University of Lucknow

Master of Science in Biotechnology Programme

Course Structure

Code	Nature		Credit
First Semester			
BTCC-101	Core	Biomolecules: Structure and Function	4
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COURSE OUTLINE

BTCC-101: Biomolecules: Structure and Function

Course Objectives:

1. Extend comprehensive knowledge about structure and properties of biomolecules (monomeric units) of the cell.
2. To teach the students how monomeric molecules of carbohydrate, amino acids, lipid and nucleotides form covalent linkages to form polymers.
3. How these polymers of biomolecules assemble with each other to form supramolecular assemblies having structural and functional role in cell.

Course Outcome: At the end of the course, a student should be able to

1. Know about structure and properties of biomolecules (monomeric units) of the cell.
2. Understand how monomeric molecules of carbohydrate, amino acids, lipid and nucleotides form covalent linkages to form polymers.
3. Understand how these polymers of biomolecules assemble with each other to form supramolecular assemblies having structural and functional role in cell.

Unit I

Carbohydrates: Classification and properties of simple carbohydrates, monosaccharides, disaccharides and polysaccharides. Structural polysaccharides: cellulose and chitin; storage polysaccharides: starch and glycogen; glycosaminoglycans; glycoconjugates: proteoglycans, glycoproteins and glycolipids

Unit II

Fatty Acids and Lipids: Structure, classification and properties of fatty acids, structure and functions of lipids: Triacylglycerides, phosphoglycerides, sphingolipids, cholesterol, steroids, eicosanoids, Lipoproteins

Unit III

Amino acids and proteins: Classification, chemical structure and general properties of amino acids. Standard and non standard amino acids found in proteins. The peptide bond and its characteristics.

Unit IV

Sturcture and functions of DNA: Base pairing: Watson-crick, Hoogsteen and Wobble base pairs, The salient features of the Watson-Crick model of B-DNA, The structure and helical parameters of B-DNA, A-DNA, and Z-DNA. Melting temperature (T_m), Forces stabilizing the B-DNA.

Unit V

Structure and functions of RNA: Physicochemical properties of RNA, classification, structure and functions of different types of RNAs (hnRNA, mRNA, rRNA, tRNA, snRNA, snoRNA, antisense RNA telomerase RNA, gRNA,etc.). The clover leaf and L-shaped structures of tRNA.

Suggested Reading:

- Biochemistry by Voet B and Voet JG, Wiley Publishers, USA
- Biochemistry 5th Revised edition by LubertStryer, Jeremy M. Berg, John L. Tymoczko, Macmillan Publishers, USA
- D.L. Nelson and M.M. Cox Lehninger Principles of Biochemistry, Publisher: WH Freeman; *8th ed.*NewYork

BTCC-102: Biophysical Techniques

Course Objectives and Outcomes

- The course is designed to provide a broad exposure to basic techniques used in Modern Biology research.
- The goal is to impart basic conceptual understanding of principles of these techniques and emphasize biochemical utility of the same.
- Student is expected to have a clear understanding of all analytical techniques such that the barrier to implement the same is abated to a great extent.
- Students will learn to combine previously acquired knowledge of physics and chemistry to understand the biochemical processes in the cell.

Unit I:

Electrochemistry: Ionization of water and its interaction with acids and bases, Buffers and buffering capacity. Determination of pH: theory and instrumentation.

Electrophoresis: Separation of biomolecules on electrophoretic gels: PAGE and agarose gels. Native PAGE, SDS-PAGE, Isoelectric focusing, 2D-PAGE,

Unit II:

Centrifugation: Basic principle of sedimentation, centrifuge and their uses. Rotors. Preparative and analytical centrifugation and their application in biochemistry.

Chromatography: Partition coefficient, Retention, Resolution, Capacity factor, theoretical plate, van Deemter curve, Gel filtration chromatography, Ion exchange chromatography, Affinity chromatography, Hydrophobic interaction chromatography, Paper chromatography, Thin layer chromatography, Fundamentals of high-performance chromatography.

Unit III:

Spectroscopic techniques: Basic concepts of molecular bonding and spectroscopy. Energy Levels. Theory of interaction of biomolecules with energy. Principle, instrumentation and applications of atomic absorption and emission spectroscopy. Concepts and applications of UV-Visible and fluorescence spectrophotometry, EPR, XRD, NMR, MS.

Unit IV:

Optical methods for determination of molecular structure: Absorption of polarized light, optical rotatory dispersion, hypochromism, circular dichroism in relation to composition and structure of biomolecules.

Unit V:

Biosensors: Basic techniques, enzyme electrode, organic salt electrode, immunoelectrodes, microbial biosensors.

Tracer techniques: Detection and measurement of isotopes and biological applications.

Suggested Reading:

- Physical Chemistry for the Life Sciences (2nd Revised Edition). Atkins, de Paula. (2015).
- Biophysical Chemistry, Allen Cooper, (2011), Royal Society of Chemistry
- Principles of Physical Biochemistry, K. E. van Holde, C. Johnson, P. S. Ho. (2010) 3rd Edn., Prentice Hall
- C.R. Cantor and P.R. Schimmel (1982) Biophysical Chemistry (Part 1-3), 2nd Edn.

- Joachim Frank (2006) Three-Dimensional Electron Microscopy of Macromolecular Assemblies, Academic Press.
- Physical Chemistry: Principles and Applications in the Biological Sciences. Tinoco, Sauer, Wang, and Puglisi. (2013) Prentice Hall, Inc.

BTCC-103: Enzymology

Course Objectives and Outcomes:

- To learn about classification, annotation.
- To learn about various mechanisms of enzyme action by taking examples of enzymes catalyzing two substrate reaction.
- To understand the techniques used for elucidating the mechanisms of enzyme action.
- The course will enable a student to have a strong foundation to the understanding of enzymes and biological catalysis

Unit- I

General properties of enzymes. Classification and nomenclature of enzymes. Intracellular localization of enzyme. Methods of enzyme assays and protein estimation.

Unit- II

Purification strategies of native enzymes. Tests of homogeneity. Physio-chemical characterization of purified enzymes (molecular weight determination, effect of pH, temperature, salt etc. on the rate of enzyme catalysis). Problems based on enzyme purification.

Unit- III

Isozyme and multiple form of enzymes. Enzyme and protein engineering. Industrial application of enzymes.

