COURSE SYLLABUS (M.Sc & PhD NEUROSCIENCE)

INTRODUCTORY MODULE

Mathematics:

Rectangular, polar, coordinates

Representing equations on a graph

Basics of integral and differential calculus

Basics of matrices and their operations

Introduction to probability

Trignometry

Physics:

Inductance, Resistance and Capacitance. Circuit theory. AC periodicity. Impedance.

Structure of atom, spectral lines, radioactivity, phosphorescence, fluoroescence

Light and Sound: wave propagation, diffraction, emission and absorption spectra

Chemistry:

Normality, Molarity, Avogadro's number, Acids and Bases,

Ionic, covalent and hydrogen bonds, C-C bond

Order of reaction, Equilibrium and rate constant, Chemical potential, Free energy, Dissociation, Catalysis, Michaelis-Menten relation.

Basics of Organic Chemistry

CELL BIOLOGY

Introduction to Cell

Universal features of cell

Membrane structure and cytoskeleton

Lipid Bilayer

Membrane proteins

The self-assembly and dynamic structure of cytoskeletal filaments

Regulation of cytoskeletal filaments

Molecular motors

Intracellular compartments

Compartmentalization of cells

Transport of molecules between nucleus and the cytosol

Transport of proteins into mitochondria

Peroxisomes

Endoplasmic reticulum

Membrane transport

Principles of membrane transport

Carrier proteins and active membrane transport

Ion channels and the electrical properties of membrane

Intracellular vesicular traffic

Molecular mechanisms of membrane transport and the maintenance of compartment diversity

Transport from trans ER through Golgi Apparatus

Transport from trans Golgi network to lysosomes

Transport from trans Golgi network to cell exterior: excecytosis

Transport into the cell from plasma membrane: endocytosis

Cellular Basis of Immunity

Cellular basis of adaptive immunity

B cell and antibodies

Generation of antibody diversity

T cells and MHC proteins

Helper T-cell and lymphocyte activation

Cell Junctions and cell adhesion and extracellular matrix

Cell Junctions

Cell-cell adhesion

Extracellular Matrix of animals

Integrins

Cell-cycle and cell death

Overview of cell cycle

Components of cell cycle control system

Intracellular control of cell-cycle events

Programmed cell death

Neuro-immunology

Immune cells in the brain, Understanding of immune-CNS interactions in neurological disease (such as Multiple sclerosis, Guillain-Barre)

Autoimmunity and Tolerance, Vaccines

Tumor immunology-Tumor immune evasion and immune surveillance

BIOCHEMISTRY

Regulation of gluconeogenesis,

Chemistry of carbohydrates,

Glucose homeostasis,

Pentose phosphate pathway,

Chemistry of Lipid,

Lipid biosynthesis,

Biosynthesis of cholesterol,

β-oxidation, Integration of metabolism,

Regulation of hormone secretion,

Amino acid,

Biosynthesis of amino acids,

Nitrogen fixation,

Structure of protein,

Separation of protein,

Glycolysis,

Glycogen metabolism,

Pyruvate oxidation and citric acid cycle,

Hormone receptor,

Types of hormones,

Urea cycle,

Enzyme kinetics and concept.

Bioenergetics

MOLECULAR BIOLOGY

1. Biochemical Evolution

   Classical experiments and hypothesis for –

   a. Generation of key molecules of life

   b. Transition of pre-biotic chemicals to replicating systems

   c. Development of energy transformation

   d. Ability to respond to changes in environment

2. Introduction to Molecular biology

   a. Structure and components of Nucleic acids

   b. Details of Double helix model of DNA

   c. Types of different RNA and differences between DNA and RNA

   d. Denaturation of DNA and RNA

3. From DNA to Protein (The Central Dogma of Molecular Biology)

   A. DNA replication

      a. Importance of DNA replication

      b. DNA polymerase and its proof reading mechanisms

      c. Replication mechanisms in bacterial and eucaryotic cells

      d. DNA damage and repair mechanisms

   B. Transcription (DNA to RNA)

      a. Details of Transcription (Initiation, Elongation and Termination)

