



FACULTY  
OF SCIENCE  
Masaryk University



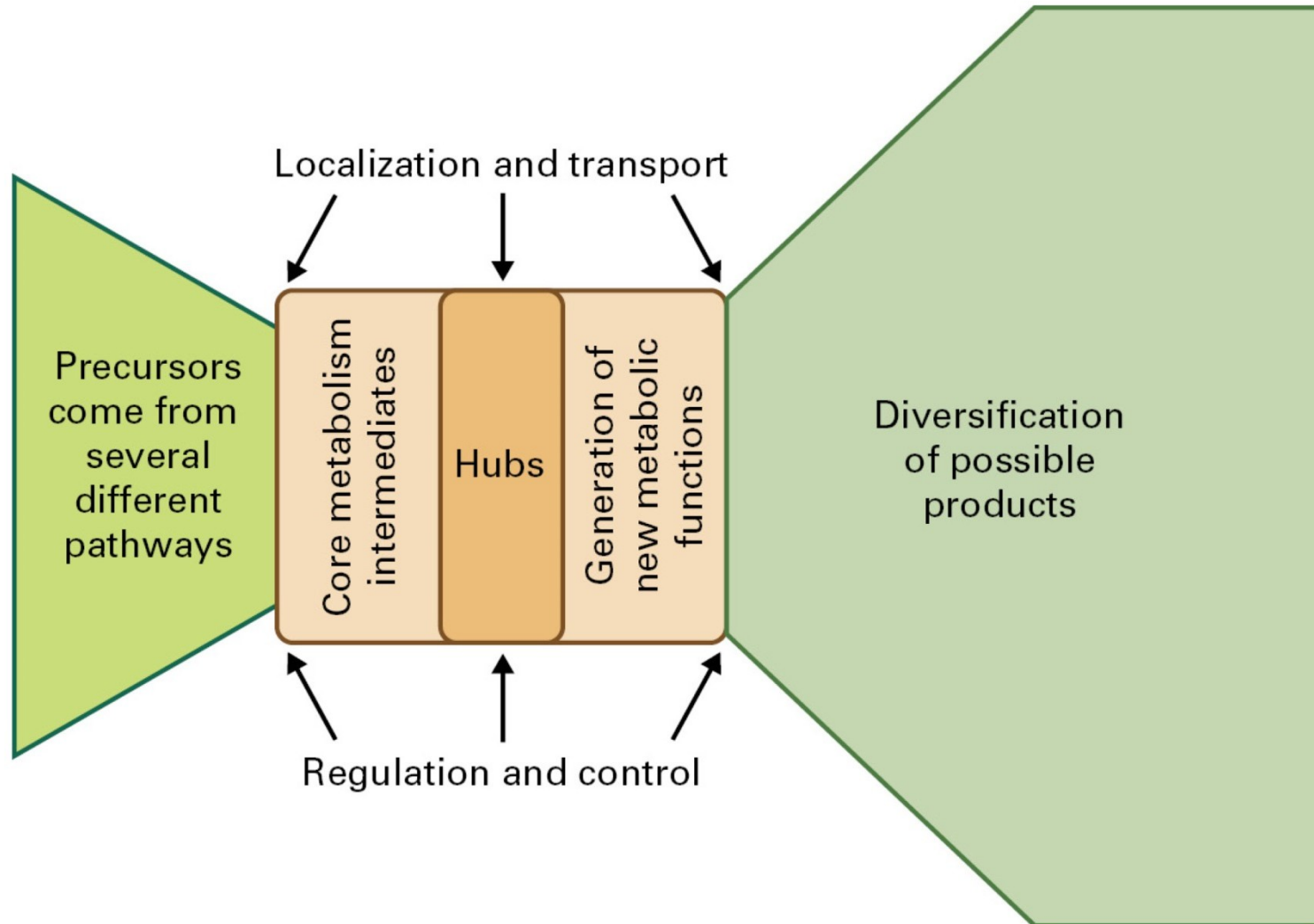
# Secondary metabolites



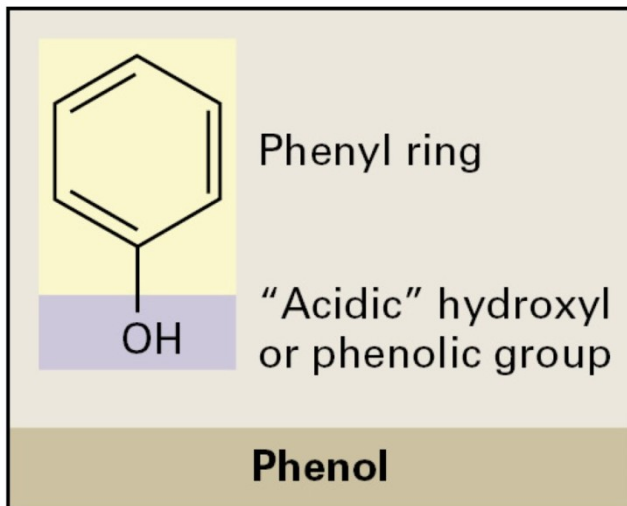
Katerina Dadakova, Department of Biochemistry

