



FACULTY  
OF SCIENCE  
Masaryk University



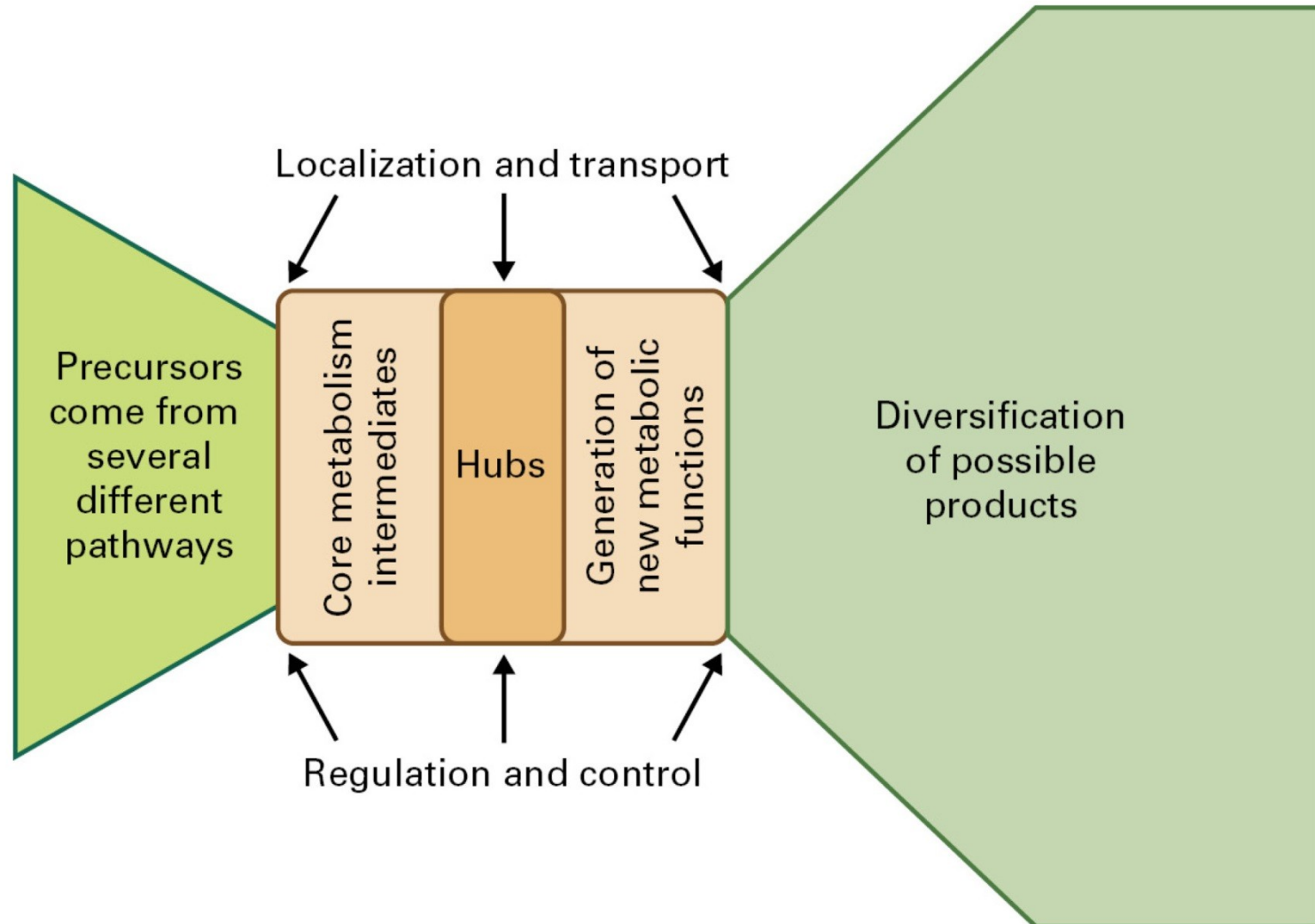
# Secondary metabolites



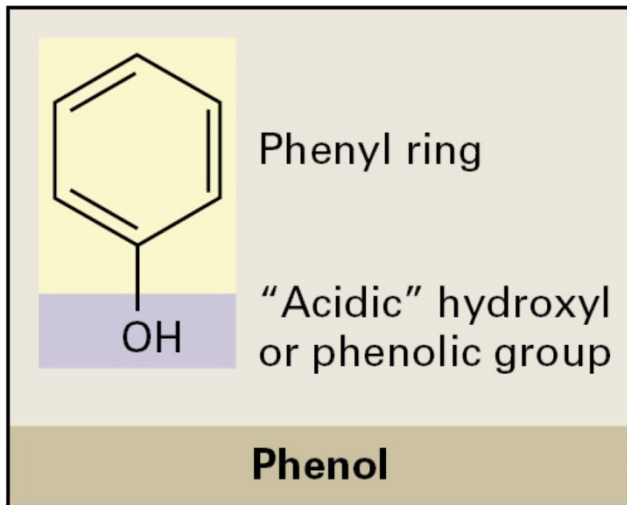
Katerina Dadakova, Department of Biochemistry