      b. RNA polymerase and proof reading mechanisms

      c. Transcription systems in bacterial and eucaryotic cells

      d. RNA processing-Pre RNA to processed mRNA

   C. Translation (RNA to Protein)

      a. The genetic code

      b. Role of tRNA and ribosomes in translation

      c. RNA synthetase and its accuracy

      d. Protein folding and Human diseases due to abnormality in folding

4. Recombinant DNA Technology, Genetic Engineering and Genomics

   a. Overview of DNA recombinant technology and cloning

   b. cDNA library: uses, construction and screening, commonly used cloning vectors

   c. Expression screening of cDNA libraries

   d. Genomic library: uses, construction and screening

   e. Sequencing of DNA

   f. 5'and 3' Rapid Amplification of cDNA Ends

   g. Production of fusion protein

   h. Polymerase Chain reaction (PCR): conventional, inverse and degenerate PCR

   i. Reverse Transcription Polymerase Chain Reaction (RT-PCR)

   j. Cloning of PCR products

   k. Blotting and Hybridization techniques: Southern, Northern, Western, South-Western, Far Western and in Situ Hybridization

   l. Protein-protein interaction: Co-immunoprecipitation, pull down chromatography, yeast two hybrid system, FRET.

   m. Site-directed mutagenesis

   n. Knock out animals: global and conditional (Cre-Lox P system, use of tissue specific and developmentally regulated promoters)

   o. Transgenic animals: global and conditional (Tet on-tet off system, use of tissue specific and developmentally regulated promoters)

   p. Antisense RNA and si RNA for knock down of expression.

   q. Chromatin Immunoprecipitation (ChIP) Assay

   r. Micro array technology

5. Signal Transduction

   (Overlaps with the Cellular and Molecular Neuroscience and Neurochemistry Course)

6. Control of Gene Expression

   a. Overview of gene control

   b. Gene regulatory proteins

   c. Transcriptional and post-transcriptional controls

7. Pathogen and Infection
    a. Introduction to Neuro-Pathogens
    b. Pathogen-host interactions at cellular and molecular level
    c. Prions as infectious proteins
    d. NeuroAIDS

NEUROANATOMY

1. Introduction, methods

   Basic plan and evolution of the vertebrate nervous system, Basic of development-formation of neural tube, vesicles and derivatives of each vesicle, Existing knowledge and Challenges-Identify and understand details and unique features of human brain, Current investigative procedures, Unique properties of brain.

2. Somatic and autonomic nervous system and components, cranial nerves

   Visceral afferent and efferent systems, Sympathetic and parasympathetic efferent systems.

3. Spinal cord

   Gross features, neuronal columns and arrangement of the functional types, Afferent somatic sensory systems and efferent motor components, Circuitry, reflex arcs and integrative functions Visceral afferent and efferent systems, Sympathetic and parasympathetic efferent systems.

4. Brain stem

   External features and transition from the spinal cord, Location, configuration and functional components of cranial nerve nuclei in the brain stem, Formation and course of tracts in the brain stem, Fourth ventricle.

5. Cerebellum

   General functions, evolution and basics of development, Location, gross features and appearance Zones, distribution of fibres and somatotopy, White matter and deep cerebellar nuclei, Cortical structure, types of neurons and internal circuitry.

6. Diencephalon

Location, boundaries, subdivisions and landmarks, Third ventricle, relations and recesses. Location and boundaries of thalamus and hypothalamus, subdivisions and their important connections, functional categorization of the thalamic nuclei.

7. Cerebrum

Gross features, Histology of gray matter and neuronal types, Types of cortex, functional areas and Brodmann's classification, Barrel and internal circuitry.

8. Basal ganglia

Development and different components, Neuronal types and connections, Lateral ventricle.

9. Limbic system

Blood supply, CSF of brain, blood brain barrier.

CELLULAR AND MOLECULAR NEUROSCIENCE

1. An overview of the nervous system

2. Neurons and glia
    - Introduction to neurons and glial cells
    - The Neuron Doctrine
    - Components of neurons and glial cells
    - Classification of neurons and glial cells
    - The Nissl and Golgi stains,
    - Cell specific markers for neurons and glial cells
  - Structure and function of neurons and glial cells
    - Different types of neurons
    - Different types of glial cells: astrocytes, oligodendrocytes and schwann cells.
    - Type of astrocytes-type I & II astrocytes, fibrous and protoplasmic astrocytes
    - Function of other glial cells: oligodendrocyte and microglial cells
  - Overview of glial and neuronal relationship in the CNS
    - Importance of astrocytes in glutamate metabolism and blood brain barrier
    - Glial – neuronal interplay in the CNS
3. Neuroendocrinology
  - An Overview of hypothalamic and pituitary hormones
  - Endocrine secretions and feedback control
  - Pineal gland and circardian rhythm
4. Neuroimmunology
  - Mechanism of inflammation-role of astrocytes and microglial cells
  - Overview of multiple sclerosis and autoimmune diseases
  - NeuroAIDS

