



IISER
B E R H A M P U R

Ph.D. Syllabus

Biological Sciences

BIO 601: Immunology (4)

This course discusses about basic Immunology. Therefore, only those Ph.D. students can register, who never studies immunology in bachelor's and master's level.

Introduction to Immune System: organs, cells and molecules; Mechanisms of barrier to entry of microbes into human body. Natural and adaptive immune responses; Differentiation of stem cells to different cellular elements in blood, role of cytokines; Introduction to inflammatory reaction, Chemokines, migration of neutrophils to the site of infection, phagocytosis and microbicidal mechanisms. Interferons and viral infections, Parasitic infections and role of Eosinophils Asthma. Basophils, IgE receptor, immediate hypersensitivity; Innate receptors (TLR, RLRs and NLRs) and sensing of PAMPs. Signal transduction. Opsonization, Fc Receptors, classification. Prostaglandins and leukotrienes. Complements structure and function. Classical and alternative pathways; Antibody structure and function. Classification of immunoglobulins, immunoglobulin domains, concept of variability, crosses reactivity. Isotypes, allotypes and Idiotypic markers; Idiotypic network Immunoglobulin genes, VJ/VDJ rearrangements and genetic mechanisms responsible for antibody diversity, affinity maturation, allelic exclusion; Class switching, receptor and soluble forms of immunoglobulin; Concept of Histocompatibility. Genetic organization of H2 and HLA complexes. Class I and class II MHC molecules, structure and function; T cell receptors, APC-T cell interaction T cell activation, Th1 Th2 cells and cytokines. Intercellular antigen presentation pathways, antigen presentation and MHC restriction; T cell differentiation in thymus, $\alpha\beta$ and $\gamma\delta$ T cells. Thymic selection and tolerance to self. Cytotoxic T cells. Super antigens; Natural Killer Cells, ADCC, Hybrid resistance, NK cell receptors and NK gene complex, inverse correlation with target MHC expression, missing self hypothesis; Immunological techniques, Hybridoma and monoclonal antibodies.

Suggested Books:

- Essential Immunology: Peter J. Delves, Seamus J. Martin, Dennis R. Burton, Ivan M. Roitt; Wiley-Blackwell; 12th edition; 2011.
- Immunobiology: The immune system in health and disease by Charles Janeway, Paul Travers, Mark Walport, Mark Shlomchik; Garland Science; 5th edition; 2001.
- Kuby Immunology; W. H. Freeman & Company; 6th edition; 2006.

BIO 602: Bioinformatics (4)

Introduction to bioinformatics, overview, concepts, utility, scope, applications, skills needed, sequences, biological data; Databases, web resources: NCBI- Entrez, PubMed, GenBank, data organization and retrieval using FTP from NCBI, DDBJ, UCSC, PDB, SwissProt, KEGG, and web resources; Sequence formats: FASTA, GenBank, EMBL, PDB, XML, Medline, GCG, etc. Conversion from one format to another, tools available for format interconversion; Sequence alignment algorithm and tools: Introduction to sequence alignment, homology, similarity, identity. Local and global alignments, multiple sequence alignments, insertions, deletions, gaps, Needleman-Wunsch algorithm, Dot matrix method, dynamic programming algorithm, scoring matrices- PAM and BLOSUM, Blast, Blat, Clustalw, MAFFT, BLOCKS, etc.; Prediction of genes and annotation methods: Concept of genes, challenges in gene prediction, ORFs, reading frames, codons and codon bias, genetic code, commonly used gene prediction methods- ORF finder, Glimmer, GeneMark, Metagene, etc. Annotation using homology-based alignment using Blast or Blat, COGs and Gene ontology based functional annotation; Phylogenetic analysis: concepts and terminologies, commonly used phylogenetic methods such as PHYLIP, MEGA. Introduction to rRNA, taxonomy and taxonomic classification. Maximum parsimony method, Distance methods, Neighbor-joining methods; Protein classification and structure prediction: Introduction to domains, motifs, fold, family, Helices, beta-sheets, loops, coils. Primary, secondary and tertiary structure. Structure visualization tools such as RasMol; Genome analysis: Introduction to genomes and packages for genomic analysis such as EMBOSS; Introduction to Linux and Perl.