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

## Diversity of plant natural products



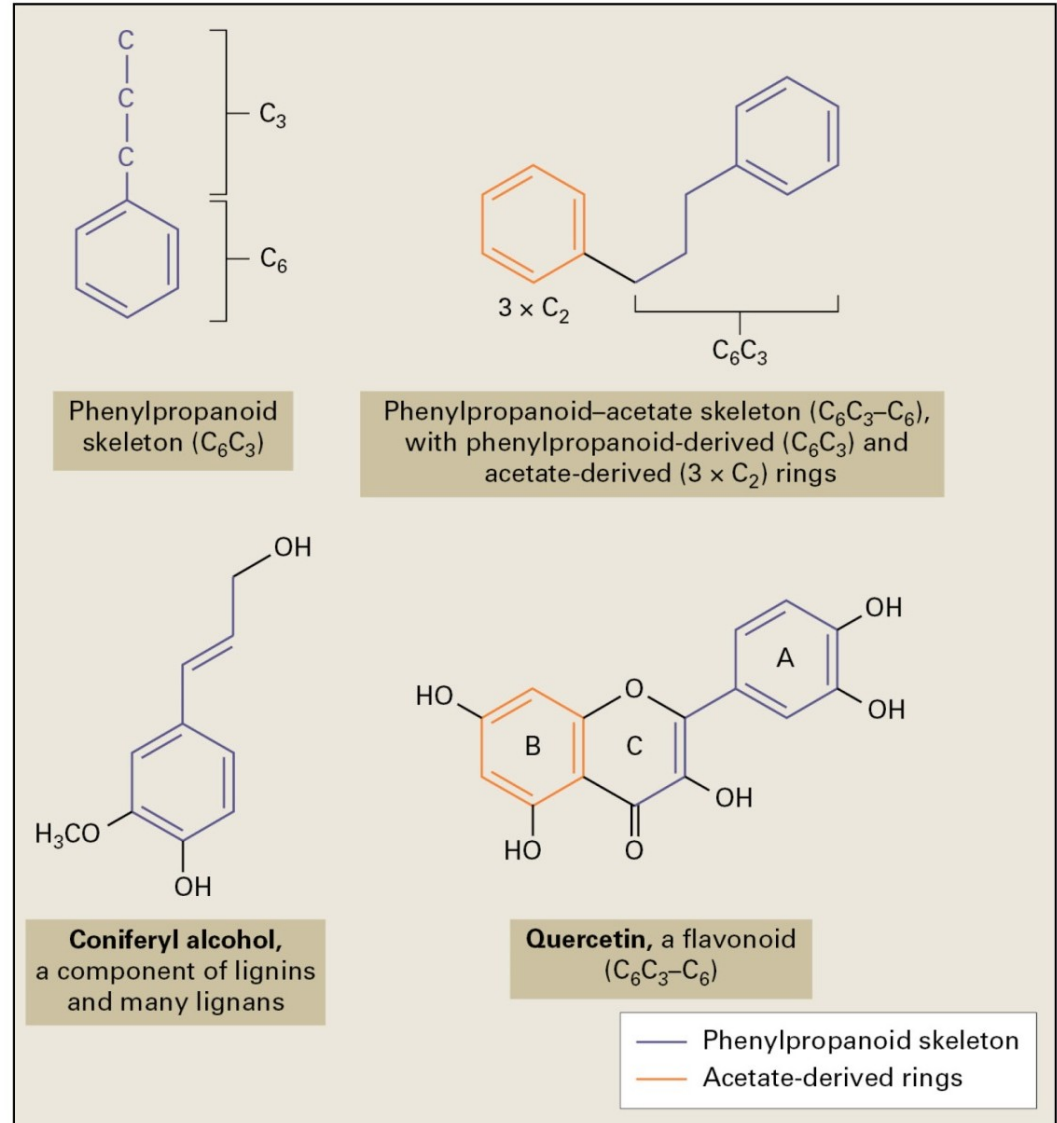
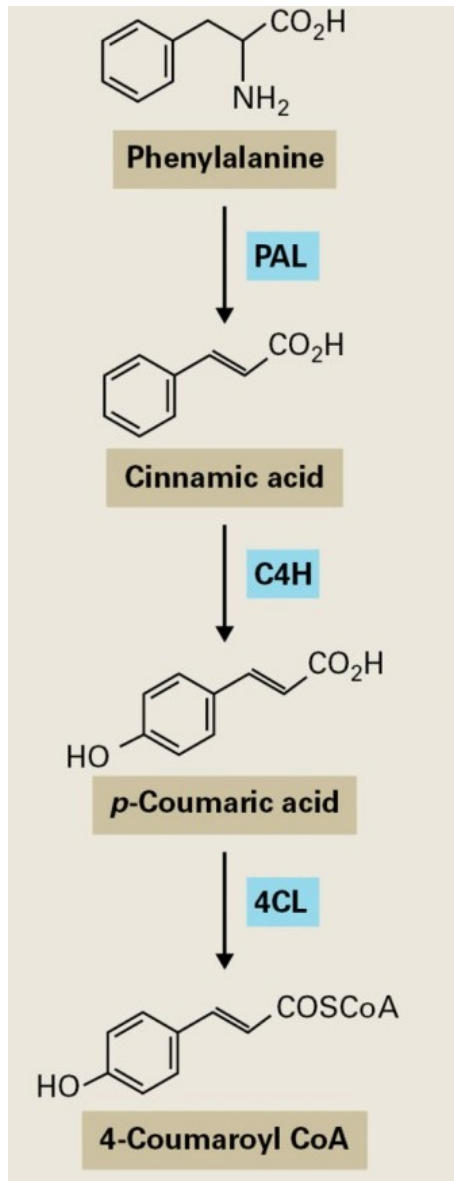
## Phenolic compounds