5. Molecular basis of sensory transduction

    - Overview of signal transduction
    - Second messengers and activation in the cell membrane (cAMP, cGMP, IP3, DAG, receptor tyrosine kinases)
    - Growth factor (BDNF) signaling

- Activation of metabotropic receptors
    - GPCRs, beta-adrenergic receptor, mGluRs
    - G-proteins: GTPase cycle, kinds of G proteins, activation and signal transduction mechanisms
    - Activation mechanisms of common protein kinases (PKA,PKC, CaMKII, cGMP-dependent kinase),
    - Common substrates of protein kinases relevant to neuroscience.
- Secondary active transport
    - Facilitated diffusion
    - Active transport
    - Secondary active transport
    - Symport and Antiport
- Phototransduction (mechanisms)
- Mechanisms of sweet taste
- Mechanisms of olfaction

6. Molecular basis of memory

- Overview of learning and memory
- Patient HM
- Animal model systems to study memory
- Commonly studied types of memories
    - Non –associative memory (habituation, sensitization, dishabituation in Aplysia)
    - Associative member (operant conditioning and classical conditioning-contextual fear conditioning, cued fear conditioning

    - Spatial memory
- Different phases of memory
- Massed and spaced training
- Consolidation, reconsolidation
- Extinction
- CAMKII-PKA-MAPK-CREB Pathways
    - In synaptic facilitation and memory in Aplysia
    - In long-term potentiation and memory in mammals
    - ERK in synaptic plasticity and memory in Aplysia and mammals
    - Protein synthesis and transcriptional requirement in synaptic facilitation, LTP and memory
    - Regulation of protein synthesis and transcription by ERK pathway
- Long-term potentiation (LTP)
    - Induction protocols
    - NMDAR-dependent and NMDAR-independent LTP
    - LTP between CA3-CA1 synapses
    - Different phases of LTP
    - Properties of LTP: associativity, co-operativity and input specificity
    - Mechanisms of LTP induction (role and properties of NMDA receptors)
- Long-term depression (LTD)
    - LTD at CA3-CA1 synapse
    - Induction protocol
    - NMDAR and Ca++ dependence
- Model to explain requirement of NMDAR and Ca++ in both LTP and LTD

- Concepts of:
  - Synaptic tagging
  - Integration of stimulatory (5HT) and inhibitory (FMRFamide) inputs at different synapses of a cell in Aplysia synaptic plasticity:
  - Local protein synthesis

7. Molecular biology of Channels

- Basic properties of ion channels
- Resting and gated ion channels
- Ligand-and voltage-gated ion channels
- Gap-junction channels
- Different states of ion channels: closed, open, refractory
- Models of open and closed channels
- Concept of driving force
- Selectivity for ions: example of Na+ and K+ channels
- Composition and structural model of common ion channels (AChR, voltage gated NA+ and K+, Ca++ channels, NMDAR)
- Excitatory and inhibitory neurotransmitter channels (NMDAR, GABAR, Glycine receptor)

8. Axoplasmic transport and protein trafficking in neurons

- Early experiments aimed at axonal transport
- Need for transport in axons and requirement of cytoskeleton
- Neuronal cytoskeleton
  - Microfilaments: actin subunits, microfilament-associated proteins
  - Neurofilaments : high, medium and low molecular weight filaments
  - Microtubules: tubulin subunits, posttranslational modification of tubulins, microtubule-associated proteins

- Retrograde and anterograde transport
    - Fast and slow axonal transport
- Mechanism, and molecules associated with the axoplasmic transport
    - Molecular motors
    - Molecular motors in anterograde and retrograde transport
    - Structure of kinesin and dynein
    - Cargos for anterograde and retrograde transport
    - Saltatory transport