Figures adopted from Buchanan et al., Biochemistry & molecular biology of plants

## Diversity of plant natural products



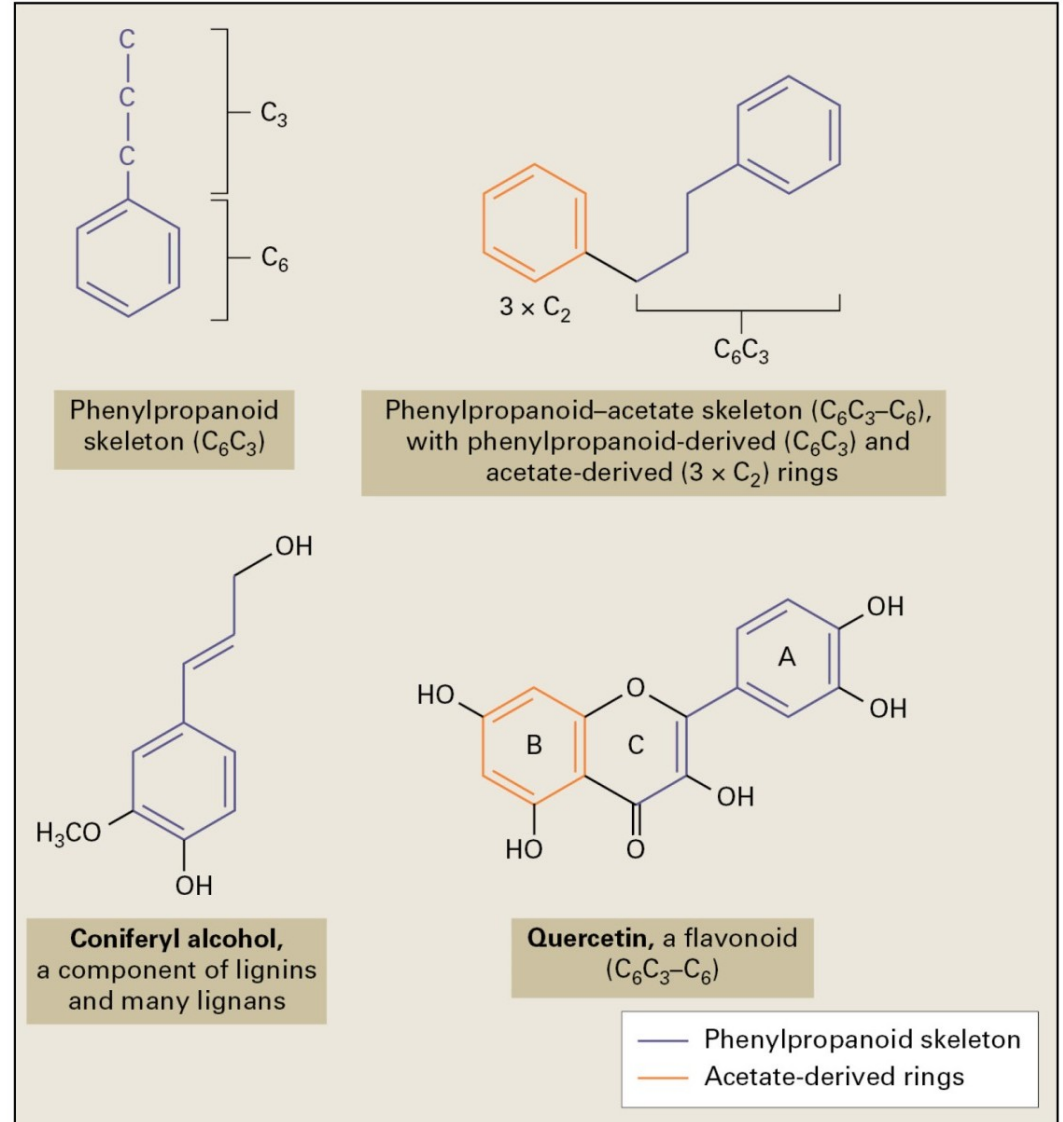
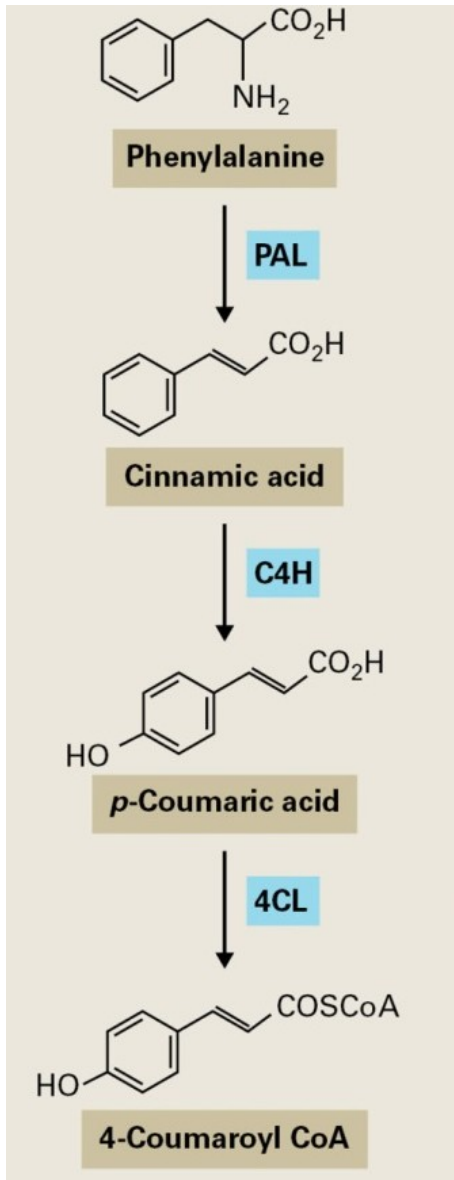
## Phenolic compounds



Major subclasses of phenolic compounds:

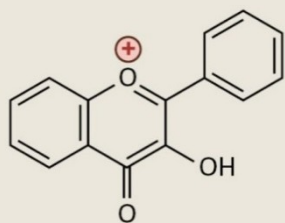
- flavonoids
  - flavones
  - flavonols
  - flavanones
  - anthocyanidins
  - isoflavones
  - chalcones
- stilbenes
- coumarins and furanocoumarins
- lignins and lignans
- naphtha- and anthraquinones
- diarylheptanoids

# Phenolic compounds

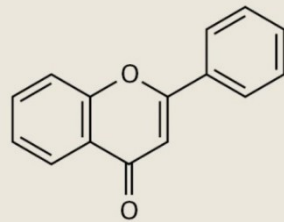


# Phenolic compounds

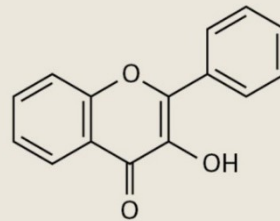
Challenge	Phenolic compounds	Pathway
UV irradiation	Flavonoids (anthocyanins, proanthocyanidins, condensed tannins, isoflavonoids, flavones, flavonols, etc.)	Phenylpropanoid-acetate
Desiccation	Suberins	Phenylpropanoid-fatty acid
Gravity	Lignins	Phenylpropanoid
Herbivores/pathogens	Stilbenes, coumarins, furanocoumarins	Phenylpropanoid-acetate
	Diarylheptanoids, gingerols, phenylphalenones, lignans, volatile aromatics	Phenylpropanoid-acetate
	Hydrolyzable tannins	Shikimate



