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Sources of Crude Drug, Plant Families, Biogenesis of Phytochemicals

SOURCES OF CRUDE DRUG

Plant	<ul style="list-style-type: none">➤ Oldest source of drugs.➤ 25% of the drugs prescribed worldwide come from plants➤ More than 200 drugs considered as basic and essential by the World Health Organisation (WHO)➤ Significant number of synthetic drugs obtained from natural precursors.➤ Example: Digoxin from <i>Digitalis</i> species, quinine and quinidine from <i>Cinchona</i> species, vincristine and vinblastine from <i>Catharanthus roseus</i>, atropine from <i>Atropa belladonna</i> and morphine and codeine from <i>Papaver somniferum</i>.
Animal	<ul style="list-style-type: none">➤ Second largest source of crude drugs.➤ Example: Honey from honeybee, beeswax from bees, cod liver oil from shark, bufalin from toad, animal pancreas is a source of Insulin, musk oil from musk, spermaceti wax from sperm whale, woolfat from sheep, carminic acid from colchineal, venoms from snake
Mineral	<ul style="list-style-type: none">➤ Highly purified form of naturally occurring mineral substances is used in medicine➤ Example: Sulphur is a key ingredient in certain bacteriostatic drugs, shilajit is used as tonic, calamine is used as anti-itching agent
Marine	<ul style="list-style-type: none">➤ Major part of earth is covered with water bodies and hence bioactive compounds from marine flora and fauna (microorganisms, algae, fungi, invertebrates, and

	vertebrates) have extensive past and present use in the treatment of many diseases
Marine	<ul style="list-style-type: none"> ➤ Serve as compounds of interest both in their natural form and as templates for synthetic modification. Several molecules isolated from various marine organisms are currently under study. ➤ Number of anticancer, anti-inflammatory, cardio tonic chemical moieties are isolated from marine plants and animals. ➤ Example: Agar-agar, a popular pharmaceutical excipient, from red algae, Carrageenans or carrageenins (linear sulfated polysaccharides) from red seaweeds
Plant tissue culture	<ul style="list-style-type: none"> ➤ It involves <i>in-vitro</i> multiplication of cells, tissues and organs on defined solid or liquid media under aseptic and controlled environment ➤ Multiplication of cells, tissues and organs on defined solid or liquid media under aseptic and controlled environment ➤ Controlled production of useful desired secondary metabolites ➤ Example: Antihypertensive ajmalicine from callus culture of <i>Catharanthus roseus</i>, anti-inflammatory berberine from suspension culture of <i>Thalictrum minus</i>, antiparkinson L-DOPA from callus culture of <i>Stizolobium hassjo</i>, immunomodulatory ginsenoside from callus culture of ginseng etc.

PLANT FAMILIES

Apocynaceae	<p>Calyx = K, Corolla = C, Androecium = A, Gynoecium = G</p> <p>Dicot family</p> <p>Floral formula: ♂K(5) C(5) A(5) G 2 or (2)</p> <p>Chemical constituents: The family is a rich source of indole and steroidal alkaloids as well as cardioactive glycosides. The other constituents are cyanogenetic glycosides, saponins, tannins, coumarins, phenolic acids and triterpenoids. Important medicinal plants of the family are as follows:</p>
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	<p>Important medicinal plants of the family are as follows:</p> <ul style="list-style-type: none"> ➤ <i>Catharanthus roseus</i>: anticancer ➤ <i>Holarrhena antidysenterica</i>: bitter and antidiysenteric ➤ <i>Rauwolfia serpentina</i>: management of essential hypertension ➤ <i>Strophanthus kombe</i>: diuretic <i>Thevetia nererifolia</i> (yellow oleander): cardioactive
<p>Compositae Asteraceae or Daisy family</p>	<p>Dicot family Floral Formula: ♂ K pappus or OC (5)G (2) Chemical constituents: A characteristic feature of the family is the storage of carbohydrate in the form of inulin; sesquiterpene lactones; polyacetylenic compounds and essential oils; alkaloids of pyridine, quinoline, diterpenoid and pyrrolizidine group in small amounts; diterpene glycoside. It includes plants having antitumour or antibacterial activity. Some members are also commercial sources of rubber latex. Important medicinal plants of the Family Important medicinal plants of the family are as follows:</p> <ul style="list-style-type: none"> ➤ <i>Artemisia annua</i>: Antimalarial ➤ <i>Calendula officinalis</i>: Topical use for skin infections ➤ <i>Arnica montana</i>: Externally in hair preparations and for bruises ➤ <i>Stevia rebaudiana</i>: Stevioside; sweetener for soft drinks.
<p>Convolvulaceae</p>	<p>Dicot family Floral Formula: ♂K (5) C(5) A (5) G(2) Chemical constituents: It includes indole, isoquinoline, pyrrolidine and tropane and pyrrolizidine alkaloids. Purgative resins, phenolic acids and triterpenoid saponins are also reported in some species. Important medicinal plants of the Family Important medicinal plants of the family are as follows:</p> <ul style="list-style-type: none"> ➤ <i>Ipomoea hederacea</i>: Purgative ➤ <i>Cuscuta reflexa</i>: As hypotensive and have bradycardiac effects ➤ <i>Ipomoea purga</i>: Strong purgative

