

Unit 1: Introduction to Plant Biotechnology

Free notes at pharmacolearn.fyi

Medicinal Plant Biotechnology, subject code MPG201T, is the first core theory subject of M.Pharm Pharmacognosy, Semester 2. It carries 4 credits and 60 hours of theory, taught at 4 hours per week, for 100 marks. Its scope, as the syllabus states it, is to explore the knowledge of biotechnology and its application in the improvement of quality of medicinal plants: to know genetic engineering in medicinal plants for higher yield of phytopharmaceuticals, and to use biotechnological techniques for obtaining and improving the quality of natural products and medicinal plants. The subject is unusual in the semester because its five units are not of equal length, and the notes follow the printed hours honestly. Unit 1 (12 hours) introduces plant biotechnology and the genetic and molecular biology beneath it: DNA, RNA and protein, the genetic code, regulation of gene expression, genome structure, cell signaling and recombinant DNA technology. Unit 2 (15 hours) teaches the tissue culture techniques themselves: organogenesis and embryogenesis, synthetic seed, somaclonal variation, protoplast fusion, hairy root and multiple shoot cultures, micropropagation, sterilization methods and gene transfer. Unit 3 (15 hours) turns culture into production: immobilization, cloning of plant cells, secondary metabolism in tissue cultures, and the use of precursors and elicitors. Unit 4 (13 hours) covers biotransformation, bioreactors and the retention of biosynthetic potential, transgenic plants, gene identification, localization and sequencing, and PCR in plant genome analysis. Unit 5 (5 hours) is a short closing unit on fermentation technology: its applications, ergot alkaloids, single cell proteins and enzymes of pharmaceutical interest. One idea holds the subject together: a medicinal plant is both a medicine factory and a genetic system, and biotechnology is the set of tools for running that factory in a dish, in a fermenter or in an improved plant, under control, instead of depending on whatever the field season happens to deliver.

1.1 Historical perspectives

Plant biotechnology grew out of a simple question: can a piece of a plant, or even a single plant cell, be persuaded to live and grow outside the plant, in a vessel, on food the scientist chooses? The theoretical foundation is totipotency, the idea, proposed at the start of the twentieth century by Gottlieb Haberlandt, that a living plant cell carries the full genetic information of the plant and can, under the right conditions, regenerate a whole plant. Haberlandt attempted to culture isolated cells and failed to keep them dividing, but the concept he stated became the charter of the whole field. Through the following decades the missing pieces were found one by one. Plant growth regulators were characterised, first the auxins and then the cytokinins, and with them came control: the classical finding that the balance between auxin and cytokinin in the medium directs development, a high cytokinin to auxin balance favouring shoot formation and a high auxin to cytokinin balance favouring root formation, with balanced levels holding cells in undifferentiated callus growth. Defined nutrient media were developed, of which the Murashige and Skoog medium became the most widely used general medium for plant tissue culture. Sterile technique matured, so that cultures could be kept free of the bacteria and fungi that otherwise outgrow slow plant cells within days.

The second half of the century added the molecular half of the subject. The structure of DNA was established, the genetic code was worked out, restriction enzymes and ligases made it possible to cut and join DNA deliberately, and recombinant DNA technology was born. Plants joined the genetic engineering era through their natural genetic engineer, the soil bacterium *Agrobacterium tumefaciens*, which transfers a segment of its own plasmid DNA into the plant genome as part of its normal infection cycle; once that

mechanism was understood, the tumour forming genes could be removed and genes of interest put in their place. Protoplast culture, cell fusion, haploid culture from anthers, and the first transgenic plants followed, and by the time the polymerase chain reaction arrived, the plant scientist held the complete toolkit this subject teaches: grow the cells, choose the cells, change the cells, and read their genes. In pharmacognosy the history matters because each technique solved a drug problem: culture answered scarcity, selection answered variability, and gene transfer answered the limits of conventional breeding.

