity, $g \approx 9.8\ m/s^2$ near Earth.
- Escape velocity: $v_e = \sqrt{(2GM/R)}$. For Earth ≈ 11.2 km/s.
- Satellite motion:
    - Geostationary orbit: altitude ≈ 35,786 km, period = 24 h.
    - Polar orbit: low altitude, Earth observation.

9.3 Work, Power, and Energy

- **Work (W):** Force × displacement × cosθ. Unit: joule (J).
- **Kinetic Energy:** KE = ½ mv^2.
- **Potential Energy:** PE = mgh (near Earth).
- **Conservation of Energy:** Energy cannot be created/destroyed, only transformed.
- **Power (P):** rate of work done. Unit: watt (W).

Applications in Daily Life:

- Hydropower plants convert potential energy of water into electricity.
- Food calories measured in kilocalories (1 kcal = 4184 J).

9.4 Light: Reflection, Refraction, Dispersion

- **Reflection:** angle of incidence = angle of reflection.
    - Plane mirror → virtual, upright image.
    - Concave mirror → real/inverted or magnified.
    - Convex mirror → diminished, wide field of view.
- **Refraction:** bending of light in different media.
    - Snell's Law: $n_1 \sin i = n_2 \sin r$.
    - Total Internal Reflection (TIR) occurs when angle > critical angle.
    - Applications: optical fibers, mirages.
- **Lens Formula:** $1/f = 1/v - 1/u$.
- **Magnification (M):** v/u.
- **Dispersion:** splitting of white light into spectrum (VIBGYOR) by a prism.

9.5 Heat and Thermometry

- **Temperature scales:**
    - Celsius (°C), Fahrenheit (°F), Kelvin (K = °C + 273).
- **Heat Transfer:**
    - Conduction: solids.
    - Convection: fluids.
    - Radiation: vacuum.
- **Specific heat capacity (c):** heat required to raise 1 kg by 1°C.
- **Latent heat:** heat absorbed/released during phase change without temperature change.
    - Example: ice at 0°C absorbs heat without rise in temperature until fully melted.
- **Thermometers:**

- Clinical (35–42 °C).
- Mercury, alcohol, thermistors, digital.

9.6 Sound

- **Nature:** longitudinal wave, requires medium.
- **Speed:** ~343 m/s in air at 20 °C. Faster in liquids, fastest in solids.
- **Properties:** frequency (Hz), wavelength (λ), amplitude.
- **Range of hearing:** 20 Hz–20 kHz.
- **Ultrasound (>20 kHz):** medical imaging, cleaning.

Applications:

- SONAR: depth measurement in oceans.
- Echo: reflection of sound (time gap ≥ 0.1 s).

9.7 Electricity and Magnetism

Current Electricity

- Ohm's Law: $V = IR$.
- Resistance in series: $R = R_1 + R_2 + \ldots$
- Parallel: $1/R = 1/R_1 + 1/R_2 + \ldots$

Electrical Power

- $P = VI = I^2R = V^2/R$.

Household Electricity

- India: 230 V, 50 Hz AC supply.
- Safety: fuses, circuit breakers, earthing.

Magnetism

- Earth's magnetic field: used in compass navigation.
- Electromagnetism: discovered by Oersted (1820).
- Applications: motors, transformers, generators.

9.8 Electromagnetic Spectrum

- Arranged by frequency/wavelength:
    - Radio waves → communication.
    - Microwaves → cooking, radar.
    - Infrared → remote controls, thermal imaging.
    - Visible → 400–700 nm.
    - Ultraviolet → sterilization, vitamin D synthesis.
    - X-rays → medical imaging.
    - Gamma rays → cancer therapy, nuclear reactions.

9.9 Atoms, Molecules, and States of Matter

- **Dalton's Atomic Theory (1803):** matter is made of indivisible atoms (later refined).
- **Modern model:** atoms = protons, neutrons, electrons.
- **Isotopes:** same atomic number (Z), different mass (A). Example: ^{12}C, ^{14}C.
- **Molecules:** group of atoms bonded chemically (H_2O, CO_2).

States of Matter

- Solid: definite shape & volume.
- Liquid: definite volume, no fixed shape.
- Gas: neither definite shape nor volume, compressible.
- Plasma: ionized gas (sun, lightning).
- Bose–Einstein Condensate: at near 0 K, atoms occupy lowest energy state.

9.10 Applications of Physics in Daily Life

- Mirrors and lenses → spectacles, telescopes, cameras.
- Electricity → appliances, industry.
- Satellites → communication, GPS.
- Nuclear physics → energy, medicine.
- Renewable physics → solar, wind energy.

9.11 Conclusion

Physics principles underlie **modern technology and everyday phenomena**. A civil services aspirant must focus on **basic definitions, laws, formulae, and practical applications** rather than deep derivations.

Section 10: Chemistry Essentials

10.1 Introduction

Chemistry is the study of **composition, structure, properties, and transformations of matter**. For civil service exams, questions are often factual, focusing on **basic principles, common compounds, industrial processes, and everyday applications**. This section will summarize key areas such as **acids, bases, salts, pH, important elements, environmental chemistry, polymers, and daily-life chemicals**.

10.2 Acids, Bases, and Salts

Acids

- Substances that release **H^+ ions** in solution.
- Taste sour, turn blue litmus → red.
- Examples:
    - Hydrochloric acid (HCl) → stomach acid.
    - Sulfuric acid (H_2SO_4) → "King of chemicals," used in fertilizers.
    - Nitric acid (HNO_3) → explosives, fertilizers.
    - Acetic acid (CH_3COOH) → vinegar.

Bases

- Substances that release **OH^- ions** in solution.

- Taste bitter, feel soapy, turn red litmus → blue.
- Examples:
    - Sodium hydroxide (NaOH).
    - Potassium hydroxide (KOH).
    - Calcium hydroxide ($Ca(OH)_2$) → lime water.
    - Ammonium hydroxide (NH_4OH).

Salts

- Formed by neutralization of acid + base.
- Examples:
    - Sodium chloride (NaCl) → table salt.
    - Sodium carbonate (Na_2CO_3) → washing soda.
    - Sodium bicarbonate ($NaHCO_3$) → baking soda.
    - Potassium nitrate (KNO_3) → fertilizers, gunpowder.

10.3 pH Scale

- $pH = -\log[H^+]$.
- Ranges from 0 to 14.
- pH < 7 → acidic, pH = 7 → neutral, pH > 7 → basic.

Examples:

- Stomach acid (HCl) → pH 1–2.
- Pure water → pH 7.
- Blood → pH 7.4.
- Soap solution → pH 9–10.

10.4 Important Elements and Compounds

Hydrogen

- Lightest element, used in fuel cells, rocket fuel.

Oxygen

- Essential for respiration, combustion.

Nitrogen

- 78% of air, inert, used in fertilizers (NH_3, urea).

Carbon

- All organic compounds, allotropes: diamond, graphite, fullerenes, graphene.

Chlorine

- Disinfectant, used in water purification, PVC manufacture.

Sodium and Potassium

- Important electrolytes in biological systems.

Calcium

- Bones and teeth ($Ca_3(PO_4)_2$), cement, lime (CaO).

Iron

- Hemoglobin, steel industry.

Copper

- Electrical wiring, alloys (bronze = Cu + Sn).

Aluminium

- Lightweight metal, aircraft, utensils, cans.

10.5 Everyday Chemicals

1. **Washing Soda ($Na_2CO_3 \cdot 10H_2O$)**
    - Water softening, detergent industry.
2. **Baking Soda ($NaHCO_3$)**
    - Baking, antacids, fire extinguishers.
3. **Bleaching Powder ($CaOCl_2$)**
    - Disinfectant, bleaching agent.
4. **Plaster of Paris ($CaSO_4 \cdot \frac{1}{2}H_2O$)**
    - Used in construction, casts for fractures.
5. **Common Salt (NaCl)**
    - Preservative, seasoning, chlorine production.