Suggested Books:

- Bioinformatics- Sequence and Genome Analysis by David W. Mount; Cold Spring Harbor Laboratory Press,U.S.; 2nd Revised edition edition; 2004.
- Introduction to Computational Genomics by Nello Cristianini and Matthew W. Hahn; Cambridge University Press; 2007.

BIO 603: Structural Biology (4)

Proteins from primary to quaternary structures: Amino acids, primary sequence, peptide bond, dihedral angle, Geometry and chemistry of di-peptide, Ramachandran map, Secondary structural elements and their geometric description. Collagen triple helix, Super secondary structure, Structural domains, Quaternary association of globular proteins; Basics of nucleic acid structure: The building blocks, DNA secondary structure: the Double Helix, Deviation from the ideal geometry, higher-order structure and nucleosomes, tertiary structure of RNA; Protein structure, function and mechanism: Examples of protein three dimensional structures, molecular mechanism of enzymatic function, protein-protein interaction, chaperons, membrane proteins; Virus structure and assembly; Structural biology and evolution; Current topics in structural biology: membrane protein structure, Signal transduction, cell motility, cell-cell interaction, immune system, protein folding and degradation.

Suggested Books:

- Biochemistry: Lubert Stryer; W. H. Freeman; 7th Edition; 2010.
- Introduction to Protein Structure: Carl Branden and John Tooze; Garland Science; 2nd edition; 1999
- Research Articles as per requirements.

BIO 604: Neurobiology (4)

Organization of the nervous system; Cytology of neurons- structural and functional blue print of neurons, sensory and motor neurons; Ion-channels- importance of ion channel in nerve physiology, characteristics of ion channels, structure of ion channels, techniques used to study ion channels; Bioelectricity, measurement of bioelectricity; Electrical properties of neurons; Membrane potentials- resting membrane potential, Ionic basis of membrane potential; Generation and propagation of action potential; Synaptic transmission- membrane trafficking at nerve terminals, local machinery at nerve terminals for vesicle recycling, genetics and cell biology of synaptic vesicle trafficking; modulation of synaptic transmission; Neurotransmitters- properties, types and classification of neurotransmitters and their synthesis neuromodulators; Synaptic plasticity and its implication in learning and memory; Introduction to perception (with emphasis on Pain, Visual and Odor perception).

Suggested Books:

- Principle of neural science: Eric R. Kandel, James Schwartz, Thomas Jessell, Steven Siegelbaum, A.J. Hudspeth; McGraw-Hill, 5th edition; 2012
- From Neuron to Brain: Nicholls, Martin, Wallace and Fuchs; Sinauer Associates; 4th edition; 2001.

BIO 606: Cancer Biology (4)

Cell division, aneuploidy, polyploidy and chromosomal translocations, consequential uncontrolled growth and cancer; Nature of cancer; carcinogens, DNA damage and mutagenesis; Inherited susceptibility to cancer; Genomic integrity and development of cancer; Cancer cell cycle and tumor suppressor proteins, cell signaling; Cellular Oncogenes, mitogens and dysregulation of pathways in cancer; Growth factors and associated signaling pathways in cancer; Epigenetics in cancer; Tumor viruses and mechanisms of oncogenesis; Tumor metastasis; Angiogenesis; Cellular immortalization and activation of telomerase in cancer; Apoptosis; Stem cells; Tumor immunology; Role of cytokines and hormones in cancer; Immunotherapy and cancer gene therapy, chemo and radiation therapy.

Suggested Books:

- The biology of Cancer: Weinberg RA; Garland Science; 2007.
- The Molecular Basis of Cancer: Mendelsohn J, Howley PM, Israel MA, Gray JW, Thompson CB (eds); Saunders Elsevier, Philadelphia; 3rd edition; 2008.

