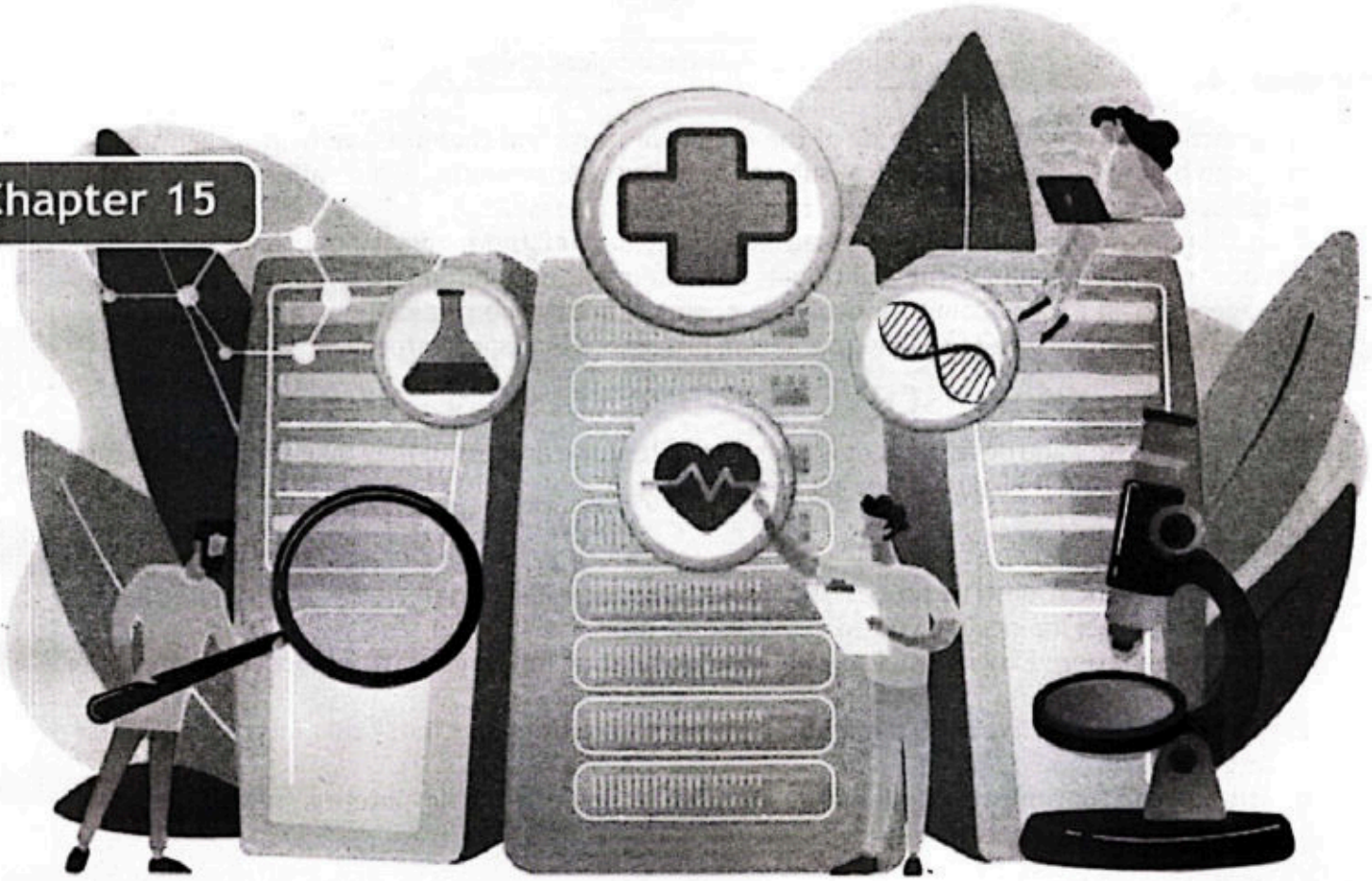
Chapter 15



PHARMACOLOGICAL DRUGS

Students' learning outcomes
After studying this chapter, students will be able to:

1. [B-12-T-01] Explain the drug discovery and development process.
2. [B-12-T-02] Define 4 classes of antibiotics (Penecillins, Tetracyclins, Fluriquinolones and Sulfonamides) and describe their mode of action.
3. [B-12-T-04] Define antivirals and antiretrovirals.
4. [B-12-T-05] Describe advantages of monoclonal antibodies enjoy compared to other drug classes.

Pharmacology is the scientific study of the effects of drugs and chemicals on living organisms. A drug can be defined as any chemical substance, natural or synthetic, which affects a biological system. A drug used to diagnose, cure, treat, or prevent disease.

Drug therapy or pharmacotherapy is an important part of the medical field. It relies on the science of pharmacology for continual advancement and on pharmacy for appropriate management. In pharmacology, a drug is a chemical substance, typically of known structure, which, when administered to a living organism, produces a biological effect.

15.1 DRUG DISCOVERY AND DEVELOPMENT PROCESS

The drug discovery and development is complex multiphase process. It may take several years, or even upto a decade. It involves several important steps.

15.1.1 Drug discovery

a. **Target identification:** The process begins with the identification of a new target molecule, a protein or other molecule involved in the disease process.
b. **Target validation:** Experiments confirm that modulating the target can produce a therapeutic effect.
c. **Hit identification:** Screening large libraries of compounds to find "hits" that interact with the target.
d. **Hit-to lead optimization:** Refining the hits to improve their potency, selectivity and pharmacokinetic properties.

15.1.2 Preclinical Development

a. **In *Vitro* Studies:** Testing the lead compounds in laboratory setting to evaluate their effects on cells and biological systems.
b. **In *Vivo* Studies:** Conducting tests in animal models to assess the safety, efficacy (the ability to produce a desired or intended result), and pharmacokinetics of the compounds.
c. **Toxicology Studies:** Evaluating potential toxicology and side effects through rigorous testing.
d. **Formulation Development:** Developing the drug formulation for stability, delivery and dosage.

15.1.3 Clinical Development

Investigational new drug application: Submitting data from preclinical studies to regulatory authorities (like the FDA) to obtain permission to begin clinical trials.

Clinical Trials are composed of four phases: Phase 1, 2, 3 and 4.

a. **Phase 1 trials:** Testing the drug in a small group of healthy volunteers (20-100 to asses's safety, dosage and pharmacokinetics.
b. **Phase 2 trials:** Expanding the study to a larger group (100-500) of patients to evaluate efficacy and further assessment safety.
c. **Phase 3 trials:** Conducting large-scale studies (1000 -3000 participants) to confirms efficacy. Monitor side effects and compare with standard treatment.
d. **Phase 4 trials:** Post marketing surveillance monitors drug side effects.

15.1.4 Regulatory Review

a. **New drug application:** Submitting comprehensive data from all studies to regulatory authorities for approval to market the drug.

b. Review process: Regulatory agencies evaluate the data for safety, efficacy and quality before granting approval.

15.1.5 Post-Marketing Surveillance (Phase 4)

a. Monitoring: After approval, the drug is continuously monitored for long-term effects, rare side effects and overall effectiveness in the general population.

b. Additional studies: Conducting further studies to explore new uses, dosage adjustments or combinations with other drugs.

In the last we can say that throughout this process, collaboration across various disciplines, such as biology, chemistry, pharmacology and regulatory affairs is essential. The drug discovery and development process is expensive and time consuming, with a high rate of failure at each stage, but it ultimately aims to bring safe and effective medications to patients.