Major subclasses of phenolic compounds:

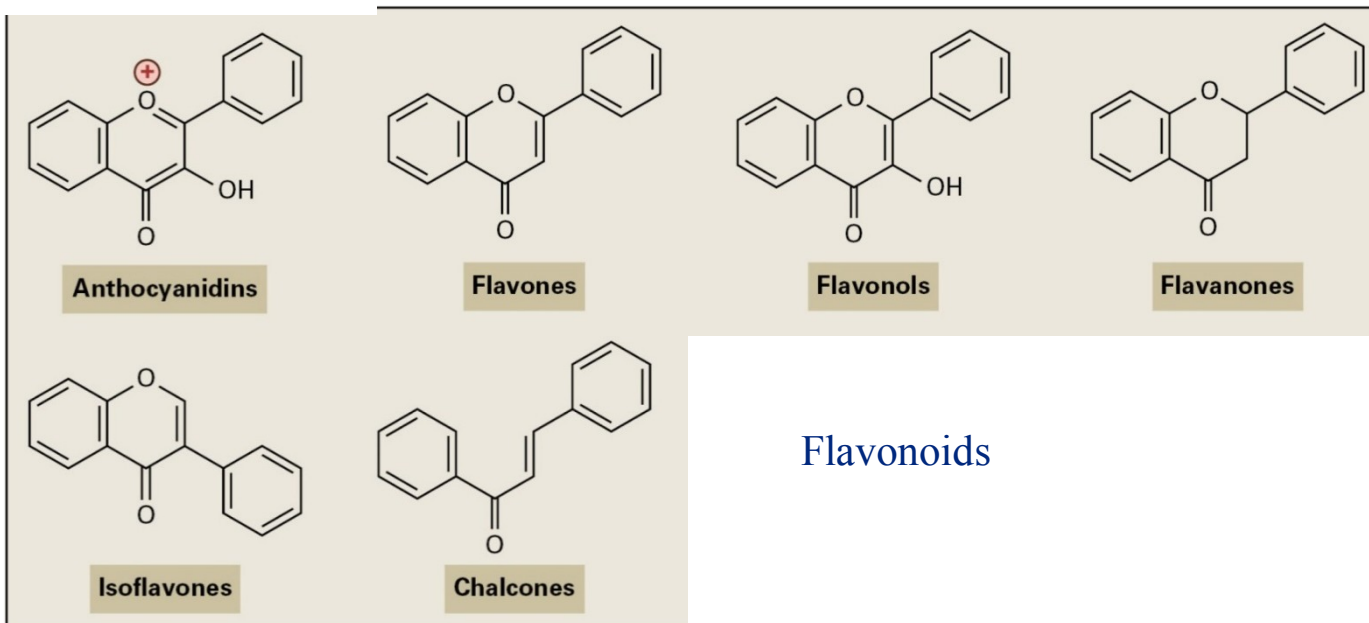
- flavonoids
  - flavones
  - flavonols
  - flavanones
  - anthocyanidins
  - isoflavones
  - chalcones
- stilbenes
- coumarins and furanocoumarins
- lignins and lignans
- naphta- and anthraquinones
- diarylheptanoids