BIO 607: Virology (4)

Overview and history; Classification of viruses; Virion components and structure; Viral entry: Viral proteins and host cell surface receptors involved; Mechanisms of viral entry; Viral replication; Viral maturation and release; Pathogenic viruses : Respiratory viruses; Gastroenteritis causing viruses; Hepatitis viruses; Herpesviruses; Haemorrhagic fever causing viruses; Enteroviruses; Congenital viral infections; Retroviruses; Arboviruses and Viral zoonoses; Oncogenic viruses; Viruses implicated in exanthematous diseases.; Agents of viral encephalitis; Emerging and re emerging viral infections (In each of the above groups, to discuss briefly on the following: (i) viruses included (ii) epidemiology (iii) viral pathogenicity); Immunology of viral infections; Strategies for control of viral infections: Antiviral agents; Active and passive immunoprophylaxis; General laboratory methods for diagnosis of viral infections; Case studies from literature, evolving and emerging areas of interest.

Suggested Books:

- Field's Virology: David M. Knipe, Peter M. Howley, Diane E. Griffin, Robert A. Lamb, Malcolm A. Martin, Bernard Roizman, Stephen E. Straus; Lippincott Williams & Wilkins; 5th edition; 2007.
- Jawetz, Melnick, & Adelberg's Medical Microbiology: Geo. F. Brooks, Karen C. Carroll, Janet S. Butel, Stephen A. Morse, Timothy A. Mietzner; McGraw-Hill Medical; 25th edition; 2010.

BIO 608: Bioinstrumentation (4)

Spectroscopy (UV/Vis spectroscopy, Fluorescence spectroscopy, CD spectroscopy); Principle of centrifugation (Density gradient centrifugation; Ultracentrifugation; Analytical centrifugation); Microscopy; (Bright field and dark field microscopy; Fluorescence microscopy; Confocal microscopy; Electron microscopy); Sequencing of protein and nucleic acid; Next generation sequencing; Realtime QPCR; Chromatography (Ion exchange, Gel filtration, Affinity, Thin-layer); Radioisotope technology. SPR, mass spectrometry, NMR and XRD instrumentation

Suggested Books:

- Analytical ultracentrifugation for the study of protein association and assembly, Geoffrey J Howlett, Allen P Minton, Germán Rivas *Current Opinion in Chemical Biology* Volume 10, Issue 5, October 2006, Pages 430–436
- Analytical Ultracentrifugation: Sedimentation Velocity and Sedimentation Equilibrium. James L. Cole, Jeffrey W. Lary, Thomas Moody, and Thomas M. Laue
- *Methods Cell Biol.* 2008; 84: 143–179
- *Molecular Cloning* by Sambrook and Russel Chapter 12
- How to study proteins by circular dichroism *Biochim. Biophys. Acta* (2005) 1751: 119
- *Principles of Fluorescence Spectroscopy* by Lakowicz
- *Confocal Microscopy for Biologists* by Alan R. Hibbs
- *Handbook of Biological Confocal Microscopy* by James Pawley

BIO 609: Biophysics (4)

Basic principle of modern biophysical methods to study macromolecules from the atomic to cellular levels; Basic introduction to molecular spectroscopy: CD, fluorescence, Mass spectrometric technique, NMR spectroscopy; Introduction to X-ray crystallography, cryo electron microscopy; High resolution light microscopy, Atomic Force Microscopy, Single molecule manipulation; Introduction to Quantum Chemistry & Molecular Spectroscopy, Introduction to Statistical Mechanics; Statistical thermodynamics, lattice statistics, molecular distribution and correlation functions, molecular dynamics simulation; The problem of protein folding. Theoretical and experimental approaches to study protein folding; Introduction to Membrane Biophysics. Structure and function of membranes, experimental and theoretical tools for studying biological membrane.

Suggested Books:

- Spectroscopy for the Biological Sciences: Gordon G; Wiley-Interscience; 1st edition; 2005.
- Biophysical Chemistry: Part II: Techniques For The Study Of Biological Structure And Function by Charles R. Cantor and Paul Reinhart Schimmel; pp 503. W H Freeman and Co, Oxford. 1980.