10.6 Environmental Chemistry

Air Pollution

- Gases: CO, SO_2, NO_2, O_3, particulate matter.
- Effects: smog, acid rain, global warming.

Greenhouse Gases

- CO_2, CH_4, N_2O, O_3, CFCs.
- Responsible for climate change.

Ozone Depletion

- Caused by CFCs releasing chlorine radicals.
- Leads to UV radiation increase → skin cancer, crop damage.
- **Montreal Protocol (1987)**: global agreement to phase out ozone-depleting substances.

10.7 Polymers

- Large molecules made of repeating monomers.

Natural Polymers

- Starch, cellulose, proteins, natural rubber (polyisoprene).

Synthetic Polymers

- Polyethylene (plastic bags).
- Polypropylene (ropes).
- Polystyrene (disposable cups).
- PVC (pipes).
- Nylon, Terylene (fabrics).

Biodegradable Polymers

- Polyhydroxyalkanoates (PHA), Polylactic acid (PLA).

10.8 Metallurgy Basics

- **Ores:** minerals containing metals.

- **Metallurgy:** extraction of metals from ores.

Examples:

- Iron → extracted from hematite (Fe_2O_3).
- Aluminium → from bauxite ($Al_2O_3 \cdot 2H_2O$).
- Copper → from chalcopyrite ($CuFeS_2$).

10.9 States of Matter and Atomic Structure

- **Solid, Liquid, Gas, Plasma, BEC**.
- Dalton's Atomic Theory.
- Modern structure: protons, neutrons, electrons.
- Isotopes (e.g., ^{12}C, ^{13}C, ^{14}C).
- Radioactive isotopes → used in medicine (I-131 for thyroid, Co-60 for cancer therapy).

10.10 Applications in Daily Life

- Soap and detergents → cleaning action by micelles.
- Refrigerants (CFCs → replaced by HFCs).
- Fertilizers → urea, DAP, MOP.
- Batteries → lead-acid, lithium-ion.
- Cement → CaO + SiO_2 + Al_2O_3 mixture.

10.11 Conclusion

Chemistry provides the foundation for **health, industry, agriculture, and environment**. Knowledge of **common compounds, everyday chemicals, environmental issues, and polymers** is vital for civil services.

Section 11: Energy Resources

11.1 Introduction

Energy is the **capacity to do work**, and energy resources are the sources from which we derive usable energy. Human civilization has progressed from reliance on **firewood and muscle power** to coal, petroleum, nuclear, and renewable sources. In India, energy security is a major concern, given the country's dependence on imports and its growing population and industrialization.

For civil service exams, focus areas include: **types of energy, distribution of resources in India, renewable energy initiatives, government schemes, and environmental impacts**.

11.2 Classification of Energy Resources

(A) Conventional (Non-renewable) Sources

- Coal.
- Petroleum and natural gas.
- Hydro power (large dams).
- Nuclear power.

(B) Non-Conventional (Renewable) Sources

- Solar.
- Wind.
- Biomass.
- Tidal and Wave.
- Geothermal.
- Small hydro.
- Hydrogen fuel.

11.3 Coal

- **Formation:** fossilized plant matter over millions of years.
- **Types:**
    - Anthracite (highest carbon, 80–95%).
    - Bituminous.
    - Lignite (brown coal).

    - Peat (lowest quality).
- **India's Reserves:** ~319 billion tonnes (2021).
- Major coalfields: Jharia, Raniganj, Bokaro (Jharkhand, West Bengal); Singrauli (Madhya Pradesh, UP); Talcher (Odisha).
- **Uses:** thermal power, steel industry (coke).

Problems:

- Air pollution (SO_2, NOx, particulates).
- Greenhouse gas emissions (CO_2).
- Land degradation, mining hazards.

11.4 Petroleum and Natural Gas

- Petroleum = mixture of hydrocarbons.
- **Refining:** fractional distillation → LPG, petrol, diesel, kerosene, lubricants.
- **Natural gas:** mainly methane (CH_4), cleaner than coal/petroleum.
- **Reserves in India:**
    - Onshore: Assam, Gujarat.
    - Offshore: Mumbai High, KG Basin (Krishna-Godavari).
- **Organizations:**
    - ONGC, OIL, Indian Oil Corporation.
    - International: OPEC (Organization of Petroleum Exporting Countries).
- **Problems:** dependence on imports (~85% of crude oil is imported).

11.5 Hydroelectric Power

- **Principle:** potential energy of water → turbine → generator.
- First hydel plant in India: **Darjeeling (1898)**.
- Major projects: Bhakra Nangal, Hirakud, Tehri, Sardar Sarovar.
- Advantages: renewable, clean, irrigation, flood control.
- Disadvantages: displacement, ecological disruption, siltation.

11.6 Nuclear Energy

- **Principle:** energy from nuclear fission (splitting of uranium-235, plutonium-239).
- **India's Nuclear Power Plants:**
    - Tarapur (Maharashtra).
    - Rawatbhata (Rajasthan).
    - Kalpakkam (Tamil Nadu).
    - Kudankulam (Tamil Nadu).
    - Kakrapar (Gujarat).
- **Fuel Resources in India:**
    - Uranium: Jharkhand, Andhra Pradesh.
    - Thorium: abundant in monazite sands (Kerala, Odisha).
- **Agencies:**
    - NPCIL (Nuclear Power Corporation of India Limited).
    - BARC (Bhabha Atomic Research Centre).
    - AERB (Atomic Energy Regulatory Board).

11.7 Renewable Energy Sources

(A) Solar Energy

- **Photovoltaic cells (solar panels):** convert sunlight → electricity.
- **Solar thermal:** for water heating, cooking, drying.
- **India's potential:** >750 GW.
- **Schemes:**
    - Jawaharlal Nehru National Solar Mission (JNNSM).
    - PM-KUSUM (solar pumps).
    - International Solar Alliance (ISA, headquartered in Gurugram).

(B) Wind Energy

- India's installed capacity ~43 GW (2022).

- Major states: Tamil Nadu, Gujarat, Maharashtra, Karnataka.
- Example: Muppandal wind farm (Tamil Nadu).

(C) **Biomass Energy**

- Energy from organic matter (wood, crop residue, animal dung).
- **Biogas:** methane-rich gas from anaerobic digestion.
- Biogas plants: Deenbandhu, KVIC models.

(D) **Tidal and Wave Energy**

- Energy from ocean tides and waves.
- India's tidal potential: Gulf of Kutch, Gulf of Cambay, Sundarbans.

(E) **Geothermal Energy**

- Energy from Earth's heat.
- Potential sites: Manikaran (Himachal Pradesh), Puga Valley (Ladakh).

(F) **Small Hydro**

- Plants <25 MW considered "small hydro."
- Environmentally friendly, suitable for hilly regions.

(G) **Hydrogen Energy**

- Hydrogen = clean fuel, water is only byproduct.
- Fuel cells generate electricity via electrochemical reaction.
- Challenges: storage, transport, cost.

11.8 Energy Conservation

- **Energy Efficiency:** LED lights, star-rated appliances.
- **Demand-side management:** rational energy use.
- **Renewable promotion:** subsidies, tax incentives.
- **National Mission on Enhanced Energy Efficiency (NMEEE).**

11.9 Environmental Impacts of Energy Use

- Fossil fuels → greenhouse gases, climate change.
- Large dams → displacement, ecological loss.
- Nuclear energy → radioactive waste, accidents (Chernobyl, Fukushima).
- Renewable sources → relatively clean but need land/technology.

11.10 Government Policies and Institutions

- **Ministry of Power**.
- **Ministry of New and Renewable Energy (MNRE).**
- **Energy Efficiency Bureau (BEE).**
- **Integrated Energy Policy (2006).**
- **National Action Plan on Climate Change (NAPCC, 2008).**

11.11 Conclusion

Energy resources are the **backbone of development**. India must focus on **energy security through diversification**, with a balance between conventional sources (coal, oil, gas) and renewable resources (solar, wind, biomass). Sustainable practices and technological innovations are key to meeting **future demand while protecting the environment**.

