Science of Living Systems (ML 201)

Second Year B. Tech. Program

Teaching Scheme
Lectures : 3 lectures/week

Examination Scheme (Marks – M)
T1-**20 M** (Classroom activity),T2-**20 M** (Assignment/s)
Semester End Examination-**60 M**

Course Education Objectives [AS16002: Science of Living Systems (SLS)]

1. To make students conversant with basic Biology regarding the life processes.

2. To impart knowledge about the common corridors of biology and engineering as biologically inspired technologies like designs in nature, bioenergetics, bioprocesses, biomaterials, biomechanics, bioimaging, bioinformatics, bioinstrumentation etc.

3. To introduce recent trends in biology viz. genetic & tissue engineering, stem cell engineering, bio and nanotechnology etc. with the objective of appreciating engineering principles in biological systems.

Course Outcome:

1. Knowing basic concepts of biology and biomolecules with their application in more meaningful way. Understnding the role of biomolecules in organization of life and its functions.
2. Understanding natural biological processes and their technical aspects in view of increasing efficiency of engineering. Understanding the energy dynamics and coordination between biological systems.
3. Understanding higher complexcity of life, communication and coordination. Introduction to interdisciplinary topics like energy transduction and cellular evolution. Understanding how different life forms protect themselves.
4. Techniques and devices used to explore and understand living systems. Understanding their specific importance in biomedical sciences. Introduction of interdisciplinary topics like genetic and tissue engineering.
5. Important and path breaking discoveries in the field of life sciences and biotechnology. Inventions that changed the human life and their impact on other fields like engineering. What engineers can learn from these discoveries and innovations.

6. Branch specific applications of SLS to engineering and vice versa.

Unit 1: Understanding Basics (6 hrs)

1. Engineering perspectives of biological sciences: Where engineering meets biology and where biology meets engineering. Biology as an integrated Science; Case studies on integrating biology with engineering.
2. Biopolymers and macromolecules – Structure and Function: Organic and inorganic molecules; Unique Properties of Carbon; Carbohydrates, Amino Acids and proteins, Lipids, Nucleic Acids, Vitamins and Minerals; The Rise of Living Systems.
3. Levels of organization of life : Cell as basic unit of life, prokaryotic and eukaryotic cells, microbes, plant and animal cells; Cell organelles – structure and function; Levels of organization of life - tissues, organs, systems and organism.

Unit 2: Biological Processes and Bioenergetics (6 hrs)

1. **Energy Dynamics in Biology –**
    a) Photosynthesis and energy assimilation: aerobic and anaerobic systems. Applications
    b) Respiration and Electron Transport Chain: Mitochondria and respiration, ATP generation.
2. **Bioenergetics:** Thermodynamic principles applied to biology, negative entropy changes in biological systems, Free Energy, Chemical Equilibrium;
3. **Optimization of biological functions**: Metabolic networks; anabolism and catabolism; flux analysis (MATLAB).

Unit 3: Living Systems (6 hrs)

1. **Transport Phenomena in Biological Systems:** Membrane channels and ion channels; Fluid flow and mass transfer
    a. In plants: Xylem and Phloem

    b. In animals: Blood and Lymph

    c. Transport of molecules and gases (Oxygen and Carbon dioxide); Heat Transport - Body temperature regulation.

2. **Communication:** Cell junctions, Cell-cell communications – cell signaling, Hormones, Pheromones; Chemotaxis. Communication in living systems by photo, bio, chemotactic methods.
3. **Defense mechanisms in plants and animals:**
    a. In plants: Herbivory, secondary metabolites.

b. In animals: Innate and Adaptive immune systems.

Unit 4: Techniques and Devices (6 hrs)

1. **Genetic Code** - Expression and Transmission of Genetic Information, The concept of DNA cloning; Mechanisms of Enzyme Action.
2. **Techniques for optimization:**
   a. At molecular level: Genetic Code and protein synthesis, DNA replication, RDT, DNA hybridization, Colony Hybrids, PCR, DNA microarray,

   b. At cell level: Hybridoma technology,

   c. At tissue level: Plant Tissue Culture, Animal Tissue Culture and Microbial Culture techniques; Tissue Engineering.

3. **Instrumental Methods of analysis** – A case study of protein purification and characterization: Principles and types of microscopy and spectroscopy, Chromatography, electrophoresis, diffusion, centrifugation, light scattering.