BIO 610: Advances in Genetics (4)

History of genetics; Mendelian Genetics; Extension of Mendelian genetics; Chromosomal theory of inheritance; Patterns of Inheritance; relationship between genotype and phenotype; Mutations and Repair; Linkage and recombination; Gene mapping; Genetic Fate mapping, Tetrad analysis; Functional genomics; Phage genetics; Genetic Analysis of populations and their evolution; Evolution at the molecular level. Making transgenic animals, Use of FLIP-FRT and Cre-lox system

Suggested Books:

- Genetic Analysis and Principles: Robert Brooker; McGraw-Hill Science/Engineering/Math; 4th edition; 2011.
- Genetics- From genes to genomes: Leland Hartwell, Leroy Hood, Michael Goldberg, Ann Reynolds and Lee Silver, 4th edition; 2010

BIO 611: Advances in Microbiology (4)

Microbial taxonomy; Microbial metabolism; Energy production in eubacteria; Energy production in archaea; Microbial genetics; Modes of DNA transfer in bacteria; Bacteriophage biology; Phage display and lambda DNA library. Virus classification; Lytic and temperate phage; Bacteriophage genetics and gene regulation; Microbial Ecology; Nitrogen cycle; Sulphur cycle; Microbial Physiology; Mechanism of drug resistance; Signal Transduction in bacteria; Quorum sensing and Two component system; Stringent response in bacteria; Applied Microbiology (Food microbiology, Microbes and agriculture, Industrial microbiology).

Suggested Books:

- Microbiology by Prescott, Harley and Klein; McGraw-Hill Science/Engineering/Math; 7th edition; 2007.
- Modern Microbial Genetics by Streips and Yasbin; Wiley-Liss; 2nd edition; 2002.
- Bacterial and Bacteriophage Genetics: Edward Birge; Springer; 5th edition (December 8, 2005).
- E. coli and Salmonella Typhimurium- Vol 1-2: Cellular and Molecular Biology by Neidhardt and Curtiss; American Society for Microbiology; 2 Volume Set edition. 1987.

BIO 612: Developmental Biology (4)

Meiosis, gametogenesis (plants and animals), fertilization and embryogenesis, morphogen gradients, differentiation, asymmetric cell division, cell fate and lineage determination; Developmental embryonic stages, zygotic division, incomplete division and consequences, Ecto, meso and endodermal development, neural plate and neural tube formation; Early asymmetric division and generation of symmetry in developing embryo in animals and plants; Introduction to plant fertilization, ovule and egg and support cells; organogenesis and morphogenesis, metamorphosis, animal life cycle, sex determination and role of apoptosis in organ development; Role of morphogens and their gradient in axis patterning and determination. Concept of anterior-posterior, dorso-ventral and medio-lateral axis formation; Root and shoot development, seed formation (monocot/dicot) and germination; flowering and nonflowering plants; Model organisms like *Drosophila*, *C. elegans*, *G. gallus*, *Xenopus*. Cellular differentiation and senescence; Meristematic tissue, development of root and leaf and floral tissues; Stem cells and pluripotency. iPS cells

Suggested Books:

- Plant Development: The Cellular Basis: R. F. Lyndon; Topics in Plant Physiology 3. Series editors M. Black and J. Chapman; Unwin Hyman Ltd, 1990.
- Plant growth and Development: a molecular approach: DE. Fosket; Academic Press 1994.
- Developmental Biology: Scott F. Gilbert; Sinauer Associates Inc; 2010.
- Essential Developmental Biology: J. Slack; Wiley Blackwell Scientific. 2nd edition; 2005.

BIO 613: Stem Cell Biology (4)

Introduction to concepts in stem cell biology- stemness, potency, lineage, renewal,clonality, etc; Stages of early development (zygote to gastrula) in mouse and human; Classification of stem cells- based on potency, tissue of origin, stage of origin; Embryonic stem cell (ESC)- molecular mechanism of cell renewal and maintenance of pluripotency, epigenetic modifications, spontaneous and directed differentiation, Embryonic carcinoma cells (ECC) and embryonic germ cells (EGC); Fetal stem cell in extra-embryonic tissues; Adult stem cell- stem cell niche, localization and identification of stem cells from various tissues and organs (skin, intestine, blood, brain, retina, muscle); Induced pluripotent stem cell (iPSC)- methods of reprogramming differentiated cells, comparison with ESC; Personalized pluripotent stem cells; Stem cells and cancer; Potential therapies using stem cells- modeling diseases using stem cells, stem cell and tissue engineering for skin graft, stem cell in corneal and retinal regeneration; stem cell therapy for sickle cell anemia, neural stem cells for central nervous system repair, stem cells to repair damaged heart, insulin producing cells for treatment of diabetes, stem cell gene therapy; Ethical issues and guidelines for stem cell research.