Section 12: Communication Systems

12.1 Introduction

Communication is the process of **transmitting information from one place/person to another**. Human progress, governance, trade, and education all rely on effective communication systems.

Modern communication involves **electronic and digital technologies** — radio, television, satellite, telephone, internet, and mobile networks. India has one of the world's largest and fastest-growing communication markets, making this topic highly relevant for civil service exams.

12.2 Elements of a Communication System

- **Transmitter:** converts message into suitable signal.
- **Channel/Medium:** medium through which signal travels (air, cable, fiber optic).
- **Receiver:** converts signal back into message.
- **Noise:** unwanted interference in transmission.

12.3 Radio Communication

- Uses **radio waves (30 Hz – 300 GHz)**.
- **Amplitude Modulation (AM):** varies amplitude of carrier wave.
- **Frequency Modulation (FM):** varies frequency, better sound quality, less noise.

Applications:

- Public broadcasting (All India Radio).
- Emergency communication.
- Rural information dissemination.

12.4 Television Communication

- Combines audio + video signals.
- Transition from **analog (Doordarshan era)** to **digital and DTH (Direct-to-Home)**.
- Satellite TV expanded channels and reach.
- Government uses TV for educational programmes (SWAYAM Prabha).

12.5 Telephone and Mobile Communication

Landline Telephony

- Works on electrical signal transmission over copper wires.

Mobile Communication

- Uses **cellular technology** — dividing area into hexagonal cells with base stations.
- Generations:
    - 1G → analog voice (1980s).
    - 2G → digital voice + SMS.
    - 3G → data + video calling.
    - 4G (LTE) → high-speed internet.
    - 5G (India launched 2022) → ultra-fast, low latency, IoT.

India's growth:

- 1.2 billion+ subscribers (TRAI, 2022).
- Major providers: Jio, Airtel, BSNL, Vodafone-Idea.

12.6 Satellite Communication

- Uses **geostationary satellites (35,786 km above Earth)**.
- Provides global coverage for TV, internet, navigation.

Types:

- **Communication Satellites (INSAT series).**
- **Remote Sensing Satellites (IRS series).**
- **Navigation Satellites (NavIC – India's regional GPS).**

Applications:

- Weather forecasting.
- Disaster management.
- Telecommunication and broadcasting.
- Defense and security.

12.7 Optical Fiber Communication

- Uses **light signals** in glass/plastic fibers.
- Principle: **Total Internal Reflection (TIR).**

- Advantages:
    - High bandwidth.
    - Low signal loss.
    - Immune to electromagnetic interference.
- Applications:
    - Internet backbone.
    - Cable TV.
    - Long-distance telephony.

India's **BharatNet project** aims to connect rural villages with optical fiber internet.

12.8 Internet and Digital Communication

- **Internet:** global network of computers.
- Services: email, social media, e-commerce, e-governance.
- **Broadband penetration in India**: growing rapidly due to Jio and BSNL fiber.
- **Digital India Programme (2015):** aims for paperless governance, universal internet.
- **Unified Payments Interface (UPI):** India's digital payment revolution.

12.9 Wireless Communication and Wi-Fi

- **Bluetooth:** short-range communication.
- **Wi-Fi (IEEE 802.11):** local wireless networks.
- **Li-Fi:** uses light waves for ultra-fast wireless communication (under development).

12.10 Defence and Space Communication

- ISRO satellites: GSAT, INSAT for communication.
- DRDO developing secure defense communication networks.
- Army uses **satellite + radio integration**.

12.11 Challenges in Communication in India

- **Digital Divide:** rural vs urban.
- **Cybersecurity threats.**
- **Data privacy concerns.**
- **Over-dependence on foreign telecom equipment.**

12.12 Government Initiatives

- **BharatNet:** connecting 2.5 lakh gram panchayats with optical fiber.
- **Digital India:** e-governance, digital literacy.
- **5G Mission:** commercial rollout by 2022–23.
- **National Digital Communication Policy (2018):** aims at 100% broadband for villages.

12.13 Future of Communication

- **6G research:** ultra-low latency, terahertz spectrum.
- **Satellite Internet:** Starlink, OneWeb, ISRO's GSAT-based systems.
- **Internet of Things (IoT):** smart homes, autonomous vehicles.
- **Quantum Communication:** hack-proof encryption (India tested in 2021).

12.14 Conclusion

Communication systems are the **nervous system of modern society**. From rural health messages to defense operations and global finance, communication technologies underpin everything. India's progress in telecom and space technology positions it to be a **global leader in digital connectivity**.

Section 13: Basics of Computers and Cybersecurity

13.1 Introduction

The computer is one of the most powerful inventions of modern science, transforming governance, education, industry, and personal life. For civil service aspirants, computers are relevant not from a programming perspective but for their **concepts, applications, and cybersecurity issues**.

Cybersecurity is equally important because digital systems form the backbone of **governance, finance, defense, and communication** in India. Civil servants must understand the basics of **cybercrime, digital safety, and government initiatives** to ensure secure governance.

13.2 History and Generations of Computers

1. **First Generation (1940–56)**
    - Based on vacuum tubes.
    - Very large, consumed huge electricity.
    - Examples: ENIAC, UNIVAC.
2. **Second Generation (1956–63)**
    - Used transistors (smaller, more reliable).
    - Examples: IBM 1401.
3. **Third Generation (1964–71)**
    - Integrated Circuits (ICs).
    - Faster, smaller, cheaper.
4. **Fourth Generation (1971–present)**
    - Microprocessors.
    - PCs, laptops.
5. **Fifth Generation (present & future)**
    - Based on Artificial Intelligence (AI), Quantum Computing, Machine Learning.

13.3 Basic Structure of a Computer

- **Input Devices:** keyboard, mouse, scanner, microphone.

- **Output Devices:** monitor, printer, speakers.
- **Central Processing Unit (CPU):**
    - Arithmetic Logic Unit (ALU).
    - Control Unit (CU).
    - Memory (registers, cache).
- **Storage Devices:** HDD, SSD, optical disks, pen drives.
- **Software:**
    - System software (OS: Windows, Linux, macOS).
    - Application software (MS Office, browsers).

13.4 Data Representation and Binary System

- Computer language = binary (0,1).
- **Bit:** smallest unit.
- **Byte:** 8 bits.
- Data units: KB (10^3), MB (10^6), GB (10^9), TB (10^{12}).

13.5 Computer Networks

- **LAN (Local Area Network):** within building.
- **WAN (Wide Area Network):** across cities, countries (e.g., Internet).
- **Client-Server Model.**
- **Protocols:**
    - TCP/IP → foundation of Internet.
    - HTTP/HTTPS → web communication.
    - FTP → file transfer.
    - SMTP → email.

13.6 The Internet

- Worldwide system of interconnected networks.
- Services:

- Email.
- World Wide Web (WWW).
- Social media.
- Cloud computing.
- E-commerce.

- Internet of Things (IoT): interconnection of devices (smart homes, wearable devices).

13.7 E-Governance in India

- **Digital India Programme (2015).**
- Services:
  - Aadhaar-enabled services.
  - UMANG app.
  - DigiLocker.
  - BHIM-UPI for digital payments.
  - e-Courts, e-Office.
- Goal: paperless, transparent governance.

13.8 Cybercrime

Cybercrime refers to **illegal activities conducted using computers and the Internet**.

Types of Cybercrime

1. **Hacking:** unauthorized access to systems.
2. **Phishing:** fake emails/websites to steal data.
3. **Identity theft:** using stolen credentials for fraud.
4. **Cyberstalking & harassment.**
5. **Ransomware:** malware encrypts files, demands ransom.
6. **Financial fraud:** credit card scams, UPI frauds.
7. **Cyber terrorism:** attacks on government or defense systems.