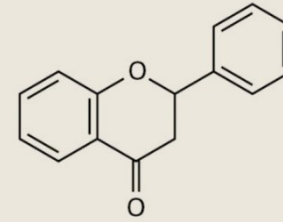
Anthocyanidins



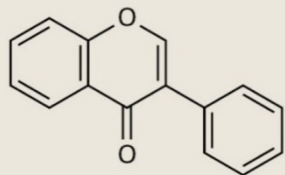
Flavones



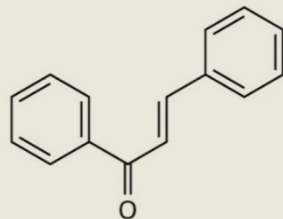
Flavonols



Flavanones



Isoflavones



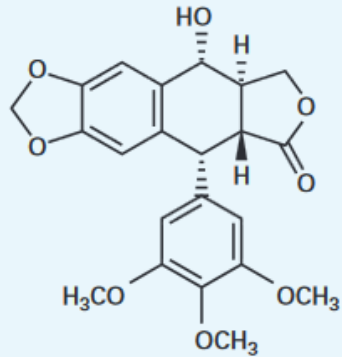
Chalcones

## Flavonoids

# Phenolic compounds

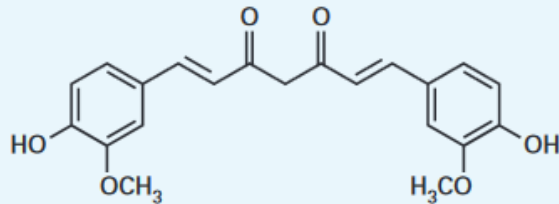
## Lignans

Podophyllotoxin

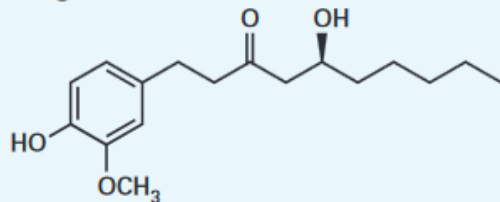


## Diarylheptanoids

Curcumin

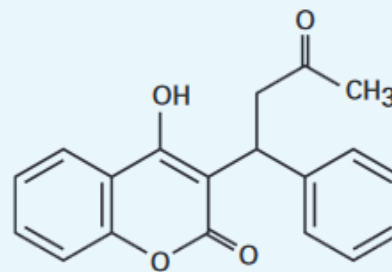


Gingerol

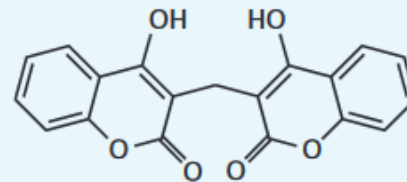


## Coumarins

Warfarin

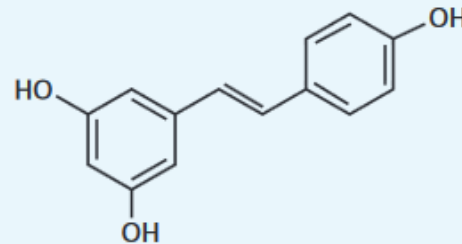


Dicoumarol



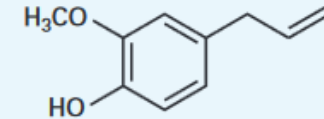
## Stilbenes

Resveratrol

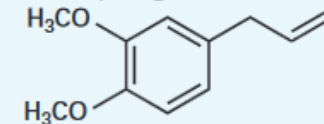


## Phenylpropenes

Eugenol

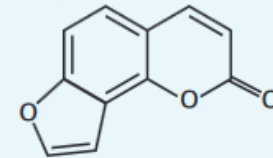


Methyleugenol

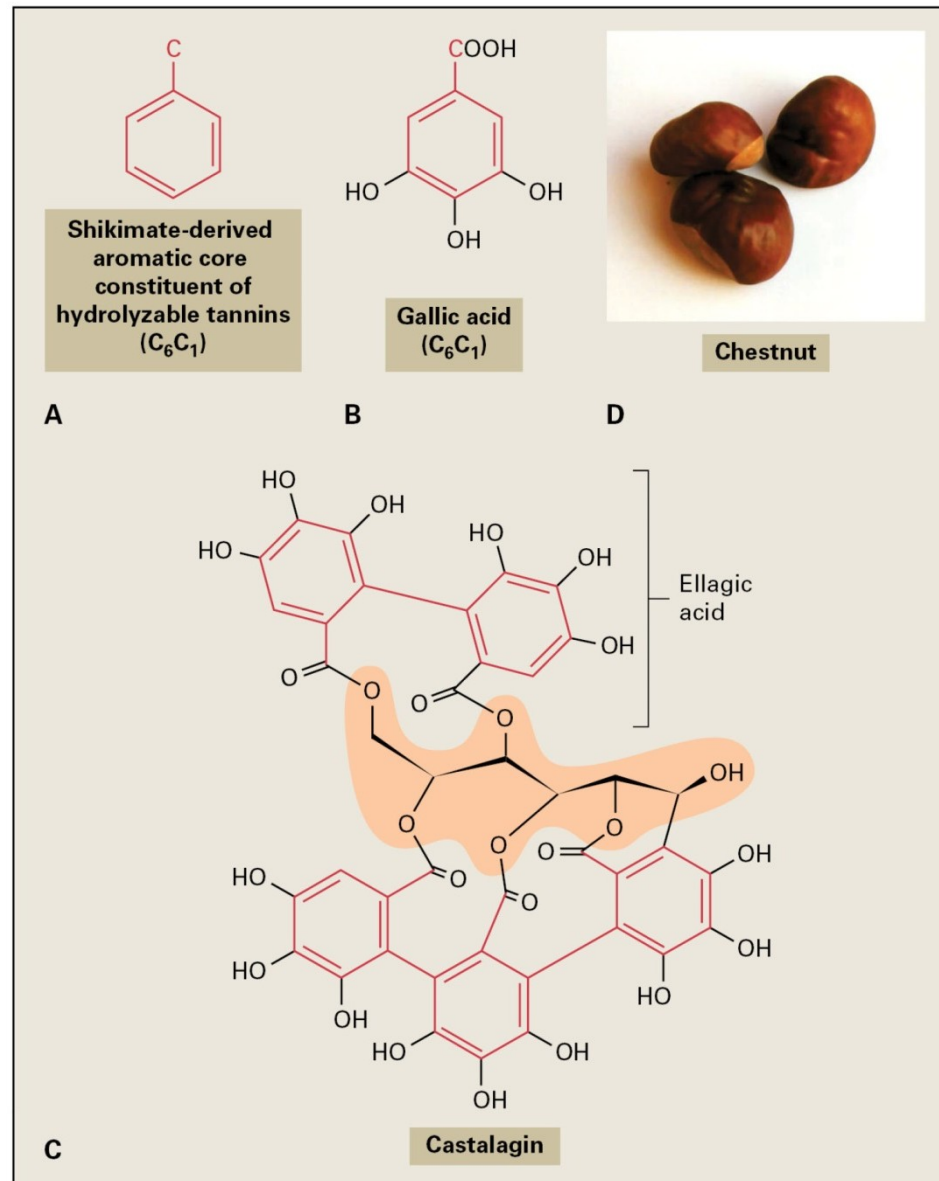


## Furanocoumarins

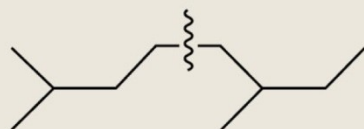
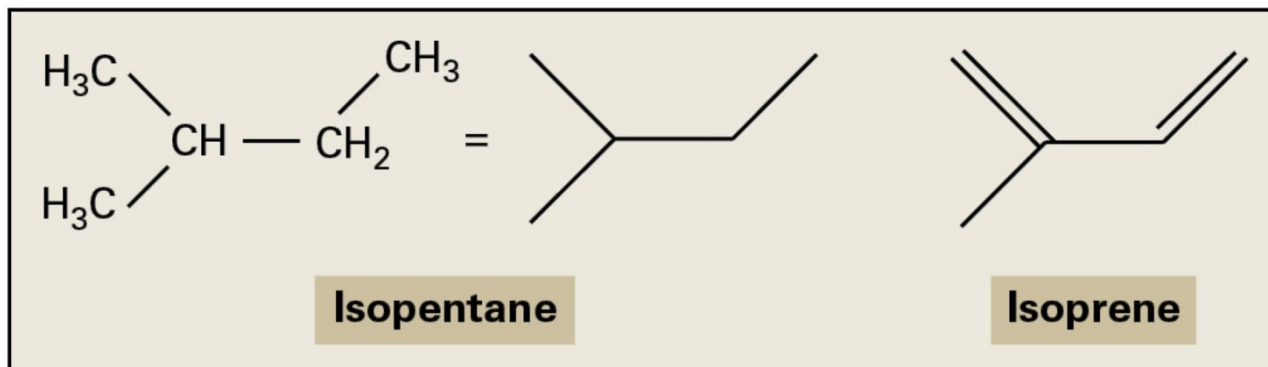
Angelicin