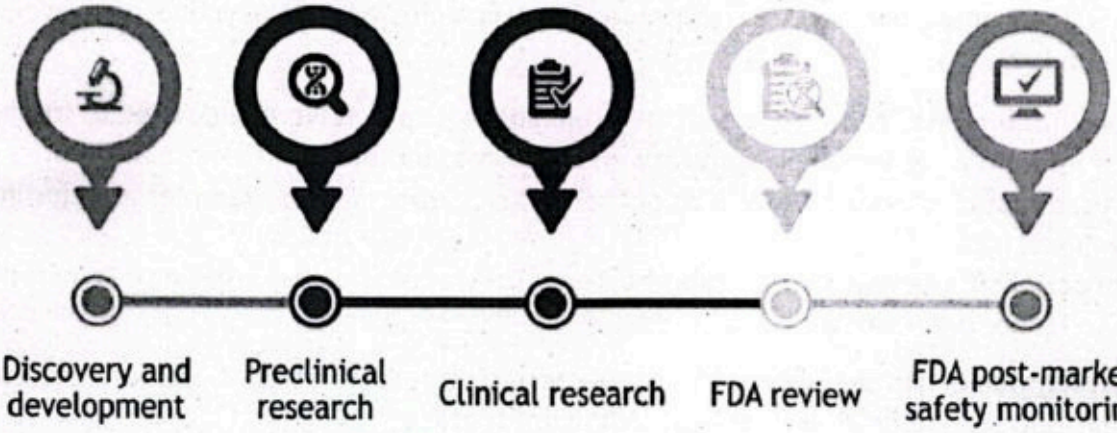


Fig. 15.1: The five drug development phases

15.2 ANTIBIOTICS AND THEIR MODE OF ACTION

Antibiotics are used to treat or prevent some types of bacterial infections.
Antibiotics are medicines that help stop infections caused by bacteria.
Antibiotics work by killing bacteria or stopping them from multiplying. For example, antibiotics can kill bacteria by destroying crucial parts they need to survive, like their cell walls or DNA. Antibiotics can stop the growth of bacteria by preventing them from making certain proteins they need to multiply. Antibiotics do not work for viral infections such as cold and flu and some coughs.

Antibiotic Resistance

Antibiotics are powerful germ-fighting tools when used carefully and safely. But up to half of all antibiotic use isn't necessary. Overuse has led to antibiotic resistance. Bacteria adapt over time and become "super bacteria" or "superbugs." Super bacteria cannot be killed by standard antibiotics because they have developed resistance through genetic mutations and natural selection, allowing them to survive and thrive despite the presence of drugs that would normally kill them.

Types of antibiotics

There are hundreds of different types of antibiotics, but most of them can be classified into four groups.

1. **Penicillins:** These are widely used to treat a variety of infections, including skin infections, chest infections and urinary tract infections. The examples are penicillin, amoxicillin, flucloxacillin etc.
Mode of action: They inhibit bacterial cell wall synthesis by binding to penicillin-binding proteins leading to cell lysis.

2. **Tetracyclines:** These can be used to treat a wide range of infections.
Mode of action: They inhibit protein synthesis by binding to 30S ribosomal subunit, blocking the attachment of aminoacyl-tRNA to ribosome. The examples are tetracycline, doxycycline and minocycline.

3. **Fluoroquinolones:** These are broad-spectrum antibiotics that were once used to treat a wide range of infections, especially respiratory and urinary tract infections; these antibiotics are no longer used routinely because of the risk of serious side effects. The examples are ciprofloxacin and levofloxacin.
Mode of action: These antibiotics inhibit bacterial DNA replication by targeting enzymes like DNA gyrase and topoisomerase IV.

4. **Sulfonamides:** These are synthetic bacteriostatic antibiotics. Sulfonamides include, Mafenide, Sulfacetamide, Sulfadiazine, Sulfanilamide etc.
Mode of action: These competitively inhibit conversion of p-aminobenzoic acid to dihydropteroate, which bacteria need for folate synthesis and ultimately purine and DNA synthesis. Humans do not synthesize folate but acquire it in their diet, so their DNA synthesis is less affected.

15.3 ANTIVIRALS AND ANTIRETROVIRALS

Antivirals and Antiretrovirals are a class of medication specifically used to treat viral and retroviral infections caused by viruses like HIV, herpes viruses, hepatitis B and C.
Antivirals: These are a class of drugs which are used to treat viral infections. They work by inhibiting the ability of viruses to multiply and spread within the body. The antiviral drugs target diverse group of viruses such as herpes, hepatitis, and influenza viruses.

Antiretrovirals: These are a subset of antivirals especially that are used to fight retrovirus infections which mainly include HIV (Human Immunodeficiency Virus). Different classes of antiretroviral drugs act on different stages of the HIV life cycle. Retroviruses are a type of virus that uses RNA as their genetic material and reverse transcriptase to replicate. Antiretrovirals inhibit the replication of retroviruses, helping to control HIV infection and reduce the risk of progression to AIDS.

Do you know?
All antiretrovirals are antivirals but not all antivirals are antiretrovirals.

15.4 ADVANTAGES OF MONOCLONAL ANTIBODIES

Monoclonal antibodies (also called moAbs or mAbs) are **proteins**. They are made in laboratories that act like proteins called **antibodies** in our bodies. Antibodies are parts of our immune system. They seek out the antigens (foreign materials) and stick to them in order to destroy them. Laboratory-made monoclonal antibodies help stimulate our own immune system. The word **"monoclonal"** refers to the fact that the antibodies created in the laboratory are clones. They are exact copies of one antibody. Monoclonal antibodies are used for diagnosis, disease treatment and research.

Do you know?

The difference between monoclonal antibodies and polyclonal antibodies is in the names. "Mono" refers to one and "poly" refers too many. Monoclonal antibodies are clones of just one antibody, and they bind to one antigen only.

SCIENCE TITBITS

Monoclonal antibodies have been used in treatment of Cancer, Organ transplant rejection, Inflammatory and autoimmune disorders, including allergies, Infections, including COVID-19, Osteoporosis, Eye disorders, Migraines, High cholesterol, Nervous system disorders. In most cases, monoclonal antibodies are given mostly as intravenous (IV) solution injected right into your vein (sometimes referred to as an infusion).

Advantages of using Monoclonal Antibodies

Monoclonal antibodies offer several advantages over traditional antibody therapies, including high specificity, consistent quality, and the ability to be produced in large quantities. They can be engineered to target specific antigens, making them effective for various applications like cancer diagnosis, therapy, and diagnostics.

Following are the advantages of using monoclonal antibiotics

1. **High Specificity**: Monoclonal antibodies are engineered to bind to a single, specific antigen or epitope, allowing for precise targeting and reducing off-target effects.
2. **Consistent Quality:** Monoclonal antibodies can be produced in large quantities with consistent quality across different batches, ensuring reproducibility and reliability.
3. **Renewable Production:** Once a hybridoma or recombinant cell line is established, monoclonal antibodies can be produced indefinitely.
4. **Versatile Applications:** Monoclonal antibodies are used in various fields, including:
   a. **Diagnostics:** Used in pregnancy tests, HIV testing and other diagnostic assays.
   b. **Therapy:** Used in cancer treatments, autoimmune disease therapies, and other drug development applications.
   c. **Research:** Used in molecular biology, biochemistry, and other research areas.
5. **Engineering Possibilities:** Monoclonal antibodies can be engineered in the lab to enhance their binding affinity or target specific molecules, allowing for tailored applications.
6. **Humanization:** Monoclonal antibodies can be humanized, minimizing the risk of immune reactions in patients.
7. **Large-Scale Production:** Recombinant DNA technology allows for the production of monoclonal antibodies in large quantities, making them accessible for various applications.

Monoclonal Antibodies Compared to Other Drug Classes

1. Monoclonal antibodies are clones of just one antibody, and they bind to one antigen only. Polyclonal antibodies come from several different types of immune cells and will bind to more than one antigen.
2. The advantages of using monoclonal antibodies to target specific cells compared to drug and radiotherapy treatments means that the drugs specifically target the cancer cells and can allow smaller doses of chemotherapy drugs to be used. This can reduce the side effects and reduce risk to healthy cells. Improving the immune system.
3. The difference between antibiotics and monoclonal antibodies is that mAbs have safety, high target-specificity, less susceptible to resistance mechanisms, longer half-lives (~21 days for IgG) compared to antibiotics.
4. The advantages of monoclonal antibodies over small molecules are that their advantage is exquisite specificity due to greater surface area for binding with antigen, resulting in decreased 'off-target' effects as compared with most small molecule drugs.