9. Synaptic vesicles
    - Overview of chemical transmission
    - Spontaneous and evoked release of neurotransmitters
    - Requirement Ca++influx
    - Early experiments that examined role of Ca++
    - Quantal release of neurotransmitters
    - Molecular structure of synaptic vesicles
    - Synthesis and transport of synaptic vesicles
    - Molecular mechanisms of endocytosis and exocytosis
        - Kiss and run hypothesis or complete fusion of synaptic vesicles
        - SNARE hypothesis of vesicle fusion
        - Proteins associated with vesicle fusion (synaptotagmin, v-SNAREs, t-SNAREs, SNAP25 etc.)
        - Proteins that are targets for various toxins
        - Role of clathrin in endocytosis and recycling of vesicles

10. Molecular structure of synapse and neuromuscular junction
    - Overview of central nervous system (CNS) synapse and NMJ
    - Kinds of CNS synapses (axo-axonic, axo-somatic, axo-dendritic)
    - Molecular components of synaptic junction
        - Presynaptic and postsynaptic specializations, postsynaptic density

- Molecular structure of neuromuscular junction
  - Composition and properties of AChR
  - Development of neuromuscular junction
  - Signaling mechanisms of AChR clustering
  - Role of agrin in the induction and maintenance of postsynaptic specialization

References:

Fundamental Neuroscience	by Zigmond
Principles of Neural Science	by Kandel
Experimental Biochemistry	by Switzer
Principle of Biochemistry	by Lehninger

SYSTEMS NEUROSCIENCE

1. Introduction to the systems approach to understand brain function

2. Somatosensory System

Peripheral receptors, spinal pathways, medullary, thalamic and cortical somatosensory structures and pathways, somatosensory areas in the cortex and their connection.

3. Visual System

Retina, organization and connections of thalamic and midbrain visual areas, cortical visual areas, dorsal vs. ventral stream.

4. Auditory System

Tonotopy in the cochlea, brainstem auditory nuclei, delay lines, thalamic nuclei and cortical auditory areas.

5. Olfactory and Gustatory Systems

Peripheral receptors for each of the chemical senses, pathways to the brain.

6. Motor System

Spinal, cerebellar and cortical motor pathways, role of basal ganglion, oculomotor pathways.

7. Plasticity of Nervous System

References:

Principles of Neural Science	by Kandel
Neuroscience – exploring the brain	by Bear

GENETICS

The Principle of segregation

Structure of DNA, NDA as genetic material, Mechanism of Replication, difference between prokaryotes and eukaryotes, Cell Division, Mitosis and Meiosis, Allele, Traits, Dominance and recessive, Mendel's laws of Inheritance, Laws of Probability and its application, Characteristic of Mendelian inheritance, Different types of Mendelian Inheritance, Dominant, Recessive, Co-dominance, Incomplete Dominance, Lethality, Sex-linked Inheritance, Epistasis, Penetrance and Expressivity.

Genes and chromosome, Molecular Organization of Chromosome

Structure of chromosome, packaging of chromosome, Constituents of chromatin, different techniques used to differentiate chromatin structure, Genome, features of different genomic regions, Repetitive DNA's SINE, LINE, Alu repeats, Transposons, P-elements, Mini and Microsatellite DNA, Selfish DNA, Spacer DNA, Application of different repetitive DNA sequences**.**

Genetic Linkage and Chromosome Mapping

Genetic recombination, Principle and mechanism of genetic recombination, homologous recombination and its application in research, Map units, Markers, LOD values.

Karyotyping and chromosome behavior

Chromosome number, Chromosomal aberrations and disease associated with it, Different methods of karyotyping, Grouping of chromosomes depending on different indices, Fish, Multicolour DNA Karyotyping, Limitations**.**

Genetics of bacteria and bacteriophage

Mechanism of selection, Auxotroph Vs Prototroph, Conjugation, fertility factor, Hfr, F, mapping of bacterial genome, Linkage, Mechanism of genetic transfer, Episomes, Transformation, Lytic and Lytic and Lysogeny, super infection**.**

Molecular genetics of cell cycle and cancer

Cell cycle stages, Important molecules associated with cell cycle, Different enzymes and differential expression in different stages. Apoptosis pathways, Mechanism and important molecules, Extracellular Vs Intracellular signals, Abberant cell cycle control and cancer, classes of oncogenes, inheritance of the tumor phenotypes.

Extra nuclear Inheritance

Origin of extra nuclear inheritance, Mitochondrial genomes, codon usage, Inheritance of organelle genes and mutation, Random Drift, Threshold effect, Maternal Inheritance, Cytoplasmic male sterility.

