Biology Notes

Section 1: NDA General Science (Biology) Syllabus

- Difference between the living and non-living.
- Basis of Life—Cells, Protoplasms and Tissues.
- Growth and Reproduction in Plants and Animals.
- Elementary knowledge of Human Body and its important organs.
- Common Epidemics, their causes and prevention.
- Food—Source of Energy for man. Constituents of food, Balanced Diet.
- Achievements of Eminent Scientists.

Section 2: The Nature of Life

This section establishes the fundamental principles that define life, moving beyond simple definitions to explore the interconnected processes that distinguish biological entities from inanimate matter.

2.1 Defining Life: The Seven Core Characteristics

Living organisms are distinguished from non-living matter by a set of integrated core characteristics. [1]

- **Cellular Organization:**
  - All living things are composed of one or more cells, the basic units of life. [1]
  - Organization is hierarchical: Atoms → Molecules → Organelles → Cells → Tissues → Organs → Organ Systems → Organism. [1]
  - This ordered structure must be maintained to stay alive, as environmental effects can cause it to break down.
- **Metabolism (Energy Processing):**
  - The sum of all chemical reactions within an organism to manage energy and material resources. [5]
  - **Anabolism:** Synthesis of complex molecules from simpler ones (requires

energy). Example: protein synthesis.
    - **Catabolism:** Breakdown of complex molecules into simpler ones (releases energy). Example: digestion of food. [7]
    - Energy is required for all maintenance processes. This energy comes from an outside source, which we call food.
- **Homeostasis:**
    - The ability to maintain a stable, constant internal environment despite external fluctuations. [2]
    - **Example:** Mammals maintain a constant body temperature through thermoregulation (shivering/sweating). [8]
    - This is an active process requiring energy. [9]
- **Growth and Development:**
    - All living things grow and develop according to a genetic blueprint (DNA). [10]
    - Growth is an internal, organized process, primarily by increasing the number and size of cells. [10]
    - This is different from the external accumulation of material seen in non-living objects like crystals. [6]
- **Response to Stimuli:**
    - Living organisms detect and respond to changes (stimuli) in their environment. [1]
    - **Examples:**
        - A plant growing towards a light source (phototropism). [1]
        - The leaves of a sensitive plant (*Mimosa pudica*) folding when touched.
        - Pulling your hand back from a hot flame.
- **Reproduction:**
    - The ability to produce offspring, ensuring the continuity of the species by passing on hereditary information (DNA). [3]
    - **Asexual Reproduction:** A single parent produces genetically identical offspring. [10]
    - **Sexual Reproduction:** Two parents combine genetic material to produce genetically unique offspring. [10]
- **Adaptation and Evolution:**
    - Populations of organisms change over generations to become better suited to their environment through natural selection. [8]

2.2 A Comparative Analysis: Living vs. Non-Living Entities

While some non-living objects may show life-like properties, they lack the complete, integrated suite of characteristics that define a biological organism. [11]

Characteristic	Living Things	Non-Living Things
Cellular Organization	Composed of one or more cells in a hierarchical order. [1]	No cellular structure. [11]
Metabolism	Undergo constant chemical reactions to process energy. [5]	Do not have metabolic reactions; do not require food. [11]
Homeostasis	Actively maintain a stable internal environment. [2]	Internal conditions change passively with the environment.
Growth	Grow from within by increasing cell size and/or number. [6]	May increase in size by external addition (accretion). [6]
Reproduction	Produce offspring, passing on genetic traits. [15]	Cannot reproduce. [11]
Response to Stimuli	React to changes in the environment. [1]	Do not respond in a coordinated, biological manner.
Evolution	Populations adapt and change over generations. [8]	Do not evolve. [11]
Lifespan	Have a finite lifespan (birth, growth, reproduction, death). [11]	Do not have a defined biological life cycle. [11]

Section 3: The Cell - The Fundamental Unit of Life

The cell is the microscopic theater where the processes of life unfold.