EXERCISE

Section I: Multiple Choice Questions
Select the correct answer:

1. What is the primary goal of target identification in drug discovery?
   A. To determine the chemical composition of a drug.
   B. To identify the biological origin of a disease and potential targets for intervention.
   C. To evaluate the safety and efficacy of a drug in animal models.
   D. To optimize the synthetic route for a drug's production.
2. Which clinical trial phase involves testing a drug on a small group of healthy volunteers to assess its safety and determine the appropriate dosage?
   A. Phase I B. Phase II C. Phase III D. Phase IV
3. The pharmacokinetic properties of a drug are mainly governed by the physicochemical properties of the drug such as it's:
   A. Solubility in aqueous solutions B. Size and structure
   C. Ability to form hydrogen bonds D. All of these
4. What is the main purpose of phase IV testing?
   A. Determine therapeutic window B. Determine unreported toxicity
   C. Determine variation in absorption D. Determine tolerability
5. Which among the following antibiotics function as protein synthesis inhibitors?
   A. penicillin B. tetracycline C. cefotaxime D. trimethoprim
6. Which of the following techniques is best for measuring the effectiveness of antibiotics on bacteria?
   A. Physical testing B. Chemical testing
   C. Biological testing D. Combined physical and chemical testing
7. Which point in the replication cycle appears most easily blocked by antivirals?
   A. Virus absorption B. Virus penetration
   C. Virus RNA and DNA replication D. Exit of viruses from the cell

8. Which is one of the main current goals of antiretroviral treatment?
   A. to suppress the viral load
   B. to cure HIV infection
   C. to allow the patient to have a pain-free death
   D. to prevent repeated infection with HIV

9. Which of the following is easily blocked by antivirals?
   A. Virus penetration
   B. Nucleic acid replication
   C. Virus absorption
   D. Removal of the virus from the cell

10. Which of the following is the primary reason why antiretroviral therapy (ART) cannot cure HIV?
   A. ART is not effective in reducing the viral load.
   B. HIV can hide within immune cells, forming latent reservoirs.
   C. ART drugs are toxic and cause severe side effects.
   D. HIV mutates too rapidly to be targeted by ART.

11. Which of the following cannot be treated by antiviral drugs?
   A. tuberculosis B. smallpox C. hepatitis D. warts

12. What is the main advantage of monoclonal antibodies over polyclonal antibodies?
   A. greater specificity and constancy.
   B. lower cost production.
   C. longer shelf life
   D. ability to target multiple antigens

13. How monoclonal antibodies are administered to patients?
   A. topically B. intravenously C. inhalation D. Orally

14. What is the main difference between Phase III and Phase IV clinical trials?
   A. Phase III tests the drug's efficacy, while Phase IV focuses on long-term safety.
   B. Phase III studies involve a small number of patients, while Phase IV studies involve a large number of patients.
   C. Phase III trials are conducted in animals, while Phase IV trials are conducted in humans.
   D. Phase III trials are conducted in one country, while Phase IV trials are conducted in multiple countries.

15. What is the purpose of a New Drug Application ?
   A. To obtain permission to conduct clinical trials on a new drug.
   B. To request a patent for a new drug.
   C. To seek regulatory approval to market a new drug.
   D. To conduct post-marketing surveillance on a new drug.

16. Antibodies are:
   A. prostaglandins B. steroids C. lipoproteins D. glycoproteins

17. What are monoclonal antibodies?
   A. Antibodies produced by a single type of immune cell.
   B. Antibodies derived from multiple individuals.
   C. Antibodies with multiple antigen-binding sites.
   D. Antibodies found in the blood of newborn

18. What is the main advantage of monoclonal antibodies over polyclonal antibodies?
    A. Greater specificity and consistency
    B. Low cost production
    C. Ability to target multiple antigens simultaneously
    D. Longer shelf life.

19. The science which deals with the drug and their action on human body is called:
    A. Physiology B. Pathology C. Pharmacology D. Microbiology

20. The study of absorption, distribution, metabolism and excretion of drug is known as:
    A. Pharmacy B. Pharmacokinetics C. Pharmacodynamics D. Pharmacopoeia

Section II: Short Answer Questions

1. Define the following:
    a. Pharmacology
    b. Drug
    c. Drug therapy
    d. Antibiotics
    e. Antivirals
    f. Antiretrovirus
    g. Monoclonal antibodies
2. What is a pharmacological drug?
3. Write the four steps of drug discovery.
4. What are the steps of preclinical development of drugs?
5. Describe clinical development of drugs.
6. Name the five drug development phases.
7. How do antibiotics work?
8. Why are monoclonal antibodies so specific?

Section III: Extensive Answer Questions

1. Explain drug discovery and development process.
2. Discuss the types antibiotics and their mode of action.
3. What are antivirus and antiretrovirus? Explain
4. What are the advantages of monoclonal antibodies?
5. Compare monoclonal antibodies to other drug classes.

GLOSSARY

Acetylcholine: One of the most common neurotransmitters, functions by binding to receptors and altering the permeability of the postsynaptic membrane to specific ions, either depolarizing or hyperpolarizing the membrane.

Actin: A globular protein which twist helically about each other, forming microfilaments in muscle and other contractile elements in the cells.

Action potential: A rapid change in the membrane potential of an excitable caused by stimulus-triggered, selective opening and closing voltage-sensitive gates in sodium and potassium ion channels.

Adaptive immunity: A type of specific immunity that develops when immune system responds to foreign substance or microorganism, such as after an infection or vaccination. It includes third line of defence

Adélie Penguins ***(Pygoscelis adeliae)*****:** A species of penguin that depends on Antarctic sea ice for breeding and feeding, threatened by warming temperatures and changing ice patterns.

Adrenal gland: One of two endocrine glands located to the kidneys in mammals. Endocrine cells in the outer portion (cortex) respond to help maintain homeostasis during long term stress. Neurosecretory cells in the central portion (medulla) secrete epinephrine and norepinephrine in response to nervous inputs triggered by short-term stress.

Adrenocorticotropic hormone (ACTH): A tropic hormone produced and secreted by the anterior pituitary that stimulates the production and secretion of steroid hormones by the adrenal cortex.

Aldosterone: An adrenal hormone that acts on the distal tubules of the kidney to stimulate the reabsorption of sodium (Na+) and the passive flow of water from the filtrate.

Allergen: a substance that can cause an allergic reaction

Allergy: An overreaction of the immune system to any harmless substance

Alveolus: One of the dead-end, multi-lobed air sacs that constitute the gas exchange surface of the lungs.

Alzheimer's disease: An age related dementia (mental deterioration) characterized by confusion, memory loss and other symptoms.

Anaphylaxis: A severe, life-threatening allergic reaction

Androgen: Any steroid hormone, such as testosterone, that stimulates the development and maintenance of the male reproductive system and sex characteristics.

Anterior pituitary: Aso called the adenohypophysis, portion of the pituitary that develops from nonneural tissue, consists of endocrine cells that synthesize and secrete several tropic and nontropic hormone.

Anthrax: A bacterial disease caused by Bacillus anthracis, capable of infecting humans and animals and used as a biological weapon.

Antibiotics: These are medicines that work by killing bacteria and preventing them from multiplying.

Antidiuretic hormone (ADH): A hormone produced in the hypothalamus and released from the posterior pituitary. It promotes water retention by the kidneys as part of an elaborate feedback scheme that helps regulate the osmloarity of the blood.

Antigen: Any substance capable of stimulating an immune response; usually a protein or large carbohydrate that is foreign to the body.

Antiretroviral therapy (ART): The treatment for HIV is called antiretroviral therapy (ART). ART involves taking a combination of HIV medicines (called an HIV treatment regimen) every day. ART is recommended for everyone who has HIV. ART cannot cure HIV, but HIV medicines help people with HIV live longer, healthier lives.

Antiretroviral: A drug used to prevent a retrovirus, such as HIV, from replicating. The term primarily refers to antiretroviral (ARV) HIV drugs.

Antivirals: These are a class of drugs which are used to treat viral infections.

Atlantic Cod ***(Gadus morhua)*****:** A species of fish in the North Atlantic Ocean whose population is affected by climate change, especially due to rising ocean temperatures that disrupt their breeding grounds and food availability.

Atlantic Meridional Overturning Circulation (AMOC): A large system of ocean currents in the

Atlantic Ocean that transports warm water from the tropics to the North Atlantic, influencing climate patterns in Europe and North America.

Autoimmune disease: The immune system attacks the healthy cells of body's organs and tissues by mistake

Axon: A typically long extension, or process, from a neuron that carries nerve impulses away from the cell body toward target cell.

B cells: A type of lymphocytes that participates in humoral immunity, gives rise to plasma cells that secrete antibodies into the circulatory system and to become memory cells.

