

**Natural Products**  
**M. S. (Pharm.)**

<b>Semester I</b>		
<b>CORE SUBJECTS (All COMPULSORY)</b>		
<b>Course Code</b>	<b>Course Name</b>	<b>Credits</b>
NP-510	Separation and Chromatographic Techniques	1
NP-520	Phytochemistry	2
NP-530	Synthetic Biology of Medicinal Plants and Agro-technologies	1
NP-540	Biomimetic synthesis, Total synthesis, and Semi-synthesis of Natural Products-I	1
MC-530	Spectral Analysis	1
MC-540	Principle and Applications of NMR	1
GE-510	Biostatistics	2
GE-511	Seminar	0.5
LG-510	General Laboratory Experience	2.5
<b>ELECTIVE SUBJECTS (FOR 4 CREDITS)</b>		
EL-501	Biochemical Engineering Fundamentals	2
EL-502	Biotechnology in Pharmaceutical Sciences	1
EL-503	Industrial safety and green chemistry	1
EL-504	Computer Application in Biomedical Engineering	1
EL-505	Biological System Analysis and Control	1
EL-506	Productivity in management and reengineering	1
EL-507	Biosynthesis of Natural Products	1
EL-508	Chemotherapy of Parasitic and Microbial Infections	1
	Choose any core courses of other department (BT/MC/MD/PA/PC/PE)	

<b>Semester II</b>		
<b>CORE SUBJECTS (COMPULSORY)</b>		
<b>Course Code</b>	<b>Course Name</b>	<b>Credits</b>
NP-610	Natural Products and Bio-organic Chemistry	2
NP-620	Natural Products based Drug Discovery	2
NP-630	Phytopharmaceuticals and its Standardization aspects	2

NP-640	Structure Elucidation of Natural Products	2
NP-650	Biomimetic Synthesis, Total synthesis and semi synthesis of Natural Products – II	1
GE-611	Seminar	0.5
LS-610	General Lab Experience in the Area of Specialization	2.5
<b>ELECTIVE SUBJECTS (FOR 4 CREDITS)</b>		
EL-601	Biomechanics	2
EL-602	Mathematical Methods in Biomedical Engineering	1
EL-603	Logistics & distribution	1
EL-604	Total quality control	1
EL-605	Lean system, 6 sigma	1
EL-606	Introduction to Ayurveda and Polyherbal Formulations	1
EL-607	Chemotherapy and Immunopharmacology	2
EL-608	Pharmacovigilance and Medical Writing	2
	Choose any core courses of other department (BT/MC/MD/PA/PC/PE)	

<b>Semester III</b>		
TH- 598	Synopsis and Presentation	9
<b>Semester IV</b>		
TH-698	Thesis Writing and Thesis Defence	9
	<b>TOTAL CREDITS (I TO IV SEMESTERS)</b>	<b>50</b>

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**Natural Products**

**M. S. (Pharm.)**

**Semester I**

**NP-510 (1 Credit)**

S. No.	Separation and Chromatographic Techniques	Hrs (20)
1	<b>Separation Techniques:</b> Need for learning separation techniques, separation techniques in natural product research and drug discovery, extraction techniques.	2
2	<b>Chromatography:</b> General principles, classification of chromatographic techniques, normal and reversed phase, bonded phase chromatography, stationary phases, activity of stationary phases, elutropic series, and separation mechanisms.	2
3	<b>Column Chromatography:</b> Column packing, sample loading, column development, and detection.	2
4	<b>Flash and Vacuum Liquid Chromatography:</b> Objectives, optimization studies, selection of column and stationary phases, selection of mobile phases. Automated flash chromatography, and reverse phase flash chromatography.	2
5	<b>High Pressure Liquid Chromatography (HPLC):</b> Principles, instrumentation, peak shapes, capacity factor, selectivity, plate number and plate height, resolution, band broadening. <b>HPLC Instrumentations:</b> Pumps, injector, detectors, and columns. Column problems, gradient HPLC, HPLC solvents, trouble shooting, sample preparation, method development.	2
6	<b>Planar Chromatography – TLC/HPTLC/OPLC:</b> Basic principles, sample application, development of plates, visualization of plates, 2D TLC, densitometry, and over pressure layer chromatography.	2
7	<b>Counter-current Chromatography:</b> Basic principles, droplet counter current chromatography, centrifugal partition chromatography, choice of solvents for SP and MP.	2
8	<b>Gas Chromatography:</b> Principles, instrumentation, split-splitless injector, head space sampling, columns for GC, detectors, and quantification.	2
9	<b>Bio-chromatography:</b> General principles, stationary phases and mobile phases of size exclusion chromatography, ion exchange chromatography, ion pair chromatography, and affinity chromatography.	2
10	<b>Hyphenated Techniques:</b> Introduction to GC-MS and LC-MS techniques and their application in natural products.	2