# 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

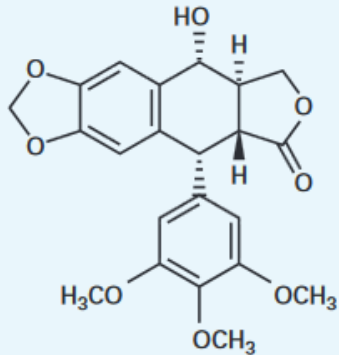


Flavonoids

# Phenolic compounds

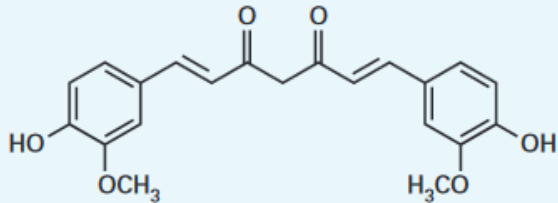
## Lignans

Podophyllotoxin

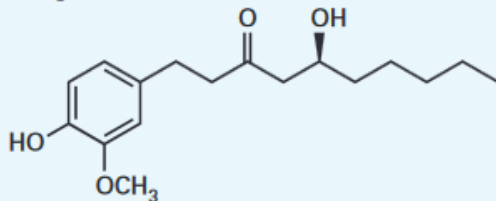


## Diarylheptanoids

Curcumin

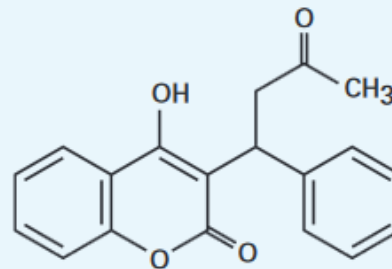


Gingerol

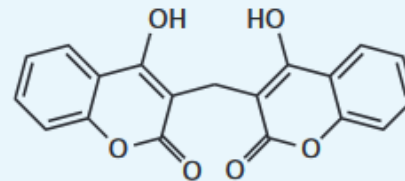


## Coumarins

Warfarin

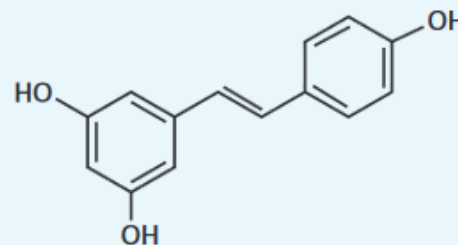


Dicoumarol