13.9 Cybersecurity

Security Measures

- **Antivirus & firewalls.**
- **Strong passwords & two-factor authentication.**
- **Encryption:** converts data into unreadable form.
- **Regular software updates.**
- **Cyber hygiene practices.**

Cybersecurity Tools

- IDS/IPS (Intrusion Detection/Prevention).
- VPN (Virtual Private Network).
- Blockchain for secure transactions.

13.10 Cybersecurity in India

Legal Framework

- **IT Act 2000**: legal recognition for e-commerce, digital signatures, cybercrime penalties.
- **IT (Amendment) Act 2008**: stronger provisions against identity theft, cyber terrorism.

Institutions

- **CERT-In (Indian Computer Emergency Response Team):** nodal agency for cyber incidents.
- **National Critical Information Infrastructure Protection Centre (NCIIPC).**
- **Cyber Crime Cells** in state police.

Initiatives

- **Cyber Swachhta Kendra (2017):** malware cleaning tools.
- **Digital Saksharta Abhiyan (DISHA):** cyber awareness.
- **Personal Data Protection Bill (under consideration).**

13.11 Artificial Intelligence and Cybersecurity

- AI helps detect threats in real time.
- Predictive analytics for fraud detection.

- Challenges: AI-driven cyberattacks, deepfakes.

13.12 Global Cybersecurity

- **Budapest Convention (2001):** first treaty on cybercrime.
- **Tallinn Manual:** international law on cyber warfare.
- India advocates for a **global cyber governance framework** but has not signed the Budapest Convention (concerns about sovereignty).

13.13 Future Trends

- **Quantum computing** will challenge current encryption.
- **5G networks** → new cybersecurity concerns.
- **Biometric authentication** replacing passwords.
- **Blockchain** for secure governance.

13.14 Conclusion

Computers and the Internet have revolutionized society, but they also bring vulnerabilities. Civil servants must be aware of **cybercrime, legal frameworks, and India's cybersecurity measures** to ensure safe digital governance.

Section 14: Scientific Instruments and Applications

14.1 Introduction

Scientific instruments are tools that allow humans to **observe, measure, and analyze natural phenomena** with precision. From microscopes to satellites, these instruments extend our senses and enable discoveries in biology, medicine, physics, chemistry, geology, and space.

In civil service exams, questions often focus on the **principles, uses, and examples** of such instruments, especially those relevant in daily life, medicine, agriculture, and national research.

14.2 Optical Instruments

(A) Microscope

- **Simple Microscope:** uses a single convex lens. Magnification up to 20×.
- **Compound Microscope:** uses two lenses (objective + eyepiece). Magnification up to 2000×.
- **Electron Microscope:** uses electron beams instead of light.
    - TEM (Transmission Electron Microscope) → internal structure.
    - SEM (Scanning Electron Microscope) → surface details.
- **Applications:** study of cells, microbes, tissues.

(B) Telescope

- **Refracting Telescope:** uses lenses to gather and focus light.
- **Reflecting Telescope:** uses concave mirrors.
- **Radio Telescope:** detects radio waves from space (e.g., GMRT in Pune).
- **Space Telescopes:** Hubble, James Webb.
- **Applications:** astronomy, astrophysics, space research.

(C) Spectrometer

- Splits light into component wavelengths.
- **Uses:**
    - Identifying elements (atomic spectra).
    - Chemical analysis.
    - Measuring refractive index of liquids.

(D) **Periscope**

- Uses mirrors/prisms to see over obstacles (e.g., submarines).

(E) **Binoculars**

- Prism-based optical instruments.
- Applications: defense, sports, wildlife observation.

14.3 Medical Instruments

(A) **Stethoscope**

- Invented by **René Laennec (1816)**.
- Amplifies heart and lung sounds.

(B) **Sphygmomanometer**

- Measures blood pressure.
- Normal BP: 120/80 mmHg.

(C) **ECG (Electrocardiogram)**

- Records electrical activity of the heart.
- Detects arrhythmias, heart attacks.

(D) **EEG (Electroencephalogram)**

- Measures brain electrical activity.
- Used in epilepsy diagnosis.

(E) **Endoscope**

- Flexible tube with camera, used for internal organ imaging.

(F) **MRI (Magnetic Resonance Imaging)**

- Uses strong magnetic field and radio waves.
- Excellent for soft tissue imaging.

(G) **CT Scan**

- Cross-sectional images using X-rays.

(H) **X-ray Machine**

- Discovered by **Wilhelm Röntgen (1895)**.

- Uses X-rays for imaging bones, lungs.

(I) Ultrasound

- Uses high-frequency sound waves.
- Safe for fetal imaging.

14.4 Instruments in Physics

- **Galvanometer:** detects current.
- **Ammeter:** measures current.
- **Voltmeter:** measures potential difference.
- **Multimeter:** measures voltage, current, resistance.
- **Ohmmeter:** resistance measurement.
- **CRO (Cathode Ray Oscilloscope):** displays waveforms.

14.5 Instruments in Chemistry

- **pH Meter:** measures acidity/alkalinity.
- **Chromatograph:** separates chemical mixtures.
- **Mass Spectrometer:** measures molecular mass.
- **Colorimeter:** measures absorbance of light by solutions.

14.6 Instruments in Earth & Space Science

- **Seismograph:** records earthquake waves.
- **Barometer:** measures atmospheric pressure.
- **Hygrometer:** humidity measurement.
- **Anemometer:** wind speed measurement.
- **Rain Gauge:** measures rainfall.
- **Altimeter:** measures altitude (aviation).
- **Compass:** navigation by Earth's magnetic field.

14.7 Modern Instruments

- **GPS (Global Positioning System):** satellite-based navigation. India's version: **NavIC**.

- **Drones (UAVs):** remote sensing, disaster management, defense.
- **Thermal Imaging Cameras:** night vision, military, rescue.
- **Particle Accelerators:** study of atomic particles (CERN's LHC).

14.8 Indian National Laboratories and Instruments

- **ISRO:** space research, satellites, PSLV/GSLV.
- **DRDO:** defense technologies.
- **BARC:** nuclear research, reactors.
- **ICMR:** medical research.
- **CSIR:** multiple labs for industrial/chemical innovations.

14.9 Applications of Instruments in Daily Life

- **Thermometers:** medical, weather, cooking.
- **Weighing scales:** commerce, laboratories.
- **Speedometers & Odometers:** vehicles.
- **Smoke Detectors:** safety in buildings.

14.10 Conclusion

Scientific instruments are the **tools of progress**. They connect theoretical science with practical application, from **detecting earthquakes** to **diagnosing heart diseases** and from **astronomy to nanotechnology**. For a civil servant, awareness of these instruments helps in **policy-making, public health, disaster management, and governance**.

Section 15: National Laboratories and Indian Scientists

15.1 Introduction

India's scientific progress has been driven by a strong network of **national laboratories, research institutes, and visionary scientists**. These institutions contribute to **space exploration, defense technologies, nuclear energy, agriculture, health, and industry**. For civil service exams, questions often focus on the **role of institutions (ISRO, DRDO, CSIR, BARC, ICMR, etc.), key achievements, and contributions of famous Indian scientists including Nobel laureates**.

15.2 Major National Laboratories and Research Institutions

(A) ISRO – Indian Space Research Organisation

- Established: **1969** by Dr. Vikram Sarabhai.
- HQ: Bengaluru.
- Achievements:
    - **SLV-3 (1980):** India's first satellite launch vehicle.
    - **PSLV (Polar Satellite Launch Vehicle):** workhorse, launched 104 satellites in one mission (2017, world record).
    - **GSLV Mk-III:** heavy lift vehicle, used for Chandrayaan-2 & Gaganyaan.
    - **Aryabhata (1975):** first Indian satellite.
    - **Chandrayaan Missions:** Chandrayaan-1 discovered water on the Moon; Chandrayaan-3 achieved soft landing on lunar south pole (2023).
    - **Mangalyaan (2013):** Mars Orbiter Mission, cost-effective interplanetary mission.
    - **NavIC:** India's regional GPS system.
- Upcoming: Gaganyaan (human spaceflight), Aditya-L1 (solar mission).