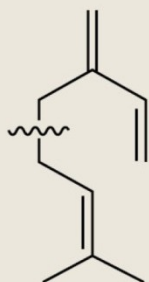
# Phenolic compounds



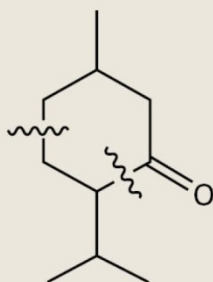
# Terpenoids



## Monoterpenes (C<sub>10</sub>)

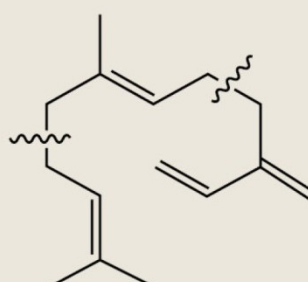


**Myrcene**

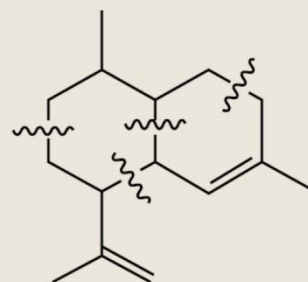


**Menthone**

## Sesquiterpenes (C<sub>15</sub>)

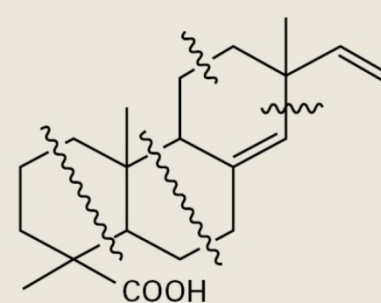


**(E)-β-Farnesene**



**Amorpha-4,11-diene**

## Diterpene (C<sub>20</sub>)



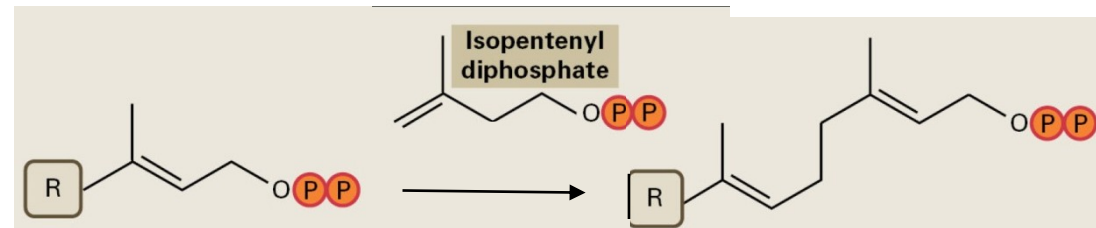
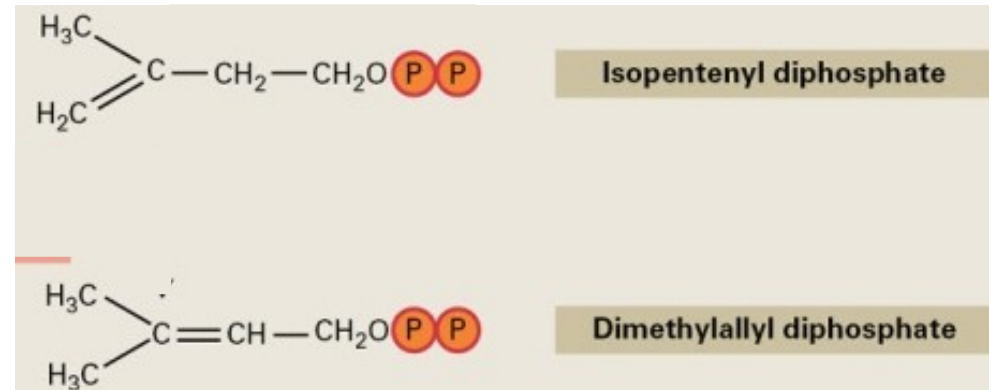
**Pimaric acid**



# Terpenoids

## Terpenoid biosynthesis:

- Biosynthesis of the basic five-carbon unit
- Repetitive additions of C<sub>5</sub> units
- Formation of parent carbon skeletons
- Modification of terpenoid skeletons

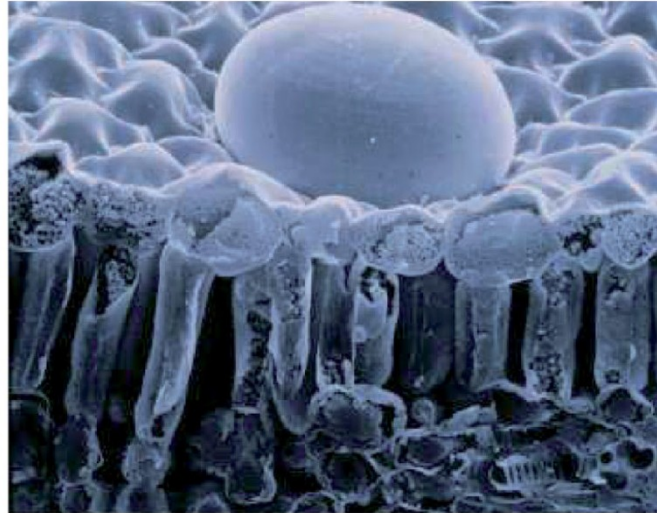


The prenyltransferase reaction

# Terpenoids



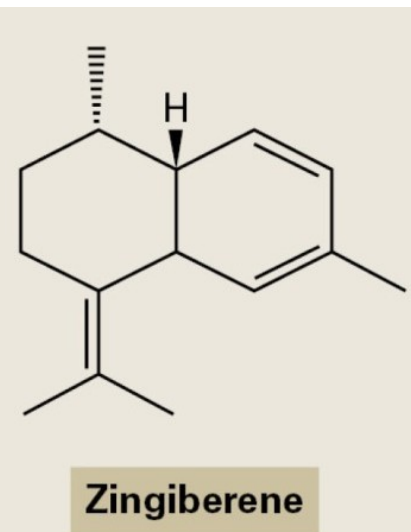
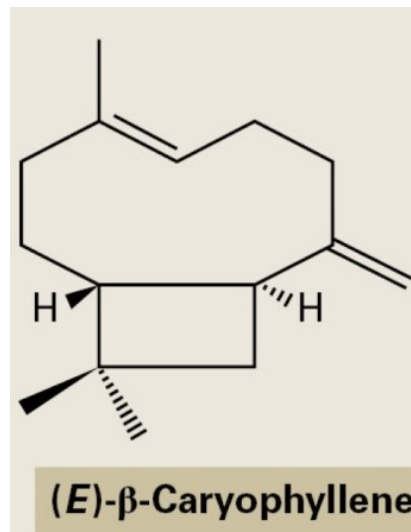
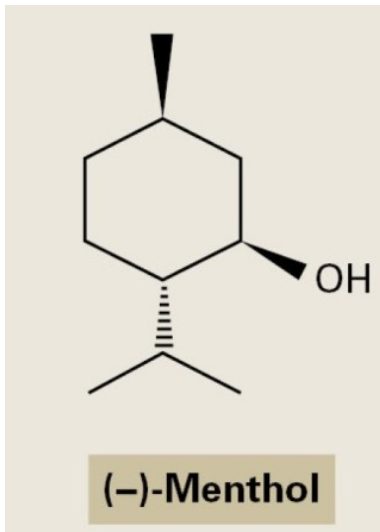
Resin



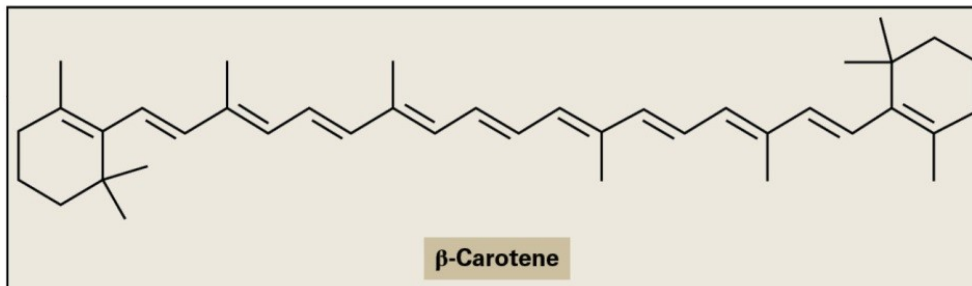
Oil stored in a glandular hair



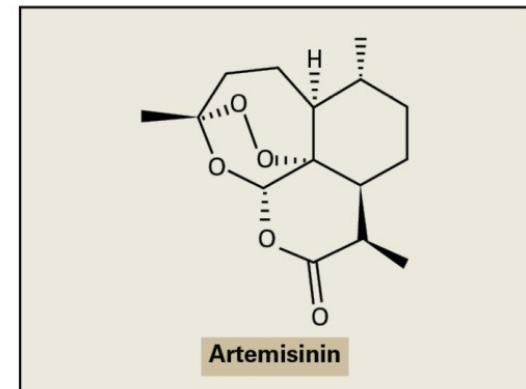
Plant latex



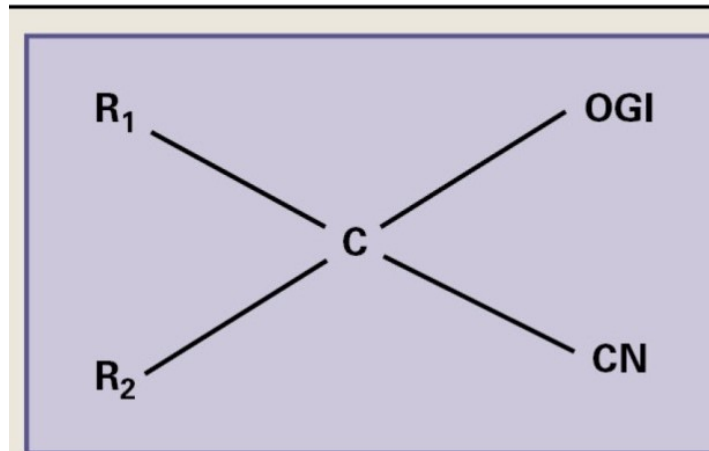
# Terpenoids



A

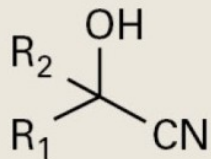


## Cyanogenic glycosides

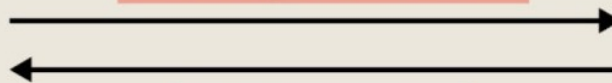


OGlc = glucose residue  
 attached by *O*-β-D-glucosyl linkage  
 CN = nitrile group  
 R<sub>1</sub> = aliphatic or aromatic group  
 R<sub>2</sub> = usually H