1.2 Prospects for development of plant biotechnology as a source of medicinal agents

The prospects named in the syllabus rest on the weaknesses of the conventional supply of medicinal agents from plants. Field supply is seasonal, geographically limited, slow for perennial and tree drugs, vulnerable to over collection, and chemically variable with soil, climate and harvest time. Some valuable producers are rare, slow growing or difficult to cultivate at all, so that demand for the drug can threaten the species itself. Biotechnology attacks each weakness at a different point, and an examination answer should map prospect to weakness rather than list techniques at random.

Cell and tissue culture offers production independent of season and geography, under controlled conditions, from a small starting sample of the plant, with the possibility of directing the culture toward the wanted constituent by medium design, precursor feeding and elicitation, the programme of Unit 3. Micropropagation offers rapid multiplication of elite, disease free planting material, so that cultivation itself starts from uniform, verified stock, the programme of Unit 2. Genetic improvement, by selection in culture, by somaclonal variation and by deliberate gene transfer, offers plants and cell lines that yield more of the active constituent, resist disease, or produce a constituent profile the wild plant does not. Hairy root cultures offer fast growing, genetically stable production systems for root derived drugs. Fermentation and bioreactor scale up offer the industrial form of all of these: contained, reproducible, documentable production of the kind the pharmaceutical industry already understands from microbial technology. The honest limit must travel with the prospects: many plant cell cultures grow slowly, produce less than the intact plant, or lose productivity over time, which is why Units 3 and 4 spend so much attention on elicitors, immobilization and retention of biosynthetic potential. The prospect is real, but it is earned culture by culture, not assumed.

1.3 Applications in pharmacy and allied fields

In pharmacy the applications follow the syllabus objectives directly. First, production of phytopharmaceuticals and secondary metabolites in culture, for drugs whose field supply is scarce, slow or variable, treated fully in Unit 3. Second, improvement of medicinal plants themselves: micropropagated uniform planting material, disease free stock, and, through gene transfer and selection, improved varieties with better constituent profiles. Third, biotransformation: cultured cells used as enzymatic reagents to convert a supplied substrate into a more valuable product, treated in Unit 4. Fourth, conservation and germplasm work: slow growth storage, synthetic seed and culture collections hold rare medicinal germplasm that field collection would endanger. Fifth, research service to pharmacognosy itself: cultures provide clean, defined material for biosynthetic pathway studies, for tracing how a constituent is built, and for screening new producers without consuming wild populations.

In allied fields the same toolkit serves agriculture, horticulture and forestry, in rapid multiplication of ornamentals, fruit and timber species, in production of virus free stock, in embryo rescue and wide hybridisation through protoplast fusion, in haploid breeding, and in the development of crops with engineered resistance and quality traits. It also serves basic science, because a culture is a controllable experimental system for studying differentiation, gene regulation and metabolism, which is why the molecular foundations occupy the rest of this unit. The examination point is that the pharmacy applications

are not a separate technology: they are the general plant biotechnology toolkit pointed at drug problems.