3.1 The Cell Theory: A Cornerstone of Modern Biology

- **Historical Context:**
  - **Robert Hooke (1665):** Observed box-like compartments in cork and named them "cells." He was seeing the non-living cell walls. [16]
  - **Antonie van Leeuwenhoek (late 1600s):** First to observe and describe living single-celled organisms ("animalcules") like bacteria and protists. [16]
- **The Three Postulates:**
  1. **All living organisms are composed of one or more cells.** (Formulated by Matthias Schleiden and Theodor Schwann, 1830s). [16]
  2. **The cell is the basic structural and functional unit of life.** [16]
  3. **All cells arise from pre-existing cells.** (Added by Rudolf Virchow, 1855). [16]

3.2 Protoplasm: The Physical Basis of Life

- **Definition:** The entire living content of a cell within the plasma membrane, described as the "physical basis of life." [26]
- **Components:**
  - **Cytoplasm:** Protoplasm outside the nucleus, containing cytosol (fluid) and organelles. [28]
  - **Nucleoplasm:** Protoplasm inside the nucleus. [28]
- **Chemical Composition:** A colloidal system, primarily 75-90% water, with organic (proteins, lipids, carbs) and inorganic (salts, ions) substances. [32]
- **Properties:**
  - **Physical:** Can exist as a fluid-like **sol** or a jelly-like **gel**. Exhibits Brownian movement and cyclosis (cytoplasmic streaming). [28]
  - **Biological:** Site of all metabolic activities; shows irritability, growth, and reproduction. [33]

3.3 Prokaryotic vs. Eukaryotic Cells: A Structural Comparison

All life is composed of either prokaryotic or eukaryotic cells, a fundamental evolutionary divergence.

Feature	Prokaryotic Cell	Eukaryotic Cell

Size	Smaller (0.1–5 µm) [37]	Larger (10–100 µm) [38]
Nucleus	Absent; genetic material in a **nucleoid** region. [39]	Present; a true nucleus enclosed by a nuclear envelope. [37]
DNA Structure	Single, circular chromosome. [38]	Multiple, linear chromosomes. [38]
Membrane-Bound Organelles	Absent. [37]	Present (mitochondria, ER, Golgi, etc.). [40]
Ribosomes	Smaller and simpler. [41]	Larger and more complex. [37]
Cell Wall	Usually present; contains peptidoglycan in bacteria. [42]	Present in plants (cellulose) and fungi (chitin); absent in animals. [43]
Cell Division	Binary fission. [44]	Mitosis and meiosis. [43]
Organism Types	Bacteria, Archaea. [38]	Protists, Fungi, Plants, Animals. [38]

3.4 The Plant Cell vs. The Animal Cell: Key Distinctions

These differences reflect their distinct lifestyles: stationary autotrophs (plants) vs. motile heterotrophs (animals).

Organelle/Structure	Plant Cell	Animal Cell	Primary Function
Cell Wall	Present (cellulose) [45]	Absent [46]	Provides rigid support and protection.
Chloroplasts	Present [47]	Absent [46]	Site of photosynthesis.
Vacuole	One large, central vacuole [48]	Small, temporary vacuoles (if any) [49]	Stores water, maintains turgor

			pressure.
Lysosomes	Generally absent [50]	Present [46]	Contains digestive enzymes.
Centrosomes	Absent in most higher plants [46]	Present [49]	Role in cell division.
Shape	Fixed, rectangular/cuboidal [50]	Irregular/rounded [49]	Due to cell wall vs. flexible membrane.
Energy Storage	Starch [50]	Glycogen [50]	Form of stored glucose.

Section 4: Tissues - The Fabric of Life

A tissue is a group of similar cells working together to perform a specific function.

4.1 An Overview of Plant Tissues

Plant tissues are categorized as meristematic (dividing) or permanent (differentiated). [51]

- **Meristematic Tissues:** Regions of actively dividing cells responsible for growth.
  - **Apical Meristems:** At root and shoot tips; for primary growth (length). [51]
  - **Lateral Meristems:** In stems/roots of woody plants; for secondary growth (girth). [51]
  - **Intercalary Meristems:** In grasses at nodes/leaf bases; for rapid regrowth. [51]
- **Permanent Tissues:** Differentiated cells that have lost the ability to divide. [52]
  - **Simple Permanent Tissues:** Composed of one cell type.
    - **Parenchyma:** Versatile; for photosynthesis (chlorenchyma), storage. [56]
    - **Collenchyma:** Provides flexible support to growing parts. [56]
    - **Sclerenchyma:** Provides rigid support; cells are dead at maturity (fibers, sclereids). [56]
  - **Complex Permanent Tissues (Vascular Tissues):** Composed of multiple cell types.
    - **Xylem:** Transports water and minerals from roots up (unidirectional); provides support. Composed of tracheids, vessel elements, parenchyma,

and fibers. [60]
    - **Phloem:** Transports sugars from leaves to other parts (bidirectional). Composed of sieve tubes, companion cells, parenchyma, and fibers. [61]