### α-Hydroxynitrile



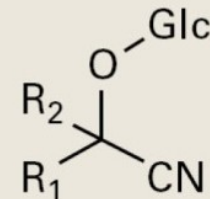
Glucosyltransferase



β-Glucosidase



### Cyanogenic glycoside



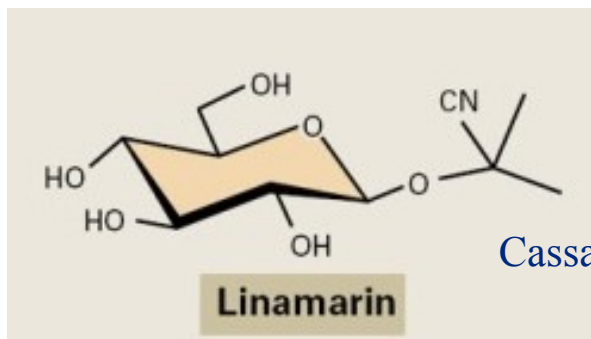
α-Hydroxynitrilases



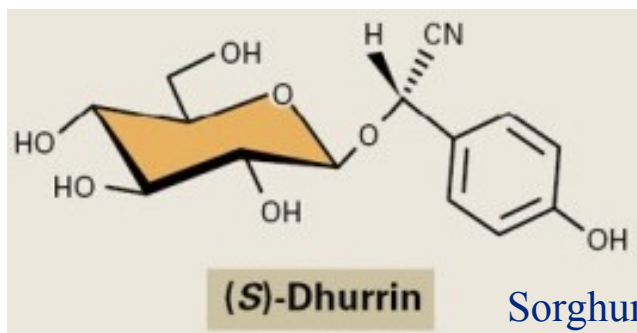
Insect defense compounds



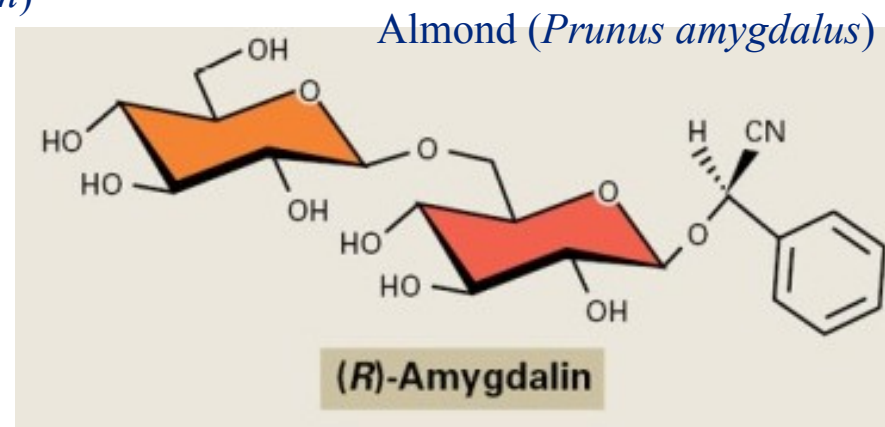
## Cyanogenic glycosides



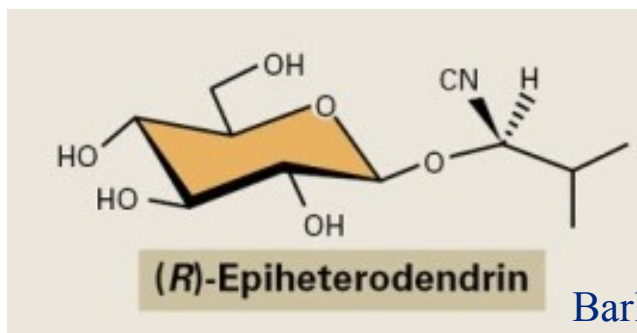
Cassava (*Manihot esculentum*)



Sorghum (*Sorghum bicolor*)

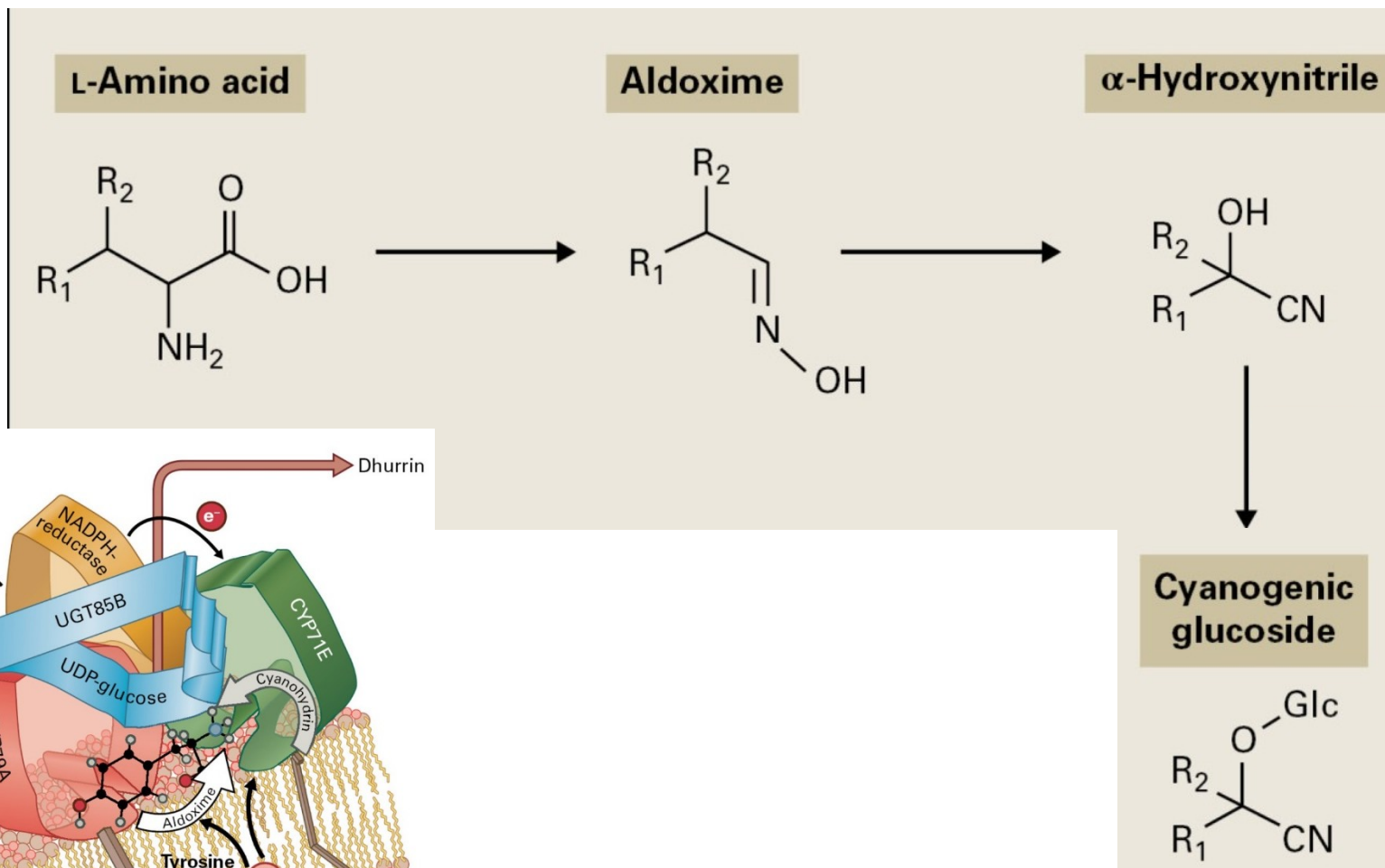


Almond (*Prunus amygdalus*)