Unit- IV

Michaelis- Menten Kinetics: Derivation of Michaelis- Menten equation based on equilibrium assumption, Briggs- Haldane steady-state approach. Methods for the determination of Km and Vmax. Computer based determination of Km and Vmax

Unit- V

Types of enzyme inhibition. Derivation of equations for different types of enzyme inhibitions. Enzyme activation.

Suggested Reading:

- Enzymes by Dixon M, Webb EC, 2ND Ed., Academic Press.
- Enzymes by Palmer, Woodhead Publishing Ltd., UK.
- Biochemistry by Voet B and Voet JG, Wiley Publishers, USA
- D.L. Nelson and M.M. Cox Lehninger Principles of Biochemistry, Publisher: WH Freeman; *8th ed.*NewYork

BTCC-104: Principles of Genetic Engineering

Course objectives and Outcomes:

- A sound knowledge of concepts of genetic engineering is very important for the students of biotechnology as it has contributed to the development of newly emerging fields such as bioinformatics, proteomics, genomics, etc.

- Recombinant DNA technology has been used commercially for the production of useful compound related to areas such as agriculture, medicine, environment and forensics. Some key examples are human insulin, growth hormone, interferon, etc.
- Genetically modified crops such as Bt Cotton, Bt Brinjal have resistance to insects and microbes and giving them different characteristics and ecofriendly in nature.

Unit I

Overview of recombinant DNA technology: historical prospective. DNA Modification and restriction: Restriction Endonuclease: general properties, nomenclature, types (Class I, II and III), and mode of action. DNA methylation.

Enzymes used in recombinant DNA technology (DNA polymerases, DNA ligase, alkaline phosphatases, polynucleotidyl kinases, nucleases etc.).

Unit II

Plasmid as cloning vector: plasmid types, properties of typical plasmid cloning vector. Phage as a cloning vector: Lambda and M13 based vectors. Hybrid vectors: Cosmids and Phagemids. Yeast based vectors: YEP, YRP, YCP, YIP, YAC. PCR and variants of PCR. Transcript expression analysis using real time PCR.

Unit III

Formation of chimeric DNA using restriction enzyme, homopolymer tailing, synthetic linkers, synthetic linkers and adaptors. Genomic and cDNA libraries, chemical synthesis of DNA

Unit IV

Blotting techniques: southern, northern, western and eastern blotting. Methods of labelling of DNA probes. Autoradiography. Selection and screening of recombinants.

Unit V

Post-transcriptional gene silencing. Applications of recombinant DNA technology in the field of agriculture, medicine and industry.

Suggested Reading:

- Genetic engineering by Smita Rastogi and Neelam Pathak Oxford University Press.
- Nicholl, D.S.T. (1994): An introduction of genetic engineering, Cambridge University Press.
- Christopler, H. (1995) Gene cloning and manipulating Cambridge University Press.
- Gene cloning – T. A. Brown, Blackwell publisher.

BTCC-105: Laboratory Course I

Course Objectives and Outcomes:

The aim of this laboratory course is to train students with the various tests/ methods employed in qualitative and quantitative analysis of biomolecules. Students will also gain practical expertise in chromatographic methods and enzyme kinetics.

Qualitative analysis of biological samples: Carbohydrates, amino acids and proteins, lipids, RNA and DNA

Quantitative estimation of biological molecules: Colorometric/ spectrophotometric methods to quantitively estimate Carbohydrates, Proteins, RNA and DNA

Chromatography techniques: Separation of amino acids by thin layer chromatography

Enzyme kinetics: Tissue homogenization, crude enzyme preparation and kinetic studies.

Suggested Reading:

Introductory Practical Biochemistry. Sawhney and Singh. Narosa Publishing House, 2020.
An introduction to Practical Biochemistry. David T plummer. Tata McGraw-Hill, 2008.

BTVC-101: Protein Structure

Course Objectives and Outcomes:

To have a knowledge base in the structure of proteins.To understand the detailed three dimensional structure of proteins, and the dynamics of their folding and unfolding.To appreciate the relationship between the structure and function of proteins in biological systems.

Unit I

Proteins as the executive molecule in the biological systems, Functional diversity of proteins. The peptide bond and its properties. Flexibility of polypeptide chains, Ramachandran plot. Hierarchy of three-dimensional structure of proteins

Primary structure of proteins: Identification of the N- and C-terminal residues, Determination of primary structure of proteins, assignment of disulfide bonds

Unit II

Secondary structure of proteins:α-helices, β-sheets, β-turns, other helical structures.

Tertiary structure of proteins: General structure of globular proteins. Supersecondary structural motifs and domains

Unit III

Quaternary structure of proteins: Symmetry in protein structure, Determination of quaternary structure of proteins: Electron microscopy, succinylation.

Protein denaturation, Melting temperature (T_m), Effect of salts on protein structure, Hofmeister series, Salting-in and Salting out, Chaotropic agents

Unit IV

Protein folding: Introduction, thermodynamic and kinetic considerations, the concept of local and global energy minima, Early protein folding experiments on RNase A, Renaturation of post-synthetically modified proteins (insulin), Folding pathways, Levinthal paradox and folding funnels, The multistage process of protein folding, Folding pathway of bovine pancreatic trypsin inhibitor (BPTI)

Unit V

Folding Accessory Proteins: Proteins disulfide isomerase (PDI), Peptidyl prolyl *cis-trans*isomerese (PPl), Heat shock proteins, Molecular chaperones

Structure and physical properties of representative structural proteins: Keratin, Silk fibroin and Collagen

Suggested Reading:

- Biochemistry. By Voet D, Voet JG, Wiley Publishers, USA
- Lehninger Principles of Biochemistry. By Nelson DL and Cox MM, Freeman WH and Company

- Biochemistry. By Berg JM, StryerL, Tymoczko J and Gatto G, Macmillan Publishers, USA
- Biochemistry. By Mathews CK, van Holde KE, Appling DR, Anthony-Cahill SJ, Pearson Publishers, USA
- Introduction to Protein Structure. By Branden C and TroozeJ, Garland Publishing, New York
- ProteinFolding. By Creighton TE, WH Freeman, Oxford, UK

BTCC-201: Molecular Cell Biology

Course Objectives and Outcomes: The course aims to an extensive coverage of molecular cell biology and shall enable the student to comprehend problems and latest research in the area. Layering a problem-oriented approach to learning will lead to independent learning of advanced cell biology concepts.

Unit I

Membrane lipids: Physical properties of lipids and their interaction with water to form membranes. Concept of fluidity and factors causing variations in fluidity. Micelles and lipid bilayers. Lipids rafts. Membrane asymmetry Modification of lipids fluidity by membrane proteins. Arrangement of proteins within lipids bilayers. Hydropathy plots and prediction of membrane spanning domains.