Basophils: A type of WBCs that defend body from allergens, pathogens and parasites. It helps detect and destroy some early cancer cells

Bile: A liquid secretion of the liver stored in the gall bladder and released into the small intestine during digestion. Bile is a complex mixture of bile salts, water, other salts, and cholesterol.

Biodefense: Measures taken to protect against biological warfare and bioterrorism, including surveillance, detection, and response strategies.

Biological warfare: The deliberate use of biological agents (bacteria, viruses, toxins) to cause harm to humans, animals, or plants as part of warfare.

Biosafety measures: To ensure safe handling and containment of biological agents to prevent accidental release or exposure.

Biosecurity: Measures to prevent unauthorized access, theft, or deliberate misuse of dangerous biological agents or materials.

Biotechnology: The use of biological processes from microorganisms to make substance or to provide service to man.

Bipolar cell: A neuron that synapses with the axon of a rod or cone in the retina of the eye.

Body cavity: A fluid-containing space between the digestive tract and the body wall.

Bone marrow: The spongy interior of the bones with stem cells

Bone: A type of connective tissue, consisting of living cells held in a rigid matrix of collagen fibres embedded in calcium salts.

Bowman's capsule: A cup-shaped receptacle in the vertebrate kidney that is the initial, expanded segment of the nephron where filtrate enters from the blood.

Brainstem: Collection of structures in the adult brain, including the midbrain, the pons, and the medulla oblongata; functions in homeostasis, coordination of movement, and conduction of information to higher brain centres.

Bramble Cay Melomys: A small rodent native to Bramble Cay island in Australia, considered the first mammal to go extinct due to climate change, mainly because of rising sea levels.

Breathing control centre: A brain centre that directs the activity of organs involved in breathing.

Breathing: The process involving alternate inhalation and exhalation of air that ventilates the lungs.

Bronchiole: One of the fine branches of the bronchus that transport air to alveoli.

Bronchus: One of a pair of breathing tubes that branch from the trachea into the lungs.

Calcifying Organisms: Marine organisms, such as corals, mollusks, and some plankton, that use calcium carbonate to build their shells or skeletons, which are affected by ocean acidification.

Calcitonin: A hormone secreted by the thyroid gland that lowers blood calcium levels by promoting calcium deposition in bone and calcium excretion from the kidneys.

Cardiac cycle: One complete heart beat.

Cartilage: A type of flexible connective tissue with an abundance of collagenous fibres embedded in chondroitin sulphate.

Cell-mediated immunity: The immune response in which foreign cells or substances are destroyed by contact with T cells.

Cellular respiration: The most prevalent and efficient catabolic pathway for the production of ATP, in which oxygen is consumed as a reactant along with the organic fuel.

Central canal: The narrow cavity in the centre of the spinal cord that is continuous with the fluid-filled ventricles of the brain.

Central nervous system (CNS): In vertebrate animals, the brain and spinal cord.

Cerebellum: Part of the vertebrate hindbrain located dorsally; functions in unconscious coordination of movement and balance.

Cerebral cortex: The surface of the cerebrum; the

largest and most complex part of the mammalian brain, containing sensory and motor nerve cell bodies of the cerebrum; the part of the vertebrate brain most changed through evolution.

Cerebral hemisphere: The right or left side of the vertebrate brain.

Cerebrospinal fluid: Blood-derived fluid that surrounds, protects against infection, nourishes, and cushions the brain and spinal cord.

Cerebrum: The dorsal portion of the vertebrate forebrain, composed of right and left hemispheres; the integrating centre for memory, learning, emotions, and other highly complex functions of the central nervous system.

Chondrocyte: Cartilage cell that secretes collagen and chondroitin sulphate.

Chytrid fungus: A pathogenic fungus that affects amphibians worldwide, with its spread being facilitated by climate change through rising temperatures and changes in humidity.

Climate change: Long-term alteration of temperature and typical weather patterns in a place, primarily driven by human activities such as burning fossil fuels, deforestation, and industrial processes.

Complement system: Over fifty types of small proteins found in the blood which provide immunity.

Computational biology: An interdisciplinary field that combines computer science, mathematics, and biology to analyse and model biological systems.

Computational evolutionary biology: An interdisciplinary field that combines evolutionary and computational biology.

Coral bleaching: A phenomenon where corals expel the symbiotic algae living in their tissues due to stress from elevated temperatures, causing them to turn white and become more vulnerable to disease and death.

Corpus callosum: The thick band of nerve fibres that connect the right and left cerebral hemispheres in placental mammals, enabling the hemispheres to process information together.

Cortical nephron: Nephrons located almost entirely in the renal coertex. These nephrons have a reduced loop of Henle.

Corticosteroid: Any steroid hormone produced and secreted by the adrenal cortex.

Countercurrent multiplier system: A countercurrent system in which energy is expended in active transport to facilitate exchange of materials and create concentration gradients. For example, the loop of Henle actively transports NaCl from the filtrate in the upper part of the ascending limb of the loop, making the urine-concentrating function of the kidney more effective.

Cytotoxic T cells: Secrete cytotoxin which triggers destruction of the pathogen's DNA or perforin which is a protein that creates holes in the pathogens plasma membrane.

Decontamination: The process of removing or neutralizing biological agents from surfaces, equipment, or environments to prevent further spread or exposure.

Dendrite: One of usually numerous, short, highly branched processes of a neuron that convey nerve impulses toward the cell body.

Dendritic cells: A special type of WBCs that is found skin which boosts immune responses by becoming Antigen Presenting Cell (APC)

Depolarization: An electrical state in an excitable cell whereby the inside of the cell is made less negative relative to the outside than at the resting membrane potential. A neuron membrane is depolarized if a stimulus decreases its voltage from the resting potential of -70 mV in the direction of zero voltage.

Dermis: Inner, comparatively thick layer containing glands, hair follicles, receptors, nerves and blood vessels

Diabetes mellitus: An endocrine disorder marked by inability to maintain glucose homeostasis. The type I form results from autoimmune destruction of insulin-secreting cells; treatment usually requires insulin injections several times a day. The type II form most commonly results from reduced responsiveness of target cells to insulin; obesity and lack of exercise are risk factors.

Diaphragm: A sheet of muscle that forms the bottom wall of the thoracic cavity in mammals; active in ventilating the lungs.

Diastole (di-as'toh-lee): Phase of the cardiac cycle in which the heart is relaxed.

Dopamine: A biogenic amine closely related to

epinehhrine and norepinephrine.

Drug: any chemical substance, natural or synthetic, which affects a biological system.

Dual-Use Research: Scientific research that can be applied for both beneficial purposes (such as medicine) and harmful purposes (such as biological warfare).

Ecosystem: A community of living organisms and their physical environment interacting as a system, which can be significantly altered by climate change.

Electrocardiogram (ECG): A record of the electrical impulses that travel through cardiac muscle during the heart cycle.

Endangered species: Species that are at risk of extinction due to a declining population or threats from environmental changes, habitat loss, and climate change.

Endocrine gland: A ductless gland that secretes hormones directly into the interstitial fluid, from which they diffuse into the bloodstream.

Endocrine system: The internal system of chemical communication involving hormones, the ductless glands that secrete hormones, and the molecular receptors on or in target cells that respond to hormones; functions in concert with the nervous system to effect internal regulation and maintain homeostasis.

Endorphin: Any of several hormones produced in the brain and anterior pituitary that inhibits pain perception.

Eosinophils: A type of WBCs that protect body from parasites, allergens, foreign bacteria and organisms

Epidemiology: The study of the distribution and determinants of health-related states or events in populations, often used in tracking outbreaks caused by biological warfare agents.

Epidermis: outermost layer of the skin, composed of tightly packed cells that provide a physical barrier.

Erythropoietin: A hormone produced in the kidney when tissues of the body do not receive enough oxygen. This hormone stimulates the production of erythrocytes.

Estrogen: Any steroid hormone, such as estradiol, that stimulates the development and maintenance of the female reproductive system and secondary sex characteristics.

Excretion: The disposal of nitrogen-containing waste products of metabolism.

Extreme weather events: Severe weather phenomena like hurricanes, droughts, heatwaves, and heavy rainfall, which become more frequent and intense due to climate change, impacting ecosystems and human activities.