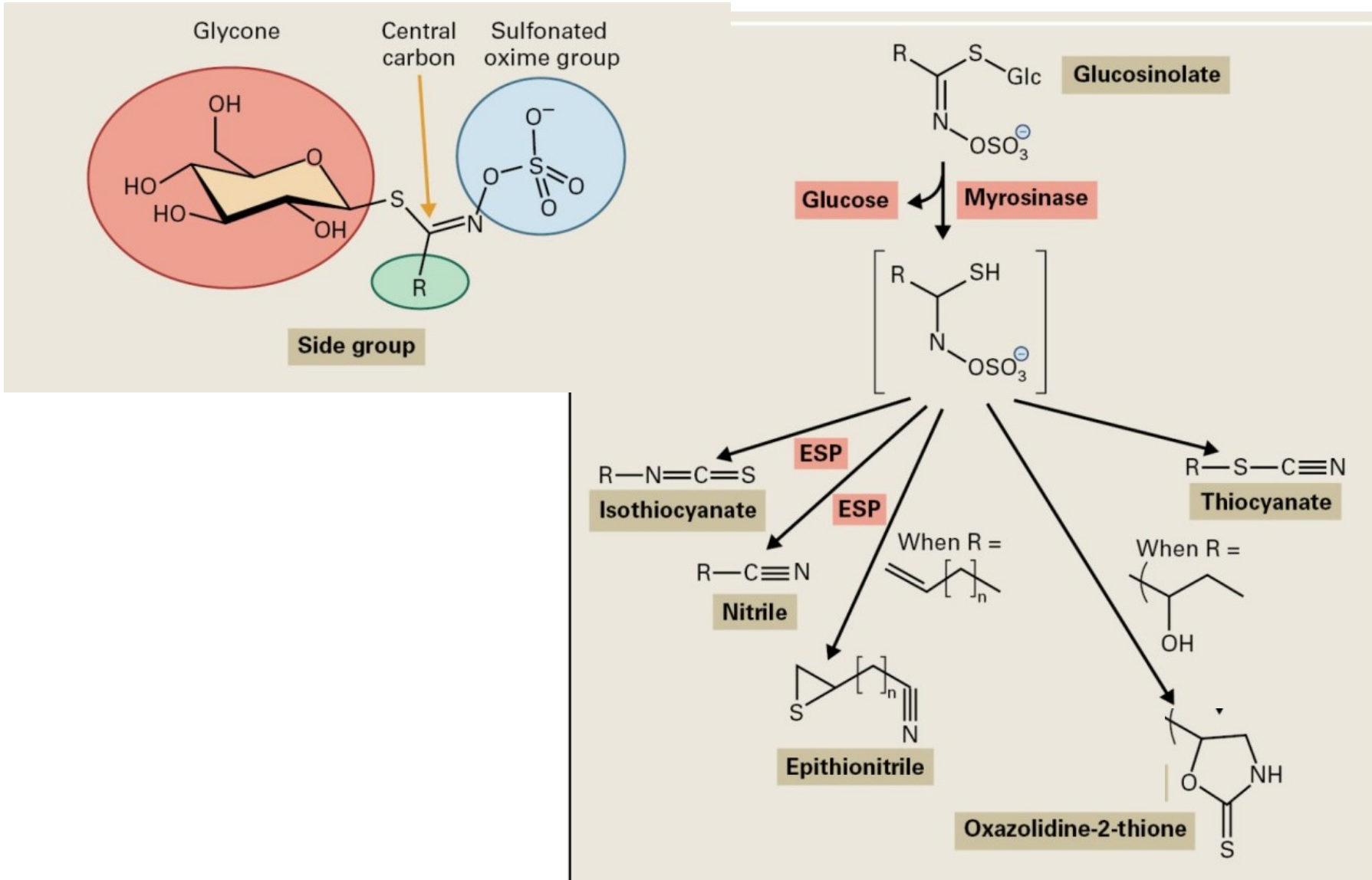


Barley (*Hordeum vulgare*)