1.4 Genetic and molecular biology as applied to pharmacognosy

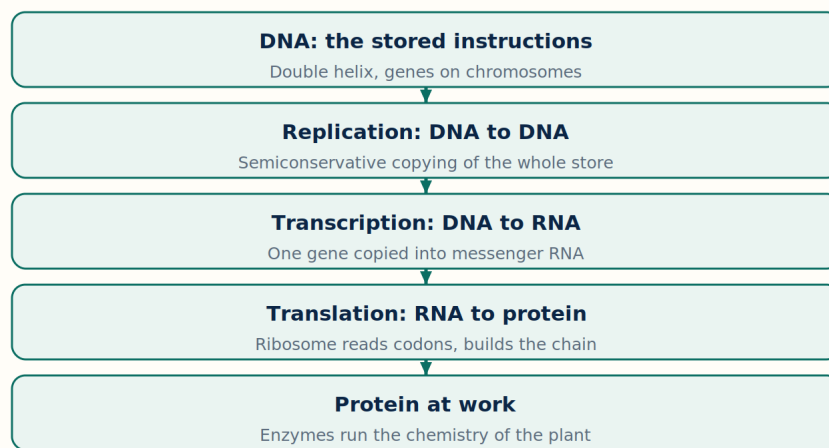
Pharmacognosy asks of a plant three questions: is it the right plant, what does it contain, and how does it make what it contains? Molecular biology gives each question a deeper instrument. Identity can be tested at the DNA level when morphology and chemistry are ambiguous, because the genome is present in every part and at every season. Content can be understood as the output of genes: every phytoconstituent is made by a pathway of enzymes, every enzyme is encoded by a gene, and differences in yield between plants are, at root, differences in genes and in how those genes are switched on and off. Manufacture can be engineered at the same level, by moving pathway genes, blocking competing branches, or transferring a pathway into a faster growing host or culture. That is the sense of the syllabus phrase: genetic and molecular biology as applied to pharmacognosy is the study of the drug plant as an information system, DNA storing the instructions, RNA carrying and regulating them, and proteins, as enzymes, doing the chemical work the pharmacognosist measures. The sections that follow teach that system in the order the syllabus lists it: replication of DNA, RNA and protein, the genetic code, regulation of expression, genome structure, signaling, and finally the recombinant technology that lets the scientist rewrite the instructions deliberately.

1.5 Study of DNA, RNA and protein: replication and the flow of information

DNA, deoxyribonucleic acid, is the hereditary material: a double helix of two antiparallel strands, each a chain of nucleotides built from a sugar, a phosphate and one of four bases, adenine, thymine, guanine and cytosine, with adenine pairing to thymine and guanine to cytosine across the strands. That complementarity is the whole secret of heredity, because each strand carries the information needed to rebuild the other. Replication is semiconservative: the helix is unwound, each parental strand serves as template for a new complementary strand, and each daughter molecule keeps one old strand and one new. The machinery should be known in outline: helicase unwinds, primase lays a short RNA primer, DNA polymerase extends the new strand only in the 5 prime to 3 prime direction, so one strand is made continuously and the other in short fragments later joined by ligase, and proofreading functions correct errors as synthesis proceeds.

Transcription copies one gene, on one strand, into RNA. RNA differs from DNA in its sugar, ribose, in using uracil in place of thymine, and in being usually single stranded. RNA polymerase binds at a promoter, unwinds a short stretch and builds the RNA complementary to the template strand; in eukaryotes the first transcript is processed, a cap and a tail are added and introns are spliced out, to give mature messenger RNA. Plants add their own features, notably RNA processing and gene silencing mechanisms of great importance in transgenic work. Translation then reads the messenger at the ribosome: transfer RNAs bring amino acids, each recognising a three base codon through its anticodon, and the ribosome joins the amino acids into the protein chain in the order the codons dictate. Replication, transcription and translation, DNA to DNA, DNA to RNA, RNA to protein, are the central flow of information on which every later topic stands, and the flow diagram below fixes it.

The flow of genetic information



Every phytoconstituent is the end of this flow: gene, enzyme, product

© 2026 PharmacoLearn, pharmacolearn.fyi

Figure: The flow of genetic information. Replication copies the whole store, transcription copies one gene into RNA, and translation builds the protein, usually an enzyme, that performs the chemistry of the plant.

1.6 The genetic code

The genetic code is the dictionary between codons and amino acids: 64 three base codons, of which 61 specify the twenty standard amino acids and three act as stop signals, with AUG serving as the usual start codon and also specifying methionine. Its properties are the examinable content, and each property has a practical consequence. The code is triplet and non overlapping, read in a fixed frame from the start codon, so an inserted or deleted base shifts the frame and garbles everything after it. It is degenerate: most amino acids are specified by more than one codon, so many base changes are silent. It is specific and nearly universal across life, which is precisely why recombinant technology works: a gene moved between organisms is still read in the same language, subject to the codon preference differences that molecular biologists manage when a gene expresses poorly in a foreign host. It contains punctuation, the start and stop codons that open and close the message. For the pharmacognosist the code is what connects a DNA sequence, read in Unit 4, to the enzyme it encodes, and the enzyme to the constituent the drug assay measures.