Population genetics and evolution population genetics

Genetics constitution of population, Frequency of gene and genotypes, Hardy and Weinberg law, Multiple allele and sex linked genes. Changes of gene frequently, Migration, mutation and selection, Changes of gene frequency is small population, Random drift, Effective population size, Minimal in-breeding, Problems associated with population analysis.

Genetics of complex inheritance

Introduction to complex trait inheritance, establish inheritance pattern, Model population for studying complex inheritance, Multifactorial inheritance, Genetic Heterogeneity, Heritability, Mapping complex trait genes, Introduction to statistical methods.

References:

Annual review of genetics by E.W. Janes

An introduction to Genetics Analysis by Griffiths e al

Genes VIII by Benjamin Lawins

BIOSTATISTICS

Descriptive Statistics: Representation of Data

Histograms, Pie charts, 3-D representation; Frequency Distribution

Different Averages, Standard Division, Moments, Skewness and Peakedness.

Finding out relationships: Correlation and Regression

Correlation coefficients, Regression coefficients, Regression equation.

The Change factor: Probability and Uncertainty

Binomial formula, Probability-Mutual and conditional, Gaussian and

Poissonian distributions, Probability density function, entropy and information.

Random Variables and Sampling

Random Number generation and tables, Randomization experiments,

Sampling Survey, Error and standard error, Double blind approach.

Inference from experimental data

The Null and the Alternative Hypotheses, Degree of significance and confidence.

The student's t-test and t-distribution Biological applications.

Testing a hypothesis: Comparing two populations

Fischer's F-distribution, The chi-squat test. Goodness of fit

From Correlation to Causation in Biology: The logic of scientific discovery

Analysis of variance: ANOVA and elated tools causation and operational analysis.

Design and Analysis of experiment: Introduction to quantitative Research Methodology

Block design, One-array/multi-array design multi-factor design, response plotting.

Non-parametric Statistics: Extracting meaning from low-quality biological data.

Difficult populations and uncertain parameters, Distribution-tree methods.

Biometry and epidemiology

Structural modelling, Path analysis, Multivariable panel design, Meta-analysis.

NEUROIMAGING

Classical Nuclear Magnetic Resonance (NMR) Spectroscopy

Nuclear Magnetism, The Bloch Equations, the One Pulse NMR Experiment, Line width and line shape.

Theoretical Description of NMR Spectroscopy

Product Operator Formalism; Operator Spaces, Basis Operators; Evolution in The Product Operator Formalism; Single- Quantum Coherence and Observable Operators; Multiple quantum Operators; Coherence Transfer and Generation of Multiple Quantum Coherence; Examples of Product Operator Calculations.

Magnetic Resonance Imaging (MRI)

Image Weighting and Contrast

Introduction: Image Contrast; Contrast mechanisms; Relaxation in Different tissues; T1 contrast; T2 Contrast; Proton Density Contrast; Weighting T2* Decay; Pulse Sequences**.**

Encoding and Image Formation

Encoding; Introduction; Gradients; Slice Selection; Frequency Encoding; Phase Encoding; Data Collection and Image Formation; introduction; K space Description; K space Filling; Fast Fourier Transform(FFT).

Important terms in imaging

Parameters and trade-offs; Introduction; Signal to Noise Ratio(SNR); Contrast to Noise Ratio (CNR); Spatial Resolution; Scan Time; Trade-offs; Voxel size and region of interest selection**.**

Pulse Sequences

Introduction; Spin Echo pulse sequences; Conventional spin echo; Fast or turbo spin echo; Inversion Recovery; Fast Inversion Recovery; STIR (Short tau inversion recovery); FLAIR (Fluid Attenuated inversion recovery); Gradient Echo Pulse

Sequence; Echo Planner imaging (EPI); Parallel Imaging Techniques.

Magnetic Resonance Spectroscopy (MRS)

Basic principles of MRS, voxel selection, single voxel and multiple voxel, pulse sequence, PRESS and STEAM.

Functional Magnetic Resonance Imaging (fMRI)

Basic principles of fMRI, Blood oxygenation dependent contrast (BOLD) and its application in fMRI; Analysis of BOLD Pulse sequence of and optimization.