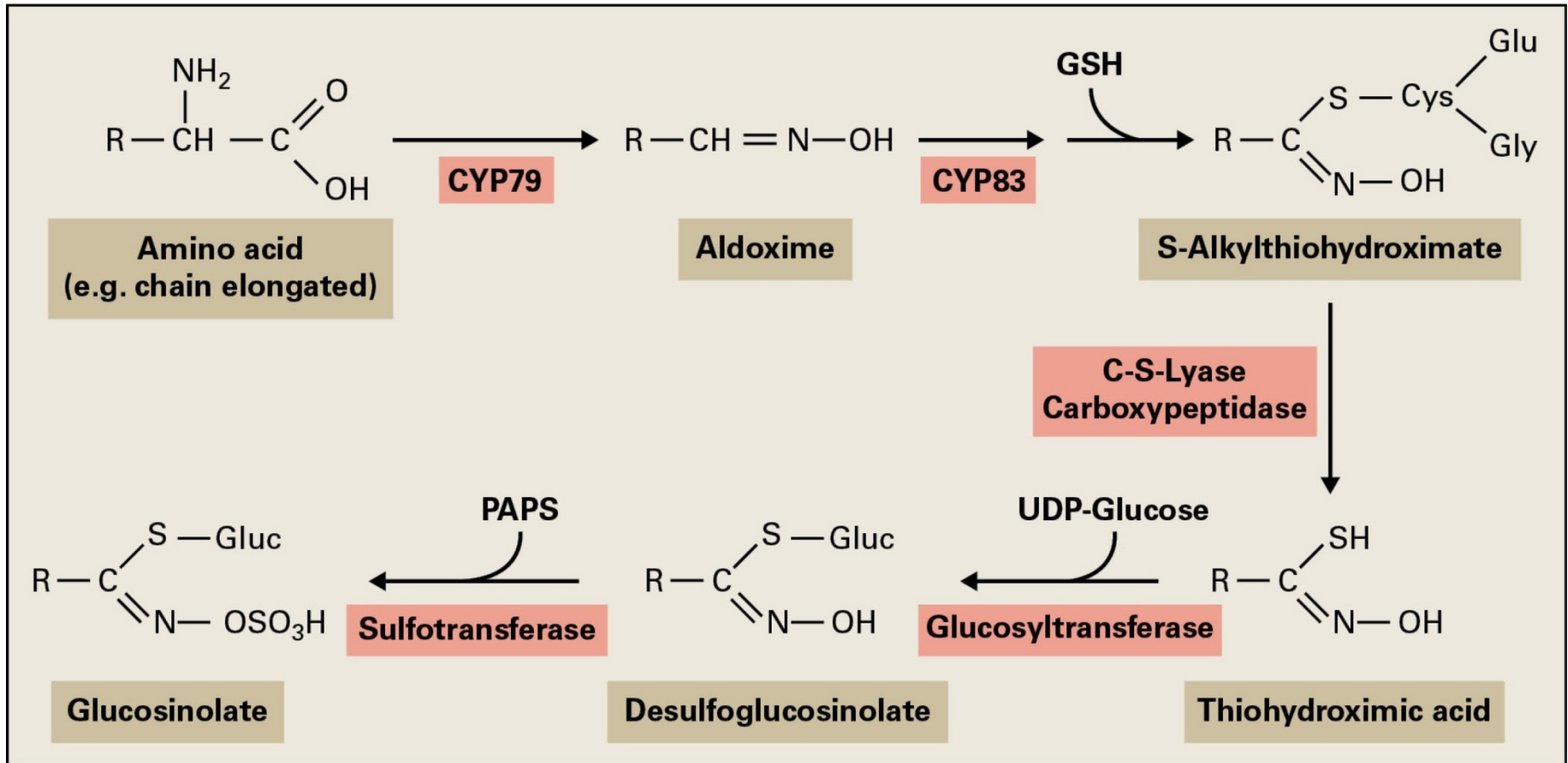
# Cyanogenic glycosides



# Glucosinolates



# Glucosinolates

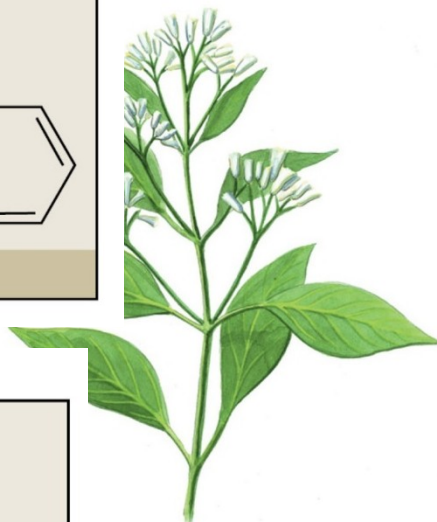
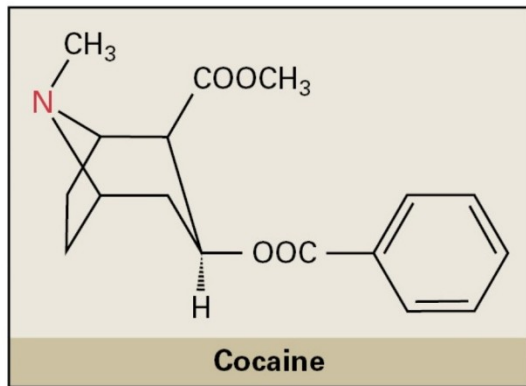




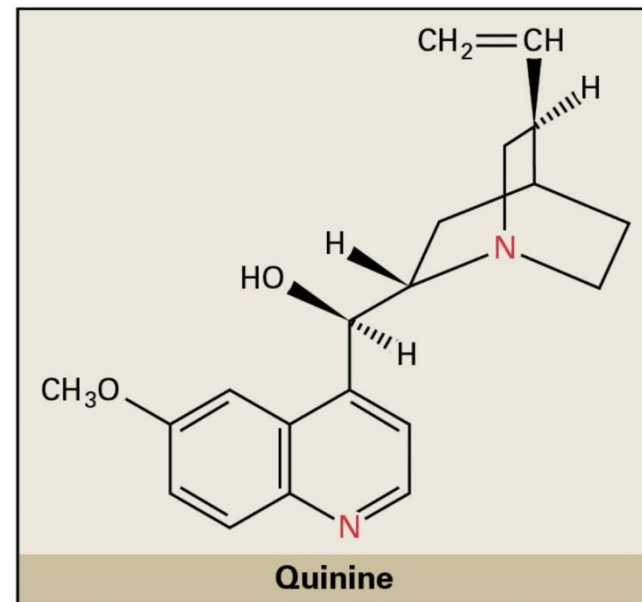
# Alkaloids



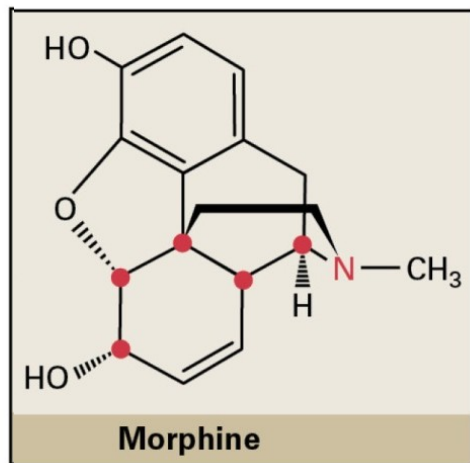
*Erythroxylum coca*



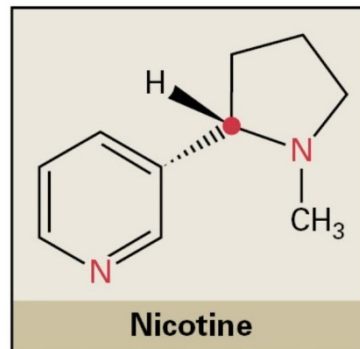
*Cinchona officinalis*



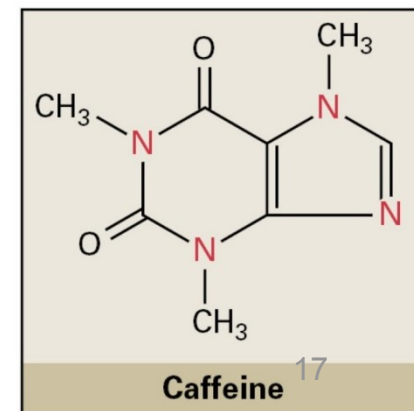
*Papaver somniferum*



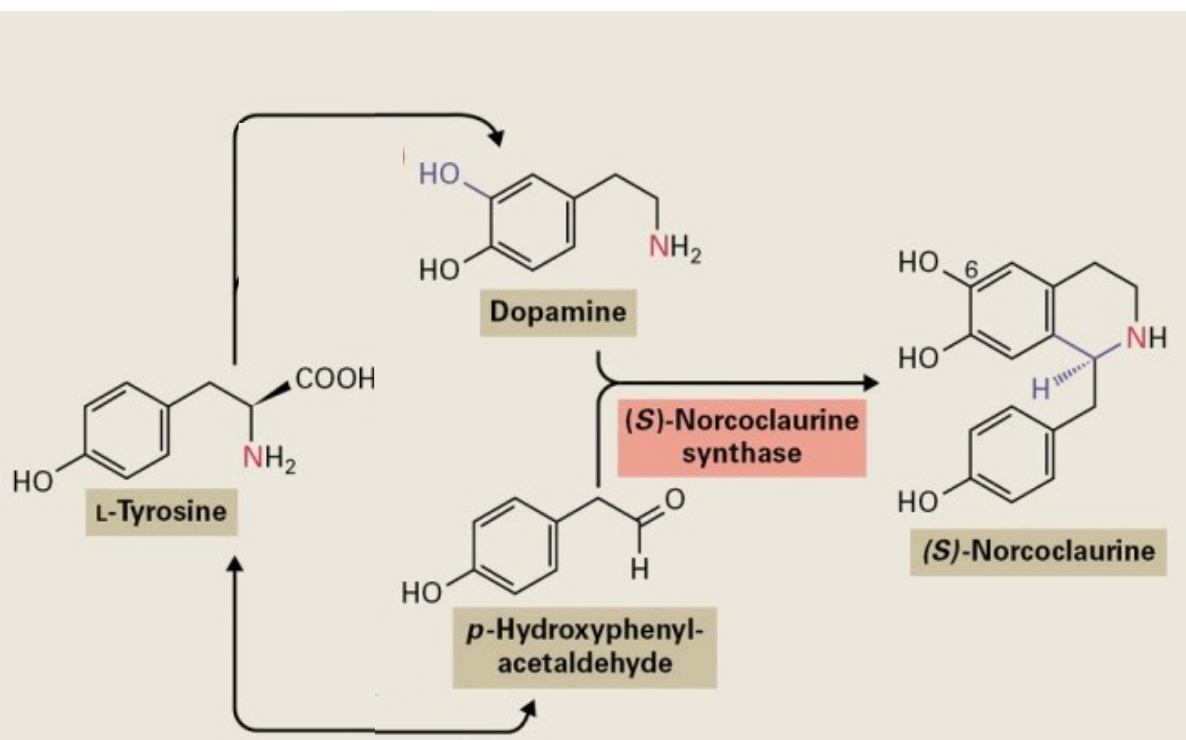
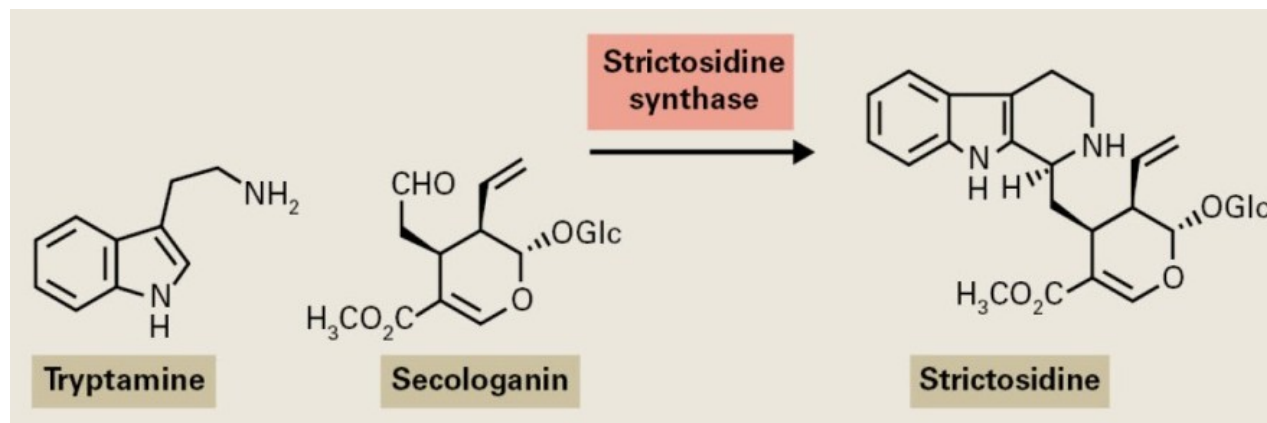
*Nicotiana tabacum*