Unit 5: Discovery and Innovation (6 hrs)

1. **Current trends and advances** in cell and molecular biology
2. **Landmark Discoveries**: Landmark discoveries in the field of Molecular Biology, Cell Biology and Genetics.
3. **Nanobiotechnology:** Micro-/Nanotechnologies for Interfacing Live Cells; Nanotechnology in Medicine – Diagnostics and Therapy; Biosensors; Nanotechnology in Agriculture; Biomemetics.
4. **Biomemetics:** Nature inspired processes applicable to the field of Engineering.

Unit 6: Branch-wise (6 hrs)
Branch: Electronics and Telecommunication Engineering
Biosensors – Introduction to Biosensors, transducers, amplifiers; **Bioimaging**-Introduction to medical imaging and different medical Imaging modalities; Review of Signals and system; Electro Physiological Signal Analysis. Bio-telemetry Communication in living systems by photo, bio, chemo, tactic methods; **Diagnostic Devices**- Radiography, X-ray Computed Tomography Nuclear Medical Imaging, Ultrasound Imaging, Magnetic Resonance Imaging. **Therapeutic Devices**-Cardiac Pacemakers, Cardiac defibrillators, Surgical Diathermy, Diagnostic application of LASERs, High frequency heat therapy, Hemodialysis, Ventilators, Anesthesia machines, Automatic Drug delivery Systems, Electro Surgical units and safety.

Branch: Instrumentation and Control Engineering
Basic concepts of **Medical Instrumentation**: Generalized medical Instrumentation System, Medical Measurement constraints, Classification of Biomedical Instruments, Generalized static and dynamic characteristics, Design criteria, Commercial Medical Instrumentation Development

process, Regulation of Medical Devices. **Biomedical transducers:** optical, photo- electric, electrochemical, electrical, mechanical, electromechanical and thermoelectric. **Specialty areas in Bioinstrumentation**—Confocal, Tunneling, Sequencing, FACS, PCR, MRI, CT,USG, Endoscopy, ECG; Introduction to biosensors and tissue engineering.

Branch: Mechanical Engineering

Biomechanics, Human body motion, Prosthetics; Introduction to Ergonomics; Elements of Anthropometry; Physiology, Anatomy; Mechanical Properties of Bone and Soft Tissues Rehabilitation engineering, Biomimetics; Bio Material Handling; Hand Tool Design; Human Information Processing; Applications of Principles of Biomechanics in two and three dimensional kinematics; Fundamentals of Fluid Mechanics; Introduction to bio sensors and tissue engineering.

Branch: Metallurgy and Material Science

Classification of biomaterials –Comparison of properties of some common biomaterials; Effects of physiological fluid on the properties of biomaterials; Biological responses (extra and intra vascular system) to Metallic, Ceramic and Polymeric implant materials; Introduction to bio sensors and tissue engineering. Metals & alloys, composites and their advantages used in bio-industries; Materials in bio-printing. **Tissue Engineering and cloning:** Engineering cells, tissues and organs; Stem cells and translational medicine; Introduction to Gene Therapy; Bioengineering at molecular, cell and systems level; 3D bio-printing; Engineering Materials for Biomedical Applications.

Branch: Production Engineering and Industrial Management

Bio chemical engineering; Fermentation Technology, Bioreactors; Bio process Engineering; Use of living organisms (mostly microbes) to produce useful products. Biomechanics and ergonomics–production innovations.

Branch: Electrical Engineering

Alternative energy sources; Electrical signaling in biological system; Bioluminescence, bioelectricity, ECG.

Branch: Civil Engineering

Environmental engineering, Understanding ancient engineering. Designs in Nature; Bio radars.

Branch: Computer and Information Technology –

Principles of Bioinformatics, Computational Biology: Role of Computational Biology in Bioengineering; Genomics, Proteomics, Bioinformatics. Computational solutions to Biological Problems, Virtual systems Artificial Intelligence in Biomedical Engineering: Basics of Artificial Neural Networks.

Selected References:

1. Lodish H, Berk A, Zipursky SL, et al. (2000) Molecular Cell Biology. W. H. Freeman.

2. Lehninger, A. L., Nelson, D. L., & Cox, M. M. (2000). *Lehninger principles of biochemistry*. New York: Worth Publishers.
3. Lewin B. (2000) Genes VII. Oxford University Press..
4. Rao CNR, et.al. Chemistry of Nanomaterials: Synthesis, Properties and Applications.
5. Eggins BR. (1006) Biosensors: An Introduction. John Wiley & Sons Publishers.
6. Palsson B.O. and Bhatia S.N. (2009) Tissue Engineering. Pearson.