Suggested Books:

- Essentials of Stem Cell Biology: Robert Lanza et al, 2nd Edition, Academic Press, 2009.
- Stem Cells: A very short introduction, Jonathan Slack, Oxford University Press, 2012.
- Developmental Biology, Scott F. Gilbert, Eighth Edn, Sinauer Associates, Inc., 2006.
- Classical/recent research papers and reviews relevant to the topics.

BIO 614: Ecology (4)

Ecology of individual organisms; population ecology; ecological communities; ecosystem ecology (food chain, food web, primary producers, primary production, secondary production, consumers, decomposers, decomposition, energy flow, biomass vs. production, ecological efficiency, detritus vs. grazing food chains, transport of production); community change: disturbance, succession, climax, phenology, seasonal pattern; adaptive evolution, neutral evolution, selection, maintenance of genetic variation, evolution of genotype, phenotype, evolution of sex, life history traits, r and K selection, group selection, extinction; trophic interactions: plant-pollinator, plant-disperser, herbivory, predation, optimal foraging, parasitism, competition, mutualism; biogeochemistry: nutrient cycling, hydrologic cycle, watershed studies, biological control of atmosphere and ocean; conservation ecology.

Suggested Books:

- *Ecology*, Second Edition by Michael L. Cain, William D. Bowman, and Sally D. Hacker, published by Sinauer Associates. 3rd edition. 2014
- *The Economy of Nature*, Robert Ricklefs, Sixth Edition, 2008. Freeman, W. H. & Company
- Cotgreave, Peter and Irwin Forseth. *Introductory Ecology*. Oxford: Blackwell Science Ltd, 2002.
- Krebs, John R. and Nicholas B. Davies. *An Introduction to Behavioral Ecology*, 3rd ed. Oxford: Blackwell Science Ltd, 1993.
- Krebs, C. J. 2008. *Ecology: The Experimental Analysis of Distribution and Abundance* (6th edition). Benjamin Cummings, Boston, MA.

BIO 615: Epigenetics and Gene Regulation (4)

Introduction to theme; Chromatin, Epigenetics and Transcription, DNA methylation and demethylation, Histone modifications; Acetylation, Methylation, Phosphorylation, Ubiquitinylation, Sumoylation, Poly-ADP Ribosylation, Heterochromatin; Histone variants; Nucleosome; Long non-coding RNA and chromatin; Epigenetics and alternative splicing; Epigenetics and mammalian development; Polycomb and Trithorax group proteins; Dosage compensation and Genomic imprinting; Epigenetics and Human Diseases, Cancer

Suggested Books:

- Thomas Jenuwein, Danny Reinberg, Marie-laure Caparros, C. David Allis, Epigenetics 1st Edition Cold Spring Harbor Laboratory Press, Usa 2008, ISBN-13 9780879698751
- Bryan M Turner, Chromatin and gene regulation, Jhon Wiley & Sons (asia) Pte Ltd 2001, ISBN-13 9780865427433
- Krishnarao Appasani, Epigenomics From Chromatin Biology to Therapeutics, Cambridge University Press 2012, ISBN-13: 978-1107003828
- Robert A. Meyers, Epigenetic Regulation and Epigenomics, John Wiley & Sons 2012, ISBN-13:978-3527326822

BIO 617: Advances In Omics

BIO 601S: Epigenetics

BIO 603S: Advances in Microscopy (2)

Light, Lenses and Images; Light Microscopy- fluorescence microscopy: considerations and controls; Basics concepts in fluorescence, fluorophores and fluorescent markers; Genetically-encoded fluorescent markers and their application; Sample preparation and Image acquisition: parameters, controls and ways to make mistakes!; Live imaging, maintaining live cells and tissues during imaging; Video Microscopy and Video cameras; Applications of scientific grade EM-CCD cameras to Biological Imaging; Confocal Microscopy: Principles, Practice and limitation; Multiphoton deep-tissue imaging; High-resolution Imaging: STED, PALM and STORM; Understanding, processing, analyzing and quantify Images and data-set from a light microscope; Discussion of research paper that led to the advancement for fluorescence imaging.