## READING MATERIAL

- 1) Theory and Practice of Chromatographic Techniques, Sanjay B. Bari, Leonard L. Williams, 2019, Pharma Med press / BSP Books.
- 2) Applied Thin Layer Chromatography, 2<sup>nd</sup> edition, Elke Hahn Deinstrop, 2006, Wiley-VCH
- 3) Thin Layer Chromatography: A Modern Practical Approach, Peter E. Wall, 2005, RSC publishing
- 4) HPLC Made to Measure: A Practical Handbook for Optimization, Stavros Kromidas, 2006, Wiley-VCH
- 5) Practical HPLC method development, Lloyd R. Snyder, Joseph J. Kirkland and Joseph L. Glajch, 1997, John Wiley and Sons.
- 6) HPLC and UHPLC for Practicing Scientists, Michael W. Dong, 2019, Wiley
- 7) Introduction to hyphenated techniques and their applications in pharmacy, Patel, K.N., Patel, J.K., Patel, M.P., Rajput, G.C. and Patel, H.A., 2010, Pharmaceutical methods, 1(1), pp.2-13.doi: 10.4103/2229-4708.72222
- 8) Hyphenated Methods, Mass Spectrometry, Jurgen H. Gross, 2004, SpringerLink, pp 475-494.

## Outcomes:

Upon completion of the course the student shall be able to:

- Design the strategy to purify a small molecule according to its physicochemical properties.
- Select an appropriate chromatographic method (HPLC, GC and TLC etc.) for quantitative and qualitative analysis of an extract/ formulation.
- Express the knowledge of HPLC and its minor troubleshooting.
- Suggest the suitability of LC-MS/GC-MS analysis in complex matrix.

**Semester I**  
**NP-520 (2 Credit)**

S. No.	Phytochemistry	Hrs (40)
1	<b>Role of Natural Products in New Drug Discovery:</b> few selected NPs, with different pharmacophore, its source, purification and its drug target interactions.	2
2	<b>Natural Products:</b> Novel drug templates, chemical diversity, and structure-based drug design	3
3	<b>Case Studies of Plant derived Natural products drugs:</b> Discovery of statins, taxol, cardiac glycosides, vinca alkaloids, morphine, quinine, and phodophylotoxins	7
4	Plant-derived molecules for perfumery, cosmetic, agrochemicals, dyes and pigments	8
5	<b>Advanced Extraction Techniques:</b> (eg. Supercritical fluid extraction; microwave assisted, semi-bionic, Ultrasonication, extraction of volatile oils, Ultrafiltration and green extractions etc.) Isolation of phytochemicals using preparative HPLC; Enrichment processes for particular class of compounds. Retention of nutritional values, its calculations, assay and regulations from source to extracts. Project Cost evaluation.	8
6	Bioassay-directed fractionation of natural products depicting examples.	2
7	Recent developments on Natural Products based adaptogens, immunomodulators, memory enhancers, anti-inflammatory agents, anti-parasitics and related bioassays methods	5
8	Basic understanding of biosynthetic pathways for selected class of Natural Products, impact of molecular biology tools to control these pathways	5

**READING MATERIAL**

- 1) Phytochemistry of Medicinal Plants, Vol. 29, J.T. Arnason, R. Mata, J. T. Romeo, 1995, Springer Science, Business Media New York
- 2) Medicinal Natural Products: A Biosynthetic Approach, 3rd Edition, P. M. Dewick, 2009, John Wiley & Sons, Ltd.
- 3) From Biosynthesis to Total Synthesis: Strategies and Tactics for Natural Products, A. L. Zografos, 2016, John Wiley & Sons, Ltd.

- 4) Natural Product Biosynthesis: Chemical Logic and Enzymatic Machinery, 1<sup>st</sup> Edition, C. T. Walsh, Y. Tang, 2017, Royal Society of Chemistry.
- 5) Trease and Evans' Pharmacognosy, 16<sup>th</sup> Edition, W. C. Evans, 2009, Elsevier.
- 6) Phytochemistry: Vol. 1, Fundamentals, Modern Techniques, and Applications, 1st Edition, C. Egbuna, J. Chinenye Ifemeje, S. C. Udedi, S. Kumar, 2018, CRC Press.
- 7) Studies in Natural Products Chemistry, Vol. 59, 1st Edition, Atta-ur-Rahman, 2018, Elsevier.
- 8) Chemistry of Natural Products, Vol. 6, S. V. Bhat, B.A. Nagasampagi, M. Shivakumar, 2005, Springer US.
- 9) Medicinal Chemistry of Bioactive Natural Products, X. T. Liang, W. S. Fang, 2005, John Wiley & Sons, Inc.