Feedback inhibition: A method of metabolic control in which the end product of a metabolic pathway acts as an inhibitor of an enzyme within that pathway.

Feedback loop: A process in which the output of a system amplifies or dampens its own production, such as how melting sea ice reduces reflectivity, leading to further warming and more ice melt.

Fever: Raised body temperature than normal

First line of defence: The external barriers of our body to stop entry of pathogens. It is nonspecific and includes skin and mucous membranes.

Fluoroquinolones: These are highly effective antibiotics with many advantageous pharmacokinetic properties including high oral bioavailability, large volume of distribution, and broad-spectrum antimicrobial activity.

Follicle-stimulating hormone (FSH): A tropic hormone produced and secreted by the anterior pituitary that stimulates the production of eggs by the ovaries and sperm by the testes.

Forebrain: One of three ancestral and embryonic regions of the vertebrate brain; develops into the thalamus, hypothalamus, and cerebrum.

Gastrin: A hormone released by the stomach mucosa; stimulates the gastric glands to secrete pepsinogen.

Genetic modification: Altering the genetic makeup of organisms, including pathogens, to enhance specific traits such as virulence or resistance.

Glial cells: Supporting cells that are essential for the structural integrity of the nervous system and for the normal functioning of neurons.

Global warming: The increase in Earth's average surface temperature due to rising levels of greenhouse gases, which is a major component of climate change.

Glomerulus: A ball of capillaries surrounded by Bowman's capsule in the nephron and serving as

the site of filtration in the vertebrate kidney.

Glucagon: A hormone secreted by pancreatic alpha cells that raises blood glucose levels. It promotes glycogen breakdown and release of glucose by the liver.

Glucocorticoid: A steroid hormone secreted by the adrenal cortex that influences glucose metabolism and immune function.

Golden Toad *(Incilius periglenes)*: A species of toad that lived in Costa Rica's Monteverde Cloud Forest, which went extinct in the late 1980s due to climate change-induced drought and shifts in temperature.

Gonadotropin: A hormone that stimulates the activities of the testes and ovaries. Follicle stimulating hormone and luteinizing hormone are gonadotropins.

Greenhouse Gases (GHGs): Gases like carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) that trap heat in the Earth's atmosphere, leading to global warming.

Grey matter: Regions of dendrites and clusters of neuron cell bodies within the CNS.

Growth hormone (GH): A hormone produced and secreted by the pituitary.

Gulf Stream: A warm and swift Atlantic Ocean current that originates in the Gulf of Mexico and flows along the eastern coastlines of the United States and Newfoundland before crossing the Atlantic Ocean.

Habitat Loss: The destruction or alteration of the natural environment where a species lives, often caused by human activities or climate change, leading to species becoming endangered or extinct.

Haemoglobin: the red, iron-containing protein pigment of erythrocytes that transports oxygen and carbon dioxide and aids in regulation of pH.

Helper T cell: T lymphocyte that facilitates the ability of B lymphocytes to form an antibody-producing clone in response to an antigen. Secrete interleukin 2 which stimulates cell division of T cells and B cells.

Hepatic: Pertaining to the liver.

Hindbrain: *One of* three ancestral and embryonic regions of the vertebrate brain; develops into the medulla oblongata, pons, and cerebellum.

Homeostasis: The steady-state physiological condition of the body.

Hormone: In multicellular organisms, one of many types of circulating chemical signals that are formed in specialized cells, travel in body fluids, and act on specific target cells to change their functioning.

Humoral mediated immune response: Immune response provided by antibodies

Hybridoma: It is a culture of hybrid cells that results from the fusion of B cells and myeloma cells. Hybridoma technology produces hybridomas. This technology was developed to produce mAbs. Hybridomas possess two important properties of B cells, production of antibodies, and immortalization of myeloma cells.

Hyperpolarization: An electrical state in which the inside of the cell is more negative relative to the outside than at the resting membrane potential. A neuron membrane is hyperpolarised if a stimulus increases its voltage from the resting potential of -70 mV, reducing the chance that neuron will transmit a nerve impulse.

Hypothalamus: The ventral part of the vertebrate forebrain; functions in maintaining homeostasis, especially in coordinating the endocrine and nervous systems; secretes hormones of the posterior pituitary and releasing factors that regulate the anterior pituitary.

Hypoxic zones: Areas in the ocean with low oxygen levels, often caused by increased water temperatures, nutrient pollution, or changes in circulation patterns, making it difficult for marine life to survive.

I band: The area near the edge of the sarcomere where there are only thin filaments.

Immune response: A specific response by the immune system to invasion of the body by particular foreign substance or microorganism, characterized by recognition of the foreign material by immune cells and its subsequent destruction by antibodies or cellular attack.

Immune system: An extensive network of tissues, organs, proteins, and cells

Immunity: The body's ability to resist or combat infections, diseases, and foreign substances

Incubation Period The time between exposure to a pathogen and the onset of symptoms.

Incubation Period The time between exposure to a

pathogen and the onset of symptoms.

Innate immunity: The body's first and second line of defence which prevents infection and attack of invading pathogens. It is present at birth and lasts a person's entire life

Insulin: It is a peptide hormone, produced by beta cells in the pancreas, and is central to regulating carbohydrate and fat metabolism in the body. It causes cells in the skeletal muscles, and fat tissue to absorb glucose from the blood.

Interferons: Antiviral agents produced by virus-infected cells.

International Biological Weapons Convention (BWC): An international treaty aimed at prohibiting the development, production, and stockpiling of biological weapons and promoting peaceful uses of biological research.

Juxtamedullary nephrons: Nephrons with well-developed loops of Henle that extend deeply into the renal medulla.

Koalas *(Phascolarctos cinereus)*: An arboreal marsupial native to Australia that faces threats from climate change due to increased heatwaves and bushfires, which are intensifying with rising temperatures.

Krause end bulbs: Nerve terminals in skin, mucosa of the oral cavity, conjunctiva, and other parts, consisting of a laminated capsule of connective tissue enclosing the terminal, branched, convoluted ending of an afferent nerve fiber; generally believed to be sensitive to touch and pressure. The end-bulbs of Krause were named after German anatomist Wilhelm Krause (1833-1910).

Lacteal: One of the many lymphatic vessels in the intestinal villi that absorb fat.

Leukopenia: It is a disease in number of white blood cells (leukocyte) found in blood, which places individuals at risk of infection.

Ligament: It comes from the Latin ligare meaning "to bind, tie," which is precisely what a ligament does. Ligaments only connect bones to bones. Ligaments allow for range of motion.

Limbic system: A group of nuclei (clusters of nerve cell bodies) in the lower part of the mammalian forebrain that interact with the cerebral cortex in determining emotions; includes the hippocampus and the amygdala.

Luteinizing hormone (LH): A tropic hormone produced and secreted by the anterior pituitary that stimulates ovulation in females and androgen production in males.

Lymph: The colourless fluid within the lymphatic vessels that is derived from blood plasma and resembles it closely in composition; contains white cells; ultimately, returns to the blood.

Lymph nodes: A mass of lymph tissue surrounded by a connective tissue capsule; manufactures lymphocytes and filters lymph. Small bean like structures that filter lymph to remove pathogens

Lymphatic system: A subsystem of the cardiovascular system; returns excess interstitial fluid to the circulation; defends the body against disease organisms.

Lymphocyte: A type of WBCs that is made in the bone marrow and is found in blood and lymph tissue

Macrophage: A type of WBCs that surrounds and kills microorganisms, removes dead cells, and stimulates the action of other immune system cells

Malpighian tubule: A unique excretory organ of insects that empties into the digestive tract, removes nitrogenous wastes from the hemolymph, and functions in osmoregulation.

Marine heatwaves: Periods of abnormally high ocean temperatures that can last for days or months, disrupting marine ecosystems and causing mass die-offs of sea life.

Medulla oblongata: The lowest part of the vertebrate brain, commonly called the medulla; a swelling of the hindbrain dorsal to the anterior spinal cord that controls autonomic, homeostatic functions, including breathing, heart and blood vessel activity, swallowing, digestion, and vomiting.

Memory B cells: On stimulation make more plasma cells and protect against future attacks by the same antigen.

Memory T cells: Provide long term immunity and are stimulated to convert into helper T cells and help fight the pathogen.

Midbrain: One of three ancestral and embryonic regions of the vertebrate brain; develops into sensory integrating and relay centers that send sensory information to the cerebrum.