4.2 An Overview of Animal Tissues

Animal tissues are classified into four principal types. [64]

- **Epithelial Tissue:**
    - **Structure:** Sheets of tightly packed cells covering body surfaces and lining internal organs. Classified by shape (squamous, cuboidal, columnar) and layers (simple, stratified). [66]
    - **Function:** Protection, absorption, secretion, filtration. [64]
- **Connective Tissue:**
    - **Structure:** Few cells scattered within an extensive extracellular matrix (ground substance + fibers like collagen and elastin). [65]
    - **Function:** Binds, supports, protects, insulates, transports. Includes bone, cartilage, fat, and blood. [65]
- **Muscular Tissue:**
    - **Structure:** Elongated cells (muscle fibers) specialized for contraction. [72]
    - **Function:** Movement, posture, heat generation. [72]
    - **Types:**
        - **Skeletal:** Striated, voluntary control. [74]
        - **Smooth:** Non-striated, involuntary control (in internal organs). [74]
        - **Cardiac:** Striated, involuntary control (only in the heart). [74]
- **Nervous Tissue:**
    - **Structure:** Composed of **neurons** (transmit electrical signals) and **glial cells** (support neurons). [76]
    - **Function:** Senses stimuli, processes information, controls body responses. Forms brain, spinal cord, and nerves. [76]

Section 5: Growth and Reproduction in Plants and Animals

Growth and reproduction are fundamental characteristics ensuring the development of individuals and the continuation of species.

5.1 Fundamental Processes: Mitosis and Meiosis

- **Mitosis:**
  - **Purpose:** Growth, tissue repair, asexual reproduction. [78]
  - **Outcome:** Produces two genetically identical diploid (2n) daughter cells from one parent cell. [78]
- **Meiosis:**
  - **Purpose:** Production of gametes (sperm and eggs) for sexual reproduction. [78]
  - **Outcome:** Produces four genetically unique haploid (n) cells from one parent cell. [78]
  - **Key Event: Crossing over** exchanges genetic material, creating genetic variation. [78]

5.2 Reproduction in Plants

5.2.1 Asexual Reproduction in Plants

Produces genetically identical offspring (clones) from a single parent. [79]

- **Vegetative Propagation:** New plants arise from vegetative parts (roots, stems, leaves). [79]
  - **Natural Methods:**
    - **Runners/Stolons:** (e.g., Strawberry)
    - **Rhizomes:** (e.g., Ginger) [81]
    - **Tubers:** Swollen stems with "eyes" (buds). (e.g., Potato)
    - **Leaf Buds:** Buds on leaf margins develop into new plants. (e.g., *Bryophyllum*)
  - **Artificial Methods:**
    - **Cuttings:** A piece of stem or leaf is planted. (e.g., Money-plant)
    - **Grafting:** A stem (scion) is attached to another plant's root system (rootstock). [81]
    - **Tissue Culture:** Plant fragments are grown in a sterile nutrient medium. [81]
- **Spore Formation:** Common in non-flowering plants (mosses, ferns) and fungi. [80]
  - Spores are tiny, single-celled reproductive units with a hard, protective coat. [79]
  - When conditions are favorable, the spore germinates. [79]
  - **Example:** Bread mould (*Rhizopus*).

5.2.2 Sexual Reproduction in Plants

Involves the fusion of male and female gametes in flowering plants (angiosperms). [80]

- **Pollination:** The transfer of pollen (contains male gametes) from the anther to the stigma. [82]
  - **Self-Pollination:** Pollen transfer on the same flower or plant. [83]
  - **Cross-Pollination:** Pollen transfer between different plants of the same species. [83]
  - **Agents:** Wind, water (abiotic), or animals like insects and birds (biotic). [83]
- **Fertilization:**
  - After pollination, a pollen tube grows down the style to the ovule. [82]
  - Angiosperms undergo **double fertilization**: [87]
    1. One sperm fuses with the egg to form the **zygote** (2n).
    2. The second sperm fuses with two polar nuclei to form the **endosperm** (3n), a nutritive tissue. [89]
- **Fruit and Seed Formation:**
  - The ovule develops into a **seed** (containing the embryo and endosperm). [91]
  - The ovary develops into the **fruit**, which protects the seed and aids dispersal. [91]

5.3 Reproduction in Animals

5.3.1 Asexual Reproduction in Animals

Common in many invertebrates.