**Outcomes:**

Upon completion of this course, the student shall be able to:

- Get insights into plant derived therapeutic leads, perfumery, cosmetic agents, dyes and pigments.
- Optimize the extraction technique according their chemical class.
- Perform a bioassay guided isolation to improve throughput for identification of potential bioactive natural products.
- Contribute towards the development of herbal formulations for the prophylactic use.

**Semester I**  
**NP-530 (1 Credit)**

S. No.	Synthetic Biology of Medicinal Plants and Agro-technologies	Hrs (20)
1	<b>Medicinal Plant Based Industry:</b> Export and import of plants, threatened/endangered medicinal plants.	3
2	<b>Plant Drug Collection and Cultivation with Plant Growth Regulators:</b> Transgenic plants, and approaches for production of transgenic plants.	2
3	<b>Plant Genome and Genomic Organization:</b> Gene families, genetic regulations in transcription and translation in plants	2
4	<b>Mutations and Mutagenesis:</b> Transposable elements, genetic manipulations and plant genetic engineering	2
5	Cultivation technology for commercial production of some selected medicinal and aromatic plants.	1
6	<b>Tissue Culture Techniques:</b> Micropropagation of medicinal and aromatic plants, secondary metabolism in tissue culture, germplasm storage, methods of cell immobilization.	2
7	Biotechnology of propagation and production of antibiotic and non-antibiotic drugs from lower plants.	2
8	<b>Use of Herbicides:</b> Weedicides and insecticides, microbial phytotoxins as herbicides.	2
9	Indian soils, soil analysis and soil fertilizers.	2
10	Ecology, biodiversity, plant, variety from one area v/s another area, genotypes.	2

**READING MATERIAL**

- 1) Text book of Industrial Pharmacognosy, First Edition, A. N. Kalia, 2007, C. B. S. Publisher, New Delhi
- 2) Principles of Gene Manipulation, Sixth Edition, S. B. Primrose, R. M. Twyman and R. W. Old, 2004, Blackwell Science.
- 3) Genes IX, Nineteenth Edition, Benjamin Lewin, 2008, Jones & Bartlett, Inc. U.S.A.
- 4) Commercial Cultivation of Medicinal and Aromatic Plants Dhananjay J. Deshpande, 2005, Himalaya Publishing House.
- 5) Elements of Biotechnology, First Edition, P. K. Gupta, 2000, Rastogi Publications, Meerut.
- 6) Genetic Engineering: Principles and Practice, Sandhya Mitra, 2015, Mcgraw Hill Education.

**Outcomes:**

Upon completion of the course the student shall be able to:



- Select the sustainable production method for commercially important natural products and express the knowledge of vaccines, antibodies and enzymes derived from plants.
- Design the strategy to improve the yield of secondary metabolites by either transgenic plants or improved cultivation practices.
- Express the knowledge of regulations associated with Medicinal Plant based industries.
- Choose the suitable fertilizer/s according to the soil analysis.

Semester I

NP-540 (1 Credit)

S. No.	Biomimetic synthesis, Total synthesis and semi synthesis of Natural Products-I	Hrs (20)
1	Overview of total synthesis and biomimetic synthesis of natural products with importance in drug discovery	4
2	Retrosynthesis: Introduction to Synthons, Synthetic equivalent groups, Umpolung strategy, Disconnection approaches, Functional group interconversion. Selected examples of retrosynthetic pathways of Natural products such as calanolide, colchicine, camptothecin	3
3	Role of protection and deprotection in natural product synthesis, Commonly utilized reagents for protection/deprotection of functional groups (carbonyl, acids, hydroxyl and amines)	4
4	Leaving groups: Good leaving groups, poor leaving groups, importance to leaving group in elimination and substitution reaction	2
5	Name reactions like Michael reaction, Coupling Reactions, Grignard reaction, Friedel's Crafts Reaction in total synthesis with examples in recent	4
6	Semi-synthesis of Medicinally important natural product such as epothilone, podophyllotoxins	3

**READING MATERIAL**

- 1) Total Synthesis of Natural Products, Jie Jack Li and E. J. Corey, 2012, Springer.
- 2) Organic synthesis: The disconnection approach, 2nd Edition, S. Warren and P. Wyatt, 2008 Wiley.
- 3) Classics in Total Synthesis: Targets, Strategies, Methods, K.C. Nicolaou and E. J. Sorenson, 1996, Wiley-VCH.
- 4) Biomimetic Organic Synthesis, Erwan Poupon and Bastien Nay, 2011, Wiley-VCH.
- 5) Greene's Protective Groups in Organic Synthesis, 4th Edition, Wuts and Greene, 2006, John-wiley & Sons.