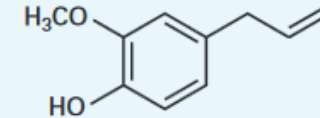
## Stilbenes

Resveratrol

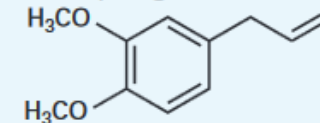


## Phenylpropenes

Eugenol

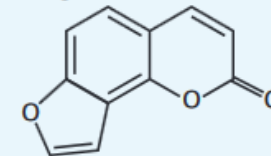


Methyleugenol

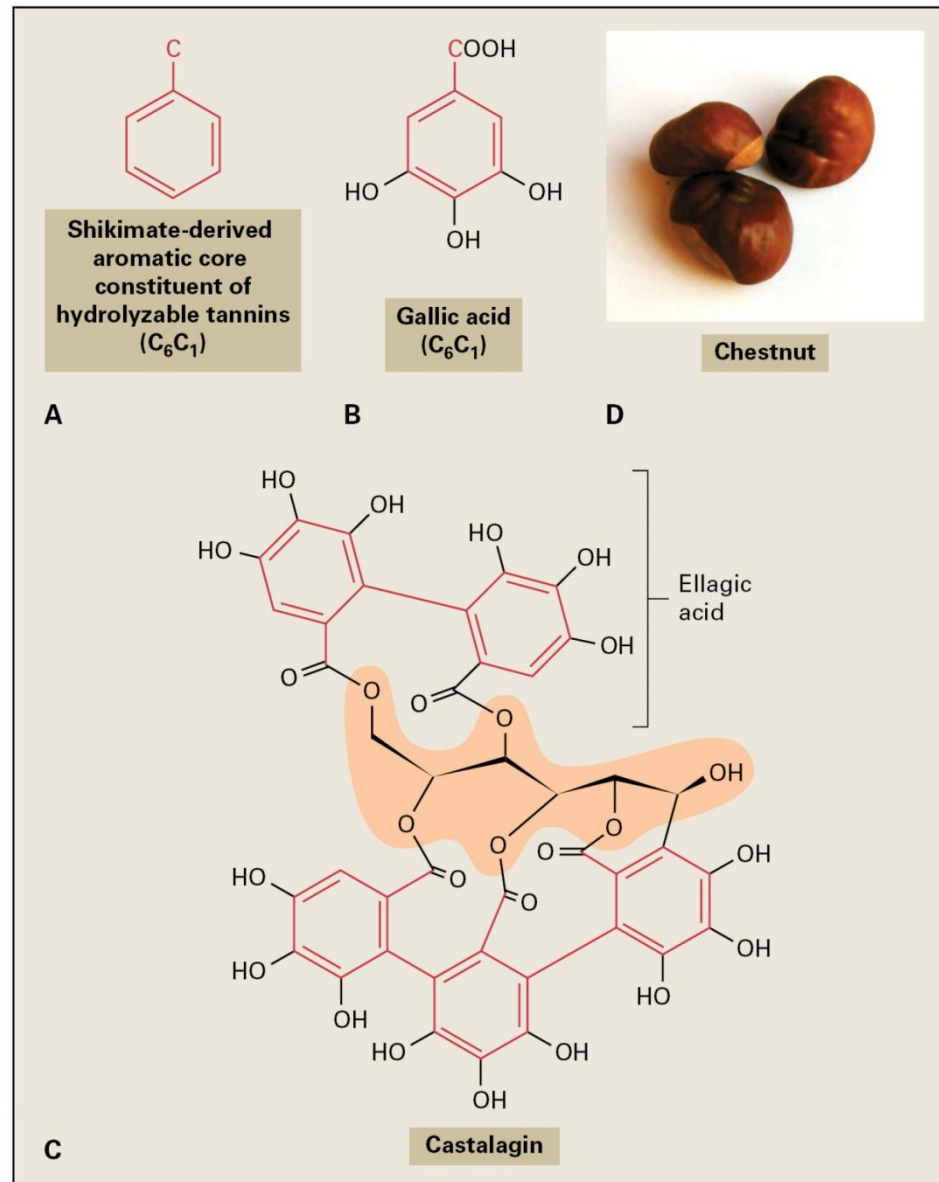


## Furanocoumarins

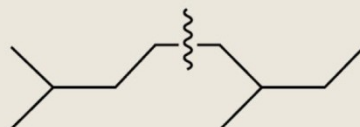
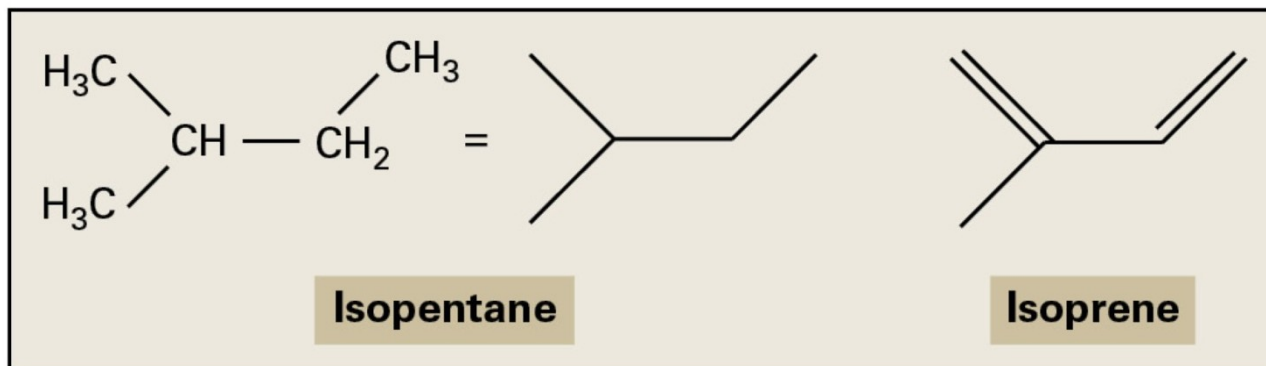
Angelicin



# Phenolic compounds

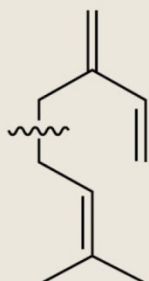


# Terpenoids

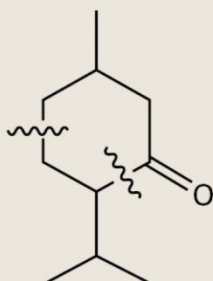