- **Fission (Binary Fission):** Parent splits into two or more identical individuals. (e.g., *Amoeba*, *Leishmania*)
- **Budding:** A new individual grows out from the parent's body. (e.g., *Hydra*)
- **Fragmentation and Regeneration:** Body breaks into pieces, and each piece regenerates into a new individual. (e.g., Sea stars, *Planaria*)
- **Parthenogenesis:** An egg develops into an individual without fertilization. (e.g., Bees, some reptiles) [93]

5.3.2 Sexual Reproduction in Animals

Involves the fusion of haploid gametes (sperm and egg). [95]

- **Gametogenesis:** Production of gametes via meiosis in the gonads. [96]

    - **Spermatogenesis:** Produces four small, motile sperm cells. Continuous from puberty. [98]
    - **Oogenesis:** Produces one large, non-motile egg and smaller polar bodies. Finite process. [98]
- **Fertilization:** Fusion of sperm and egg.
    - **External Fertilization:** Occurs outside the body, typically in water. (e.g., Fish, amphibians) [101]
    - **Internal Fertilization:** Occurs inside the female's reproductive tract. (e.g., Reptiles, birds, mammals) [103]
- **Embryonic Development:**
    - **Oviparity:** Lays fertilized eggs that develop outside the mother's body. (e.g., Birds) [103]
    - **Ovoviviparity:** Retains fertilized eggs, but embryo is nourished by yolk; born live. (e.g., Some sharks, snakes) [103]
    - **Viviparity:** Embryo develops inside the mother, receiving nourishment via a placenta. (e.g., Most mammals) [103]

Section 6: Elementary Knowledge of the Human Body

The human body is a complex, integrated system organized in a hierarchical manner.

6.1 The Hierarchy of Organization

1. **Chemical Level:** Atoms and molecules.
2. **Cellular Level:** The fundamental units of life.
3. **Tissue Level:** Groups of similar cells.
4. **Organ Level:** Different tissues joined together (e.g., heart, stomach). [65]
5. **Organ System Level:** Organs working together for a common purpose. [106]
6. **Organismal Level:** All 11 organ systems working in coordination.

6.2 Overview of Major Organ Systems

There are 11 major organ systems that collaborate to maintain homeostasis. [107]

Organ System	Major Organs	Primary Functions

Integumentary	Skin, hair, nails [109]	Protective barrier, temperature regulation. [110]
Skeletal	Bones, cartilage, ligaments [111]	Support, protection, movement, blood cell formation. [112]
Muscular	Skeletal, smooth, cardiac muscles [72]	Movement, posture, heat generation. [72]
Nervous	Brain, spinal cord, nerves [116]	Control and communication network. [117]
Endocrine	Pituitary, thyroid, adrenal glands, pancreas [120]	Produces hormones to regulate growth, metabolism, etc. [120]
Cardiovascular	Heart, blood vessels, blood [123]	Transports oxygen, nutrients, hormones, and wastes. [124]
Lymphatic & Immune	Lymph nodes, spleen, thymus [127]	Returns fluid to blood; defends against pathogens. [127]
Respiratory	Lungs, trachea, bronchi [130]	Facilitates gas exchange (oxygen in, carbon dioxide out). [131]
Digestive	Mouth, stomach, intestines, liver, pancreas [133]	Breaks down food, absorbs nutrients, eliminates waste. [134]
Urinary (Excretory)	Kidneys, bladder, ureters [137]	Filters waste from blood to produce urine; regulates blood volume. [139]

Reproductive	Testes, penis (Male); Ovaries, uterus (Female) [141]	Produces gametes and enables production of offspring. [141]

Section 7: Common Epidemics: Causes and Prevention

An epidemic is the rapid spread of a disease to a large number of people.