**Outcomes:**

Upon completion of the course the student shall be able to:

- Express the role of total synthesis and biomimetic synthesis in natural products research.
- Develop the basic concepts and plan retrosynthesis, protection/deprotection in total synthesis of small molecules.
- Analyze the targeted molecule and propose strategies for semi-synthesis of natural products.

**Semester I**  
**EL-507 (1 Credit)**

S. No.	Biosynthesis of Natural Products	Hrs (20)
1	<b>Secondary Metabolism:</b> Building blocks and construction mechanisms- Alkylation reactions: nucleophilic substitution, electrophilic addition, Wagner–Meerwein rearrangements, Aldol and Claisen reactions, Imine formation and the Mannich reaction, Amino acids and transamination, Decarboxylation reactions, Oxidation and reduction reactions, Phenolic oxidative coupling, Halogenation reactions, Glycosylation reactions.	8
2	<b>The Acetate Pathway:</b> Fatty acids and polyketides	3
3	<b>The Shikimate Pathway:</b> Aromatic amino acids and phenylpropanoids	3
4	<b>The Mevalonate and Methylerythritol Phosphate Pathways:</b> Terpenoids and steroids	3
5	Factors affecting synthesis of secondary metabolites.	3

**READING MATERIAL**

- 1) Medicinal Natural Products: A Biosynthetic Approach, 3rd Edition, Paul M. Dewick, 2009, Wiley.
- 2) From Biosynthesis to Total Synthesis: Strategies and Tactics for Natural Products, Alexandros L. Zografos, 2016, Wiley.
- 3) Natural Product Biosynthesis: Chemical Logic and Enzymatic Machinery, Christopher T Walsh and Yi Tang, 2017, RSC.
- 4) Trease and Evan's Pharmacognosy, 16th Edition, W.C. Evans, 2009, Elsevier.
- 5) Influence of abiotic stress signals on secondary metabolites in plants. Plant signaling & behavior. Akula R, Ravishankar GA, 2011, 6(11),1720-31.

**Outcomes:**

Upon completion of the course the student shall be able to:

- Express the concept of secondary metabolites and their biosynthetic pathways
- Analyze the factors affecting the biosynthesis of secondary metabolites and apply the concept to improve the yield / modification of scaffolds.
- Elucidate the biosynthetic pathways.

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Semester II

NP-610 (2 Credit)

S. No.	Natural Product and Bio-Organic Chemistry	Hrs (40)
1	<b>Importance of Marine Natural Products Chemistry in Drug Development:</b> Chemistry and biology of marine natural products, marine chemical ecology, marine biomedicinals and marine toxins from bacteria, microalgae, rhodophyta, chlorophyta, porifera, ascidians, corals, nudibranchs, biosynthesis of marine natural products.	5
2	<b>Bioactive Compounds from Microorganisms:</b> Antibiotics, non-antibiotic drugs from fungal and other microbial sources, microbial phytotoxins.	4
3	<b>Carbohydrates:</b> Mono, di, oligo- and polysaccharides, separation and isolation, purification, structure determination, linkage stereochemistry, biological activity.	4
4	<b>Glycoproteins, lipoproteins and glycopeptidolipids:</b> Structure and biological activity, isolation, purification, degradation, structure determination	3
5	<b>Glycosides and saponins:</b> Classification, separation and isolation, linkage stereochemistry, structure determination, biological activity, study of examples.	3
6	<b>Alkaloids:</b> Classification, methods of isolation, stereochemistry, biological activity, general theory of biogenesis. UV quantification for alkaloids.	6
7	<b>Terpenoids:</b> Classification, methods of isolation, stereochemistry, biological activity, general theory of biogenesis. UV quantification for terpenoids	5
8	<b>Flavonoids:</b> Classification, isolation, stereochemistry, biological activity, biosynthesis. UV quantification for Flavonoids.	4
9	<b>Coumarins and lignans:</b> Classification, isolation, stereochemistry, biological activity, biosynthesis. UV quantification for coumarins.	3
10	<b>Lipids and Prostaglandins:</b> Classification, identification, biological activity, study of examples. Quality of different edible oils.	3

### READING MATERIAL

- 1) Pharmacognosy, Phytochemistry, Medicinal Plants, 2nd Edition, Jean Bruneton, 1999, Intercept Ltd. New York.
- 2) Pharmacognosy, Fourth Edition, C. K. Kokate, 2005, Nirali Prakashan, Pune.
- 3) Trease and Evan's Pharmacognosy, 16<sup>th</sup> Edition, W.C. Evans, 2009, Elsevier.