Migration Patterns: The regular movement of

species between habitats, often in response to seasonal changes. Climate change can alter these patterns, affecting species' survival and ecosystems.

Monarch Butterflies *(Danaus plexippus)*: A species of butterfly known for its long migrations. Climate change alters their migratory patterns and reduces the availability of milkweed, their primary food source.

Monoclonal antibodies: A single type of antibody that are produced by identical immune cells (clones).

Monocytes: A type of largest WBCs which mature to become macrophages or dendritic cells

Mucous membrane: The moist, inner lining of some organs and body cavities including digestive and respiratory tract

Mucus: A slippery sticky substance produced especially by mucous membranes which it moistens and protects

Myelin sheath: In a neuron, an insulating coat of cell membrane from Schwann cells that is interrupted by nodes of Ranvier, where saltatory conduction occurs.

Myofibril: A myofibril (also known as a muscle fibril) is a basic rod-like unit of a muscle.[1] Muscles are composed of tubular cells called myocytes, also known as muscle fibers, and these cells in turn contain many chains of myofibrils. They are created during embryo development in a process known as myogenesis. Myofibrils are composed of long proteins such as actin, myosin, and titin, and other proteins that hold them together. These proteins are organized into thin filaments and thick filaments, which repeat along the length of the myofibril in sections called sarcomeres. Muscles contract by sliding the thin (actin) and thick (myosin) filaments along each other.

Myofilaments: These are the filaments of myofibrils constructed from proteins.There are three different types of myofilaments, thick, thin, and elastic filaments.

Myoglobin: An oxygen-storing, pigmented protein in muscle cells.

Myosin: A type of protein filament that interacts with actin filaments to cause cell contraction.

Negative feedback: A primary mechanism of homeostasis, whereby a change in a physiological variable that is being monitored triggers a response that counteracts the initial fluctuation.

Nephron: The tubular excretory unit of the vertebrate kidney.

Nerve: A ropelike bundle of neuron fibers (axons and dendrites) tightly wrapped in connective tissue.

Neuron: A nerve cell; the fundamental unit of the nervous system, having structure and properties that allow it to conduct signals by taking advantage of the electrical charge across its cell membrane.

Neurosecretory cells: These are specialized nerve cells that produce and secrete hormones. Well-known examples of neurosecretory cells are oxytocin- and vasopressin-secreting neurons in the hypothalamus and cells in the adrenal medulla. These cells are found in vertebrates and invertebrates.

Neurotransmitter: A chemical messenger released from the synaptic terminal of a neuron at a chemical synapse that diffuses across the synaptic cleft and binds to and stimulates the postsynaptic cell.

Neutrophils: A type of white blood cell that act as immune system's first line of defence

Nissl body: Also known as Nissl or tigroid substance is a large granular body found in neurons. These granules are rough endoplasmic reticulum (RER) with rosettes of free ribosomes, and are the site of protein synthesis. It was named after Franz Nissl, a German psychiatrist who invented the Nissl staining method.

NK cells: A type of WBCs that kills virus infected cells, and detects and controls early signs of cancer

Nociceptor: A class of naked dendrites in the epidermis of the skin.

Norepinephrine: Also called noradrenaline or 4,5-ß-trihydroxy phenethylamine is a catecholamine with multiple roles including those as a hormone and a neurotransmitter.

Ocean acidification: A process where the ocean absorbs excess atmospheric CO_2, leading to the formation of carbonic acid and a reduction in the pH of seawater, negatively impacting marine life, especially organisms that form shells.

Ocean warming: The increase in ocean

temperatures due to global warming, which affects marine ecosystems and contributes to phenomena like coral bleaching and rising sea levels.

Osteoblast: A bone-forming cell that deposits collagen.

Osteon: The repeating organizational unit forming the microscopic structure of hard mammalian bone.

Oxyhaemoglobin: Haemoglobin that has combined with oxygen.

Oxytocin: It is a mammalian neurohypophysial hormone. Produced by the hypothalamus and stored and secreted by the posterior pituitary gland, oxytocin acts primarily as a neuromodulator in the brain. It is released in large amounts after distension of the cervix and uterus during lab or, facilitating birth, maternal bonding, and, after stimulation of the nipples, lactation. Childbirth and milk ejection result from positive feedback mechanisms.

Pacemaker (of the heart): The sinoatrial (SA) node of the heart; specialized cardiac muscle where each heartbeat begins.

Pain receptor: A kind of interoreceptor that detects pain; also called a nociceptor.

Parathyroid gland: Any of four small endocrine glands, embedded in the surface of the thyroid gland, that secrete parathyroid hormone.

Parathyroid hormone (PTH): A hormone secreted by the parathyroid glands that raises blood calcium level by promoting calcium release from bone and calcium retention by the kidneys.

Penicillin: It is a class of antibiotic medications. Penicillins treat bacterial infections like strep throat, ear infections and urinary tract infections. They work by attaching to and damaging the cell walls of bacteria.

Pepsin: An enzyme produced in the stomach that initiates digestion of proteion.

Peripheral nervous system (PNS): The sensory and motor neuron that connect to the central nervous system.

Peristalsis: Rhythmic waves of muscular contraction and relaxation in the walls of hollow tubular organs, such as the ureter or parts of the digestive tract, that serve to move the contents through the tube.

Peritubular capillaries: The network of tiny blood vessels that surrounds the proximal and distal tubules in the kidney.

Phagocytosis: Literally," cell eating"; a type of endocytosis by which certain cells engulf food particles, microorganisms, foreign matter, or other cells.

Pharmacokinetic properties: Pharmacokinetic properties of a drug are mainly governed by the physicochemical properties of the drug such as its solubility in aqueous solutions, lipophilicity, size and structure, ability to form hydrogen bonds, polar surface area, chemical stability, and susceptibility to enzymatic reactions.

Pineal gland: A small gland on the dorsal surface of the vertebrate forebrain that secretes the hormone melatonin.

Pinta Island Tortoise *(Chelonoidis abingdonii)*: A species of giant tortoise from the Galápagos Islands, with the last known individual, "Lonesome George," dying in 2012. Climate change contributed to habitat alteration that affected the species' survival.

Pituitary gland: An endocrine gland at the base of the hypothalamus; consists of a posterior lobe (neurohypophysis), which stores and releases two hormones produced by the hypothalamus, and an anterior lobe (adenohypophysis), which produces and secretes many hormones that regulate diverse body functions.

Plasma B cell: Stimulated B cells become plasma cells and secrete a great deal of antibodies

Plasma cell: Cell that secretes antibodies; differentiated B lymphocyte.

Platelets: Cell fragments in the blood that function in clotting; also called thrombocytes.

Polar Bears *(Ursus maritimus)*: A species of bear that relies on Arctic sea ice for hunting seals. The melting ice due to global warming threatens their survival.

Positive feedback: A physiological control mechanism in which a change in some variable triggers mechanisms that amplify the change.

Posterior pituitary: Also called the neurohypophysis; an extension of the hypothalamus composed of nervous tissue that secretes oxytocin and antidiuretic hormone made in the hypothalamus; a temporary storage site for these hormones.

Postsynaptic cell: The target cell at a synapse.

Presynaptic cell: The transmitting cell at a synapse.

Primary immune response: Response after first contact of the immune system with an infectious agent

Prolactin (PRL): A hormone produced and secreted by the anterior pituitary with a great diversity of effects in different vertebrate species. In mammals, it stimulates growth of and milk production by the mammary glands.

Prostaglandin (PG): One of a group of modified fatty acids secreted by virtually all tissues and performing a wide variety of functions as local regulators.

Protein Data Bank (PDB): A freely accessible online database that stores and provides 3D structural information of biomolecules.

Pulse: Alternate expansion and recoil of an artery.

Pyrogens: Cause the temperature set point of the hypothalamic thermostat of the body to rise and produce fever.

Quarantine: Isolating individuals or populations exposed to infectious diseases to prevent their spread.

Refractory periods: The short time immediately after an action potential in which the neuron cannot respond to another stimulus, owing to an increase in potential permeability.

Renal artery: The blood vessel bringing blood to the kidney.

Renal cortex: The outer portion of the vertebrate kidney.

Renal medulla: The inner portion of the vertebrate kidney, beneath the renal cortex.