7.1 Diseases Caused by Bacteria

- **Cholera**
  - **Agent:** *Vibrio cholerae*. [144]
  - **Transmission:** Contaminated food or water (fecal-oral route). [144]
  - **Symptoms:** Severe watery diarrhea ("rice-water stools"), vomiting, rapid dehydration. [144]
  - **Prevention:** Safe drinking water, sanitation, hygiene (handwashing), oral vaccines. [144]
- **Typhoid Fever**
  - **Agent:** *Salmonella typhi*. [147]
  - **Transmission:** Contaminated food or water (fecal-oral route). [148]
  - **Symptoms:** Sustained high fever, weakness, stomach pain, headache, rash. [148]
  - **Prevention:** Safe water, sanitation, hygiene, vaccination. [148]
- **Tuberculosis (TB)**
  - **Agent:** *Mycobacterium tuberculosis*. [150]
  - **Transmission:** Airborne (spreads through coughs, sneezes). [150]
  - **Symptoms (Active TB):** Prolonged cough (sometimes with blood), chest pain, fever, night sweats, weight loss. [152]
  - **Prevention:** BCG vaccine for infants in high-prevalence areas; isolation of infected individuals. [150]

7.2 Diseases Caused by Viruses

- **Influenza (Flu)**
  - **Agent:** Influenza viruses. [153]
  - **Transmission:** Respiratory droplets (coughs, sneezes). [153]

    - **Symptoms:** Fever, cough, sore throat, muscle aches, fatigue. [153]
    - **Prevention:** Annual vaccination, good hygiene. [153]
- **Measles (Rubeola)**
    - **Agent:** Measles virus. [155]
    - **Transmission:** Highly contagious airborne disease. [155]
    - **Symptoms:** The "3 Cs" (**c**ough, **c**oryza, **c**onjunctivitis), high fever, Koplik's spots in the mouth, widespread rash. [155]
    - **Prevention:** MMR vaccine. [155]
- **Hepatitis**
    - **Agent:** Hepatitis viruses (A, B, C, D, E). [157]
    - **Transmission:** A & E via contaminated food/water; B, C, & D via infected blood/body fluids. [157]
    - **Symptoms:** Jaundice, fatigue, abdominal pain. Chronic B & C can cause liver cancer. [157]
    - **Prevention:** Vaccines for Hepatitis A & B; safe sex, not sharing needles. [157]
- **AIDS (Acquired Immunodeficiency Syndrome)**
    - **Agent:** Human Immunodeficiency Virus (HIV). [159]
    - **Transmission:** Through specific body fluids (blood, semen, etc.), primarily via unprotected sex and sharing needles. [159]
    - **Mechanism:** HIV attacks the immune system (CD4 cells), making the person vulnerable to opportunistic infections. [159]
    - **Prevention:** No cure, but controlled with antiretroviral therapy (ART). Prevention includes condoms, PrEP, and PEP. [159]

7.3 Diseases Caused by Protozoa

- **Malaria**
    - **Agent:** *Plasmodium* parasites. [161]
    - **Transmission:** Bites of infected female *Anopheles* mosquitoes. [162]
    - **Symptoms:** Cycles of fever, chills, and sweating. [161]
    - **Prevention:** Avoiding mosquito bites (nets, repellent), antimalarial drugs, vaccine. [161]
- **Amoebic Dysentery (Amebiasis)**
    - **Agent:** *Entamoeba histolytica*. [163]
    - **Transmission:** Contaminated food or water (fecal-oral route). [163]
    - **Symptoms:** Abdominal pain, diarrhea, bloody stools. [163]
    - **Prevention:** Good hygiene, proper sanitation. [163]

Section 8: Food and Nutrition

Food provides the energy and building materials required to sustain life.

8.1 Food as a Source of Energy

- The body derives energy from the chemical bonds in food molecules. [165]
- **Cellular Respiration:** The process of converting food into usable energy. [165]
    - Macronutrients are broken down into smaller subunits (e.g., carbohydrates into glucose).
    - In the presence of oxygen, glucose is oxidized to produce carbon dioxide, water, and energy. [165]
    - This energy is stored in **adenosine triphosphate (ATP)**, the cell's energy currency. [165]

8.2 Constituents of Food: Macronutrients and Micronutrients

A balanced diet includes macronutrients (needed in large amounts) and micronutrients (needed in small amounts). [169]

8.2.1 Macronutrients

Provide energy and are the body's building blocks. [171]

- **Carbohydrates:**
    - **Function:** Main source of energy (broken down into glucose). [173]
    - **Sources:**
        - **Simple (Sugars):** Fruits, milk, processed foods. [176]
        - **Complex (Starches, Fiber):** Whole grains, legumes, starchy vegetables. [171]
- **Proteins:**
    - **Function:** Essential for growth, repair, and maintenance of tissues; function as enzymes, hormones, and antibodies. [178]
    - **Structure:** Made of **amino acids**. Nine are **essential** and must be obtained from food. [181]