	<p>➤ <i>Argyrea speciosa</i>: Roots in rheumatic afflictions and leaves in skin diseases and wounds</p>
<p>Leguminosae (legume, pea, or bean family)</p>	<p>Dicot family Floral Formula: % ♂K(5)C(5)A(9) + 1G1 It is divided into three sub families: Papilionaceae (Fabaceae): Many fabaceae host bacteria in their roots within structures called root nodules. These bacteria, known as rhizobia, called nitrogen fixation. Important medicinal plants of the Family are as follows: Papilionaceae (Fabaceae) <i>Psoralea corylifolia</i>: Various skin infections <i>Mucuna pruriens</i>: Parkin-sonism <i>Astragalus gummifer</i>: Demulcent, suspending and emulsifying agent <i>Trigonella foenagraceum</i>: Source of steroids <i>Glycyrrhiza glabra</i>: Expectorant <i>Tolu balsam</i>: Cough mixtures and antiseptic <i>Peru balsam</i>: Antiseptic and expectorant Caesalpinaceae <i>Cassia acutifolia</i>: Laxative <i>Cassia angustifolia</i>: Laxative <i>Caesalpinia sappan</i>: Red dye <i>Cassia tora</i>: Laxative <i>Cassia occidentalis</i>: Laxative <i>Cassia fistula</i>: Laxative Mimoseae <i>Acacia senegal</i>: Gums <i>Acacia catechu</i>: Astringent, tanning and dyeing industry <i>Acacia farnesiana</i>: Perfumery <i>Albizia lebbek</i>: Timber tree</p>
<p>Labiatae Laminaceae or Mint family</p>	<p>Dicot family Floral Formula: ♂K(5)C(5)A4G(2) Chemical constituents: Volatile oils; menthol and thymol; other constituents include: Diterpenoids and triterpenoids, saponins, polyphenols, tannins, iridoids and their glycosides and coumarins. Pyridine and pyrrolidine alkaloids are also present.</p>

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	<p>Important medicinal plants of the family are as follows:</p> <ul style="list-style-type: none"> ➤ <i>Ocimum sanctum</i>: Antipyretic, respiratory problems ➤ <i>Mentha piperita</i>: Source of menthol; Flavouring, carminative ➤ <i>Thymus vulgaris</i>: Antispasmodic ➤ <i>Rosemarinus officinalis</i>: Carminative and spasmolytic <p><i>Lavendula angustifolia</i>: Carminative and spasmolytic</p>
Rubiaceae	<p>Dicot family Floral Formula: ♂K(4-5)C(4-) A (4-5)G(2) Chemical constituents: A large diversity in constituents; alkaloids indole, oxindole, quinoline and purine type are common; catechins; anthraquinones, di and triterpenoids; irridoid glycosides.</p> <p>Important medicinal plants of the family are as follows:</p> <ul style="list-style-type: none"> ➤ <i>Cinchona ledregiana</i>: Antimalarial, bitter tonic ➤ <i>Cephaelis ipecacuanha</i>: Rxpectorant and emetic ➤ <i>Uncaria gambier</i>: Astringent, tanning and dyeing industry ➤ <i>Coffea arabica</i>: Stimulant ➤ <i>Morinda citrifolia</i>: Traditional drug, Anthraquinones
Rutaceae	<p>Dicot family Floral Formula: ♂K4-5C4-5A8, 10 G (4, 5) Chemical constituents: Essential oil, Vitamin-C and citric acid are the common constituent of this family. Essential oil is found in lysigenous secretory cavities in the parenchyma and pericarp. Furano and pyranocoumarins are the typical constituents of this family. Imidazole, acridone and benzyltetra hydro isoquinoline type of alkaloids have been also reported.</p> <p>Important medicinal plants of the family are as follows:</p> <ul style="list-style-type: none"> ➤ <i>Citrus aurantium</i>: As food, flavouring agent ➤ <i>Citrus limonia</i>: Vitamin C ➤ <i>Aegle marmelos</i>: Immunomodulatory activity ➤ <i>Ruta graveolens</i>: Formerly used as

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	<p>emmenagogue and spasmolytic</p> <ul style="list-style-type: none"> ➤ <i>Pilocarpus jaborandi</i>: Pilocarpine, used in glaucoma treatment
<p>Scrophulariaceae Figwort family</p>	<p>Dicot family Floral Formula: ♂K(5)C(5)A₄or 2G(2) Chemical constituents: Cardiac glycosides, bitter irridoid glycosides, other constituents include: steroidal and triterpenoid saponins, cyanogenetic glycosides and anthraquinones. Important medicinal plants of the family are as follows: <i>Digitalis purpurea</i> : Cardioactive <i>Digitalis lanata</i> : Cardioactive <i>Picrorhiza kurroa</i> : Liver ailments <i>Baccopa monnieri</i> : Brain and nerve tonic</p>
<p>Solanaceae</p>	<p>Dicot family Floral Formula: ♂K(5)C(5)A(5)G(2) Chemical constituents: Tropane and steroidal type of alkaloids. Important medicinal plants of the family are as follows: ➤ <i>Atropa belladonna</i>: Pain relief, inflammatory conditions, anti-emetic ➤ <i>Datura stramonium</i>: Spasmodic affections of the respiratory organs ➤ <i>Hyoscyamus niger</i>: Spasmolytic and anticholinergic properties; atropine is used in ophthalmology. ➤ <i>Withania somniferum</i>: Antioxidant, immunomodulatory ➤ <i>Solanum nigrum</i>: Source of steroids, hepatoprotective ➤ <i>Capsicum annum</i>: Counter irritant ➤ <i>Nicotiana tabacum</i>: Source of nicotine; insecticide</p>
<p>Umbelliferae Presently called as Apiaceae</p>	<p>Dicot family Floral Formula: %♂K5C5A5G(2) Chemical constituents: Rich source of essential oils; some species accumulate alkaloids and furanocoumarins, coumarins, terpenes and sesquiterpenes and triterpenoid saponins.</p>