References:

- The Essential physics of Medical Imaging (J.T. Bushberg et al.)
- Magnetic Resonance Spectroscopy and its application in Alzheimer's disease. Concepts in Magnetic Resonance, Pravat K Mandal, Vol 30A 1-25 (2007)
- MRI in practice (Westbrook, Roth and Talbot)

MEMBRANE BIOPHYSICS

Neural Signals (2)

Overview of Neurons, Synapses and Networks

Stimulus → Sensory Perception → Motor Action / Higher Brain Function

Chemical and Electrical Signalling Within a Circuit

Methods to Record Electrical Activity of a Neuron

Resting Membrane Potential (V_R) (2)

Membrane Structure

Definitions (Charge, Current, Voltage, Capacitance, Depolarization, Repolarization, Hyperpolarization etc)

Resting Ion Channels and Generation of V_R

Equilibrium Potential

Nernst Equation

Na-K-Pump

Goldman's Equation

Methods to record membrane potential

Current-voltage relation

Passive Membrane Properties (2)

Electrical Equivalent Circuit of Membrane

Membrane Resistance

Membrane Capacitance

Axial Resistance

Axon Diameter and Conduction Velocity-Compound Action Potential

Myelination and Saltatory Conduction

Action Potential (2)

Role of Voltage-Gated Channels-Na^+, K^+, C1 in generating Action Potential

Voltage Clamp Experiments

Capacitative and Leakage Currents

General of Action Potential

Regenerative Current, Spike Threshold, Refractory Periods

Hodgkin-Huxley Model

Membrane Excitability and Ca^{2+} Channels

Variation in Excitability Among Neurons and Within a Neuron

Methods to Record Action Potentials, Current Clamp

Cell Membrane and Ion Channels (3)

Ion Channels – Structure, Major Types

Ion Permeability and Selectivity

Ligand-gated vs. Voltage-gated Channels

Channels Gating: Activation and Inactivation

Gating Current

Methods for Quantifying Channels

Methods to Study Channel Structure

Principles of Synaptic Transmission (4)

Electrical and Chemical Synapses

Structure and operation of Chemical Synapse

Direct vs. Indirect Gating of Synaptic Channels

Exocytosis and capacitance measurement

Gray classification of synapses

Neuromuscular Junction

Neurotransmitter release and Ca++ hypothesis

Electrical Model of Postsynaptic Membrane

Excitatory and Inhibitory Synaptic Transmission

References:

1. *Principles of Neural Science by Kandel, Schwartz, Jessel*
2. *Neuron to Brain by Nicholls, Martin and Wallace*
3. *Ion Channels of Excitable Membranes- Hille*
4. *Molecular and Cellular Physiology of Neurons by Fain*

NEUROCHEMISTRY

1) Synaptic transmission: History and discovery of synapse and chemical transmission, electrical and chemical synapses, structure and their properties, transmission mechanism, synaptic vesicles, vesicle release mechanism, EPSP and IPSP, temporal and special summation, presynaptic modulation, voltage dependent calcium channel and their blockers.

2) Synapse and brain disorders: synaptic dysfunction and psychiatric disorders, synaptic dysfunction and neurodevelopmental disorders, synapse and critical period of development of various brain function, enriched environment and experience-dependent synaptic plasticity, channelopathies.

3) Classification of neurotransmitters and neurotransmitter receptors, receptor binding assays, determination of affinity and binding capacity of receptor, Scatchard plot. Receptor agonists and antagonists. G-protein coupled receptor, Phospholipase C pathways, second messengers, Activation of PKA, PKC etc., cross-talk between signalling pathways. Nuclear receptors and their superfamily, mechanism of steroid hormone action.

4) Acetylcholine: History, neuromuscular transmission, end plate potential, nicotinic and muscarinic acetylcholine receptors and their classification, structure, agonist and antagonists, clinical chemistry, NMJ diseases, anti-ChE agents and their applications, cholinergic projections in the brain, cholinergic neurons and Alzheimer's disease.

5) Amino acids neurotransmitters: Excitatory and inhibitory neurotransmitters, GABA, glycine and glutamate and their receptors, GABA-A receptor structure, its agonist and antagonists, different types of GABAergic interneurons, dysfunction of GABAergic neurons and Huntington's disease. AMPA, Kainate and NMDA receptors, glutamate mediated synaptic transmission, NMDA receptor, LTP and LTD, glutamate excitotoxicity and its involvement in stroke and chronic neurodegenerative disorders, various exogenous and endogenous neurotoxins working through NMDA, kinate or AMPA receptors, neurolathyrism.

