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UGC CSIR NET DBT

LIFE SCIENCES



UGC-CSIR-DBT National Eligibility Test (NET) for Junior Research Fellowship and Lecturer-ship

LIFE SCIENCES SYLLABUS

1. **Structure and Function of Biomolecules**
2. **Cellular Organization**
3. **Fundamental Processes**
4. **Cell Communication and Cell Signaling**
5. **Developmental Biology**
6. **System Physiology – Plant**
7. **System Physiology – Animal**
8. **Inheritance Biology**
9. **Evolution and Diversity of Life Forms**
10. **Ecology and Behavioural Biology**
11. **Bioinformatics and Computational Biology**
12. **Biochemical Engineering and Industrial Biotechnology**
13. **Advances in Biotechnology**
14. **Methods in Biology**

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1. STRUCTURE AND FUNCTION OF BIOMOLECULES

A. Structure of atoms, molecules and chemical bonds.

B. Composition, structure and function of biomolecules (carbohydrates, lipids, proteins, nucleic acids and vitamins).

C. Stabilizing interactions (van der Waals, electrostatic, hydrogen bonding, hydrophobic interaction, etc.).

D. Principles of biophysical chemistry (pH, buffer, reaction kinetics, thermodynamics, colligative properties).

E. Bioenergetics, glycolysis, oxidative phosphorylation, coupled reactions, group transfer, biological energy transducers.

F. Principles of catalysis, enzymes and enzyme kinetics, enzyme regulation, mechanism of enzyme catalysis, isozymes

G. Conformation of proteins (Ramachandran plot, secondary structure, domains, motif and folds).

H. Conformation of nucleic acids (Structural characteristics of A, B and Z DNA; RNA conformation).

I. Stability of proteins and nucleic acids.

J. Metabolism of carbohydrates, lipids, amino acids, nucleotides and vitamins.

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2. CELLULAR ORGANIZATION

A. Cell wall and cell membrane: structure and function

Cell wall, physical structure of model membranes in prokaryotes and eukaryotes, lipid bilayer, membrane proteins, diffusion, osmosis, ion channels, active transport, membrane pumps, mechanism of sorting and regulation of intracellular transport, electrical properties of membranes.

B. Structural organization and function of intracellular organelles

Nucleus and its organization and dynamics, mitochondria, Golgi bodies, lysosomes, endoplasmic reticulum, peroxisomes, plastids, vacuoles, chloroplast, structure & function of cytoskeleton and its role in motility.

C. Organization of genes and chromosomes

Operon, unique and repetitive DNA, interrupted genes, gene families, structure of chromatin and chromosomes, heterochromatin, euchromatin, transposons.

D. Cell division and cell cycle

Mitosis and meiosis, their regulation, steps in cell cycle, regulation and control of cell cycle, apoptosis, necrosis and autophagy.

E. Microbial Physiology

Growth kinetics, strategies of cell division, stress response, antimicrobial resistance (AMR).

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3. FUNDAMENTAL PROCESSES

A. DNA replication, repair and recombination

Unit of replication, enzymes involved, replication origin and replication fork, fidelity of replication, extrachromosomal replicons, DNA damage and repair mechanisms, homologous and site-specific recombination.

B. RNA synthesis, processing and regulation

Mechanism and regulation of transcription, transcriptional inhibitors, transcription factors and machinery, transcription activators and repressors, RNA polymerases, capping, RNA processing, RNA editing, splicing, and polyadenylation, structure and function of different types of RNA, RNA transport, ribozyme, riboswitches, non-coding RNA.

C. Protein synthesis, processing and degradation

Ribosome, mechanism of translation and its regulation, translational inhibitors, post-translational modification of proteins, protein trafficking and transport, protein degradation.

D. Control of gene expression at transcription and translation level

Regulation of gene expression in phages, viruses, prokaryotes and eukaryotes, role of chromatin in gene expression and gene silencing, epigenetic regulation.

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4. CELL COMMUNICATION AND CELL SIGNALING

A. Cell signaling

Hormones and their receptors, cell surface receptors, signaling through G-protein coupled receptors, signal transduction pathways, second messengers, regulation of signaling pathways, bacterial and plant two-component systems, light-signaling in plants, bacterial chemotaxis and quorum sensing.

B. Cellular communication

General principles of cell communication, cell adhesion and roles of different adhesion molecules, gap junctions, extracellular matrix, integrins, neurotransmission and its regulation, regulation of haematopoiesis.