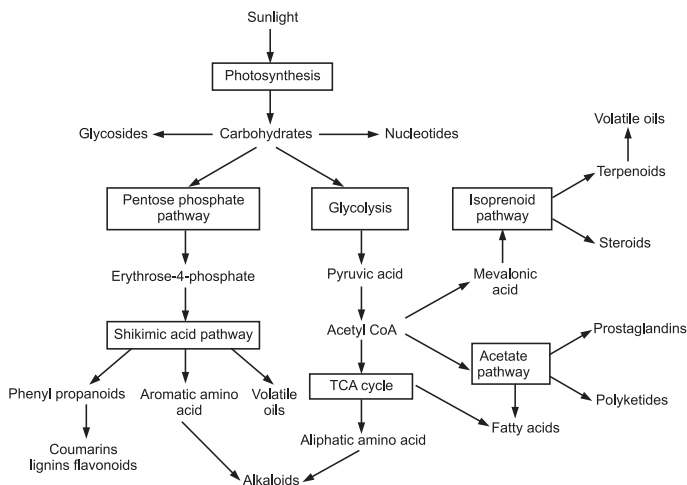
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	<p>Important medicinal plants of the family are as follows:</p> <p><i>Carum carvi</i>: Carminative and spice <i>Coriandrum sativum</i>: Carminative and spice <i>Cuminum cyminum</i>: Carminative and spice <i>Anethum graveolens</i>: Carminative and spice <i>Foeniculum vulgare</i>: Mild carminative and an excellent eye wash</p>
Liliaceae (Lily family)	<p>Monocot family Floral Formula: P₃+3A₃+3G(3) Chemical constituents: sulphur containing compounds, anthraquinone and saponin glycosides, rarely alkaloids Important medicinal plants of the family are as follows:</p> <ul style="list-style-type: none"> ➤ Aloe (<i>Aloe vera</i>): Anthraquinone glycosides ➤ Colchicum (<i>Colchicum autumnale</i>): alkaloids ➤ Safed musli (<i>Chlorophytum borivilianum</i>): Saponins ➤ Shatavari (<i>Asparagus recemosus</i>): Saponins
Gramineae or Poaceae (Grass family)	<p>Monocot family Floral Formula: P₂+4 a₄ or 6 G₂(-3) Chemical constituents: Polysachharides, sugar Important medicinal plants of the family are as follows:</p> <ul style="list-style-type: none"> ➤ Sugarcane (<i>Saccharum officinarum</i>) ➤ Corn (<i>Zea mays</i>): Edible
Papaveraceae (Poppy family)	<p>Dicot family Floral Formula: Ca 2Co₂+2A∞G(2-25) Woody shrubs or small tropical trees. Chemical constituents: Latex, alkaloids Important medicinal plants of the family are as follows:</p> <ul style="list-style-type: none"> ➤ <i>Chelidonium majus</i> : alkaloid chelidonine ➤ <i>Papaver somniferum</i> L.(opium): narcotic alkaloids.
Cruciferae or Brassicaceae (Mustard family)	<p>Dicot family Floral Formula: Ca₂+2Co₄A₂+4G(2) or (4) Herbs/shrubs Chemical constituents: Glucosinolates</p>

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	<p>Important medicinal plants of the family are as follows:</p> <ul style="list-style-type: none"> ➤ <i>Brassica oleracea</i> : edible ➤ <i>Brassica nigra</i>: seed oil is useful in cosmetics ➤ <i>Sysimbrium officinale</i>: leaves and stem used in curing scurvy. ➤ <i>Lepidium sativum</i>: seeds are used for treating liver disorders.
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BIOGENESIS



*Overview of Biosynthesis of
Primary and Secondary Metabolites in Plants*

BIOSYNTHESIS OF ALKALOIDS

S.No.	Type of alkaloids	Examples	Amino acid precursor
1	Tropane alkaloids	➤ Hygrine (sedative), methylecogine and cocaine (CNS stimulant): <i>Erythroxylum coca</i> , erythroxylaceae	Ornithine

		<ul style="list-style-type: none"> ➤ Hyoscine, hyoscyamine and atropine (anticholinergic): <i>Datura metel</i>, <i>Datura stramonium</i>, <i>Atropa belladonna</i>, solanaceae 	
2	Pyrrrolizidine	<ul style="list-style-type: none"> ➤ Senecionine (oxytocic, controls heamorrhage): <i>Senecio aegyptius</i>, Asteraceae ➤ Lycospamimne: <i>Symphytum officinalis</i>, Boraginaceae ➤ Indicine-N-oxide: <i>Heliotropium indicum</i>, Boraginaceae 	
3	Piperidine	<ul style="list-style-type: none"> ➤ Pelletriene: <i>Punica granatum</i>, Punicaceae ➤ Anaferine: <i>Withania somnifera</i>, solanaceae lobeline (Respiratory stimulant): <i>Lobelia inflata</i>, Campanulaceae ➤ Sedamine: <i>Sedum acre</i>, Crassulaceae ➤ Piperine: <i>Piper nigrum</i>, piperaceae 	Lysine
4	Quinolizidine	<ul style="list-style-type: none"> ➤ Lupinine: <i>Lupinis luteus</i>, Fabaceae ➤ Sparteine: <i>Cytisus scoparius</i>, Fabaceae cytisine: <i>Cytisus laburnum</i>, Fabaceae 	
5	Indolizidine	<ul style="list-style-type: none"> ➤ Swainsonine: <i>Swainsona canescens</i>, Fabaceae ➤ Castanospermine: <i>Castanospermum australe</i>, Fabaceae 	
6	Pyridine	<ul style="list-style-type: none"> ➤ Nicotine and anabasine (Insecticide): <i>Nicotiana tabacum</i>, Solanaceae ➤ Ricinine: <i>Ricinus communis</i>, Euphorbiaceae ➤ Arecoline: <i>Areacatechu</i>, Areaceae 	Niconitic acid
7	Tetrahydroisoquinoline	<ul style="list-style-type: none"> ➤ Hordenine (Cardiotonic): <i>Hordeum vulgare</i>, Graminae ➤ Mescaline, anhalamine and 	Tyrosine