Renal pelvis: Funnel-shaped chamber that receives processed filtrate from the vertebrate kidney's collecting ducts and is drained by the ureter.

Renal vein: The blood vessel draining the kidney.

Renin: A protein enzyme secreted by the kidneys into the blood stream, where it helps to maintain blood pressure.

Rennin: An enzyme found in gastric juice which cause coagulation.

Replication fork: A Y-shaped region on a replicating DNA molecule where new strands are growing.

Residual volume: The amount of air that remains in the lungs after forcefully exhaling.

Respiratory pigment: A protein that transports most of the oxygen in blood.

Respiratory surface: The part of an animal where gases are exchanged with the environment.

Resting potential: The membrane potential characteristic of a nonconducting, excitable cell, with the inside of the cell more negative than the outside.

Ricin: A highly toxic protein derived from castor beans, considered a bioregulator and potential biological weapon.

Rigor mortis: The stiffness of joints and muscular rigidity of a dead body, caused by depletion of ATP in the tissues. It begins two to four hours after death and lasts up to about four days, after which the muscles and joints relax

Rugae: Folds, such as those in the lining of the stomach.

Saltatory conduction: Rapid transmission of a nerve impulse along an axon, resulting from the action potential jumping from one node of Ranvier to another, skipping the myelin-sheathed regions of membrane.

Sarcomere: The fundamental repeating unit of striated muscle, delimited by the Z lines.

Sarcoplasmic reticulum: A specialized endoplasmic reticulum that regulates the calcium concentration in the cytosol.

Sea ice: Frozen ocean water that forms, expands, and melts in the ocean. It plays a crucial role in reflecting sunlight and regulating the Earth's temperature.

Sea-level rise: An increase in the level of the world's oceans due to the melting of ice caps and glaciers and the expansion of seawater as it warms.

Second line of defence: When pathogens successfully enter the skin or mucous membranes, it is activated to combat these foreign invaders. It is nonspecific and includes some WBCs, inflammation, fever and protective proteins

Second messenger: Molecule inside cells that acts to transmit signals from a receptor to a target. The term second messenger was coined upon the discovery of these substances in order to distinguish them from hormones and other molecules that function outside the cell as "first

messengers" in the transmission of biological information. Many second messenger molecules are small and therefore diffuse rapidly through the cytoplasm, enabling information to move quickly throughout the cell. Examples of second messenger molecules include cyclic AMP, cyclic GMP, inositol trisphosphate, diacylglycerol, and calcium.

Secondary immune response: Faster and stronger immune response after second and further contact of the immune system with an infectious agent

Semilunar valves: Valves between the ventricles of the heart and the arteries that carry blood away from the heart.

Sensory neuron: A nerve cell that receives information from the internal and external environments and transmits the signals to the central nervous system.

Septum (pl. septa)**:** A cross-wall or partition; for example, the walls that divide a hypha into cells. Permanently attached to sessile one location. Coral animals, for example, are sessile.

Sequence homology: The study of similarities and relationships between biological sequences, such as DNA, RNA, or protein sequences

Skeletal muscle (striated muscle): Muscle generally responsible for the voluntary movements of the body.

Skin: The body's largest organ which protects body from germs and regulates body temperature

Sliding-filament model: The theory explaining how muscle contracts, based on change within a sarcomere, the basic unit of muscle organization, stating that thin (actin) filaments slide across thick (myosin) filaments, shortening the sarcomere. The shortening of all sarcomeres in a myofibril shortens the entire myofibril.

Small intestine: Portion of the vertebrate digestive tract that extends from the stomach to the large intestine.

Snow Leopards *(Panthera uncia)*: A large cat species native to mountain ranges in Central and South Asia, threatened by climate change as warming temperatures shrink their habitat and prey base.

Somatic nervous system: The branch of the motor division of the vertebrate peripheral nervous system composed of motor neurons that carry signals to skeletal muscles in response to external stimuli.

Species extinction: The complete disappearance of a species from Earth, often accelerated by climate change, habitat loss, pollution, and over-exploitation.

Spleen: A lymphoid organ located near stomach which stores blood cells

Staghorn coral: A type of branching coral that is especially vulnerable to coral bleaching due to ocean warming and acidification, leading to the loss of coral reefs.

Stomach: Muscular region of the vertebrate digestive tract extending from the oesophagus to the small intestine.

Structural biology: Study of the 3D structure and organization of biological molecules

Structural homology: The study of similarities in three-dimensional (3D) structures between biological molecules, such as proteins, RNA, or DNA

Sulfonamides: These are synthetic bacteriostatic antibiotics that competitively inhibit conversion of p-aminobenzoic acid to dihydropteroate, which bacteria need for folate synthesis and ultimately purine and DNA synthesis.

Suppressor T cells: Shut down the immune response after infection is successfully removed

Symbiotic Algae: Algae that live inside the tissues of corals, providing them with nutrients through photosynthesis. The relationship is crucial for coral health, and stress from warming oceans can cause corals to expel these algae, leading to bleaching.

Synapse: The locus where one neuron communicates with another neuron in a neural pathway; a narrow gap between a synaptic terminal of an axon and a signal-receiving portion (dendrite or cell body) of another neuron or effector cell. Neurotransmitter molecules released by synaptic terminals diffuse across the synapse, relaying messages to the dendrite or effector.

Synaptic cleft: A narrow gap separating the synaptic knob of a transmitting neuron from a receiving neuron or an effctor cell.

Synaptic terminal: A bulb at the end of an axon in which neurotransmitter molecules are stored and released.

Synaptic vesicle: Membranous sac containing neurotransmitter molecules at the tip of the presynaptic axon.

Systole: the part of the cardiac cycle when the heart is contracting.

T cell (T lymphocyte): lymphocyte that is processed in the thymus. T cells have a wide variety of immune function but are primarily responsible for cell-mediated immunity.

T cells: A type of WBCs that kill virus infected cells, cancerous cells and help other B and T cells to perform their functions

T-cell receptor: a protein receptor located on the surface of a T cell which binds a specific antigen and triggers the immune response of the cell.

Testosterone: The most abundant androgen hormone in the male body.

Tetracyclines: These are a class of broad-spectrum antibiotics used in the management and treatment of a variety of infectious diseases.

Thalamus: One of two integrating centres of the vertebrate forebrain. Neurons with cell bodies in the thalamus relay neural input to specific areas in the cerebral cortex and regulate what information goes to the cerebral cortex.

Therapeutic: The branch of medicine concerned with the treatment of disease and the action of remedial agents.

Third line of defence: specific adaptive immunity and consists of immune cells that target specific antigens

Threshold: The potential an excitable cell membrane must reach for an action potential to be initiated.

Thrombus: A blood clot formed within a blood vessel or within the heart.

Thromcytopenia: When the number of blood platelets is lower than the normal i.e. 150,000 to 450,000.

Thymus gland: A tiny organ below the breast bone which is responsible for T-cell maturation.

Thyroid gland: An endocrine gland, located on the ventral surface of the trachea, that secretes two iodine-containing hormones, triiodothyronine (T3) and thyroxine (T4), and calcitonin.

Thyroid-stimulating hormone (TSH): A tropic hormone produced and secreted by the anterior pituitary that regulates the release of thyroid hormones.

Thyroxine (T4): One of the two iodine -containing hormones that are secreted by the thyroid gland and help regulate metabolism, development and maturation in vertebrates.

Tonsils: Lymphoid tissue near pharynx which trap and kill harmful pathogens that enter through mouth and nose

Trachea: The windpipe; that portion of the respiratory tube that has C-shaped cartilaginous rings and passes from the larynx to two bronchi.

Transplant rejection: Triggers the transplant recipient's immune mechanisms, which may act to destroy the donor tissue

Tridothyronine (T3): One of the two iodine -containing hormones that are secreted by the thyroid gland and help regulate metabolism, development and maturation in vertebrates.

Tris HCl: Tris, or tris(hydroxymethyl) amino methane, or known during medical use as tromethamine or THAM, is an organic compound with the formula $(HOCH_2)_3CNH_2$. It is extensively used in biochemistry and molecular biology as a component of buffer solutions such as in TAE and TBE buffers, especially for solutions of nucleic acids. It contains a primary amine and thus undergoes the reactions associated with typical amines, e.g. condensations with aldehydes. In medicine, tromethamine is occasionally used as a drug, given in intensive care for its properties as a buffer for the treatment of severe metabolic acidosis in specific circumstances. Some medications are formulated as the "tromethamine salt" including hemabate (carboprost as trometamol salt), and "ketorolac trometamol"

Urea: A soluble nitrogenous waste produced in the liver by a metabolic cycle that combines ammonia with carbon dioxide.