C. Innate and adaptive immune system

Cells and molecules involved in innate and adaptive immunity, antigens, antigenicity and immunogenicity, B and T cell epitopes, structure and function of antibody molecules, generation of antibody diversity, monoclonal antibodies, antibody engineering, antigen-antibody interactions, MHC molecules, antigen processing and presentation, activation and differentiation of B and T cells, B and T cell receptors, humoral and cell- mediated immune responses, primary and secondary immune modulation, the complement system, Toll-like receptors, cell-mediated effector functions, inflammation, hypersensitivity and autoimmunity, immune response during bacterial, parasitic and viral infections, congenital and acquired immunodeficiencies, vaccines.

D. Host pathogen interaction

Recognition and entry processes of different pathogens like bacteria, viruses into animal and plant host cells, alteration of host cell behaviour by pathogens, virus-induced cell transformation, pathogen-induced diseases in animals and plants, cell-cell fusion in both normal and abnormal cells.

E. Cancer

Genetic rearrangements in progenitor cells, oncogenes, tumor suppressor genes, cancer and the cell cycle, virus-induced cancer, metastasis, interaction of cancer cells with normal cells, therapeutic interventions of uncontrolled cell growth.

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5. DEVELOPMENTAL BIOLOGY

A. Basic concepts of development

Potency, commitment, specification, induction, competence, determination and differentiation, morphogenetic gradients, cell fate and cell lineages, stem cells, genomic equivalence and the cytoplasmic determinants, imprinting, mutants and transgenics in analysis of development.

B. Gametogenesis, fertilization and early development

Production of gametes, cell surface molecules in sperm-egg recognition in animals, zygote formation, cleavage, blastula formation, embryonic fields, gastrulation and formation of germ layers in animals.

Male gametophyte development, embryo sac development and double fertilization in plants, embryogenesis, establishment of symmetry in plants, seed formation, embryo and endosperm developmental dynamics and germination.

C. Morphogenesis and organogenesis in animals

Cell aggregation and differentiation in Dictyostelium, axes and pattern formation in Drosophila, amphibia and chick; organogenesis - vulva formation in Caenorhabditis elegans, eye lens induction, limb development and regeneration in vertebrates, differentiation of neurons, post embryonic development - larval formation, metamorphosis; environmental regulation of normal development; sex determination.

D. Morphogenesis and organogenesis in plants

Organization of shoot and root apical meristem, shoot and root development, leaf development and phyllotaxy, transition to flowering, floral meristems, organogenesis and floral development.

E. Programmed cell death, aging and senescence in animals and plants

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6. SYSTEM PHYSIOLOGY - PLANT

A. Photosynthesis

Light harvesting complexes, mechanisms of electron transport, photoprotective mechanisms, CO2 fixation - C3, C4 and CAM pathways.

B. Respiration and photorespiration

Citric acid cycle, plant mitochondrial electron transport and ATP synthesis, alternate oxidase, photorespiratory pathway.

C. Nitrogen metabolism

Nitrate and ammonium assimilation; amino acid biosynthesis, biological nitrogen fixation.

D. Plant hormones

Biosynthesis, storage, breakdown and transport, physiological effects and mechanisms of action.

E. Sensory photobiology

Light perception, structure, function and mechanisms of action of phytochromes, cryptochromes and phototropins, stomatal movement, photoperiodism and biological clock.

F. Solute transport and photoassimilate translocation

Uptake, transport and translocation of water, ions, solutes and macromolecules from soil, through cells, across membranes, through xylem and phloem, transpiration, mechanisms of loading and unloading of photoassimilates.

G. Secondary metabolites

Biosynthesis of terpenes, phenolics, alkaloids, phenylpropanoids, nitrogenous compounds and their roles, metabolic engineering in plants.

H. Stress physiology

Physiological and molecular responses of plants to biotic and abiotic stresses, innate immunity.

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7. SYSTEM PHYSIOLOGY - ANIMAL

A. Blood and circulation

Blood corpuscles, haemopoiesis and formed elements, plasma function, blood volume, blood volume regulation, blood groups, haemoglobin, immunity, haemostasis.

B. Cardiovascular system

Comparative anatomy of heart structure, myogenic heart, specialized tissue, ECG – its principle and significance, cardiac cycle, heart as a pump, blood pressure, neural and chemical regulation of cardiovascular system.

C. Respiratory system

Comparison of respiration in different species, anatomical considerations, transport of gases, exchange of gases, waste elimination, neural and chemical regulation of respiration.

D. Nervous system

Neurons, action potential, gross neuroanatomy of the brain and spinal cord, central and peripheral nervous system, neural control of muscle tone and posture.