- 4) Bioactive Marine Natural Products, D.S. Bhakuni and D.S. Rawat, 2005, Springer.
- 5) Natural Product Isolation, Second Edition, In: Methods in Biotechnology Vol 20, Satyajit Sarker, Zahid Latif and Alexander Gray, 2005, Humana Pres Inc., Totowa, NJ.
- 6) Chemistry of Natural Products, 1st Edition, S. V. Bhat, B. A. Nagasampagi and M. Sivakumar, 2008, Narosa Publishing House.
- 7) Chemistry of Plant Natural Products: Stereochemistry, Conformation, Synthesis, Biology, and Medicine, S. K. Talapatra and B. Talapatra, 2015, Springer.

**Outcomes:**

Upon completion of the course the student shall be able to:

- Get insights of marine and microbial derived natural products.
- Classify natural products according to their chemical structure and their occurrence and to suggest their possible biosynthetic pathways.
- Design the appropriate strategy to isolate and characterize different class of natural products.
- Develop industrially relevant method for quantification of different class of natural products.

**Semester II**  
**NP-620 (2 Credit)**

S. No.	Natural Products based Drug Discovery	Hrs (40)
1	<b>Role of Natural Products (NP) in Drug Discovery:</b> Case studies of taxol, artemisinin, etc	4
2	<b>Ethnopharmacology Based NP Drug Discovery:</b> Case studies of development of drug from folk medicine: e.g. Withaferin A	4
3	Challenges associated with NP drug discovery	2
4	Role of advance instrumentations to overcome NP drug discovery associated challenges; Dereplication, Advancement in NMR, Mass Spectrometry etc.	7
5	<b>New Trends in Field of Natural Product Drug Discovery:</b> Multidisciplinary approach to natural products drug discovery using innovative technologies	4
6	Role of Omics approaches in NP drug discovery; Genomics, Proteomics and Metabolomics	4
7	Combinatorial library for constituents obtained from natural resources, extracts used for developing new drugs.	3
8	Terrestrial, marine and microbial based bioactive scaffolds; role of in silico approaches for finding suitable targets in drug discovery	4
9	<b>Bioactivity:</b> Activity versus toxicity, rapid screening methods, correlation between enzyme inhibition and pharmacological activity, general screening of enzyme, inhibitors; Advances in screening for bioactive components from medicinal plants; e.g. affinity ultrafiltration mass spectrometry, High throughput screening <i>etc.</i>	4
10	<b>Radio Ligand Receptor Binding Assays:</b> Adrenoreceptors, opiate, benzodiazepine, ion channels, 5 HT, dopamine, adenosine, muscarinic, histamine, ATPase, GABA.  Cytotoxicity tests and Bioassay-guided fractionations	4

**READING MATERIAL**

- 1) Lead Generation Approaches in Drug Discovery, Chapter 7: Role of Natural Products in Drug Discovery, Hugo Lachance, Stefan Wetzal, Herbert Waldmann, 2010, Wiley online library.
- 2) Integrated Approach to Nature as Source of New Drug Lead, Open access peer-reviewed chapter, In book: Molecular Insight of Drug Design, Seema Kohli, 2018, Intechopen.
- 3) Innovative Approaches in Drug Discovery, Ethnopharmacology, Systems Biology and Holistic Targeting, 1<sup>st</sup> edition, Bhushan Patwardhan and Rathnam Chaguturu, 2014, Academic Press is an imprint of Elsevier.

- 4) Natural Products and Drug Discovery An Integrated Approach, 1<sup>st</sup> edition, Subhash C. Mandal, Vivekananda Mandal and Tetsuya Konishi, 2018, Academic Press is an imprint of Elsevier.
- 5) Natural Products Analysis: Instrumentation, Methods, and Applications, Kindle edition, Vladimir Havlicek, Jaroslav Spizek, 2014, Wiley online library.
- 6) Screening Methods for Detection and Evaluation of Biological Activities of Plant Preparations, in: Bioassay Methods in Natural Product Research and Drug Development, Vol 43, A. J. Vlietinck, 1919, Springer Netherlands.
- 7) Radioligand Binding Assays: Theory and Practice, in: Current Directions in Radiopharmaceutical Research and Development, (Mather SJ ed), Davenport AP and Russell FD, 1996, Springer Netherlands.
- 8) Combinatorial Synthesis of Natural Product-Based Libraries (Critical Reviews in Combinatorial Chemistry), 1st Edition, Armen M. Boldi, 2006, CRC Press.
- 9) Innovative omics-based approaches for prioritisation and targeted isolation of natural products as new strategies for drug discovery, Wolfender J-L, Litaudon M, Touboul D and Queiroz EF, Natural Product Reports, 2019, 36:855-868.
- 10) Omics-based natural product discovery and the lexicon of genome mining, Machado H, Tuttle RN and Jensen PR, Curr Opin Microbiol. 2017 Oct;39:136-142. doi: 10.1016/j.mib.2017.10.025. Epub 2017 Nov 23.