Membrane transport: Channels, transporters and pumps. Active and passive transport. P-and F-type pumps and ABC transporters. Ion channels and electrical properties of membranes. Voltage and ligand gated channels

Unit II

Cytoskeleton: Actin microfilaments, microtubules and intermediate fiber assemblies. Actin and tubulin dynamics and roles of modifying /accessory proteins. Roles of microfilaments and microtubules in cellular structure and function. Control of assembly through signaling processes.

Unit III

Cell Signaling: General principles of signaling switches. Receptor characteristics. Identification and characteristics of receptor proteins, G-proteins and receptor tyrosine kinase mediated signaling Ca^{2+} flux and its interpretation in cytoplasm, role of Ca^{2+} binding proteins.

Unit IV

Intracellular vesicular trafficking: Import of proteins into ER and processing in the ER and Golgi. Mechanism of vesicle formation and fusion. Import of relevant nuclear coded proteins into chloroplasts and mitochondria.

Unit V

Cell Cycle and cancer: Overview and control. Cyclins, CDKs and Ubiquitin-proteasome dependent control of cell cycle. Checkpoints. Transition from normal to cancerous cell growth. Genetic instability and mutations as causative Agents. Oncogenes and retroviruses P_{53} and associated proteins as tumor suppressors

Apoptosis: The role of programmed cell death in maintaining the social order of cells and in tissue sculpting. Pathways and hallmarks of apoptosis. Role of caspases and Bcl2 family proteins.

Suggested Reading:

- Molecular Biology of the Cell-Alberts *et al*
- Molecular Cell Biology-Lodish *et al*
- Cells-Lewin
- Becker's World of Cell-Hardin *et al*
- The Cell: A molecular Approach-Cooper and Hausmann

BTCC-202: Microbiology and Metabolic Processes

Course Objectives and Outcomes:

The objectives of this course are to introduce the students to the field of microbiology with special emphasis on microbial diversity, morphology, physiology and nutrition; methods for control of microbes, their role in environment, food microbiology, preservation methods and metabolic processes.

Aims to educate students to identify and demonstrate the structural, physiological, and genetic similarities and differences of the major categories of microorganisms, to identify and demonstrate how to control microbial growth, to demonstrate and evaluate the interactions between microbes, hosts and environment.

Unit I

Microbial characteristics: Introduction to microbiology and microbes, morphology, structure, growth and nutrition of bacteria.

Unit-II

Bacterial growth curve, bacterial culture methods; bacterial genetics: mutation and recombination in bacteria, plasmids, transformation, transduction and conjugation. Gram positive and Gram negative organisms, biosynthesis of bacterial cell wall.

Unit-III

Role of microorganisms in nitrogen, biological nitrogen fixation; carbon; sulfur; and phosphorus cycles,

Domestic and industrial sewage treatment. Food microbiology: Microbial spoilage of food products (fresh and canned), food borne infection, food preservation methods

Unit-IV

Glycolytic and non-glycolytic pathways. Pentose phosphate pathway, tricarboxylic acid cycle, anaplerotic sequences in metabolism, glyoxylate pathway. Degradation and biosynthesis of saturated and unsaturated fatty acids.

Unit-V

Transamination, deamination and decarboxylation of amino acids, urea cycle. Biosynthesis of purine and pyrimidine nucleotides.

Suggested Reading

- Pelczar, M. J., Reid, R. D., & Chan, E. C. (1977). Microbiology (5th ed.). New York: McGraw-Hill.
- Willey, J. M., Sherwood, L., Woolverton, C. J., Prescott, L. M., & Willey, J. M. (2011). Prescott's microbiology. New York: McGraw-Hill.
- An Industrial Microbiology Waites MJ, Morgn NL, Rockey JS, Higton G, Blackwell Science Ltd, 1rst Indian reprint, 2005

BTCC-203: Molecular Biology

Course Objectives:

1. To teach the dynamic properties of chromatin and its folding.
2. To teach topological properties of DNA, reassociation kinetic, transposable elements and genetic code
3. To provide students with a deep insight and mechanism of the various cellular processes such as DNA Replication, Transcription and Translation.

Course Outcomes: At the end of the course, a student should be able to

1. To learn the dynamic properties of chromatin and its folding.
2. To learn topological properties of DNA, reassociation kinetic, transposable elements and genetic code
3. To understand the mechanism of the various cellular processes such as DNA Replication, Transcription and Translation.

Unit I

DNA topology: DNA supercoiling, linking number, twist and writhe.

Organization of DNA in chromosomes: The dynamic structure of chromatin. Structure of histone core. Histone association with DNA.

DNA melting and reassociation kinetics: Classes of DNA sequences, $C_o t$ curves. Analysis of DNA complexity

Transposable elements: Transposonsof bacteria - IS, composite transposons, Tn transposons of Drosophila: P and Copia, Transposons of maize: Ac, Ds, Spm (En), dSpn, Retrotransposons.

Unit II

DNA replication: Modes of DNA replication, components of cellular replisomes and their function (topoisomerase, helicase SSB proteins, primase, DNA polymerase ligase, etc.). Origin of replication in prokaryotes, Eukaryotic orgin of replication, Licensing factors and control of eukaryotic replication, Replication of telomeric DNA

Gene stability, DNA damage and DNA repair: DNA repair enzymes, photoreactivation; Nucleotide excision repair; mismatch correction; SOS repair

Unit III

Transcription in prokaryotes: Introduction, promoter architecture, structure of RNA polymerase, role of sigma factor in initiation of transcription, alternative sigma factors and their physiological functions, Termination of transcription, Antitermination in bacteriophage lambda.

Unit IV

Transcription in eukaryotes: Introduction, Transcription factors. Types of RNA polymerase and architecture of their promoters. Initiation of transcription by RNA polymerase I, II, and III. Elongation and termination of transcription; Enhancers and activators

Unit V

Genetic code: Universal genetic code; features of the genetic code, degeneracy of codons; Termination codons; wobble hypothesis; genetic code in mitochondria

Translation: Adaptor role of tRNA, amino acyl tRNA synthetase, A and P sites, initiation codon, formation of 70 S initiation complex, role of initiation factors, peptidyl transferase, translation and elongation factors, role of termination factors.