E. Sense organs: Vision, hearing and tactile responses.

F. Excretory system

Comparative physiology of excretion, kidney, urine formation, urine concentration, waste elimination, micturition, regulation of water balance, blood volume, blood pressure, electrolyte balance, acid-base balance.

G. Thermoregulation: Comfort zone, body temperature – physical, chemical, neural regulation, acclimatization.

H. Stress and adaptation

I. Digestive system: Digestion, absorption, energy balance, BMR.

J. Endocrinology and reproduction: Endocrine glands, basic mechanism of hormone action, hormones and diseases; reproductive processes, gametogenesis, ovulation, neuroendocrine regulation.

K. Concept of metaorganisms/holobionts: Gut microbiome in physiology; study of gut microbiome; germ-free animals; gut-brain axis, dysbiosis, and disease

L. Interorgan communication and energy homeostasis; metabolic health and disorders

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8. INHERITANCE BIOLOGY

A. Chromosomal and extrachromosomal inheritance

Principles of Mendelian inheritance, codominance, incomplete dominance, penetrance and expressivity, gene interactions, pleiotropy, genomic imprinting, linkage and cross-over, sex-linked inheritance, inheritance of mitochondrial and chloroplast genes, maternal inheritance.

B. Genes and mutations

Allele, multiple alleles, pseudoallele, complementation tests; Mutation types, causes and detection; mutant types – lethal, conditional, biochemical, loss of function, gain of function, dominant-negative; germinal verses somatic mutations.

C. Genetic analysis

Linkage maps, mapping with molecular markers in plants, animals and bacteria, tetrad analysis, gene transfer in bacteria: transformation, conjugation, transduction, sex-duction, fine structure analysis of gene, development of mapping population in plants.

D. Human genetics

Pedigree analysis, LOD score for linkage testing, karyotypes, genetic disorders.

E. Quantitative genetics

Population genetics and Hardy-Weinberg equilibrium, polygenic inheritance, heritability and its measurements, molecular mapping.

F. Structural and numerical alterations of chromosomes

Recombination, deletion, duplication, inversion, translocation, ploidy and their genetic implications.

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9. EVOLUTION AND DIVERSITY OF LIFE FORMS

A. Evolution of Life and Life Forms

Origin of life and early evolution; Evolution of cellular structures, functions and multicellularity; Mechanisms of evolution - Natural selection, genetic drift, gene flow, and mutation; Mechanisms of speciation; Extinction events and their role in shaping biodiversity; Adaptive radiation and convergent evolution; Coevolution and evolutionary arms races; Human evolution.

B. Principles & Methods of Taxonomy

Concepts of species and hierarchical taxa, biological nomenclature, classical & quantitative methods of taxonomy of plants, animals and microorganisms.

C. Microbial Life

Bacteria and Archaea: diversity and ecological roles; Viruses: structure, replication, and impact on life; Economically and pathologically important microbes.

D. Protists

Algae; Protozoa; Slime molds and water molds; Ecological roles of protists.

E. Fungi

Diversity of fungal groups: chytrids, zygomycetes, glomeromycetes, ascomycetes, and basidiomycetes; Important fungal pathogens of plants and humans.

F. Plant Life

Evolution and diversity of land plants: bryophytes, ferns, gymnosperms, and angiosperms; Plant morphology, anatomy, and reproduction.

G. Animal Life

Evolutionary relationships and key characteristics of Invertebrates and Vertebrates.

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10. ECOLOGY AND BEHAVIORAL BIOLOGY

A. Introduction to Ecology

Levels of organization- individual, population, community, ecosystem, biosphere; Abiotic and biotic ecological factors, Ecological adaptations.

B. Population Ecology

Population growth models- Exponential growth, logistic growth, density-dependent and density-independent factors, life tables, survivorship curves; Population dynamics- Age structure, sex ratio, life history strategies (r-selected vs. K-selected); Metapopulations- Habitat fragmentation, connectivity, and extinction risk.

C. Community Ecology

Community structure - Food webs, trophic levels, keystone species; Species interactions - Competition, predation, mutualism, parasitism; Succession- Primary and secondary succession, community stability.

D. Ecosystem Ecology

Energy flow in ecosystems- Primary production, trophic levels, energy pyramids; Biogeochemical cycles- Carbon, nitrogen, phosphorus, water cycles; Ecosystem services and human impacts.

E. Human Impacts on Ecosystems

Anthropogenic pressures: Land use and land-cover change; Climate change, pollution, invasive species.

F. Biodiversity and Conservation

Biodiversity and its importance; Threats to biodiversity; IUCN categories of threat; Conservation genetics; Population viability analysis (PVA); Ex-situ and in-situ conservation strategies; Community-based conservation and the role of indigenous knowledge; International and national conservation policies and legislation.