Ureter: A duct leading from the kidney to the urinary bladder.

Uric acid: An insoluble precipitate nitrogenous waste excreted by land snails, insects and many reptiles and birds.

Urinary bladder: The pouch where urine is stored prior to elimination.

Vaccines: Boosts immunity by introducing a small, harmless piece of a pathogen (antigen) to the body, which triggers a specific immune response

Vasa recta: In the blood supply of the kidney, the vasa recta renis (or straight arteries of kidney, or straight arterioles *of kidney*) are a series of straight capillaries in the medulla (Latin: vasa, "vessels"; recta, "straight"). They lie parallel to the loop of Henle.

Vasoconstriction: A decrease in the diameter of superficial blood vessels triggered by nerve signals that contract the muscles of the vessel walls.

Vasodilation: An increase in the diameter of superficial *blood vessels* triggered by nerve signals that relax the muscles of the vessel walls.

Ventilation: Any method of increasing contact between the respiratory medium and the respiratory surface.

Ventricle: (1) A heart chamber that pumps blood out of a heart. (2) A space in the vertebrate brain, filled with cerebrospinal fluid.

Viscera: The internal body organs, especially those located in the abdominal or thoracic cavities.

Vocal cord: One of two small bands of muscle within the larynx. These muscles vibrate to produce the voice. The vocal cords form a "V" inside the larynx, a 2-inch-long, tube-shaped organ in the neck. When we talk, the vocal cords tighten up and move closer together. Air from the lungs is forced between them and makes them vibrate, producing the sound of our voice. The tongue, lips, and teeth form this sound into words

X-ray crystallography technique: Provides precise 3D structure of the biomolecule, revealing its atomic arrangement, bond lengths, and angles

Z lines: The border of a sarcomere.

ABOUT THE AUTHORS

Prof. (R) Jawaid Mohsin Malik

Prof. Jawaid Mohsin was born on 12th February in 1945 in the province of Bihar. Malik is the title given to his ancestor Syed Ibrahim by the king Tughlaq. Syed Ibrahim was a saint, the commander in chief of the army and conqueror of Bihar. Syed Ibrahim is the descendent of Hazrat Ghos-e-Azam, Syed Abdul Qadir Jilani (رحمۃ اللہ علیہ) at the seventh generation. The ancestors of Syed Ibrahim migrated from Iraq to Afghanistan and settled in the village "Bunt Nagar" near Ghazni. Prof.Jawaid is a former head for the department of Zoology, Federal Government Postgraduate College, H-8 Islamabad` where he served for more than twenty-five years. He is also a former Principal, Federal Government College, H-9, F-10/4 Islamabad and Director Colleges and Director and Director Administration, Federal Directorate of Education, Islamabad. He has contributed his services to FBISE in various capacities such as paper setter, head examiner etc. He developed the modern question paper of FBISE which consists of three parts i.e., MCQ's, short answer question and extensive answer questions is now used all over Pakistan. In 1968 he did his post-graduation in zoology with specialization in Entomology, from Dhaka University, East Pakistan (former). He taught in Muhammadpur College, Quaid-e-Azam College and the prestigious Notre Dame College of Dhaka. He taught various classes for more than forty-five years in various capacities. He has also worked as Education Officer, in Nigeria for four years. He has successfully completed the 61st advance course in administration and development held in 1996 at National Institute of Public Administration (NIPA), Karachi. In 1995. He was awarded a shield by the honourable Mr. Rafiq Tarar, the then President of Pakistan, for his services to humanity. He has published four research papers in Science Journals of Pakistan on Butterflies of Pakistan. He has contributed articles on science and sports in Urdu and English dailies of Islamabad. He is co-author and managing author of more than fifty textbooks on General Science and Biology as well as Biology Practical Notebooks. He has travelled to Singapore, Thailand, Indonesia, India, Bangladesh, UAE, Saudi Arabia, Egypt, Italy, Holland, UK, Qatar, USA and Nigeria. He has also served as a National Consultant, Science Education, JICA sponsored project for the promotion of Student centered and Inquiry based SCIB) learning, National Institute of Science and Technical Education, Ministry of Education, Islamabad, He retired from survive on 12th November 2005. He has published four literary books in Urdu on which a student has obtained M.Phil., Degree from a university in Islamabad. He has served as book reviewer at National curriculum Council (NCC) and member interview committee of FPSC for selection of faculty for a number of years.

Ruqayya Shaikh

Ruqayya Shaikh did her M.Sc and M.Phil in Animal Sciences from Quaid-i-Azam University, Islamabad. She started her professional career as a Zoology lecturer at Islamabad College for girls, F-6/2, Islamabad. At present she is working as Associate Professor in the same institute. She has been teaching General Science to secondary school classes, Biology to SSC, HSSC and BS classes, Zoology to B.Sc classes for the last two decades. Recently she certified in instructional leadership, College of Education, University of Massachusetts, USA.
She was the part of the General science Curriculum development team, Grade 4-8, under National Curriculum council. She worked as textbook reviewer for General science Grade 4, General Science Grade 5, Biology HSSC I and Biology HSSC II. She served as FBISE Biology course committee member. The author conducted a number of teacher training programs. She is the co- author of General Science 6, 7 and Biology 9 and 10. Her video lectures of General Science and Biology are available on youtube channel Ruqayya Shaikh ICG.

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Dr. Kashif Ali

Dr. KASHIF ALI is Associate Professor, coordinator at center of excellence and Vice Principal at IMCB, F-7/3, Islamabad. Dr. Kashif did MSc (Zoology), M.Phil (Developmental biology) and PhD (Molecular Genetics and Cancer cell Biotechnology). He received Indigenous and IRSIP merit Fellowship from HEC for PhD studies at Pakistan and UK. He completed his PhD research from COMSATS University Islamabad and Cardiff University-Peeking University Cancer Institute, Cardiff, UK. He has multiple, well cited publications in international research journals.

He has 23 year experience of Biology teaching at SSc and HSSc levels and has also been teaching to BS, and MS classes at QAU and Bahria University Islamabad. He has been awarded best biology teacher award (2023) by FDE. He received multiple teaching trainings from different national and international training institutes including National Academy of Higher Education (NAHE), Professional Competency Enhancement Program for Teachers (PCEPT), Cisco Networking Academy Islamabad and Incheon metropolitan city office of education, Incheon, South Korea.

He has been working as member of committee of courses, super checker, paper setter and judge in scientific exhibitions at FBISE, master trainer for teacher training at FDE, book reviewer at National curriculum council (NCC) and member interview committee of FPSC for selection of faculty.

Abid Ali

Mr. Abid Ali Mughal is currently the Assistant Professor and Head of the Biology Department at Islamabad Model College for Boys H-9 Islamabad. He completed his M.Sc (Hons) in Plant Sciences from the University of Sindh Jamshoro in 2002, where he was awarded the Vice Chancellor's Medal for achieving first position. From 2002 to 2003, he served as a Research Fellow at PAEC's Nuclear Institute of Agriculture Tandojam. In 2003, he began his teaching career as a lecturer in Botany at F.G. Degree College Wah Cantt. His research interests include investigating factors affecting tDNA transfer from Agrobacterium to Soybean for his M.Phil in Biotechnology, and studying the effects of chronic exposure to antibiotics on rural populations for his Ph.D. in Environmental Sciences. Mr. Mughal has presented his research papers at international conferences in Lithuania, the Netherlands, and France. He is the Co-author of NBF Biology for grades 11 & 12 according to the curriculum 2006, and the Principal author of Biology for grade 12 of KPK textbook board based on Curriculum 2006. His interactive video lectures covering all biology topics are available on his website www.BiologyGuardian.com and YouTube channel www.youtube.com/c/BiologyGuardian. Currently, he is a member of the Course Committee of SSC and HSSC Biology in the Federal Board and a Co-opted member of the Board of Studies of Botany at Quaid-i-Azam University Islamabad.