Suggested Reading:

- Molecular biology of the gene by Watson et. Al (5th edition), Pearson Publishers, USA
- Genes XII by Benjamin Lewin, Oxford University Press
- Biochemistry by Voet B and Voet JG, Wiley Publishers, USA
- Biochemistry 5th Revised edition by LubertStryer, Jeremy M. Berg, John L. Tymoczko, Macmillan Publishers, USA
- D.L. Nelson and M.M. Cox Lehninger Principles of Biochemistry, Publisher: WH Freeman; *8th ed.*NewYork

BTCC-204: Immunology

Course Objectives and Outcomes:

- To provide a basic knowledge and to appreciate the components of the human immune response that work together to protect the host.
- To understand the concept of immune-based diseases as either a deficiency of components or excess activity as hypersensitivity.
- To gain an insight into the mechanisms that lead to beneficial immune responses, immune disorders, and immunodeficiencies.
- The basic overview of Immunology strengthens their foundations for a career in Biochemistry.

Unit I: Introduction to Immunology

Innate and Acquired Immune system. Cells, Tissues and Organs of Immune System. Antigen and Antibody. Inflammatory Mediators. Cell Surface Receptors.

Unit II: Host Pathogen Interaction and Intervention Mechanisms I

Antigen Processing, Presentation and Recognition. Mechanisms Involving Cell Mediated and Humoral Immune Response. Mucosal Immune System. Complement System and Associated Deficiencies. Hypersensitivity Reactions.

Unit III: Host Pathogen Interaction and Intervention Mechanisms II

Aspects of Microbial Pathogenesis and Host Defense Mechanisms. Mechanisms of immunological Tolerance. Immunodeficiency diseases – primary and secondary. Autoimmunity and autoimmune disorders.

Unit IV: Host Pathogen Interaction and Intervention Mechanisms III
Basic Transplantation Strategies and Graft Rejection Mechanisms. Mechanisms of Tumor Formation and Evasion Strategies of Host. Vaccination Approaches.

Unit V: Immunology Techniques and Methodologies
Strategies of Antigen and Antibody Purification. Immunoblotting, Agglutination, Precipitation Reactions, Complement Fixation Assays, Fluorescence, Dyes, ELISA, RIA, Microscopy. Concept and Applications of Flow Cytometry.

Suggested Reading:

- Essential Immunology (2005) Roitt I.M. and Delves P.J.
- Essential Immunology (2011) Delves P J., Martin S. J., Burton D R, Roitt I.M.
- Immunology (2001) Roitt I, Bostoff J. & Male D.6th edition
- Immunology (2006) Luttmann M, Bratke K., Kupper M., &Myrtek D
- Immunology (2007) Goldsby R.A,,Kindt T.J., Osbrne B.A and Kuby J.

BTCC-205: Animal Biotechnology and Cell Culture

Course Objectives and Outcomes:
The course is designed to make students understand the principles, basic concepts and applications of animal cell culture. It makes students understand different approaches to generate transgenic animals for various applications.
The concept of transfer of genes of interest in animal cells and animal cloning along with gene therapy for the treatment of various diseases will be imparted to the students.

Unit I
Basic techniques in animal cell culture. Cell culture media, serum free media, maintenance of the culture and cell lines. Cryopreservation. Detection of contamination and laboratory management.

Unit II
Monolayer culture techniques including dispersion and disruption of tissue, measurement of growth and viability, micro-carrier culture, cell synchronization.

Unit III

Stem cells, Embryonic stem cells: Basics of cell culture and their applications.

Unit IV
Genetic engineering of mammalian cells: Mammalian cell lines, Mammalian cell expression system, Gene transfer techniques in mammalian cells, Gene knockout technology

Unit-V
Somatic cell nuclear transfer and transgenic animals.

Suggested Reading

Culture of Animal Cells: A Manual of Basic Technique and Specialized Applications. Edited by R. Ian Freshney. 6th Ed. Wiley Blackwell, 2010.
JM Davis. Basic Cell Culture. Oxford University Press. New Delhi, 2008.
Gene cloning and DNA analysis by T.A. Brown by Willey and sons.
Lewin's gene XI Krebs J.E, Kilpatrick S.T, and Bartlett publications.

BTCC-206: Laboratory Course II

Course Objectives and Outcomes:

Laboratory course is designed to provide students hands on training on various microbiological and immunological assays.

Safety and laboratory guidelines

Methods of sterilization and preparation of liquid and solid culture media.

Isolation of microorganisms from soil samples. Dilution and pour plating. Pure culture techniques: streaking and spreading methods

Identification of isolated bacteria: Smear preparation and Gram staining, spore staining methods, metabolic characterization.

Growth curve of microorganisms. Enumeration of bacteria – Quantitative estimation of microorganisms – total and viable counts.

Immunological assays: Ouchterlony double diffusion; Immunoelectrophoresis; ELISA; agglutination.

Suggested Reading:

Essentials of practical Microbiology. Sastry AS and Bhat S. Jaypee Brothers Medical Pub Ltd, 2017.

Microbiology Practical Manual by Shukla Das and RumpaSaha, CBS Publishers and Distributors, 2019.

Microbiology: Laboratory Theory and Application. Michael J. Leboffe and Burton E. Pierce. Morton *Publishing* Company. 3rd Ed.2016

BTVNC-201: Biosafety and Bioethics

Course Objectives and Outcomes:

- To provide basic knowledge on biosafety and bioethics and their implications in biological research.
- To become familiar with India's biosafety and bioethics policies.
- To learn biosafety and risk assessment of products derived from biotechnology and regulation of such products.
- To become familiar with ethical issues in biological research. This course will focus on consequences of biomedical research technologies such as cloning of whole organisms, genetic modifications, DNA testing.

Unit I

Introduction to Biosafety; Biological Safety Cabinets; Primary Containment for Biohazards; Biosafety Levels; Biosafety Levels of Specific Microorganisms; Recommended Biosafety Levels for Infectious Agents and Infected Animals.

Unit II

Biosafety guidelines – Government of India; Definition of GMOs & LMOs; Roles of Institutional Biosafety Committee, RCGM, GEAC etc. for GMO applications in food and agriculture; Environmental release of GMOs.

Unit III

Risk Analysis; Risk Assessment; Risk management and communication; Overview of National Regulations and relevant International Agreements including Cartagena Protocol.

Unit IV

Ethical conflicts in biological sciences - interference with nature, bioethics in health care - patient confidentiality, informed consent, euthanasia, artificial reproductive technologies, prenatal diagnosis, genetic screening, gene therapy, transplantation.