G. Act and policies

Biodiversity Act 2002; Agricultural biodiversity; International Treaty on Plant Genetic Resources for Food and Agriculture (PGRFA); Conservation strategies for seed gene bank; Climate change and conservation of plant genetic resources; Strategies on PPVFR and Biodiversity Acts.

H. Behavioural Ecology

Introduction to animal behaviour- Proximate and ultimate causes of behaviour; Foraging behaviour; Communication; Conflict and aggression; Migration, dispersal, and navigation; Social behaviour; Sexual selection and mating systems; Parental care.

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11. BIOINFORMATICS AND COMPUTATIONAL BIOLOGY

A. Major Bioinformatic Resources

Sequence databases, gene expression databases, 3D structure database, pattern sequence databases.

B. Basic Concepts of Sequence Analysis

Database searches, BLAST and FASTA, sequence identity and similarity, definitions of homologues, orthologues, paralogues, repeat finding, scoring matrix, pairwise sequence alignments, multiple sequence alignments (MSA), application in taxonomy and phylogeny, comparative genomics.

C. Gene annotation

Prediction of gene function using homology, context, structures, networks; Genetic variation-polymorphism, deleterious mutations; Phylogenetics.

D. Molecular Modelling and Dynamics

3-D structure visualization and simulation, Basic concepts in molecular modeling, Molecular Mechanics, Force fields etc.

E. Classification and comparison of protein 3D structures

Anatomy of proteins – Hierarchical organization of protein structure, Secondary and tertiary structure prediction, homology/comparative modeling, fold recognition, threading approaches, and ab initio structure prediction methods, AI-based methods of structure prediction (eg. AlphaFold).

F. Drug design

Chemical databases like NCI /PUBCHEM, Fundamentals of Receptor-ligand interactions, Structure-based drug design, Ligand based drug design: Structure-Activity Relationship, QSARs and pharmacophores, in silico predictions of drug activity and ADMET.

G. Systems Biology

Data science applications in biology, health and drug discovery, mathematical modelling of metabolic pathways and disease, digital health, personalized medicine.

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12. BIOCHEMICAL ENGINEERING AND INDUSTRIAL BIOTECHNOLOGY

A. Introductory Mathematics

Calculus review, Ordinary differential equations, Second and higher order differential equations, Linear algebra, Numerical methods.

B. Engineering Principles

Material and energy balance, Steady state energy and material balance, Properties of substances, Introduction to transport phenomena, momentum transfer, heat and mass transfer, Introduction to mass transfer equipment.

C. Thermodynamics in Biological Systems

First and second law of thermodynamics, Biological systems as open non-equilibrium systems, Failure of classical thermodynamics in describing biological processes, Concepts of thermodynamics flux and force, Concept of entropy production, Constitutive equations, Thermodynamics of coupled biochemical reactions, Thermodynamic analysis of oxidative phosphorylation, Glycolytic oscillations; biological clocks.

D. Bioprocess Engineering and Technology

Principles of microbial growth and factors affecting growth, Growth kinetics and substrate utilization in batch, fed-batch and continuous systems, Introduction to bioreactors: batch and fed-batch, plug flow, continuous, enzyme reactors, Sterilization, Mass and energy balance in microbial process-effects of dissolved oxygen, Mass transfer of oxygen, aeration and agitation, fluid rheology, Fermentation technology for antibiotics, organic acids, alcohol, bioplastics, vitamins, enzymes; biotransformation of steroids, Process flow sheet and process economics.

E. Enzymes and microbial technology

Enzymes in organic solvents and ionic liquids, biocatalysts, enzyme engineering, random and rational approach to protein engineering, Biocatalysis, techniques of immobilization of enzymes and whole cells: design, operation and kinetics of immobilized enzyme reactors, diffusional resistance and Thiele modulus.

F. Downstream processing in biotechnology

Biomass removal and disruption, Precipitation by salts, solvents, Membrane based purification, Adsorption and chromatography, Extraction (solvent, aqueous two-phase, super critical), Drying.

G. Bioprocess Plant Design

General design information, Process flow sheet, Scale-up and scale-down issues, Scale up of downstream processes. Selection and specifications of bioprocess equipment.

H. Metabolic Engineering and Synthetic Biology

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13. ADVANCES IN BIOTECHNOLOGY

A. Recombinant DNA technology

Molecular cloning, expression of recombinant proteins, In vitro mutagenesis and deletion techniques, gene knock out in bacterial and eukaryotic organisms, genome editing techniques. Protein sequencing methods, DNA sequencing methods, strategies for genome sequencing and gene expression analysis.