*Coffea arabica*



## Alkaloids



# Alkaloids

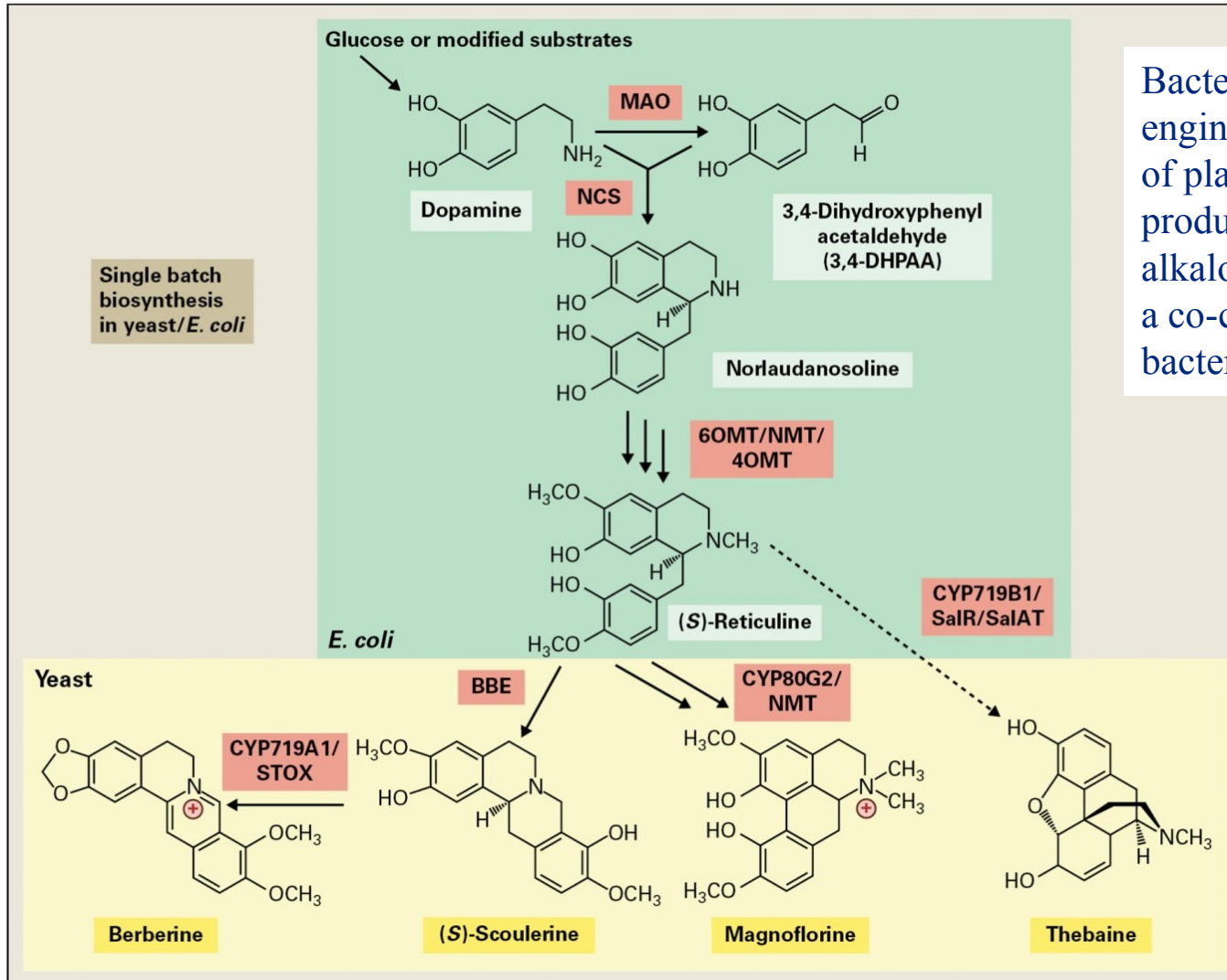


Ꝛ Throchiscorum Stiliticorum Ꝛ xij .  
 Viperinorum ,  
 Magmatis Hedycroi ,  
 Piperis longi ,  
 Opy Toctaci ana Ꝛ v j ,  
 Rosarum rubrarum ,  
 Iridis ,  
 Succu Glycyrrhiza ,  
 Seminis Buniadis ,  
 Scordij ,  
 Opopassani ,  
 Cinnamonu ,  
 Agarici ana Ꝛ ii j ,  
 Costi ,  
 Nucis Indica ,  
 Diacardii Celtici ,  
 Rhizomatis ,  
 Radicis Pentaploidi ,  
 Zinziberis ,  
 Prasi albi ,  
 Stachadis Arabica ,  
 Schanantbi ,  
 Seminis Petroselini Macedonici ,  
 Calamintha montana ,  
 Caffie lignea ,  
 Croci ,  
 Piperis albi ,  
 Nigri ,  
 Miris Trogloditidis ,  
 Turpis confendi ,  
 Thorschingina Chia ,  
 ana Ꝛ j b ,  
 Radicum Gentiana ,  
 Asoni Feri ,  
 Mtu Athamantici ,  
 Valeriana majoris ,  
 Nardi Celtica ,  
 Anoni Taurini ,  
 Chamelyris ,  
 Camis Hyperici ,  
 Seminis Amico ,  
 Thlaspedos ,  
 Anisi ,  
 Feniculi ,  
 Sileos Massiliensis ,  
 Cardamomi minoris ,  
 Malabathri ,  
 Coma Polymontani ,  
 Chamadyos ,  
 Carpopaljami ,  
 Succi Hypocistidis ,  
 Gummi Arabici ,  
 Styracis Calamiae ,  
 Terra Lemnia ,  
 Chalchitidis ,  
 Sagapeni ana Ꝛ j ,  
 Radicum Aristolochidensis ,  
 Coma Centaurii minoris ,  
 Seminis Drauci Cretici ,  
 Opopassani ,  
 Galbani ,  
 Bisummi Indici ,  
 Castorei anni Ꝛ b ,  
 Mellis optimi de sumati lb xxviii .  
 Vini generosi quantum satis .





# Alkaloids



Bacteria and yeast have been engineered with a combination of plant and animal genes to produce isoquinoline alkaloids. Single batch means a co-culture of yeast and bacterium.