Unit V

Bioethics in research – cloning and stem cell research, Human and animal experimentation, animal rights/welfare.

Suggested Reading:

- Biosafety and bioethics (2006) Rajmohan Joshi. Gyan Publishing House.
- Laboratory biosafety manual. (2004). World Health Organization. WHO press, 2004.
- Biological safety: principles and practices (2000) Diane O. Fleming, Debra Long Hunt. ASM Press.
- CRC handbook of laboratory safety. (2000) A. Keith Furr. CRC Press.
- Craig, W., Tepfer, M., Degrassi, G., &Ripandelli, D. (2008). An Overview of General divisions/csurv/geac/annex-5.pdf F. (2009). Problem Formulation in the Environmental Risk
- Assessment for Genetically Modified Plants. Transgenic Research, 19(3), 425-436. doi:10.1007/s11248-009-9321-9
- Features of Risk Assessments of Genetically Modified Crops. Euphytica
- International Union for the Protection of New Varieties of Plants. http://www.upov.int
- Karen F. Greif and Jon F. Merz, Current Controversies in the Biological Sciences - Case
- Studies of Policy Challenges from New Technologies, MIT Press
- Kuhse, H. (2010). Bioethics: an Anthology. Malden, MA: Blackwell.
- National Biodiversity Authority. http://www.nbaindia.org
- Recombinant DNA Safety Guidelines, 1990 Department of Biotechnology, Ministry of Science and Technology, Govt. of India. Retrieved from http://www.envfor.nic.in/

BTCC-301: Microbial Technology and Bioprocess Engineering

Course Objectives and Outcomes:

The objectives of this course are to introduce the students to the field of microbial technology with special emphasis on isolation and improvement of strains, bioreactor design, functional aspects of upstream and downstream processes in fermentation industry.

Aims to educate students about the fundamental concepts of bioprocess technology and its related applications, thus preparing them to meet the challenges of the new and emerging areas of biotechnology industry.

Unit-I

Microbial strains: Isolation, maintenance, improvement and preservation of industrial strains. Principles of sterilization of media and air.

Unit-II

Whole cell Immobilization: kinetics of immobilized systems. Fermentation media formulation: Criteria for media selection, its types and composition and inoculum development

Unit-III

Principles and Kinetic characteristics of Batch culture, Fed-batch culture and continuous culture. Industrial fermenter design and its analysis: Basic functions, body construction, maintenance of aseptic conditions, aeration and agitation, valves and steam traps. Instrumentation, control and monitoring

Unit-IV

Transport phenomena in bioprocesses: Fluid flow and mixing in bioreactors, Methods of heat transfer, mass transfer.

Unit-V

Downstream Processing and Product Recovery Separation of insoluble products - filtration, centrifugation, sedimentation, flocculation; Cell disruption; separation of soluble products: liquid-liquid extraction, precipitation, chromatographic techniques, reverse osmosis, ultra and micro filtration, final purification: drying; crystallization

Suggested Reading

Stanbury, P. F., & Whitaker, A. (1997). Principles of fermentation technology. Oxford: Pergamon Press.

Comprehensive Biotechnology-The Principles, Applications, Regulations of Biotechnology in Agriculture, Industry and Medicine. Vol II- The Principles of Biotechnology- Engineering considerations. Cooney CL, Humphrey AE. Editor-in-chief: Murray Moo Young, Elsiever, 2004

Biotechnology. Smith JE. Cambridge University Press, 3rd ed, 1996.

Bioprocess Engineering Principles. Doran, Academic Press Ltd, 2005.

BTCC-302: Laboratory Course III

Course Objectives and Outcomes:

Laboratory course is designed to help the students learn the number of molecular biology techniques including transformation, cloning, PCR, RT-PCR and data analysis using various bioinformatic tools

Preparation of competent cells.
Cloning of foreign DNA into plasmid vector.
Transformation with recombinant plasmid DNA.
Isolation of plasmid DNA.
Identification of recombinants.
Isolation, separation and visualization of native DNA and RNA.
Restriction digestion of plasmid and genomic DNA.
PCR and Real Time PCR experiment
DNA and RNA sequencing and interpretation of data, genetic data bases and homology search and related bioinformatic skills (demonstration).

Suggested Reading

BTEL-301: Bioinformatics, Genomics and Proteomics

Course Objectives:

- To learn about this relatively newer branch bioinformatics, its definition, objectives and applications.
- To learn about databases and mining tools
- To learn about techniques used in genomics, genome sequencing, annotation.
- To understand about differences between prokaryotic and eukaryotic genomes as well as forward and reverse genetics.
- To impart knowledge about the advances in structural and functional genomics. To understand the use of proteomics techniques

Course Outcomes: At the end of the course, a student should be able to

- Access various global bioinformatics centers such as NCBI, EBI and GenomNet etc.
- Do pairwise and multiple sequence alignments using database mining tools
- Explain the detailed characteristics of prokaryotes and eukaryotes genome
- Apply structural and functional genomics approaches on newly sequenced genome for functional characterization of genes.

Unit I

Introduction to bioinformatics. Different types of data. Databases: nucleic acid database, protein database. Database mining tools for mining of nucleic acid, protein database and other databases.

Unit II

Accessing and retrieving sequence information from databases. Use of sequence alignment tools, BLAST.

Unit III

Introduction to genomics: Structural genomics; genome sequencing projects. Comparative genomics: organization of genome in prokaryotes, eukaryotes and organelles.

Unit IV

Overview of functional genomics: expression profiling, transcriptomics, DNA microarray.

Unit V

Introduction of Proteomics. Branches and applications of proteomics. Techniques of proteomics.

Suggested Reading:

- 3rd Edition, By S. B. Primrose and R. L. Twyman, Blackwell publishing
- Bioinformatics and Functional Genomics, 3rd Edition, By Jonathan Pevsner, Wiley-Blackwell
- Plant Biotechnology by B. D. Singh, Kalyani Publishers

BTEL-302: Techniques in Cell and Molecular Biology

Course Objectives and Outcomes:
The course aims to provide a general understanding of the techniques involved in cell and molecular biology and is designed to complement the courses focused more on theoretical aspects. This will enable students to comprehend problems and latest research in the area in a more meaningful manner.

Unit I
Molecular probes for analyzing cellular structure and function: Fluorescent Resonant Energy Transfer (FRET). Cell imaging, including fluorescence and confocal imaging of live cells. Fundamentals of pseudocolor image capture, image analysis and live imaging. Fluorescent protein tagging as a tool for determining molecular organization, intracellular localization and trafficking.