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		<p>anhalonine, (hallucino- genic): <i>Lophophora williamsii</i>, Cactaceae</p> <p>➤ Lophocerine: <i>Lophophora schottii</i>, Cactaceae</p> <p>➤ Papaverine and narceine (Narcotic analgesic): <i>Papaverum somniferum</i>, Papavaraceae</p> <p>➤ Tubocuranine (arrow poison): <i>Chondrodendron tomentosum</i>, Menispermaceae</p>	
8	Benzyltetrahydro-isoquin-oline	<p>➤ Morphine, codiene and thebaine: <i>Papaverum somniferum</i>, Papavaraceae</p> <p>➤ Salturadine, stephanine: <i>Stephania bancroftii</i>, Menispermaceae</p> <p>➤ Aristolochic acid: <i>Aristolochia serpentina</i>, Aristolochiaceae</p> <p>➤ Berberine (antiinflammatory): <i>berberis aristata</i>, Berberidaceae</p> <p>➤ Hydrastine: <i>Hydrastis canadensis</i>, Ranunculaceae</p>	
9	Phentyl isoquinoline	<p>➤ Autumnaline, colchicine, demecolcine, and deacetylcholchicine (antigout): <i>Colchicum autumnale</i>, Liliaceae</p>	
10	Terpenoid tetrahydro-isoquinoline	<p>➤ Emetine, cephaline (antiemoebic): <i>Cephalis ipecacuhana</i>, Rubiaceae</p>	
11	Indole alkaloids		
	Simple indole	<p>➤ Psilocine (Halucinogenetic): <i>Psilocybe mexicana</i>, Strophariaceae</p>	Tryptophan
	Beta carboline Indole	<p>➤ Harmine, harman (Narcotic hallucinogenic): <i>Peganum harmala</i>, Rutaceae</p>	
	Terpenoid indole	<p>Coryanthe type:</p> <p>➤ Ajmalicine (Antiarythmic): <i>Catharanthus roseus</i>, Apocynaceae</p>	

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		<ul style="list-style-type: none"> ➤ Yohimbine, reserpine and deserpidine (Antihypertensive): <i>Rauwolfia serpentina</i>, Apocynaceae ➤ Akuammicine, strychnine, brucine: <i>Strychnos nux-vomica</i>, Loagniaceae 	
		<p>Aspidosparma type :</p> <ul style="list-style-type: none"> ➤ Tabersonine: <i>Tabernaemontana corymbosa</i>, Apocynaceae ➤ Vindoline and vincamine: <i>Catharanthus roseus</i>, Apocynaceae 	
		<p>Iboga type :</p> <ul style="list-style-type: none"> ➤ Ibogaine (psychoactive): <i>Taberanthe iboga</i>, Apocynaceae, ➤ Catharanthine (antihypertensive): <i>Catharanthus roseus</i>, Apocynaceae 	
12	Pyrroloindole	<ul style="list-style-type: none"> ➤ Physostigmine (cholinergic): <i>Physostigma venenosum</i>, Fabaceae ➤ Ergometrine (oxytocic) and ergotamine (migrane treatment): <i>Claviceps purpurea</i>, Clavicipataceae 	
13	Quinoline alkaloids	<ul style="list-style-type: none"> ➤ Quinine, quinidine, chinchonine, chinchonidine (Antimalarial): <i>Chinchona succirubra</i>, Rubiaceae ➤ Camptothecin (Potent anticancer): <i>Camptotheca acuminata</i>, Nyssaceae 	
14	Quina-zoline	<ul style="list-style-type: none"> ➤ Vasicine/peganine (brochodialator): <i>Adhatoda vasica</i>, Acanthaceae 	Anthranilic acid
15	Acridine	<ul style="list-style-type: none"> ➤ Dictamnine: <i>Dicatamus albus</i>, Rutaceae Skimmianine: <i>Skimmia japonica</i>, Rutaceae 	
16	Imidazole	<ul style="list-style-type: none"> ➤ Pilocarpine and pilosine (Mitotic): <i>Pilocarpus jaborandi</i>, Rutaceae 	Histidine

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17	Amine	<ul style="list-style-type: none"> ➤ Connine (Anticonvulsant): <i>Conium maculatum</i>, Apiaceae ➤ Pinidine: <i>Pinus</i> species 	Acetate
		<ul style="list-style-type: none"> ➤ Ephedrine and pseudoephedrine, (CNS stimulant, bronchodilator): <i>Ephedra gerardiana</i>, Ephedraceae ➤ capsaicine (counter irritant): <i>Capsicum annum</i>, Solanaceae 	Phenylalanine
18	Terpenoid	<ul style="list-style-type: none"> ➤ Actinidine: <i>Actinidia polygama</i>, Actinidiaceae gentianine (Apetizer): <i>Gentiana lutea</i>, Gentianaceae ➤ Aconitine: <i>Aconitum napellus</i>, Ranunculaceae 	Monoterpenes
19	Steroid	<ul style="list-style-type: none"> ➤ Solasodine: <i>Solanum nigrum</i>, <i>S. tuberosum</i>, Solanaceae ➤ Tomatidine: <i>Lycopersicon esculente</i>, Solanaceae ➤ Conessine: <i>Holarrhena antidysentrica</i>, Apocyanaceae 	Steroids
20	Purine	<ul style="list-style-type: none"> ➤ Caffiene: <i>Coffea arabica</i>, <i>C. liberica</i>, Rubiaceae ➤ theobromine and theophylline: <i>Thea sinensis</i>, Theaceae, <i>Theobroma cacao</i>, Sterculiaceae 	Purine

BIOSYNTHESIS OF VITAMINS

Common Name	Chemical Name	Deficiency Disease	Biosynthetic Origins
Vitamin A	Retinol, retinal	Night-blindness	Mevalonate pathway
Vitamin B ₁	Thiamine	Beriberi	Isoprenoid/DXP pathway
Vitamin B ₂	Riboflavin	Ariboflavinosis	GTP and Ribulose-5-phosphate
Vitamin B ₃	Niacin, niacinamide	Pellagra	Tryptophan
Vitamin B ₅	Pantothenic acid	Paresthesia	Methylene tetrahydrofolate and beta alanine