1.7 Regulation of gene expression

A plant cell contains the genes for roots, leaves, flowers and defence chemistry in every nucleus, yet expresses only a fraction of them in any cell at any time. Regulation of gene expression is the system of switches that decides which genes are on, how strongly, and for how long, and it is the molecular explanation of facts the pharmacognosist already knows: that a constituent is made in the root but not the leaf, in the young plant but not the old, or only after the plant is attacked. Regulation operates at several levels. At the gene level, transcription factors bind promoters and regulatory sequences and permit or prevent transcription, responding to developmental programmes, to light and hormones, and to stress signals. Chromatin state matters: genes packaged tightly are inaccessible and silent, and chemical marks on DNA and its packaging proteins can hold a gene in an on or off state. After transcription, processing, stability and translation of the messenger add further control points, and small RNAs can silence specific messengers, a mechanism plants use heavily and transgenic science borrows for deliberate gene silencing. The tissue culture consequences are direct and should be stated: dedifferentiated callus often stops making the constituents of the specialised tissue it came from, because the genes are switched off out of their normal context, and much of Units 3 and 4, elicitation, differentiation into roots and shoots, selection of high

producing lines, is in reality applied regulation of gene expression.

1.8 Structure and complexity of genome

The genome is the complete DNA content of the organism, and its structure in plants has features an examination answer should place correctly. Nuclear DNA is organised into chromosomes, linear molecules of DNA packaged with proteins, in a set characteristic of the species; many medicinal plants are polyploid, carrying multiple sets, which complicates breeding and analysis. Only a small fraction of a large plant genome typically codes for protein: genes, each with coding regions interrupted in eukaryotes by introns, regulatory regions before and after, sit within large amounts of non coding DNA, including repetitive sequences and transposable elements that can move and create variation. Plants carry two further genomes outside the nucleus: the chloroplast genome and the mitochondrial genome, each a small circular DNA inherited usually from the mother in flowering plants. The chloroplast genome matters commercially as a transformation target, because a gene placed there can be present in very many copies per cell and is contained by maternal inheritance. Genome complexity explains practical difficulties: large, repetitive, polyploid genomes are harder to sequence, map and engineer than compact ones, and the gene hunting methods of Unit 4 are designed around that complexity. Complexity also explains richness: gene families, duplicated pathway genes and regulatory variety are the raw material from which the chemical diversity of medicinal plants is built.

1.9 Cell signaling

Cell signaling is how a cell receives information, from hormones, light, wounding and invading microbes, and converts it into a change in gene expression and metabolism. The standard sequence should be known: a signal molecule, the ligand, binds a receptor, at the cell surface or inside the cell; the activated receptor triggers an intracellular relay, often a chain of protein kinases passing a phosphate signal from one to the next, sometimes with small second messenger molecules carrying the signal inside the cell; the relay reaches transcription factors, which switch the appropriate genes on or off; and the cell responds, by growing, differentiating, or switching on defence chemistry. In plants the classical signaling molecules include the growth regulators of tissue culture itself, auxins and cytokinins, together with gibberellins, abscisic acid, ethylene, jasmonates and salicylic acid. Two syllabus connections give this section its weight. First, tissue culture is applied signaling: the auxin to cytokinin balance of Section 1.1 works because it speaks to the receptors and relays that steer development. Second, defence signaling is the mechanism behind elicitation in Unit 3: jasmonate signaling is a principal switch for secondary metabolite pathways, which is why jasmonate type elicitors wake those pathways in culture. Signaling is therefore not a digression into general biology; it is the wiring diagram between the medium the scientist prepares and the chemistry the culture performs.