    - **Sources:**
        - **Complete (all 9 essential amino acids):** Meat, fish, eggs, dairy, soy. [171]
        - **Incomplete:** Most plant-based foods (beans, nuts, grains). [171]
- **Fats (Lipids):**
    - **Function:** Concentrated energy source, energy storage, insulation, absorption of fat-soluble vitamins (A, D, E, K). [182]
    - **Types:**
        - **Unsaturated (Healthy):** Olive oil, avocados, nuts, fatty fish. [183]
        - **Saturated:** Meat, dairy, coconut oil. [185]
        - **Trans:** Fried foods, baked goods. [185]

8.2.2 Micronutrients

Vitamins and minerals crucial for physiological functions. [186]

- **Vitamins:** Organic compounds essential for metabolism. [188]
    - **Fat-Soluble (A, D, E, K):** Stored in fatty tissues. Important for vision, bone health, and blood clotting. [188]
    - **Water-Soluble (C and B-complex):** Not stored in the body. Important for energy metabolism, immune function, and iron absorption. [188]
- **Minerals:** Inorganic elements.
    - **Macrominerals:** Calcium (bones), Phosphorus (membranes), Sodium/Potassium (fluid balance). [187]
    - **Trace Minerals:** Iron (hemoglobin), Zinc (immune function), Iodine (thyroid hormones). [186]

8.3 The Concept of a Balanced Diet

A balanced diet provides all essential nutrients in the correct proportions. [192]

- Base meals on high-fiber starchy foods (potatoes, bread, rice).
- Eat at least five portions of fruit and vegetables daily.
- Include dairy or dairy alternatives.
- Consume beans, pulses, fish, eggs, meat, and other proteins.
- Choose unsaturated oils and spreads in small amounts.
- Limit foods high in fat, salt, and sugar.
- Stay hydrated.

Section 9: Achievements of Eminent Scientists in Biology

9.1 The Foundations of Modern Biology

- **Robert Hooke (1635–1703):**
  - First to observe and name "cells" in 1665 after viewing cork under a microscope. [18]
  - His work *Micrographia* provided the basic unit for cell biology. [19]
- **Antonie van Leeuwenhoek (1632–1723):**
  - Known as the "Father of Microbiology." [21]
  - First to observe and describe living microorganisms ("animalcules"), including bacteria and protozoa, using his powerful single-lens microscopes. [20]
- **Carl Linnaeus (1707–1778):**
  - Known as the "Father of Modern Taxonomy." [198]
  - Standardized **binomial nomenclature**, giving each species a unique, two-part Latin name (e.g., *Homo sapiens*). [201]

9.2 The Germ Theory and the Dawn of Microbiology

- **Louis Pasteur (1822–1895):**
  - Provided definitive proof for the **germ theory of disease**. [203]
  - Invented **pasteurization** to kill harmful microbes in liquids like milk and wine. [205]
  - Developed the first effective **vaccines** for anthrax and rabies by attenuating (weakening) microbes. [206]
- **Alexander Fleming (1881–1955):**
  - Discovered the world's first antibiotic, **penicillin**, in 1928. [208]
  - Observed that the mold *Penicillium notatum* had accidentally contaminated a bacterial culture and was killing the bacteria around it. [208]
  - His discovery ushered in the antibiotic era, saving millions of lives. [210]

9.3 The Genetic Revolution

- **Gregor Mendel (1822–1884):**
  - Known as the "Father of Modern Genetics." [212]
  - Through experiments with pea plants, he formulated the fundamental **Laws of**

Inheritance: [212]

1. **Law of Dominance:** One trait masks the effect of another.
2. **Law of Segregation:** Alleles for a trait separate during gamete formation.
3. **Law of Independent Assortment:** Genes for different traits are inherited independently.

- **Charles Darwin (1809–1882):**
  - Proposed the theory of **evolution by natural selection** in his 1859 book, *On the Origin of Species*. [214]
  - His theory is based on key observations: variation exists in populations, traits are heritable, and there is a struggle for existence. [216]
  - Individuals with traits better suited to their environment are more likely to survive and reproduce ("survival of the fittest").
- **James Watson (1928–) and Francis Crick (1916–2004):**
  - Elucidated the **double helix** structure of DNA in 1953. [219]
  - Their model was critically dependent on the X-ray diffraction images of DNA taken by **Rosalind Franklin** and **Maurice Wilkins**. [220]
  - This discovery launched the era of molecular biology.