### **Outcomes:**

Upon completion of course work, students will be able to

- Rationalize the contribution of natural products in new drug discovery.
- Express the challenges encountered in different stages of natural products based drug discovery.
- Identify the merits of innovative and multidisciplinary approach for the discovery of new lead molecules from different sources of natural products.
- Plan different bioassay screening methods for evaluation of natural products.

**Semester II**  
**NP-630 (2 Credit)**

S. No.	Phytopharmaceuticals and its Standardization Aspects	Hrs (40)
1	Introduction of Phytopharmaceuticals, Nutraceuticals, Herbal Cosmetics, Natural food colours and other value added products from natural resources; product development, advantages, market size and regulations.	6
2	<b>Identification and Authentication of Plant Drugs:</b> Taxonomical Identification of plant, morphological and anatomical description, Natural habitat, geographical distribution of plant, source (wild or cultivated), Season and time of collection, post-harvest processing.	4
3	<b>Quality Control of Plant Drugs:</b> Foreign matter, total ash, acid insoluble ash, Pesticide residue, Heavy metals, Microbial load, Chromatographic finger print with respect to four phytochemical reference markers, bio assay for phytochemicals.	6
4	Process for extraction and subsequent fractionation: Steps involved in processing of plant material by retaining the medicinal and nutritional values (phytochemical active principal ingredient -pAPI). Examples: Spray Drying, Lyophilization and Bead milling.	6
5	Quality specification of pAPI: Details of solvent used, Extractive values, Solvent residue, Microbial load, Heavy metals, Chromatographic finger print profile with respect to reference markers.	4
6	Biological Activity/ Efficacy Data of pAPI: <b>Primary screen</b> detail [with reference] (target- based/phenotypic with comparator/ standard drug at appropriate concentration); EC <sub>50</sub> of pAPI and bioactive Marker, CC <sub>50</sub> (cell line used), Selectivity Index (SI). <b>Secondary screen</b> detail ( <i>in-vivo</i> model; if more than one, please provide details for all); ED <sub>50</sub> /dose for curative efficacy, Criterion for Go/No-Go decision (superiority/non-inferiority with standard of care).	4
7	<b>Stability data of pAPI:</b> Procedures, predictable chemical and galenical changes, technical limitations, testing methods. Stability data of the finished product in the pack intended for marketing.	3
8	Bioavailability and pharmacokinetics (PK) aspects for Phytopharmaceuticals with examples. Phytoequivalence, pharmaceutical equivalence. PK in mice/rat (dose and route); primary parameters wrt bioactive marker.	3
9	Importance of monographs of standards of medicinal plants and their parts, comparative study of BHP, API, Chinese, Japanese Herbal Pharmacopoeia, USP,	4



	European pharmacopoeia, US formulary, WHO, CODEX, EMEA and ESCOP guidelines for herbal medicinal products. Preparation of Drug Master File (DMF) for herbal medicines.	
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## READING MATERIAL

- 1) New Look to Phytomedicine; Advancements in herbal products as novel drugs leads, Mohd Sajjad Ahmad Khan, Iqbal Ahmad, Debprasad Chattopadhyay, 2018, Academic Press.
- 2) Therapeutic Medicinal Plants: From Lab to the Market, Marta Cristina Teixeira Duarte and Mahendra Rai, 2016, Taylor and Francis group, CRC.
- 3) Herbal Drugs and Phytopharmaceuticals: A Handbook for Practice on a Scientific Basis, Franz-Christian Czygan, 2004, CRC press.
- 4) Taxonomy of Angiosperms A.V. S. S. Sambamurt K., 2008, International Pvt. Ltd., New Delhi
- 5) Textbook of Industrial Pharmacognosy, First Edition, A. N. Kalia, 2007, C. B. S. Publisher, New Delhi.
- 6) Advanced Plant Taxonomy A. K. Mondal, 2016, New Central Book Agency (P) Ltd.
- 7) Quality Control Herbal Drugs – An Approach to Evaluation of Botanicals, First Edition, Pulok K. Mukherjee, 2002, Business Horizons, New Delhi.
- 8) Laboratory Handbook for the Fractionation of Natural Extracts, First Edition, Houghton PJ and Amala Raman, 1998, Chapman & Hall, London.
- 9) Standardisation of Botanicals: Testing and Extraction Methods of Medicinal Herbs, Vol. 1, 2<sup>nd</sup> Edition, V. Rajpal, 2011, Bio-Green Books.