Unit II
Study of membrane dynamics and composition: Fluorescence recovery after photobleaching (FRAP) and other tools for measuring membrane fluidity. Detergents, Solubilization and reconstitution of membrane-protein systems. Use of patch clamping to study ion channel activity.

Unit-III
Examining molecular interactions: Study of protein-protein, protein-ligand interactions based techniques. Pulldown assays, Western and Southwestern hybridization techniques. CHIP assays, FRET and related techniques.

Unit-IV
Nucleic acid and gene expression analysis: Pulsed Field Gel Electrophoresis, Nucleic acid blotting and hybridization techniques. Quantitative Real-time PCR in gene expression analysis. Microarrays: Classes and applications in gene expression analysis. Fluorescence *in situ* hybridisation.

Unit-V
Next-Generation sequencing, analysis of protein-nucleic acid interactions through footprinting and EMSA.

Suggested Reading:
- Becker's World of Cell-Hardin *et al*
- Cells-Lewin
- Molecular Biology of the Cell-Alberts *et al*
- Molecular Cell Biology-Lodish *et al*
- The Cell: A molecular Approach-Cooper and Hausmann

BTEL-303: Biostatistics and Computer Applications

Course Objectives and Outcomes:
- Understanding of data and its analysis with the help of computers, Interpretation of data analysis.
- Understanding the basics of computers and computational data analysis which in-turn can be used for interpretation of data analysis.

Unit I
Handling and description of data: tabulation and graphical representation. Sampling techniques. Measure of central tendency: Mean, Median, Mode, Percentile, Decile and Quartiles.

Unit II
Measure of dispersion: Range, mean deviation, standard deviation, quartile deviation and coefficient of variation.

Unit III
Correlation and simple linear regression. Use of computer for statistical data analysis.

Unit- IV
Test of significance: types of errors, χ^2 (Chi-square test) and contingency table, t, f, and z tests, Overview of ANOVA.

Unit- V
Computer: Definition, historical evolution, types and generations, Hardwares and Softwares, Low-level and High-level languages. Introduction to MS Office: MS Word, MS Excel, MS Power point, Internet/Intranet and its applications.

Suggested Reading:

Research Methodology and Biostatistics: A comprehensive Guide for Health Care Professionals. By Sharma Suresh.

Biostatistics and Computer Applications by G.N. Rao, N. K. Tiwari

Biostatistics: Basic Concepts and Methodology for the Health Sciences. By Wayne W. Oaniel.

Fundamentals of Biostatistics by Khan and Khanum

BTEL-304: Understanding Cancer Biology

Course Objectives and Outcomes:
The course on cancer biology intends to provide basic information about the cancer, its types, causes and a cross talk of molecular cascades in cancer pathogenesis. It helps students to learn the concept of tumor heterogeneity, concept of cancer stem cells and advancements in cancer therapies.

Unit-I
Introduction to cancer. Causes of cancer: Age distribution; Environment; Initiators and Promoters

Unit-II
Tumor classification. Tumor behavior: Preneoplastic conditions; Preinvasive states; Benign tumors; Malignant tumors; tumor heterogeneity

Unit III
Oncogenes and tumor suppressor genes: their role in cancer. Molecular mechanisms of cancer pathogenesis

Unit-IV
Tumor angiogenesis, extracellular matrix, overview of invasion and metastasis

Unit-V
Cancer treatment: Chemotherapy; Radiotherapy; new approaches to treatment. Biology of cancer stem cells and resistance to therapies

Suggested Reading:
Alberts B, Bray D, Lewis J, Raff M, Roberts K, and Watson JD. Molecular Biology of the Cell Garland Science.
Introduction to Cancer Biology, Robin Hesketh, University of Cambridge, 2013
Understanding Cancer: From Basic Science to Clinical Practice, Alison MR and Sarraf CE, Cambridge University Press. 1997

BTIER-301: Environmental Awareness

Course Objectives and Outcomes:

- There is urgent need to spread awareness about important environment related issue such as ever-increasing air pollution and its effect on animal, plant and human health. Furthermore, detailed knowledge of water pollution, its sources waste water management, control and remedial measures in the prevention of spread of various water borne diseases.
- Knowledge about environment problems such as Green house effect, global warming – causes, consequences and remedial measures is of paramount importance to save our planet.

Unit I:
Air Pollution:Basic Concept, Sources, Suspended Particulate Matter (SPM), Acid Rain, effect of air pollution on plants, animals, human beings and buildings, control of air pollution.

Unit II:
Water Pollution:Source, River water pollution, Waste Water Treatment, BOD, and Control of Water Pollution.

Unit III:
Soil Pollution:Sources, Soil Erosion, Preservative Measures, Bioremediation.

Unit IV:
Xenobiotic Transformation:Phase I and Phase II Reactions.

Unit V:
Greenhouse effect, Global Warming, Chlorofluorocarbons (CFC's), Ozone depletion.

Suggested Reading:

- Environmental Biochemistry. Neelima Rajvaidya, Dilip Kumar Markandey. APH Publishing, 2005.
- Biochemical Ecotoxicology: Principles and Methods. Francois Gagne. Elsevier, 2014.
- Environmental Biochemistry. Erik Hamilton (Editor). Larsen and Keller Education (21 June 2017)

BTCC-401: Regulation of Gene Expression

Course Objectives and Outcomes:

To have a knowledge base in the structure and functions of the genes, and to demonstrate the concept and knowledge of different regulatory strategies in regulation of gene expression in prokaryotes and eukaryotes

Unit I

Basic concept and necessity of regulation of gene expression in prokaryotes and eukaryotes. Principle levels at which regulation is exercised.