(B) DRDO – Defence Research and Development Organisation

- Established: **1958**.
- HQ: New Delhi.

- Works on defense technologies in aeronautics, armaments, electronics, missiles, naval systems.
- Achievements:
    - **Missile systems:** Agni, Prithvi, Akash, Nag.
    - **Ballistic Missile Defence Programme.**
    - **Arjun Tank, Tejas Fighter Aircraft.**
    - **Light Combat Helicopter (LCH).**
    - **Nuclear submarine (INS Arihant) support.**

(C) **CSIR – Council of Scientific and Industrial Research**

- Established: **1942**.
- India's largest research network (38 laboratories).
- Fields: aerospace, chemicals, drugs, genomics, environment, food.
- Key labs:
    - **NPL (National Physical Laboratory), Delhi.**
    - **CCMB (Centre for Cellular and Molecular Biology), Hyderabad.**
    - **IIP (Indian Institute of Petroleum), Dehradun.**
- Contributions: generic drugs, affordable medicines, leather technology.

(D) **BARC – Bhabha Atomic Research Centre**

- Established: **1954** (as Atomic Energy Establishment, renamed after Homi J. Bhabha).
- HQ: Trombay, Mumbai.
- Focus: nuclear energy, atomic research, reactors.
- Achievements:
    - **India's first nuclear reactor:** Apsara (1956).
    - Heavy water reactors, nuclear fuel cycle.
    - Research in food irradiation, cancer therapy, desalination.

(E) ICMR – Indian Council of Medical Research

- Apex body for biomedical research.
- Contributions: disease control, vaccines, nutrition studies.
- Played key role during COVID-19 (testing, Covaxin trials).

(F) Other Important Institutes

- **TIFR (Tata Institute of Fundamental Research), Mumbai.**
- **IISc (Indian Institute of Science), Bengaluru.**
- **IIA (Indian Institute of Astrophysics), Bengaluru.**
- **IGCAR (Indira Gandhi Centre for Atomic Research), Kalpakkam.**
- **NIO (National Institute of Oceanography), Goa.**

15.3 Indian Nobel Laureates in Science

1. **C.V. Raman** – Nobel Prize in Physics (1930)
    - Discovery: **Raman Effect** (scattering of light, inelastic scattering).
    - National Science Day celebrated on **28 February**.
2. **Har Gobind Khorana** – Nobel Prize in Medicine (1968)
    - Work on **genetic code and protein synthesis**.
3. **Subrahmanyan Chandrasekhar** – Nobel Prize in Physics (1983)
    - Chandrasekhar Limit (~1.44 solar masses), white dwarfs collapse → neutron stars/black holes.
4. **Venkatraman Ramakrishnan** – Nobel Prize in Chemistry (2009)
    - Structure and function of ribosomes.
5. **Abhijit Banerjee** – Nobel Prize in Economics (2019, with Esther Duflo, Michael Kremer).
    - Not science directly, but major Indian-origin Nobel contribution.

15.4 Other Great Indian Scientists

- **Jagadish Chandra Bose**: pioneer in radio waves, plant physiology.
- **Meghnad Saha**: Saha ionization equation (astrophysics).

- **Satyendra Nath Bose**: collaborated with Einstein, Bose–Einstein statistics, bosons named after him.
- **Homi J. Bhabha**: father of India's nuclear programme.
- **Vikram Sarabhai**: father of India's space programme.
- **M.S. Swaminathan**: father of Green Revolution in India.
- **A.P.J. Abdul Kalam**: missile scientist, "Missile Man of India," former President.

15.5 Modern Contributions

- **ISRO scientists:** Chandrayaan-3, Aditya-L1, Gaganyaan missions.
- **Biotechnology scientists:** development of Covaxin, indigenous vaccines.
- **Young innovators:** contributions in AI, nanotechnology, sustainable agriculture.

15.6 International Collaboration

- **CERN:** Indian physicists contributed to Higgs boson discovery.
- **ITER (France):** India part of nuclear fusion research.
- **Artemis Accords:** India joined lunar exploration missions with NASA (2023).

15.7 Conclusion

India's progress in **space, nuclear, agriculture, medicine, and defense** rests on the shoulders of its national laboratories and scientists. Recognizing their contributions is essential to inspire the next generation and to ensure that India achieves its vision of **scientific self-reliance (Atmanirbhar Bharat)**.

Section 16: Everyday Science Applications

16.1 Introduction

Science is not limited to laboratories or research institutions; it pervades our **daily lives, household practices, transport, communication, healthcare, agriculture, and environment**. Everyday applications of science make life easier, safer, and more productive.

Civil service exams often test candidates on **practical aspects of science** — how common gadgets work, how environmental technologies improve life, and how public health benefits from scientific advances.

16.2 Household Science Applications

Cooking and Food Preservation

- **Pressure Cooker:** increases boiling point of water by raising pressure, cooking food faster.
- **Refrigerators:** cooling by vapor compression cycle; slows bacterial growth.
- **Microwave Oven:** uses microwave radiation (2.45 GHz) to excite water molecules → heat.
- **Pasteurization:** heating milk to destroy microbes (named after Louis Pasteur).
- **Preservatives:** salt, sugar, vinegar prevent microbial spoilage.

Cleaning and Hygiene

- **Soaps and Detergents:** micelles trap grease and dirt.
- **Disinfectants:** phenyl, bleaching powder, alcohol-based sanitizers.
- **Water Purifiers:** reverse osmosis (RO), UV sterilization, activated carbon filters.

16.3 Gadgets and Appliances

- **Electric Bulb:** filament heated to incandescence.
- **Fluorescent Tubes (CFLs):** coated with phosphor, UV → visible light.
- **LEDs (Light Emitting Diodes):** energy-efficient, long-lasting.
- **Fans and Coolers:** convert electrical to mechanical energy.
- **Air Conditioner:** works on refrigeration cycle, dehumidifies air.
- **Induction Cooktop:** electromagnetic induction heats vessels directly.

- **Smartphones:** combine radio communication, computer, GPS, sensors.

16.4 Science in Transportation

- **Internal Combustion Engines:** petrol (spark ignition) and diesel (compression ignition).
- **Hybrid Vehicles:** combine IC engine + electric motor.
- **Electric Vehicles (EVs):** powered by lithium-ion batteries.
- **Jet Engines:** Newton's Third Law — thrust from high-speed exhaust gases.
- **Railways:** use of electric traction, magnetic levitation (maglev trains).
- **Navigation:** GPS/NavIC for route guidance.

16.5 Science in Communication

- **Mobile Phones:** cellular networks, 4G/5G internet.
- **Wi-Fi and Bluetooth:** wireless data exchange.
- **Satellites:** global communication and broadcasting.
- **Internet of Things (IoT):** smart appliances, wearable devices.

16.6 Science in Health and Medicine

- **Vaccination:** immunization against diseases.
- **Antibiotics:** e.g., penicillin discovered by Alexander Fleming.
- **Painkillers:** aspirin, paracetamol.
- **Diagnostic Tools:** thermometers, glucometers, sphygmomanometers.
- **Imaging:** X-rays, CT scans, MRIs, ultrasounds.
- **Surgical Advances:** robotic surgery, laparoscopic techniques.
- **Wearables:** smartwatches measure heart rate, SpO_2, step count.

16.7 Science in Agriculture

- **Tractors and Combines:** mechanization.
- **Fertilizers and Biofertilizers:** higher yield.
- **Pesticides and Biopesticides:** pest control.
- **Irrigation:** drip, sprinkler systems.
- **Greenhouses:** controlled environment farming.