6) Dopamine: Dopamine synthetic pathway, Dopamine receptor structure, function, agonist and antagonists, dopaminergic pathways and their physiological role,

dopamine transporters, MPTP, Parkinson's disease, Schizophrenia, amphetamine, cocaine and their mode of action.

7) Serotonin and other catecholamine's structure, synthesis, classifications and their receptors. Serotonergic projections and their physiological role. Serotonin, mood, anxiety and depression. Stress, HPA axis and hippocampus and amygdala. Histaminergic projections and their physiological function. Histamine synthesis and its receptors.

8) Opiates and their receptors, agonists and antagonists, endogenous ligands of opiate receptors, morphine and pain relief. Neurobiological basis of placebo effect. Drug addiction, tolerance and withdrawal phenomenon. Cannabinoid receptors and their physiological significance.

9) Neuropeptides and their precursors structure, common features, synthesis and processing and regulation. Differences between classical and peptide neurotransmitters.

COGNITIVE NEUROSCIENCE

A Brief History of Cognitive Neuroscience

Methods in cognitive neuroscience:

Behaviour, Modelling, Imaging, electrophysiological recordings, etc.

Paradigm design: ***Introduction to E-prime (lab based)***

Characterizing mental operations

Disorders of perception: visual, auditory, language, motor

Failures of object recognition

Agnosia and its subtypes – Prosopagnosia

Auditory scene analysis, perception of complex auditory events such as speech and music, and their disorders

Neuropsychology of Language Disorders: Aphasia, Alexia, Dyslexia

Action, Motor control & coordination

Reflex arc, muscle, synergy,

Speed-accuracy trade off,

Eye-hand movements.

Attention, selective attention

Learning and Memory

Theories of Memory

Sensory and short-term memory mechanisms

Models of short-term memory

Models of long-term memory

Memory and Brain

Human memory, brain damage, and amnesia

Language and the Brain

Theories of Language

The storage of words and concepts

The mental lexicon

Perceptual analyses of the linguistic input

The recognition of words and Integration of words in sentences

Speech production

Executive Functions and Frontal Lobes

The Lateral Prefrontal Cortex and Working Memory

Distinguishing between stored knowledge and activated information

Working memory versus associative memory

The frontal lobes and the temporal organization of memory

Source memory

The selection of task-relevant information

Goal-oriented behavior

The anterior cingulate as a monitoring system

References:

The New Cognitive Neuroscience - by Gazziniga M.S.R.B. Lvry & G.R. Mangun.

Additional reading:

Oliver Sacks, Damasio

DEVELOPMENTAL NEUROBIOLOGY

1. Neural induction
    - Overview of early embryology +details of hydra, C. elegans (indentation), Drosophila (delamination), frog, zebrafish, chick and humans (invagination).
    - 'Organiser 'of differentiation- Spemann and Mangold experiments, Keller sandwich.
    - Molecular nature of neural inducer- Noggin, chordin, follistatin, activing, BMP4-WNT signalling- important for formation of neural plate.
    - Neuroblast induction-acheate scute, lateral inhibition and details – notch delta signalling pathway- important for formation of neuroblasts.
2. Polarity and Segmentation
    - Overview of polarity and brain architecture, rhombomeres
    - AP-Axis in Drosophila-Bicoid and nanos, homeobox genes, ANT-C and BX-C in flies, effect of homeobox genes on hindbrain development in mammals.
    - Upstream control of hox genes, transformers-RA, WNT-b-catenin, FGF
    - Mesencephalon/metencephalon boundary organiser-WNT1, ENGRAILED1, FGF8.
    - Forebrain development in mammals-pax genes
    - DV-axis polarity-sonic hedgehog(shh) induces the ventralisation (floorplate).
    - Dorsal neural tube development- again WNT/BMP and shh signalling
    - Patterning the cerebral cortex-pax6, emx2, fgf8 and fgf18
3. Genesis and Migration
    - Methods to visualise lineage and timing of a neurons birth-thymidine, BrdU, retroviral GFP, thymidine dating
    - Molecular control of neuron number-intrinsic proteins and also mitogens like FGF, IGF
    - What separates neurons from glia
    - Cerebral and cerebellar cortex formation