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Common Name	Chemical Name	Deficiency Disease	Biosynthetic Origins
Vitamin B ₆	Pyridoxine, pyridoxamine, pyridoxal	Anemia, peripheral neuropathy	Isoprenoid/ DXP pathway
Vitamin B ₇	Biotin	Dermatitis, enteritis	Pimelic acid
Vitamin B ₉	Folic acid	Birth defects	Shikimate pathway
Vitamin B ₁₂	Cyanocobalamine, methylcobalamine	Megaloblastic anemia	Glutamate
Vitamin C	Ascorbic acid	Scurvy	D-glucose
Vitamin D	Ergocalciferol, cholecalciferol	Rickets and Osteomalacia	Mevalonate pathway
Vitamin E	Tocopherols, tocotrienols	Deficiency is very rare	Shikimate pathway
Vitamin K	phylloquinone, menaquinones	Hemorrhage	Shikimate pathway

BIOSYNTHESIS OF CARBOHYDRATES

Class	Pathway	Precursor	Examples
Mono saccharides	Photosynthesis	Glyceraldehyde-3-Phospahte	Glucose (dextrose), fructose (levulose) and galactose
Oligosaccharides	Photosynthesis	Glucose	Maltose, sucrose, and lactose
Poly saccharides	Photosynthesis	Glucose	-
Homo- Poly saccharides	Photosynthesis	Glucose	Cellulose, starch, chitin
Hetero - Poly saccharides	Photosynthesis	Glucose	Heparin

BIOSYNTHESIS OF GLYCOSIDES

Class	Pathway	Precursor	Examples
Anthraquinones	Acetate pathway	Polykedite	Rhein, aloe-emodin, emodin
Cardioactive sterols	Acetate mevalonate pathway	Squalene (Triterpenoid) moiety	Digotoxigenin, digoxigenin

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Class	Pathway	Precursor	Examples
Saponins	Acetate mevalonate pathway	Squalene (Triterpenoid) moiety	Diosgenin
Flavonoids	Shikimic acid pathway	Cinnamoyl-Coa	Quercetin, hesperidin, kaemferol
Cyanogenetic	Shikimic acid pathway	Amino acid phenylalanine and tyrosine	Amygdalin, prunasin
Coumarin	Shikimic acid pathway	Cinnamic acid	Psoralen, khellin
Isothiocyanate	Amino acids	Methionine, phenylalanine	Sinigrin, sinablin

BIOSYNTHESIS OF TANNINS

Class	Pathway	Precursor	Examples
Hydrolysable tannins	Shikimic acid	Quinic acid	Gallic acid, egallic acid
Non-hydrolysable tannins	Shikimic acid pathway	Cinnamoyl-CoA	Tannic acid

BIOSYNTHESIS OF ESSENTIAL OIL AND TERPENOIDS

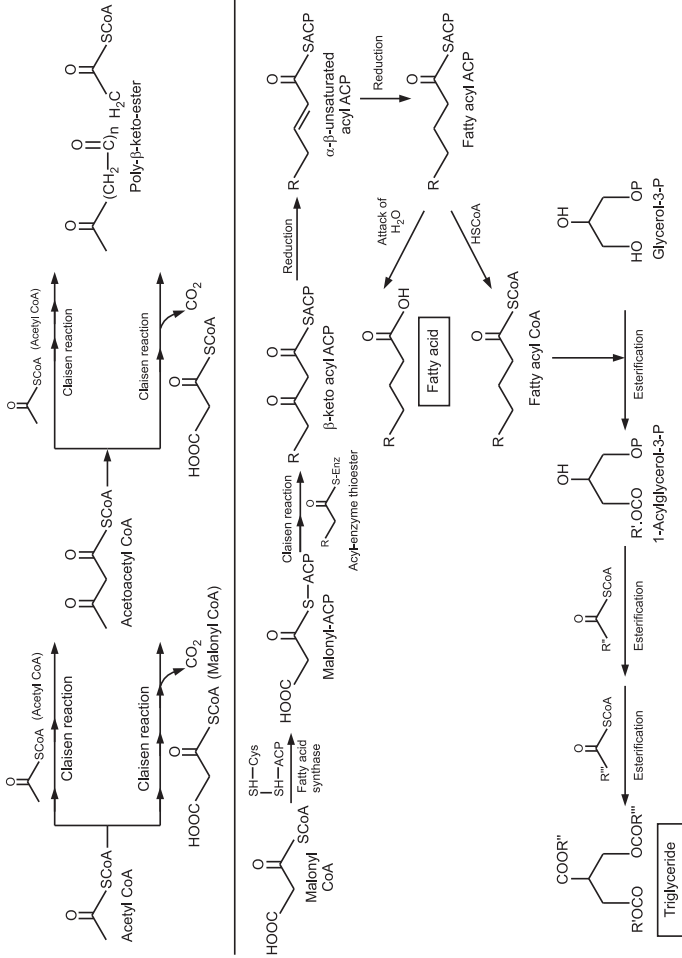
Class	Pathway	Precursor	Examples
Hemiterpenes	Mevalonate pathway	Mevalonic acid	Isoprene
Mono-terpenoids (Geranyl pyrophosphate)	Mevalonate pathway	Mevalonic acid	Citral, citronellal, citronellol, linalool, limonene, menthol, thymol, carvacrol, pinene, Camphor, borneol and eucalyptol
Sesqui-terpenoids (Farnesyl pyrophosphate)	Mevalonate pathway	Mevalonic acid	Zingiberene, caryophyllene
Di-terpenoids (geranylgeranyl pyrophosphate)	Mevalonate pathway	Mevalonic acid	Phytane, labdane, abietane, taxadiene
Tri-terpenoids (Squalene)	Mevalonate pathway	Mevalonic acid	Triterpenoid saponins: glycyrrhizetic acid, cucurbitacins