- **Genetically Modified Crops:** pest resistance, improved nutrition.
- **Drones:** crop monitoring, pesticide spraying.

16.8 Environmental Technology

- **Air Purifiers:** HEPA filters remove particulates, activated carbon absorbs gases.
- **Wastewater Treatment Plants:** biological treatment using microbes.
- **Solid Waste Management:** composting, recycling, waste-to-energy.
- **Renewable Energy:** solar panels, wind turbines, biogas plants.
- **Electric Buses and Metro Systems:** reduce pollution.
- **Plastic Alternatives:** biodegradable polymers, paper straws, bamboo cutlery.

16.9 Public Safety and Disaster Management

- **Smoke Detectors:** ionization/photoelectric sensors.
- **Metal Detectors:** electromagnetic induction.
- **CCTV Cameras:** surveillance.
- **Earthquake-resistant Buildings:** base isolation, flexible materials.
- **Cyclone Warning Systems:** satellite-based early warnings.
- **GIS (Geographic Information Systems):** disaster mapping and relief planning.

16.10 Space Applications in Daily Life

- **Weather Forecasting:** satellites (INSAT series).
- **Disaster Management:** remote sensing for floods, landslides.
- **Navigation:** NavIC and GPS for transport, fishing, aviation.
- **Agriculture:** crop monitoring by satellites.

16.11 Science in Finance and Governance

- **Digital Payments:** UPI, RuPay, mobile wallets.
- **E-Governance:** online services, paperless offices.
- **Cybersecurity Tools:** digital signatures, Aadhaar-based authentication.

- **Blockchain:** secure records in governance, banking.

16.12 Science in Entertainment

- **Television:** digital transmission, DTH.
- **Music Players:** MP3 compression.
- **VR (Virtual Reality) & AR (Augmented Reality):** immersive gaming, training.
- **OTT Platforms:** streaming via high-speed internet.

16.13 Conclusion

Science and technology **permeate every sphere of life**. From cooking to communication, agriculture to aerospace, everyday applications of science are what truly make it **people-centric**. Civil servants must appreciate these practical aspects, as policies in **health, environment, energy, and education** are directly tied to them.

Section 17: Space, Astronomy, and India's Achievements in Space Science

17.1 Introduction

Astronomy, one of the oldest sciences, studies **celestial bodies, space, and the universe as a whole**. Space science goes further by applying physics, chemistry,

and technology to **understand the cosmos** and use it for practical applications like communication, navigation, weather forecasting, and defense.

India has a proud tradition in astronomy — from **Aryabhata and Varahamihira** to **modern ISRO achievements** such as **Chandrayaan and Mangalyaan**. This section covers the **basics of astronomy, solar system, satellites, telescopes, and India's space programme**.

17.2 Basics of Astronomy

- **Universe:** All matter and energy, ~13.8 billion years old (Big Bang theory).
- **Galaxy:** large system of stars, gas, dust. Our galaxy is the **Milky Way**, ~100,000 light years across.
- **Stars:** massive bodies of hot gases, mostly hydrogen and helium. Produce energy by **nuclear fusion**.
- **Constellations:** groups of stars forming patterns (Orion, Ursa Major).
- **Light Year:** distance light travels in one year (~9.46 trillion km).

17.3 The Solar System

- **Sun:** main star, ~1.39 million km diameter, source of solar energy via fusion of hydrogen to helium.
- **Planets:**
    - **Inner (Terrestrial):** Mercury, Venus, Earth, Mars.
    - **Outer (Gas Giants):** Jupiter, Saturn, Uranus, Neptune.
- **Dwarf Planets:** Pluto, Ceres, Eris, Haumea, Makemake.
- **Moons:** Earth has 1, Jupiter has 79+, Saturn 80+.
- **Other Objects:** asteroids (between Mars–Jupiter), comets (icy bodies), meteors (shooting stars).

17.4 Earth and the Moon

- Earth: only known planet with life.
- Atmosphere: N_2 (78%), O_2 (21%), CO_2, Ar, trace gases.
- Seasons caused by tilt (23.5°) of Earth's axis.
- Moon: Earth's natural satellite, ~3.84 lakh km away.
- Phases: new moon, crescent, half, gibbous, full moon.
- Eclipses:
    - Solar eclipse (Moon between Earth & Sun).
    - Lunar eclipse (Earth between Sun & Moon).

17.5 Satellites

- **Natural Satellite:** e.g., Moon.
- **Artificial Satellites:** man-made, orbiting Earth.

Types of Artificial Satellites

- **Communication satellites:** GSAT, INSAT.
- **Weather satellites:** INSAT, Kalpana-1.
- **Remote sensing satellites:** IRS series.
- **Navigation satellites:** NavIC (Indian GPS).
- **Scientific satellites:** Astrosat (India's space observatory).
- **Military satellites:** RISAT, Cartosat series.

17.6 Indian Space Programme

(A) **Early Phase**

- **INCOSPAR (1962):** set up under Vikram Sarabhai.
- **Aryabhata (1975):** first Indian satellite.

- **SLV-3 (1980):** first launch vehicle, placed Rohini satellite in orbit.

(B) Growth Phase

- PSLV (Polar Satellite Launch Vehicle) – reliable, launched hundreds of satellites.
- GSLV (Geosynchronous Satellite Launch Vehicle) – used for heavier satellites.
- GSLV Mk-III (LVM3) – India's heaviest rocket.

(C) Major Missions

- **Chandrayaan-1 (2008):** first lunar mission, discovered water molecules on Moon.
- **Mangalyaan (Mars Orbiter Mission, 2013):** India became the **first Asian nation** to reach Mars orbit, cost-effective (~₹450 crore).
- **Chandrayaan-2 (2019):** orbiter successful, lander failed.
- **Chandrayaan-3 (2023):** successful soft landing at lunar south pole — first in world history.
- **Aditya-L1 (2023):** India's first solar mission.
- **Gaganyaan (upcoming):** human spaceflight mission.

17.7 Indian Observatories

- **Astrosat (2015):** India's first dedicated multi-wavelength space observatory.
- **Giant Metrewave Radio Telescope (GMRT):** Pune, world's largest radio telescope array.
- **Aryabhatta Research Institute of Observational Sciences (ARIES):** Nainital.
- **Indian Astronomical Observatory:** Hanle, Ladakh (one of world's highest).

17.8 International Space Collaboration

- India collaborates with **NASA, ESA, Roscosmos, CNES, JAXA**.

- Chandrayaan-1 had NASA's Moon Mineralogy Mapper.
- Mangalyaan data shared internationally.
- India signed **Artemis Accords (2023)** for lunar exploration.

17.9 Space Technology Applications in Daily Life

- **Communication:** TV, internet, mobile.
- **Navigation:** NavIC for fishermen, disaster management.
- **Weather Forecasting:** cyclones, monsoons.
- **Remote Sensing:** agriculture, forestry, urban planning.
- **Disaster Management:** mapping floods, landslides, earthquakes.

17.10 India's Future Space Vision

- **Gaganyaan:** human spaceflight programme.
- **Shukrayaan:** proposed Venus mission.
- **Exoplanet studies:** search for habitable worlds.
- **Expansion of NavIC:** regional → global.
- **Space industry reforms:** private players encouraged (IN-SPACe, NSIL).

17.11 Conclusion

Astronomy inspires curiosity, while space science provides **practical benefits for communication, defense, and governance**. India's achievements like **Mangalyaan, Chandrayaan-3, and Aditya-L1** demonstrate self-reliance and global leadership in affordable space exploration. The future holds opportunities for **human spaceflight, interplanetary missions, and commercial space industry growth**.

Section 18: Environmental Science and Ecology

18.1 Introduction

Environment refers to the **sum total of external conditions — physical, chemical, biological, and social — that affect life**. Ecology is the study of **interactions among organisms and their surroundings**.