B. Medical Biotechnology

Application of immunological principles (autoimmunity, transplantation, tumor immunology, stem cell therapy, cell-based vaccines), vaccines (Live, killed, attenuated, subunit, and recombinant nucleic acid vaccines) and diagnostics, adjuvants, cell therapy, stem cell therapy, immunotherapy, r-DNA based therapy, antibody engineering, phage display libraries, tissue engineering.

Stem cell technology: induced pluripotent stem cells, guided/directed differentiation methods; application in drug screening and disease biology; Organoid: Stem-cell based, self-organizing 3D models for disease and developmental biology.

Neurobiology: Electrophysiological studies of the brain, behavioural tests.

Medical devices and implants, Biosensors

C. Animal Biotechnology

Transgenic animals, animal breeding, conservation of germplasm, genetic health monitoring, molecular medicine and surgery, concept of molecular diagnosis of pathogens, cell cloning and selection, cell and tissue culture methods in biotechnological applications.

D. Agriculture Biotechnology

Transgenic plants, molecular approaches to diagnosis and strain identification; genomics and its application to agriculture, development of ESTs, molecular markers for plant genotyping and germplasm analysis, marker assisted breeding for various traits, foreground and background selection, gene introgression and pyramiding, non-gel based techniques for plant genotyping, impact of GE crops on biodiversity; tissue and cell culture methods in plants, plantibodies.

E. Marine Biotechnology

Important marine organisms, their biology and behaviour, marine resources assessment, Population study and marine environment protection, role of microbes in marine environment, microbial metabolites, seafood microbiology, marine pharmacology, fouling and corrosion, biofilms; oceanography

F. Environmental Biotechnology

Wastewater treatment systems, Pollution control, Environment friendly technologies: Biosurfactants, biofertilizers, biopesticides, microbially enhanced oil recovery, integrated waste management, biogas & biofuel from waste, bioremediation, phytoremediation.

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14. METHODS IN BIOLOGY

A. Molecular Biology Techniques

Isolation, separation and analysis of biological macromolecules (DNA, RNA, proteins, carbohydrates and lipids), chromatography, electrophoresis and centrifugation.

B. Biophysical Methods

Spectroscopy (UV/visible, fluorescence, circular dichroism, NMR and ESR), molecular structure determination using X-ray diffraction, cryo-electron microscopy and NMR, Molecular analysis using light scattering, different types of mass spectrometry methods and surface plasma resonance.

C. Genomics, Transcriptomics, Proteomics and Metabolomics

Structure and organization of prokaryotic and eukaryotic genomes, Comparative genomics, Global gene expression analysis, Comparative transcriptomics, Differential gene expression; protein interaction analysis and mapping, targeted and untargeted metabolic profiling, DNA finger printing and its applications, DNA bar coding, Single-cell sequencing, single-cell omics.

D. Radiolabeling techniques

Detection and measurement of different types of radioisotopes normally used in biology, incorporation of radioisotopes in biological tissues and cells, molecular imaging of radioactive material, safety guidelines.

E. Histochemical and Immunotechniques

Antibody generation, Detection of molecules using ELISA, RIA, western blot, immunoprecipitation, flow cytometry and immunofluorescence microscopy, detection of molecules in living cells, in situ localization by techniques such as FISH and GISH.

F. Microscopic techniques

Visualization of cells and subcellular components by light microscopy and advanced microscopic techniques, resolving power of microscopes, microscopy of living cells, scanning and transmission microscopes, sample preparation techniques for microscopy.

G. Electrophysiological methods

Single neuron recording, patch-clamp recording, ECG, Brain activity recording, lesion and stimulation of brain, pharmacological testing, PET, MRI, fMRI, CAT.

H. Methods in field biology

Methods of estimating population density of animals and plants, ranging patterns through direct, indirect and remote observations, sampling methods in the study of behaviour, habitat characterization: ground and remote sensing methods.

I. Statistical Methods

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Concepts of precision and accuracy in experimental measurements, signal to noise ratio, Measures of central tendency and dispersal; probability distributions (Binomial, Poisson and normal); Sampling distribution; Difference between parametric and non-parametric statistics; Confidence Interval; Errors; Levels of significance; Regression and Correlation; t-test; Analysis of variance; X2 test; basic introduction to multivariate statistics, etc.

J. IPR, Biosafety and Bioethics

Intellectual property rights, types of IP, Patent databases; Biological safety measures, biosafety levels, regulatory guidelines, animal ethics, research ethics, publication ethics, plagiarism, use of AI in research and publication.

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