## Outcomes:

Upon completion of the course the student shall be able to:

- Design the strategy to standardized the natural products based formulations such as Phytopharmaceuticals, Nutraceuticals, and Herbal Cosmetics.
- Propose an environment friendly and cost effective extraction process for development of herbal medicines.
- Contribute to the preparation of stability study protocols for herbal based finished products.
- Communicate the knowledge of quality aspects mentioned in the monographs in pharmacopeia's such as USP, EP etc .

**Semester II**  
**NP-640 (2 Credit)**

S. No.	Structure Elucidation of Natural Products	Hrs (40)
1	<b>Structure Elucidation of Natural Products:</b> General strategies for structure elucidation of natural products with few examples	3
2	<b>Chemical Methods for identification of the following class of phytoconstituents:</b> Alkaloids Steroids Flavonoids/ Polyphenols/Tannins Terpenoids Polyketides Proteins/Peptides Saponins <b>Note:</b> The procedure along with mechanism involved in the mentioned methods should be discussed along with its applications and limitations	3
3	<b>Mass Spectroscopy:</b> Applications in structure elucidation with examples include MALDI TOF Introduction to nitrogen rule, mass defect, and neutral loss/diagnostic fragment ions filtering methods etc.	6
4	<b><sup>1</sup>H NMR and <sup>13</sup>C NMR Spectroscopy:</b> Chemical shifts, coupling constant, advanced 1D NMR experiments such as NOE, DEPT, D <sub>2</sub> O exchange experiment. Quantitative NMR methods.	6
5	<b>Homonuclear 2D NMR:</b> <sup>1</sup> H- <sup>1</sup> H COSY, NOESY, DQF-COSY, TOCSY, <sup>13</sup> C- <sup>13</sup> C correlations INADEQUATE.	4
6	<b>Heteronuclear 2D NMR:</b> HSQC/HMQC, HMBC	3
7	<b>Optical and Chiroptical Techniques:</b> CD, Circular birefringence and circular dichroism, and cotton effect.	3
8	<b>Structure Elucidation:</b> Case studies with examples from alkaloids, flavonoids, sterols, coumarins, triterpenes, and xanthenes.	12

**READING MATERIAL**

- 1) Spectrometric Identification of Organic compounds, 8th Edition, R. M. Silverstein, F. X. Webster, D. J. Kiemle, John Wiley & Sons Inc. 2015, P. S. Kalsi, New Age Publishers, New Delhi.
- 2) Organic Chemistry, Vol I: The Fundamental Principles, 6th Edition, I. L. Finar, 2006, Darling Kindersley (India) Pvt. Ltd.
- 3) Phytochemical Methods, 2<sup>nd</sup> Edition, J. B. Harborne, 1984, Springer, Dordrecht.
- 4) Classical Methods in Structure Elucidation of Natural Products, R. W. Hoffmann, 2018, Hoffmann, Wiley

- 5) Modern NMR Approaches to the Structure Elucidation of Natural Products: Vol. 2: Data Acquisition and Applications to Compound Classes, R. R. Gil and A. Navarro-Vázquez, 2014, RSC.
- 6) Natural Products Chemistry III, Atta-ur-Rahman, 1988, Springer link.
- 7) One and Two Dimensional NMR Spectroscopy, Atta-ur-Rahman, 1989, Elsevier
- 8) Organic Structure Analysis, P. Crews, J. Rodriguez, M. Jaspars, 2009, Oxford University Press.

**Outcomes:**

Upon completion of this course, the student shall be able to:

- Detect different class of natural products using simple chemical methods.
- Predict the plausible empirical formula based on accurate mass analysis.
- Choose and apply appropriate 1D and 2D NMR experiments to elucidate the structure of small molecules.
- Utilize optical and chiroptical techniques to establish stereochemistry of unknown compound.

**Semester II**  
**NP-650 (1 Credit)**

<b>S. No.</b>	<b>Biomimetic Synthesis, Total synthesis and semi-synthesis of Natural Products – II</b>	<b>Hrs (20)</b>
1	Concepts for Efficiency in the Total Synthesis of Natural Products: Selectivity, Atom and step economy, multicomponent reaction, convergent synthesis, etc.	3
2	Modern strategies and Technologies in Natural Product Synthesis: Visible-Light Photochemistry, Flow Chemistry, C-H functionalization, etc. recent examples of each strategies reported in literature.	4
3	Introduction to Renewable Resource-Based Building Blocks/Chirons for the Total Synthesis of Natural Products: examples based on Natural Chirons (amino acids and carbohydrates)	3
4	Total synthesis of selected natural products such as Taxol, Prostaglandins (PGF <sub>2α</sub> , PGF <sub>E2</sub> ) with their retrosynthetic approaches. Mechanism of important reaction steps involved in total synthesis.	5
5	Semi-synthesis/biomimetic synthesis of important natural products (Indole alkaloids, quinoline alkaloids, lignans, etc.) and structural diversification for drug discovery	5