For civil service exams, environmental science is highly important due to its link with **climate change, biodiversity conservation, pollution control, and sustainable development policies**.

18.2 Components of Environment

- **Abiotic (non-living):** air, water, soil, temperature, light.
- **Biotic (living):** plants, animals, microorganisms.
- **Anthropogenic (human-made):** cities, industries, technology.

18.3 Ecology and Ecosystems

- **Ecosystem:** interaction between biotic and abiotic components.
- Types:
    - Natural → forests, grasslands, deserts, wetlands, oceans.
    - Artificial → agricultural fields, aquariums.
- **Food Chain & Food Web:** flow of energy.
- **Trophic levels:** producers, consumers, decomposers.
- **Ecological Pyramid:** pyramid of number, biomass, energy.

18.4 Biodiversity

- Variety of life at **genetic, species, ecosystem levels**.
- India: one of 17 “mega-diverse” countries, 7–8% of world’s biodiversity.

- **Biodiversity hotspots in India:**
    - Himalaya.
    - Indo-Burma (North-East, Andaman).
    - Indo-Malayan (Nicobar).
    - Indo-Gangetic Plains, Deccan, Western Ghats, Sundarbans.

Conservation Efforts

- **Protected Areas:** national parks, wildlife sanctuaries, biosphere reserves.
- **Project Tiger (1973):** conservation of tigers.
- **Project Elephant (1992).**
- **National Biodiversity Act (2002).**

18.5 Environmental Pollution

Air Pollution

- Pollutants: CO, SO_2, NO_2, O_3, particulates.
- Effects: smog, respiratory diseases, acid rain.
- Control: scrubbers, filters, CNG vehicles.

Water Pollution

- Sources: sewage, industrial waste, agricultural runoff.
- Effects: eutrophication, fish kills, waterborne diseases.

Soil Pollution

- Pesticides, fertilizers, plastics.
- Depletes soil fertility, groundwater contamination.

Noise Pollution

- From vehicles, industries, construction.
- Effects: hearing loss, stress, sleep disturbance.

Radioactive Pollution

- Nuclear accidents (Chernobyl 1986, Fukushima 2011).
- Radioisotopes contaminate soil and water.

18.6 Climate Change

- Caused by **greenhouse gases (GHGs): CO_2, CH_4, N_2O, CFCs**.
- Leads to global warming, sea-level rise, extreme weather.
- India vulnerable due to long coastline, Himalayan glaciers, monsoon dependence.

International Agreements

- **UNFCCC (1992).**
- **Kyoto Protocol (1997):** binding targets for developed countries.
- **Paris Agreement (2015):** limit warming to well below 2°C, preferably 1.5°C.
- India's **NDCs:** renewable energy targets, afforestation, emissions intensity reduction.

18.7 Environmental Disasters

- **Floods:** recurring in Assam, Bihar.
- **Cyclones:** e.g., Fani (2019), Amphan (2020).
- **Earthquakes:** Himalayan belt vulnerable.
- **Landslides:** Himalayan and Western Ghats.
- **Droughts:** Vidarbha, Bundelkhand.

Disaster management requires **early warning, evacuation, resilient infrastructure**.

18.8 Environmental Laws and Policies in India

- **Environment Protection Act (1986).**
- **Air Act (1981), Water Act (1974).**
- **Forest Conservation Act (1980).**
- **Wildlife Protection Act (1972).**
- **National Green Tribunal (NGT, 2010):** speedy disposal of environmental cases.

18.9 Renewable Energy and Sustainable Development

- **Solar, wind, biomass, hydro, geothermal.**

- **Energy Efficiency Bureau (BEE).**
- **Sustainable Development Goals (SDGs, 2015–30).**
- **NAPCC (National Action Plan on Climate Change, 2008):**
    - Missions on solar energy, energy efficiency, sustainable habitat, water, Himalayan ecosystem, green India.

18.10 International Environmental Efforts

- **IPCC (Intergovernmental Panel on Climate Change):** provides climate science reports.
- **Montreal Protocol (1987):** ozone protection.
- **Convention on Biological Diversity (CBD, 1992).**
- **Ramsar Convention (1971):** wetlands conservation.
- **Stockholm Convention:** restricts persistent organic pollutants (POPs).

18.11 Role of Technology in Environmental Protection

- **GIS & Remote Sensing:** mapping forests, monitoring pollution.
- **Bio-remediation:** microbes to clean oil spills, toxic waste.
- **Electric vehicles:** reduce air pollution.
- **Smart grids:** improve energy efficiency.
- **Green buildings:** energy-efficient design.

18.12 Case Studies (India)

1. **Chipko Movement (1973):** community movement for forest conservation.
2. **Silent Valley Project (Kerala):** campaign saved tropical rainforest.
3. **Narmada Bachao Andolan:** against displacement from big dams.
4. **National Solar Mission:** success in scaling solar energy.

18.13 Conclusion

Environmental science links **ecology, economy, and society**. Civil servants must balance development with conservation. India's challenge is to achieve **rapid**

growth without compromising biodiversity, climate goals, and ecological stability.

Section 19: Recent Advances in Science and Technology

19.1 Introduction

Science and technology are **dynamic, ever-evolving fields**. Recent decades have seen revolutionary advances in **artificial intelligence, biotechnology, nanotechnology, quantum science, renewable energy, space exploration, and defense technologies**. These breakthroughs have transformed governance, industry, health, and everyday life.

For civil service exams, the focus is not on technical depth but on **concepts, applications, benefits, and challenges** of these new technologies, especially their **impact on India's development**.

19.2 Artificial Intelligence (AI) and Machine Learning (ML)

- **AI:** simulation of human intelligence in machines.
- **ML:** subset of AI where systems learn from data.
- **Applications:**
    - Governance: predictive policing, smart traffic.
    - Healthcare: diagnosis from scans, drug discovery.
    - Agriculture: crop yield prediction, pest control.
    - Finance: fraud detection, algorithmic trading.
    - Defense: autonomous drones, surveillance.

Concerns:

- Job displacement.
- Data privacy.

- Bias in algorithms.
- Ethical governance.

India's Initiative: **National AI Strategy (NITI Aayog, 2018)** – "AI for All."

19.3 Robotics and Automation

- Robots: machines programmed to perform tasks autonomously.
- **Industrial Robots:** automobile assembly lines.
- **Medical Robots:** robotic surgery, prosthetics.
- **Military Robots:** bomb disposal, surveillance drones.
- **Service Robots:** cleaning, logistics, hospitality.

India: **DRDO's Daksh robot** (bomb disposal), robotic surgery in AIIMS.

19.4 Quantum Science and Technology

- **Quantum Computing:** uses qubits, superposition, entanglement.
- Much faster than classical computers for certain tasks.
- Applications: cryptography, drug discovery, optimization problems.
- **Quantum Communication:** unhackable due to quantum entanglement.
- India: **National Mission on Quantum Technologies and Applications (₹8000 crore, 2020).**

19.5 Nanotechnology

- Deals with materials at **1–100 nm scale**.
- Applications:
    - Medicine → targeted drug delivery, cancer therapy.
    - Electronics → nanochips, memory devices.
    - Energy → nano-solar cells, hydrogen storage.
    - Agriculture → nano-fertilizers, sensors.
- Risks: toxicity, environmental concerns.

India: **Nano Mission (2007, extended 2017)**.

19.6 Biotechnology Advances

- **Genetic Engineering:** CRISPR-Cas9 editing.
- **Stem Cell Therapy:** regeneration of tissues.
- **Synthetic Biology:** creating artificial organisms.
- **Biopharming:** producing medicines in plants/animals.
- India: development of **Covaxin (ICMR + Bharat Biotech)**.

19.7 Information Technology

- **Cloud Computing:** remote data storage, SaaS.
- **Blockchain:** decentralized secure ledger. Uses → cryptocurrency, land records, supply chains.
- **Cybersecurity:** encryption, firewalls, CERT-In (India's cyber emergency team).
- **5G Networks:** launched in India (2022).
- **Internet of Things (IoT):** smart homes, agriculture, industry automation.