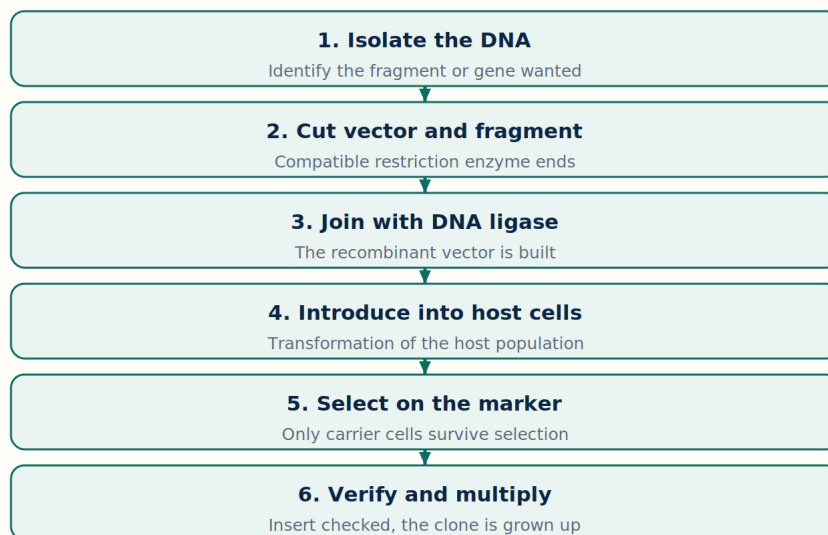
1.10 Recombinant DNA technology

Recombinant DNA technology is the deliberate construction of new DNA combinations in vitro and their introduction into a living host. Its toolkit is standard and should be listed with the job each tool does. Restriction endonucleases cut DNA at specific short recognition sequences, generating defined ends. DNA ligase joins DNA fragments. Vectors, most simply plasmids, are small DNA molecules that carry inserted DNA into a host and are maintained and copied there; a useful vector carries an origin of replication, a selectable marker so that only cells taking up the vector survive selection, and cloning sites where foreign DNA can be inserted. Host cells, classically bacteria for copying and storing DNA, receive the vector by transformation. From these tools the standard workflow is built: isolate the gene or DNA fragment, cut vector and fragment compatibly, join them, introduce the recombinant molecule into the host, select the cells that carry it, and verify the insert, by size, by sequence or by the PCR methods of Unit 4. Libraries of

DNA fragments, genomic and complementary DNA libraries made from messenger RNA, hold a whole genome or a whole expressed gene set in clonable form for gene hunting. The workflow below states the sequence as a text flow.

```
Isolate the DNA and identify the fragment or gene wanted
|
Cut fragment and vector with compatible restriction enzymes
|
Join the fragment into the vector with DNA ligase
|
Introduce the recombinant vector into host cells
|
Select the cells that carry the vector on its marker
|
Verify the insert and multiply the chosen clone
|
Use the cloned DNA: study it, sequence it, or express it
```

Recombinant DNA: gene to clone



Selection proves the vector; verification proves the insert inside it

© 2026 PharmacoLearn, pharmacolearn.fyi

Figure: The recombinant DNA workflow. Selection proves the vector is present; verification proves the right insert is inside it, and both proofs are required.

In plants the technology meets its special delivery systems, Agrobacterium mediated transfer and direct DNA delivery, taught in Unit 2, and its special purposes: adding a pathway gene to raise yield, silencing a gene to remove an unwanted constituent or a competing branch, and inserting reporter and marker genes that let the scientist follow expression. Recombinant technology also underlies the reading tools, sequencing and PCR, that Unit 4 applies to the plant genome. With it, Unit 1 closes: the student has the history, the prospects, the applications, and the molecular grammar, DNA, RNA, protein, code, regulation, genome, signaling and recombinant construction, that the culture techniques of Unit 2 put to work.

More free M.Pharm notes and unit wise PDFs at pharmacolearn.fyi
Free video lectures on the PharmacoLearn YouTube channel