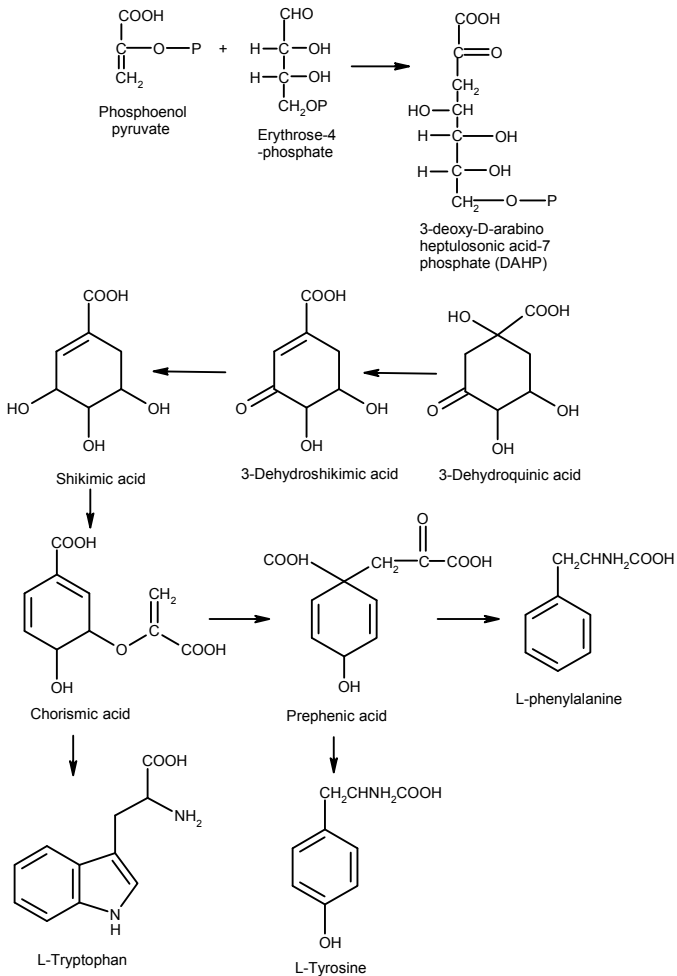
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Class	Pathway	Precursor	Examples
Tetra-terpenoids (Carotenoids)	Mevalonate pathway	Mevalonic acid	Carotenes, xanthophylls, lycopenes
Polyterpenoids	Mevalonate pathway	Mevalonic acid	Rubber

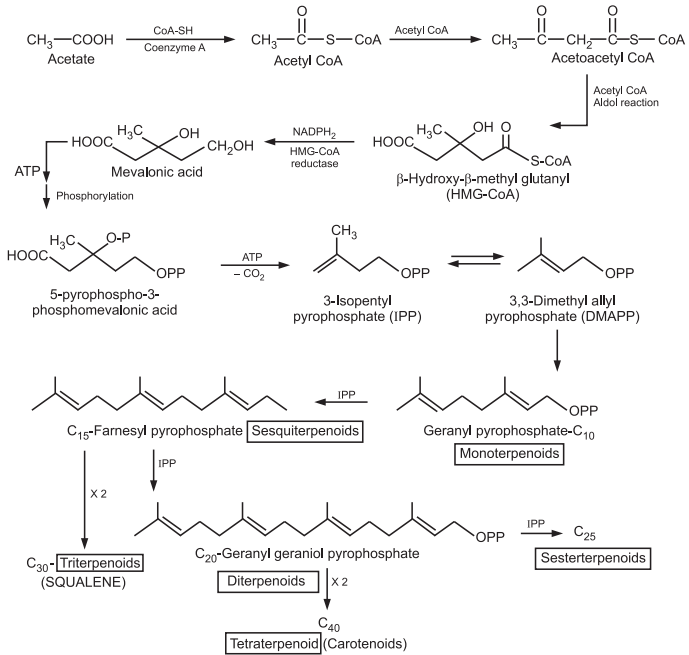
OTHER CLASSES

Class	Pathway	Precursor	Examples
Lignans	Shikimic acid pathway	Cinnamoyl-CoA	Pinoresinol, podophyllotoxin, and steganacin
Quassinoids	Mevalonate pathway	Triterpenoid	Quassin, neoquassin
Xanthophylls (Oxygenated carotenoids)	Mevalonate pathway	Tetraterpenoid	Zeaxanthin, lutein, and violaxanthin
Leuco-anthocyanides	Shikimic acid pathway	Cinnamoyl-CoA	Leucocyanidin leucodelphinidin leucofisetinidin leucomalvidin leucopelargonidin
			leucopaeonidin leucorobinetinidin melacacidin
Anthocyanins	Shikimic acid pathway	Cinnamoyl-CoA	Aurantidin cyanidin delphinidin europinidin pelargonidin malvidin peonidin petunidin, rosinidin
Phenyl-propanoids	Shikimic acid pathway	Cinnamic and p-coumaric acid	Caffeic acid, stilbenes (resveratrol), flavonoids, lignans, lignins
Coumarins	Shikimic acid pathway	Cinnamic acid	Furanocoumarins