Regulation of gene expression in prokaryotes by substitution of σ factor, and by antitermination of transcription

The operon concept: Circuits of regulation of operons. The *lac* operon: repressor control and catabolite repression. The *trp* operon: repressor control and attenuation

Unit II

Maturation of 5' and 3' ends of eukaryotic mRNA: Capping, cleavage and polyadenylation. Function of the cap and the poly *A* tail of eukaryotic mRNA, and their roles in regulation of gene expression

mRNA splicing and regulation of eukaryotic gene expression: Exons and introns, classification and properties of introns. Autocatalytic splicing, splicing of Group II and Group I introns. Splicing of nuclear pre-mRNA introns. Alternative splicing, mechanism of alternative splicing and its regulation, Role of alternative splicing in sex determination of *Drosophila melanogaster*

Unit III

Activation of transcription factors: Types of transcription factors; mechanisms of activation of transcription factors; Regulation of many genes by a single transcription factor; Regulation of a single gene through different circuits; combinatorial principle of gene expression. Regulation of the *hsp* and *metallothionein* gene

Control of gene expression by DNA methylation, CpG islands

Unit IV

DNA-protein interaction: Physicochemical characteristics of DNA-protein interaction. DNA binding motifs: Homeodomain, Zinc fingers, *b/zip*, *b/HLH*, *b/HLH/zip* motifs

Experimental techniques for study of DNA-protein interactions: Gel retardation assay, DNase I footprinting, Modification protection assay, Modification interference assay

Unit V

Control of gene expression by histone modification: Histone acetylation, deacetylation and methylation. Enzymes associated with these modifications. Chromatin remodeling and chromatin remodeling complexes

Genomic regulatory domains: Introduction to regulation of expression of gene clusters; locus control region (LCR): structure and function LCR of mouse globin gene cluster; Insulators, structure and functions, the insulators of *hsp70* genes of *Drosophila melanogaster*; Genomic imprinting of *Igf-2* and *H-19* genes.

Suggested Reading:

- Lewin's Genes XII. By Krebs JE, Goldstein ES and Kilpatric ST, Jones & Bartlett Learning, Burlington, MA, USA

- Molecular Biology of the Gene. By Watson JD, Baker TA, Bell SP, Gann A, Levine M, Losick R, Pearson Publishers, USA
- Molecular Biology of the Cell. By Alberts B, Johnson A, Lewis J, Raff M, Roberts K and Walter P, Garland Science Inc., New York, USA
- Principles of Gene Manipulation: An Introduction to Genetic Engineering. By Old RW and Primrose SB, Blackwell Scientific Publication, Oxford-London-Edinburgh-Boston-Melbourne

BTEL-401: Advanced Enzyme Kinetics

Course Objectives and Outcome: At the end of the course, students will be able to understand advanced kinetics of enzymes especially those catalyzing bisubstrate reactions. They will learn classification, annotation and kinetics of bisubstrate reactions, its kinetics and properties of allosteric enzymes, various mechanisms of enzyme action by taking examples of some important enzymes catalysing two substrate reaction.

Unit I

Two substrate systems: kinetic mechanisms, Sequential and ping pong pathways, Cleland representation and nomenclature, forms of initial rate equations for random, ordered and ping-pong pathways and their primary and secondary plots.

Unit II

Regulation of Enzyme activity: feedback inhibition, allosteric concept, qualitative description of concerted and sequential models, negative cooperativity and half-site reactivity, Hill and Scatchard plots,

Unit III

Regulation of enzyme activity by covalent modification. Mechanisms of enzyme action: Proximity orientation effect, strain and distortion theory, Acid-base catalysis, covalent catalysis,

Unit IV

Techniques for studying the mechanism of enzyme action; chemical modification, site directed mutagenesis, general mechanistic principles.

Unit V

Physicochemical properties and mechanism of action of enzymes, alcohol dehydrogenase, chymotrypsin, lysozyme and hexokinase.

Suggested Reading:

- Enzymes by Dixon M, Webb EC, 2 ND Ed., Academic Press
- Enzymes by Palmer, Woodhead Publishing Ltd., UK
- Biochemistry by Voet B and Voet JG, Wiley Publishers, USA
- Biochemistry 5th Revised edition by Lubert Stryer, Jeremy M. Berg, John L.
- Tymoczko, Macmillan Publishers, USA
- D.L. Nelson and M.M. Cox Lehninger Principles of Biochemistry, Publisher: WH
- Freeman; 8th ed.NewYork

BTEL-402: Metabolic Processes

Course Outcome: Students will be taught the metabolic pathways of carbohydrate, amino acid, lipid and coenzymes and their regulation. At the end of the they will be able to distinguish between different metabolic processes and their impact in metabolism of biomolecules.

Unit I

Control of carbohydrate metabolism, Regulation of glycolysis, Krebs' cycle, glycogen breakdown and glycogen synthesis.

Unit II

Biosynthesis of lipids: biosynthesis of triglycerides, glycerophospholipids, cerebrosides, ether lipids galactolipids and sulpholipids. Control of lipid metabolism.

Unit III

Biosynthesis of amino acids; biosynthesis of α-ketoglutarate, oxaloacetate, puruvate family amino acids and the controlof their synthesis.

Unit IV

Biosynthesis of amino acids; biosynthesis of ribose-5 phosphate, 3-phospoglycerate and phosphoenolpyruvate plus erythrose-4-phosphate family amino acids and the controlof their synthesis.

Unit V

Biosynthesis of coenzymes; Coenzyme A, NAD and NADP, FMN and FAD.

Suggested Reading:

- Geoffrey L. Zubey, Biochemistry, Fourth Edition: Wm.C. Brown Publishers, 1998
- Biochemistry by Robert Roskoski. W.B. Saunders, Philadelphia, ISBN 0-7216-5174-7
- D.L. Nelson and M.M. Cox Lehninger Principles of Biochemistry, Publisher: WH Freeman; 8th ed.NewYork.
- Biochemistry 5th Revised edition by LubertStryer, Jeremy M. Berg, John L. Tymoczko (ISBN: 8601300395166)

BTEL-403: Plant Biotechnology and Tissue Culture

Course objectives and Outcomes:

The objectives of this course is to introduce students to the principles, practices and applications of plant biotechnology, plant tissue culture, genetic transformation and transgenics to produce superior varieties.Students will learn the various applications of plant tissue culture and methods of gene transfer, and the production of hybrid varieties of plants in crop improvement.

Unit I

Cloning in plant cells: Biology of Agrobacterium tumefaciens. Structure of Ti-plasmid, T-DNA and gene transfer mechanisms, selection marker genes and reporter genes. Methods of direct gene transfer, Chloroplast transformation. Effect of gene copies and position in transgenic production.

Unit II
Transgenic plants: Applications in phytoremediation, biopesticides, biodegradable plastics, pesticide and herbicide resistance plants, improving horticultural and nutritional value of plants.

Unit III
Plant tissue culture: Historical perspective and general techniques for plant tissue culture. Tissue culture media, media preparation – nutrients and plant hormones; sterilization techniques.

Unit IV
Maintenance of callus, cell suspension culture, protoplast isolation and culture, somatic hybridization, haploid production.