Suggested Books:

- Confocal microscopy for biologists by Allan R Hibbs
- Handbook of Biological Confocal Microscopy by James Pawley

BIO 605S: Metagenomics and Genome Sequencing

BIO 607S: Structural Basis of Diseases

BIO 609S: Signal Transduction

BIO 611S: Cell Science and Technology (2)

Basics of Cell Culture - Cell culture- primary culture and secondary culture, confluence, different morphologies of cell culture. Types and use of monolayer, suspension culture, different uses based on cell-types. How in vitro experiments are different from in vivo, special requirements for cells for culture and its importance in immunological studies. Cryogenic Preservation, Storage and Recovery Different Biosafety Levels Labs/facility, Need for biosafety Labs/facility. Contamination in animal cell culture

Handling and Manipulating Cell Cultures - Passaging techniques by trypsin, scraping, EDTA, passaging of suspension cultures. Introduction of foreign material into cells through different transfection and electroporation techniques.

Cloning of gene and its Identification - Characteristics of vector and foreign DNA and uses based up on the size of DNA fragment being cloned. Mammalian expression vectors and its application. Different strategies for identification of clone-insertional inactivation, blue-white colony screening Site-directed mutagenesis

Techniques associated with Study of Gene - Studying location of a gene, Fluorescent In-Situ Hybridization, Genome In-Situ Hybridization, Studying Location and Dynamics of Gene Expression- Bioluminescence [luciferase assay and in vivo imaging], Microarray Technology

Cell Therapy as Regenerative Medicine - Organ Culture, Stem cell therapy, Cases of cardiovascular diseases and diabetes, Generating blood cells for transfusion

Suggested Books:

- Culture of Animal Cells: A Manual of Basic Technique and Specialized Applications by R. Ian Freshney
- Essential immunology by *Ivan M. Roitt*
- Immunobiology by Janeway
- Latest research papers.

BIO 613S: Immunotechnology (2)

Basic Antigen-Antibody Interaction based techniques - Agglutination, Precipitation, Flocculation, ELISA, ELIPSOT, RIA, Immunoblotting, Immunofluorescence, Polyclonal and Monoclonal antibody, FACS and MACS, Ferritin-Antibody Conjugate System

Classical Serological Techniques - Cellular Antigen, Agglutination-Haemagglutination Assay, Haemagglutinin Inhibition and Blood grouping, Lysis-Bacteriolysis and Haemolysis, Soluble Antigen-Precipitation, Immunodiffusion and Immunoelectrophoresis (1D, 2D and Radial)

Classical Serological cell based Techniques - Complement Fixation, Coomb's test, HLA typing, Tetramer Assay, Mixed Lymphocyte Reaction

Basic nucleic acid based Techniques - PCR Based Methods- Real-Time and Reverse Transcriptase PCR, Chromatin Immunoprecipitation.

Suggested Books:

- Essential immunology by *Ivan M. Roitt*
- Culture of Animal Cells: A Manual of Basic Technique and Specialized Applications by R. Ian Freshney.
- Immunobiology by Janeway
- Latest research papers.

BIO 615S: Stress Biology

BIO 617S: Membrane Biology (2)

Diversity in biological membranes; ion channels and transporters, the structure and function of ion channels including coverage of the classical work of Hodgkin and Huxley as well a description of our current understanding of the molecular structure of ion channels as deduced from sequence analysis of the channel proteins and high resolution x-ray crystallography, and current hypotheses about the structural basis of channel selectivity and gating; freeze fracture and negative stain analysis of membrane structure, localization of antibodies and other probes by fluorescence and electron microscopy, quantitative stereology of membranes, autoradiography, and electron probe analysis. Role of membrane lipids and proteins in signaling and human diseases.