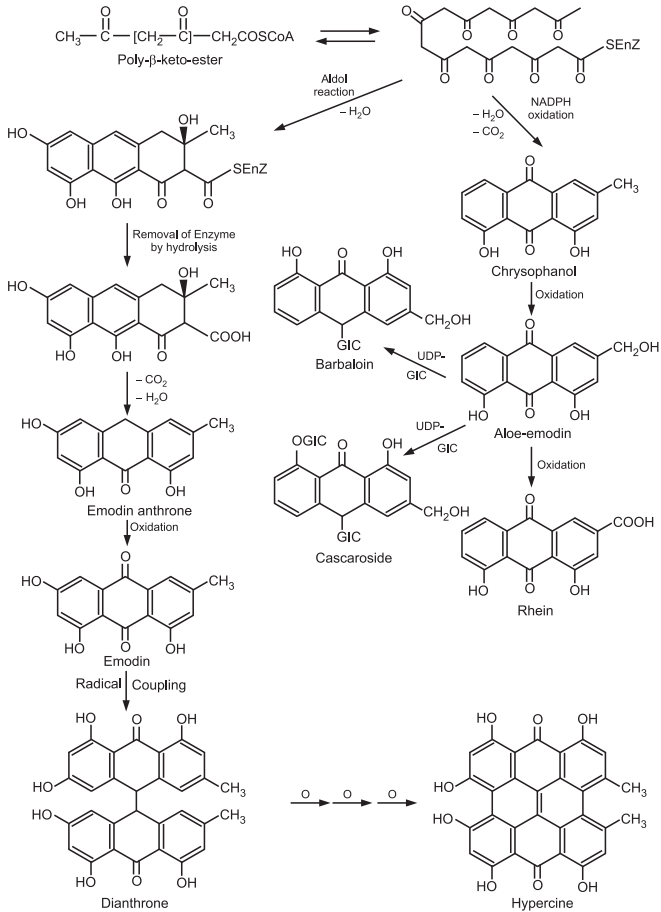


*Shikimic acid pathway*

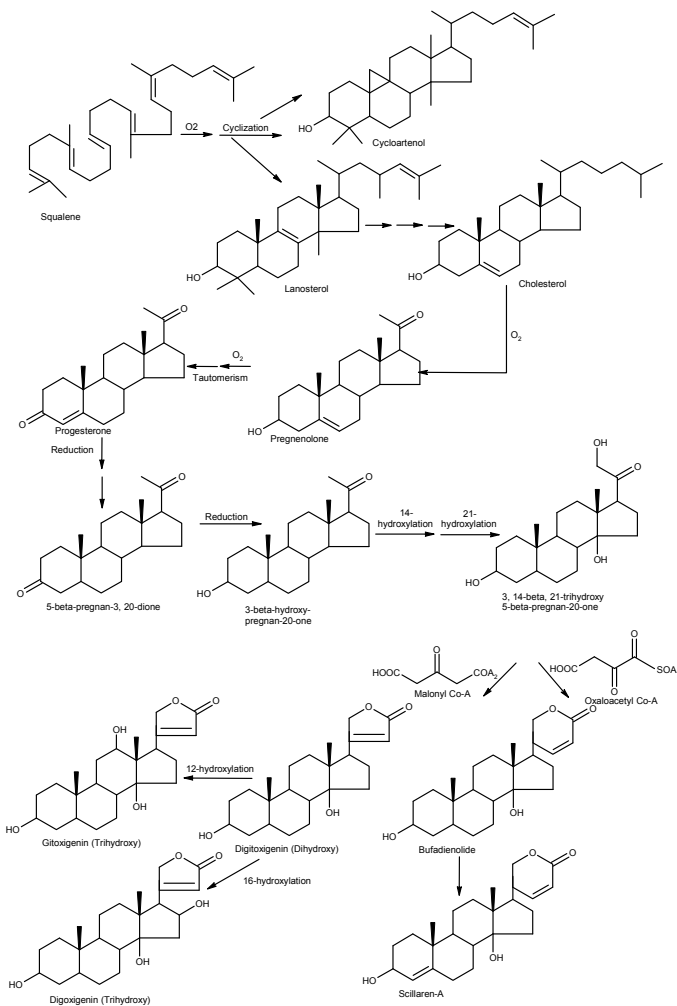
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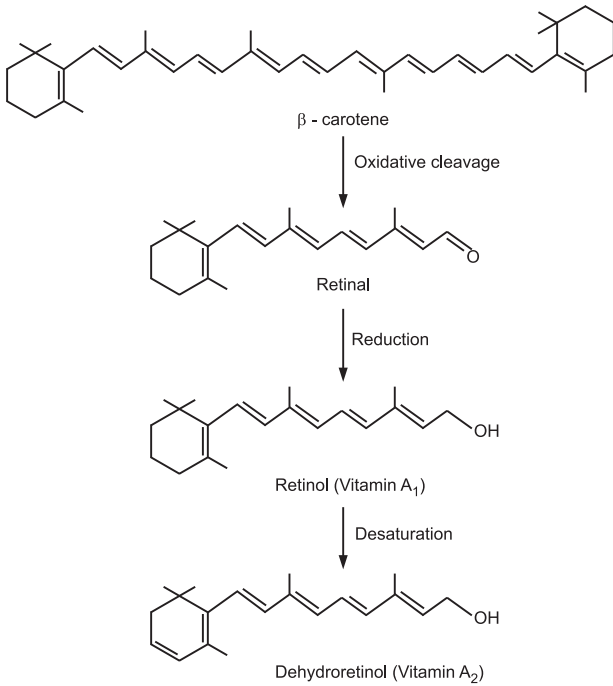
Acetate Mevalonate (Isoprenoid) Pathway