**READING MATERIAL**

- 1) Efficiency in natural product total synthesis / edited by Pei-Qiang Huang, Zhu-Jun Yao, Richard P. Hsung, 2018, Wiley.
- 2) Total Synthesis of Natural Products, Jie Jack Li and E.J. Corey, 2012, Springer.
- 3) Classics in Total Synthesis: Targets, Strategies, Methods, K.C. Nicolaou and E. J. Sorenson, 1996, Wiley-VCH
- 4) Biomimetic Organic Synthesis: Erwan Poupon and Bastien Nay, 2011, Wiley-VCH.
- 5) Chemistry of Natural Products, 1st Edition, S. V. Bhat, B. A. Nagasampagi and M. Sivakumar, 2008, Arosa Publishing House.

**Outcomes:**

Upon completion of the course the student shall be able to:

- Get insight into the total synthesis, structural modification of bioactive leads.
- Plan various approaches for efficient natural product synthesis including biomimetic synthesis, semi-synthesis and total synthesis.
- Design the convenient synthetic route for potential natural products analogues to support the structure activity relationship (SAR) study.

## Semester II

### EL-606 (1 Credit)

S. No.	Introduction to Ayurveda and Polyherbal Formulations	Hrs (20)
1	History of Ayurveda and herbal drugs, concept of Ayurveda, Ayurvedic philosophy of health, disease and treatment.	2
2	<b>Global Ayurvedic Medicine Market:</b> Size, share, trend and forecast including organic herbs & extracts (NOP, USDA etc.).	2
3	<b>Ayurvedic /Polyherbal Formulations (PHF):</b> Types of Ayurvedic formulations, single herb vs polyherbal formulations, Advantages and challenges associated with PHF.	3
4	Preparation and detoxification methods for Ayurvedic formulations.	2
5	<b>CCRAS Guidelines for Ayurvedic Formulation:</b> development, standardization, quality assurance, toxicity and clinical evaluation.	3
6	Amendments in Drugs and Cosmetic Act for quality control of Ayurvedic medicines.	2
7	Government policies and initiatives for development of Ayurveda.	2
8	<b>Introduction to Ministry of AYUSH and its Allied Organizations:</b> Pharmacopoeia Commission for Indian Medicine & Homoeopathy, Central Council for Research in Ayurvedic Sciences (CCRAS), National Medicinal plant board (NMPB). FSSAI Sustainability of Indian medicinal plants- CITES and Indian Govt. initiatives.	2
9	Case paper of an herb of commerce by students-Herb, herb processing, extraction, standardization by gravimetric and hyphenated techniques, process patents & important commercial suppliers.	2

### READING MATERIAL

- 1) An introduction to Ayurveda, M.S. Valiathan, 2013, Orient Blackswan Private Limited - New Delhi.
- 2) Ayurveda, the Science of Self-healing: A Practical Guide, 2nd edition, Vasant Lad, 1987, Lotus Press.
- 3) Ayurvedic Healing: A Comprehensive Guide, Revised edition, David Frawley, 2012, Lotus Press
- 4) Prakriti: Your Ayurvedic Constitution, 2 Revised edition, Svoboda, Dr. Robert, 1998, Lotus Press.
- 5) Handbook of Ayurvedic Medicines with Formulation, Eiri Board, 2009, Engineers India Research Institute.
- 6) Regulatory and Pharmacological Basis of Ayurvedic Formulations, Kindle edition, Amritpal Singh, 2016, CRC Press.

- 7) General guidelines for Drug development of Ayurvedic formulations, Guidelines Series-I, Central Council For Research In Ayurvedic Sciences, Ministry Of Ayush, Government of India, New Delhi. (Accessed on 04 May 2020)
- 8) <http://ayush.gov.in/> (Accessed on 04 May 2020)
- 9) <http://www.fao.org/3/af285e/af285e00.pdf> (Accessed on 04 May 2020)
- 10) <https://www.nutraingredients.com/Article/2019/12/16/NutraIngredients-2019-review-predictions-vs.reality-part-1> (Accessed on 04 May 2020)
- 11) <https://www.cites.org/> (Accessed on 04 May 2020)

### **Outcomes:**

Upon completion of course work, students will be able to

- Define the concepts of Ayurveda and its treatment philosophy.
- Express the global demand of Ayurvedic medicines.
- Get insights into quality standards mentioned in the herbal pharmacopeia; various challenges associated with its quality and efficacy.
- Execute the preparation of polyherbal formulations as per the standard Ayurvedic texts.
- Convey the regulatory guidelines of Government authorities related to Ayurvedic medicines.