19.8 Green and Renewable Energy

- **Solar PV and Solar Thermal.**
- **Wind and Tidal Power.**
- **Hydrogen Economy:** hydrogen as clean fuel.
- **Bioenergy:** waste-to-energy, biogas.
- India:
    - **International Solar Alliance (ISA).**
    - **National Green Hydrogen Mission (2023).**
    - Renewable capacity >170 GW (2023).

19.9 Space Science

- **Reusable Rockets:** SpaceX Falcon 9, ISRO RLV.

- **Private Space Industry:** IN-SPACe, NSIL in India.
- **ISRO Recent Missions:**
    - Chandrayaan-3 (2023) → soft landing on Moon's south pole.
    - Aditya-L1 (2023) → solar observatory.
    - Gaganyaan → human spaceflight (expected 2025).

Global: Artemis (NASA), Mars missions (China, UAE).

19.10 Medical and Health Technologies

- **Telemedicine:** remote consultations.
- **Wearable Devices:** smartwatches track vitals.
- **3D Bioprinting:** artificial tissues, organs.
- **Gene Therapy:** experimental treatments.
- **AI Diagnostics:** cancer detection from scans.

India: **eSanjeevani telemedicine platform** used during COVID-19.

19.11 Defense and Security Technologies

- **Hypersonic Missiles:** >Mach 5.
- **Cyber Warfare Tools.**
- **Drones & UAVs:** surveillance, combat.
- **Laser and Directed Energy Weapons.**
- **Nuclear Submarines, Aircraft Carriers.**

India:

- DRDO developing hypersonic technology demonstrator.
- INS Arihant nuclear submarine.
- Agni-V missile (ICBM, >5000 km range).

19.12 Environmental and Climate Technologies

- **Carbon Capture and Storage (CCS).**
- **Smart Grids and Energy Efficiency.**

- **Electric Vehicles (EVs):** promotion through FAME scheme.
- **Bio-remediation and Biofuels.**
- **Precision Farming:** satellite + drone-based monitoring.

19.13 Ethical and Social Issues

- **AI Ethics:** bias, accountability, privacy.
- **Biotechnology:** cloning, gene editing, designer babies.
- **Data Ownership:** personal data misuse.
- **Dual-use Technology:** civilian vs military applications.

19.14 India's Policy Initiatives

- **National Policy on Science, Technology and Innovation (2013).**
- **Digital India Programme (2015).**
- **Atal Innovation Mission (AIM).**
- **Start-Up India.**
- **National Supercomputing Mission.**

19.15 Conclusion

Recent advances in science and technology offer **immense opportunities for development**, but also pose **challenges of ethics, inequality, and security**. For India, balancing innovation with inclusiveness is vital to achieve the goal of becoming a **global leader in technology while ensuring sustainable growth**.

Section 20: Current Developments in Indian Science and Technology

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20.1 Introduction

India has emerged as one of the fastest-growing nations in **science, technology, and innovation (STI)**. The government promotes STI as a driver of **economic growth, national security, sustainable development, and global leadership**.

Civil service aspirants must be familiar with **current schemes, institutions, policies, awards, and missions** in India's science and technology landscape, along with their **applications in governance, health, agriculture, environment, and defense**.

20.2 National Policies and Frameworks

- **Science, Technology and Innovation Policy (STIP 2013):** foster research, encourage private sector participation.
- **Draft STIP 2020:** open science, innovation-driven entrepreneurship, gender equity in STEM.
- **National Education Policy (NEP 2020):** focus on critical thinking, coding, AI, vocational skills.
- **Make in India & Atmanirbhar Bharat:** promote indigenous technology and manufacturing.

20.3 Key Institutions and Agencies

- **NITI Aayog:** AI strategy, Atal Innovation Mission.
- **Department of Science and Technology (DST).**
- **Department of Biotechnology (DBT).**
- **Department of Space (DoS).**
- **Department of Atomic Energy (DAE).**
- **ICMR (Indian Council of Medical Research).**
- **CSIR (Council of Scientific & Industrial Research).**
- **DRDO (Defence Research & Development Organisation).**
- **ISRO (Indian Space Research Organisation).**

20.4 Recent Flagship Missions

(A) Space and Astronomy

- **Chandrayaan-3 (2023):** India became the first country to land on the Moon's south pole.
- **Aditya-L1 (2023):** India's first solar observatory mission.
- **Gaganyaan (2025 target):** India's first human spaceflight.
- **NISAR (NASA–ISRO Synthetic Aperture Radar):** Earth observation satellite.

(B) Nuclear and Energy

- **India's thorium-based nuclear reactor research** (Kalpakkam).
- **National Green Hydrogen Mission (2023):** promote hydrogen as clean fuel.
- **FAME-II scheme (2019):** incentivizes electric vehicles.

(C) Digital India and Emerging Tech

- **5G launch (2022):** India's rollout of ultra-fast networks.
- **India Semiconductor Mission (2021):** building chip manufacturing ecosystem.
- **National Quantum Mission (2023):** ₹6,000 crore investment in quantum tech.
- **National AI Mission (proposed):** ethical and scalable use of AI.

(D) Health and Medicine

- **COVID-19 response:** development of indigenous vaccine Covaxin (ICMR + Bharat Biotech).
- **Telemedicine platform eSanjeevani.**
- **Ayushman Bharat Digital Mission (ABDM, 2021):** creating digital health IDs.

20.5 Awards in Indian Science

- **Shanti Swarup Bhatnagar Prize:** India's top science award (annual).
- **Infosys Prize:** for research in engineering, science, humanities.
- **Kalam Innovation in Governance Awards.**
- **National Technology Awards (by TDB).**
- **Padma Awards (Padma Shri, Padma Bhushan, Padma Vibhushan):** many scientists honoured.

20.6 Public-Private Partnerships

- **Startup India (2016):** promotes innovation.
- **BIRAC (Biotechnology Industry Research Assistance Council):** funds biotech startups.
- **TIFAC (Technology Information, Forecasting and Assessment Council).**
- Collaborations with global tech giants (Google, Microsoft, Tesla, etc.).

20.7 Current Challenges

- Low expenditure on R&D (~0.7% of GDP, vs 2–3% in developed countries).
- Brain drain of talent.
- Need for indigenous semiconductor and advanced manufacturing.
- Cybersecurity threats.
- Balancing growth with sustainability.

20.8 India's Roadmap to 2047

By the centenary of independence, India aims to be a **global scientific power**:

- **Self-reliance in critical technologies** (semiconductors, AI, defense).
- **Green energy leader** (solar, hydrogen, EVs).
- **Global space power** (manned missions, interplanetary exploration).
- **Digital economy powerhouse** with universal connectivity.
- **Healthcare innovation hub** (affordable medicines, biotech leadership).

20.9 International Collaborations

- **International Solar Alliance (ISA):** launched by India, HQ in Gurugram.
- **CERN (Switzerland):** India contributed to Higgs boson discovery.
- **ITER (France):** India part of nuclear fusion project.
- **Artemis Accords (NASA, 2023):** India joined lunar exploration initiative.
- **BRICS S&T Collaboration.**

20.10 Role of Science in Governance

- **Digital governance:** e-Office, UMANG, Aadhaar-based services.
- **Smart Cities Mission:** ICT-enabled urban services.
- **GIS-based governance:** disaster management, land records.
- **Agri-tech:** drones, satellite crop monitoring.
- **Fintech revolution:** UPI, RuPay, BHIM app.

20.11 Conclusion

India's recent advances in **space, nuclear, digital, health, and environmental technologies** have placed it among global leaders. The government envisions a **science-driven growth model**, where technology becomes the engine of economic prosperity and social equity. Civil servants must stay updated with these developments to integrate them into **policy-making, governance, and national development**.