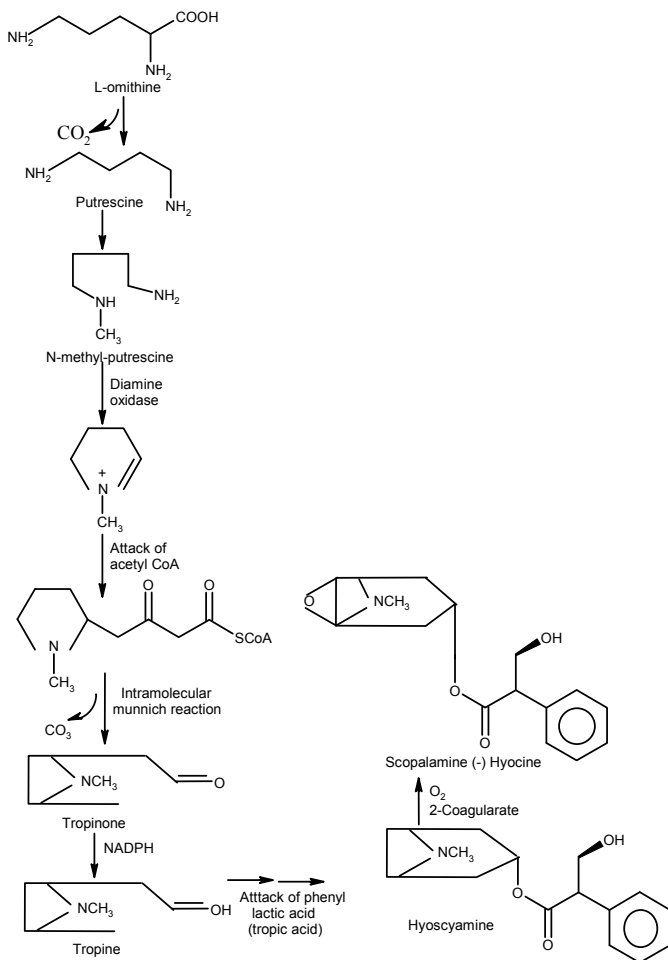
Anthraquinone biosynthesis Pathway



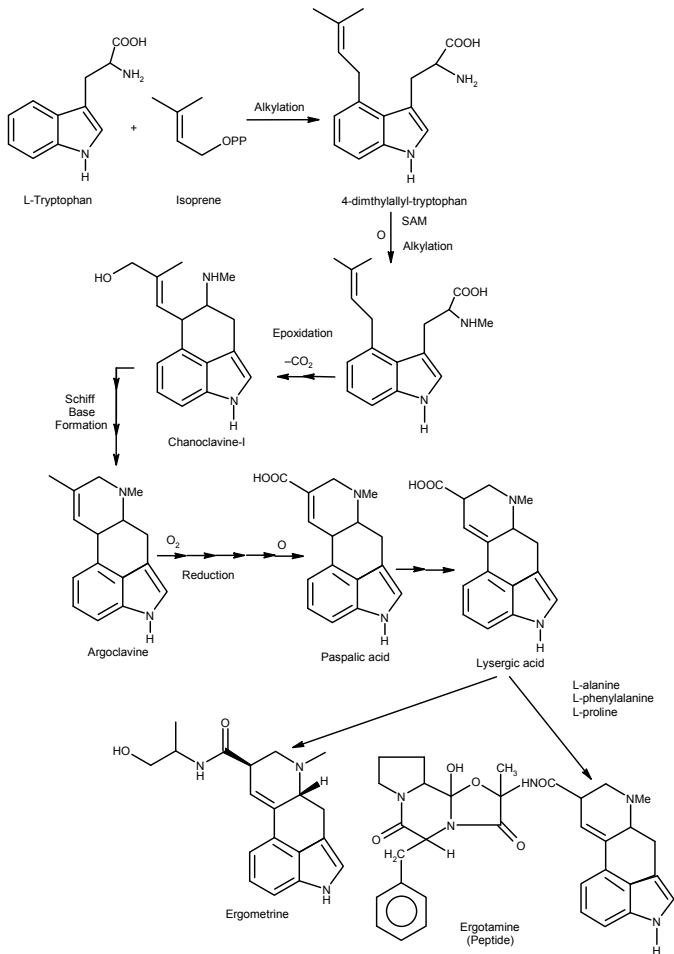
Cardioactive sterol biosynthesis pathway

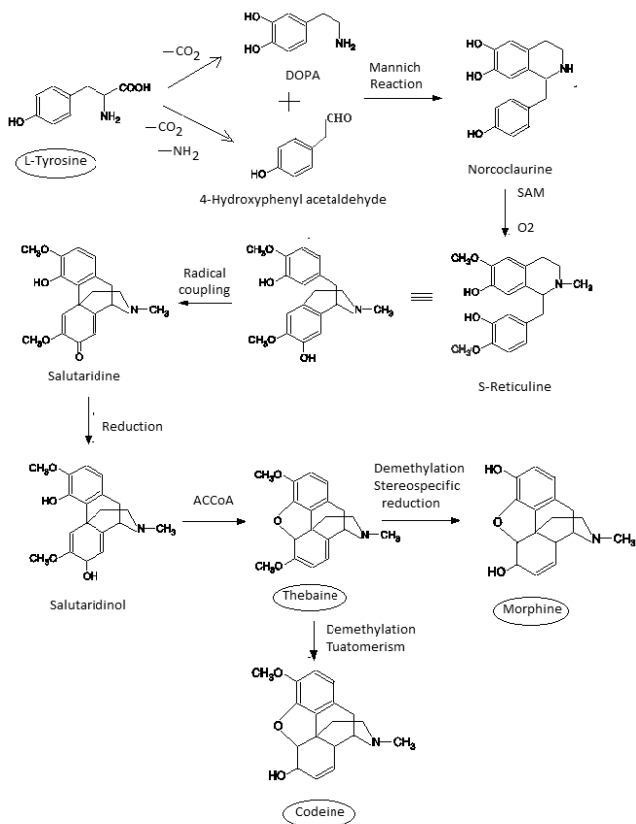


Vitamin A biosynthesis



Tropane alkaloid biosynthesis pathway

**Indole alkaloid (ergot) alkaloid biosynthetic pathway**



Opium alkaloid biosynthetic pathway