Suggested Books:

- Molecular Cell Biology by Lodish et al
- Membrane Microdomain Signaling: Lipid Rafts in Biology and Medicine by Mark Mattson

BIO 619S: Bimolecular NMR Spectroscopy

Bio 626 (Neuroimaging: Understanding Brain Structure and Function)

Total: Lectures: 31; Lab hours: 11; Tut: 2; SS: NA Credits: 3

I. Magnetic Resonance Imaging- Applications in Brain Structure Investigations: Nuclear properties, Longitudinal Relaxation (T1), Transverse Relaxation (T2) and Spin Echoes. Fourier Transformation and FID Manipulation, Magnetic Field Gradients, Slice Selection and Frequency Encoding, Phase Encoding, T1 and T2 Relaxation Mapping, Magnetic Field B_0 and B_1 Mapping, Basic Imaging Sequences: Spin-echo and Gradient Echo, T1 weighted imaging, T2/T2*-weighted imaging, Fluid Attenuated Inversion Recovery (FLAIR), Proton Density Imaging (PD), Susceptibility Weighted Imaging (SWI), Echoplanar Imaging.

Practical and Tutorials: Brain Segmentation Toolbox: Freesurfer, FSL. Lesion segmentation, Brain Tumor Segmentation

(Lectures: 10, Lab/Practical Session Hours: 3, Tutorials: 1 hours)

II. Functional Magnetic Resonance Imaging: Functional Neuroimaging Principle, Neuronal Activity and Hemodynamics, Blood-Oxygen Level Dependent fMRI, T2 and T2* weighted BOLD signal changes, Block designs and Event Related Paradigms, Echoplanar fMRI acquisition methods: Gradient echo and Spin echo, Functional Connectivity Analysis (DMN, ECN, SN, DAN, SMN).

Practical and Tutorials: Hemodynamic Analysis Methods, DPARSB method of resting state functional connectivity. Methods of task-based brain function study

(Lectures: 8, Lab/Practical Session Hours: 2, Tutorials: 1 hours)

III. Perfusion and Diffusion MRI: Cerebral Perfusion and Neurovascular Coupling, Cerebral Blood Volume (CBV) and Cerebral Blood Flow (CBF), Exogenous Perfusion MRI, Dynamic Susceptibility Contrast Enhanced perfusion MRI, Endogenous Perfusion MRI, MR Perfusion: Acquisition and Processing Methods, Arterial Spin Labeling (ASL) MR Perfusion: Continuous ASL and pseudo-Continuous ASL (pCASL). Diffusion Tensor Imaging and derived scalars, MR Tractography and Biological applications.

Practical and Tutorials: Calculation of diffusion flux, displacement, and diffusivity.

Demonstration of White fiber tracking. Brain Blood Flow Quantification

(Lectures: 5, Lab/Practical Session Hours: 2, Tutorials: NA)

IV. Magnetic Resonance Spectroscopy and Spectroscopic Imaging: Introduction to *in vivo* MR Spectroscopy, Localization methods: Single-voxel MRS, STEAM, PRESS, LASER, Introduction to Spectroscopic Imaging (CSI): 2D and 3D, Spectral Editing, Advanced Pulse Sequences and Techniques, Biomedical applications of MRS, Processing MRS Data: Analysis and Quantification, Advanced Pulse Sequences and Techniques. Matlab basics and Numerical Simulations.

Practical and Tutorials: Demonstration of Hyperfine splitting. Metabolic Signal pattern Analysis. LC Model based Quantification of Metabolite concentration

(Lectures: 8, Lab/Practical Session Hours: 4, Tutorials: NA)

Selected Readings: Texts / References. Web references may be given, especially for ebooks. Complete details of Texts/References should be provided. Book: Authors (Initials & Last name), Title, Edition (Optional), Publisher, Year. Journal Articles: Authors (Initials & Last name), Title, Journal name, Volume, Page nos., Year. Web References: Authors/Organization, Title, Year (if available), URL.). For e references mention the elink.

- 1) Malcom H. Levitt, Spin Dynamics, Basics of Nuclear Magnetic Resonance, 7th Edition, WILEY, April 2008.
- 2) Matt Bernstein, Kevin King, Xiaohong Zhou, Handbooks of MRI Pulse Sequences, 1st Edition, ELSEVIER, 2004
- 3) Richard B. Buxton, Introduction to Functional Magnetic Resonance Imaging: Principles and Technique, 2nd Edition, Cambridge Press
- 4) Robin A. de Graaf; In vivo NMR Spectroscopy Principles and Techniques, 3rd Edition, WILEY, 2008