- Molecular control of migration of neurons, adult neurogenesis

4. Determination and differentiation
    - Determination-various transcription factors involved (intracellular factors)
    - Asymmetric cell division – eg NB, GMC, neuron – (numb and prospero) and drosophila eye
    - Local environmental factors- eg Drosophila eye imaginal disc (MF) and chick-quail transplant studies
    - Histogenesis-loss of competence Eg layers of the cortex by transplantation studies and retina by heterochronic experiments
    - Neuronal differentiation form neural stem cell, embryonic stem cell and induced pluripotent cell-basic principle and methodology
5. Axon growth and guidance
    - Overview of growth cone and axonal pathfinding. Initial study
    - Guidance cues for growth cone – Netrin, Semaphorin and Ephrins
    - Substrates for growth of developing axon – Role of cell adhesion molecule in growth cone guidance
    - Mechanism of axon guidance-guidance cues and the control of cytoskelata dynamic, localized translational of growth cone guidance, changing response to guidance cues
    - Axon regeneration
6. Development of neuronal connectivity
    - Target selection-Defasiculation of axon terminal, target recognition and entry, prevention of inappropriate targeting
    - Topograpic mapping-Chemoaffinity hypothesis and role of Ephrins
    - Synapse formation- factors influencing formation of neuromascular synapse
    - Synapse formation in the central nervous system-molecules involved in development of pre-synaptic and post-synaptic compartment
    - Role of neuronal activity in synapse formation
    - Synapse elimination-factors influencing synapse elimination, role of neuronal activity

- Synapse specificity – role of surface recognition molecule in synapse specificity

7. Survival and growth

- Overview of neuronal death-elimination of neural progenitor cell and differentiated neuron
- Role of synaptic target in neuronal survival
- Role of neurotrohins in neuronal survival and death
- Signalling mechanisms of neuronal death-intracellular mechanisms, role of Caspases, neurotrophins and nerve growth factor
- Effect of synaptic transmission in neuronal survival

COMPUTATIONAL NEUROSCIENCE

1. Introduction to dynamical system. Spiking neuron as a dynamical system.

   Phase portraits –why is it useful to study ion channel dynamics in the phase space. Bifurcation-Resting, Spiking, bursting.

   Hodgkin classification of spiking

2. Linear Systems, Differential equations, Hodgkin-Huxley model, Fitzhugh-Nagumo model.
3. Neural Encoding: Spike Trains and Firing Rates, Spike Train Statistics,

   The Neural Code, Estimating Firing Rates, Introduction to Receptive Fields-neuronal tuning.

4. Introduction to Neural Decoding and Information theory: Entropy, Mutual Information.
5. Neuronal populations, Macroscopic recordings, Pulse to wave conversions, Basics of EEG and MEG: Neuro-electromagnetism, Field theoretic approaches.

References:

Theoretical Neuroscience- Computational and Mtahematical Modelling

of Neural System by Dayan and Abbot

Dynamical Systems in Neuroscience by Eugene Izikevich

Tutorial on Neurobiology: Single neuron to brain chaos by Walter Freeman

MATLAB

Introduction to computation Source code to execution, compiling, debugging: Flow charts

Program structure & Flow of control

Arrays, Strings, Structures

Getting started with MATLAB

Basic Syntax variables

Overview of matlab functions

Mathematics with Vectors and Matrices

M and Mat files, function files and scripts.

Manipulation of data

Control flow and loops

Writing and debugging MATLAB program.

References: -

Essential MATLAB for Scientists and Engineers - by Butterworth Heinemann and Brain D. Hahn

Getting Started with MATLAB: A Quick Introduction for Scientist and Engineers - by Rudra Pratap

CLINICAL NEUROSCIENCE

Static Neurological Disorders

- Stroke
- Traumatic Brain Injury
- Epilepsy

Progressive Neurological Disorders

- Parkinson's disease
- Huntington's disease and other movement disorders
- Aging, dementia and Alzheimer's disease
- Motor Neuron Disease
- Neuromuscular disorders

Secondary Progressive Neurological Disorders

- Multiple Sclerosis
- CNS infections
- CNS tumors

Psychiatric disorders

- Schizophrenia
- Mood disorders and depression
- Substance use disorders

Miscellaneous topics: genetic, developmental and functional disorders of the nervous system

Translating neuroscience from bench to bedside

References:

Diseases of the Nervous System by Harald Sontheimer