Unit-V
Molecular Markers: RFLP maps, RAPD markers, STS, micro satellites, SCAR (sequence characterized amplified regions), SSCP (single strand conformational polymorphism) AFLP, QTL, map based cloning, molecular marker assisted selection.

Suggested Reading:

- Plant tissue culture: Theory and Practice, a revised edition. Bhojwani SS, Razdan MK. An Imprint of Elseiver, First Indian reprint, 2004.
- Buchanan, B. B., Gruissem, W., & Jones, R. L. (2015). Biochemistry & molecular biology of plants.Chichester, West Sussex: John Wiley & Sons.
- Glick, B. R., & Pasternak, J. J. (1994). Molecular biotechnology: Principles and applications of recombinant DNA. Washington, D.C.: ASM Press.
- Brown, T. A. (2006). Gene cloning and DNA analysis: An introduction. Oxford: Blackwell Pub.
- Primrose, S. B., &Twyman, R. M. (2006). Principles of gene manipulation and genomics. Malden, MA: Blackwell Pub.

BTEL-404: Intellectual Property Rights

Course objectives and Outcomes:
Detailed knowledge of various forms of intellectual property right such as patent, copyrights, geographical indications, industrial design, trade mark etc, filing of patent application, infringement of patent rights is very important for MSc. Students of life sciences as intellectual property rights and technological innovation have played an important role in improving the economy of Nations.

Unit I:
IPR: Definition, Basic Concepts, Types, Innovation, Invention, Importance in modern era.

Unit II:
Patents: Infringement of Patent Rights, Rights of Patent Owner, importance of patents in modern era.

Unit III:
Trademark and Copyright: definition, basic concepts, Infringement, Registration.

Unit IV:
Industrial design, Semiconductor Integrated circuits Layout design:Definition, basic concepts, Infringement, Registration.

Unit V:
Geographical Indications, plant variety protection act and trade secrets.

Suggested Reading:

- Indian Patent Law. Kalyan C Kankanala ; Arun K. Narasani ; Vinita Radhakrishnan.Oxford University Press, New Delhi.
- Fundamentals of Intellectual Property. Dr.Kalyan C.Kankanala.Asia Law House
- Universal's Guide to Patents Law. Manish Arora.Universal Law Publishing House
- IPR, Biosafety and Bioethics, Deepa Goel &Shomini Parashar. Pearson Publication

BTIRA-401: Pandemics: Covid-19

Course Objectives and Outcomes:

- Covid-19 Pandemic hit the whole world very hard. The economy of virtually lots of developed as well as developing nations the world was crippled and people with little financial security were most susceptible and the worst hit.
- It is very important to have awareness about pandemics and Covid-19 in particular. Knowledge about Source, Mechanism of infection, worldwide status, Medication, Vaccine strategies will be imparted to students.
  This course has been designed to create awareness among students of different faculties about various aspects of Covid-19 pandemic so that they become aware about modes of transmission of the virus, how to boost immunity and how to protect against the viral infection.

Unit I
Introduction to virology: definition, structure, types and properties of viruses. Zoonotic viruses: definition, transmission, prevention and examples of few zoonotic viruses. Host virus interactions: mechanism of viral entry, incubation time, immune response towards virus

Unit II
Corona virus pandemic: difference between endemic, epidemic, pandemic and sporadic diseases, worldwide effect of COVID-19. Origin of corona virus pandemic, morphology of the virus. Causes of COVID-19: sources of spread, transmission

Unit III
Mechanism of infection: mechanism of entry of virus into the host, mechanism of replication, immunological response of the body. Health effects: symptoms, pulmonary embolism in COVID-19 patients

Unit IV
Medication: use and efficacy of hydroxychloroquine, remdesivir and other antiviral drugs, antibody therapy, plasma therapy
Vaccination: strategies employed by therapeutic companies, stages of clinical trials, human trials

Unit V

Preventive measures: meaning of quarantine and social distancing, steps to prevent the spread, preventive measures while travelling, Lockdown (commencement & different stages), division of country into 3 zones, guidelines to follow for future prevention, awareness among general public (including use of Aarogyasetu app)

Ways to boost immunity: foods that boost antiviral immunity, healthy lifestyle, exercising, managing stress (including importance of Yoga & Ayurveda), not relying on supplements

Suggested Reading:

- COVID-19: An editorial by leaders in infectious medicine, this article elegantly summarises what is known about the disease. Fauci, Anthony S., et al. 'Covid-19: navigating the unchartered.' New England Journal of Medicine, Vol. 382, No. 13, 26 February 2020 pp. 1268-69.
- Responding to COVID-19: Bill Gates writes a must-read opinion piece on the pandemic and the steps that need to be taken to combat it. Gates Bill 'Responding to Covid -19: A Once –in-a –Century Pandemic?' New England Journal of Medicine, Vol. 382, No. 18,2020 pp1677-79.
- Cheng, Vincent C.C., et.al. 'Severe Acute Respiratory Syndrome Coronavirus as an Agent of Emerging and Re-emerging Infection.' *Clinical Microbiology Reviews*, Vol. 20, No. 4, 2007, pp. 660-94.
- Zhang, Haibo, et.al. 'Angiotensin-Converting Enzyme 2 (ACE2) as a SARS-CoV-2 Receptor: Molecular Mechanisms and Potential Therapeutic Target.' *Intensive Care Medicine*, Vol. 46, No. 4,2020, pp. 586-90.
- Pharmacologic Treatments for COVID-19: This article provides an overview of pharmacotherapy being tested and used for COVID-19. Sanders, James, M., et. Al. 'Pharmacologic Treatments for Coronavirus Disease 2019 (COVID-19).' *JAMA*, Vol. 323, No. 18,2020, pp. 1824-36.
- Characteristics of SARS-CoV-2 and COVID-19 Ben Hu, Hua Guo, Peng Zhou & Zheng-Li Shi, *Nature Reviews Microbiology* (2020).
- Coronavirus Pathogenesis and the Emerging Pathogen Severe Acute Respiratory Syndrome Coronavirus, Susan R. Weiss, Sonia Navas-Martin, Microbiology and Molecular Biology Reviews.
- How Moderna's Vaccine Works, Jonathan Corum and Carl Zimmer, The New York Times.
- *COVID-19 and D-dimer, Drs. Morayma Reyes Gil, Aggie Lee, Nigel Key, Dan Sabath, Cindy Leissinger, Oksana Volod, Geoff Wool, Lisa Baumann Kreuziger, American Society of Haematology*