**Head-to-tail**

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

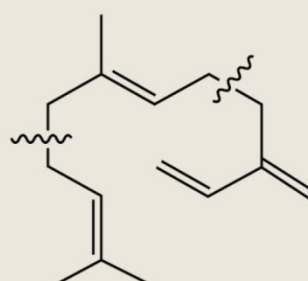


**Myrcene**

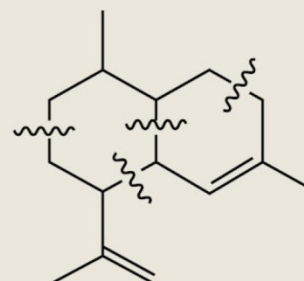


**Menthone**

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

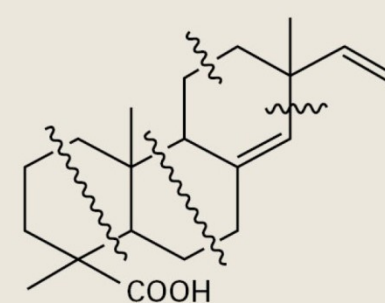


**(E)-β-Farnesene**



**Amorpha-4,11-diene**

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



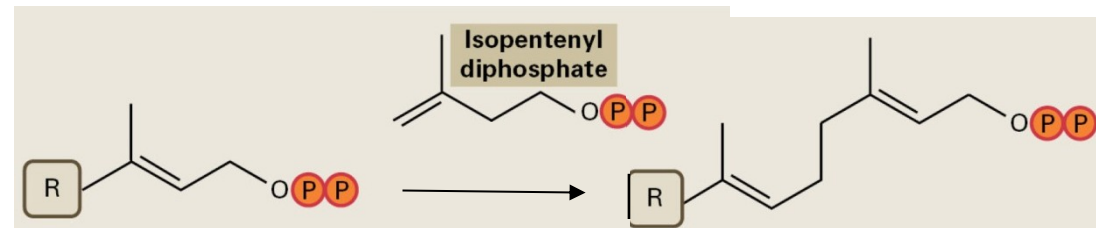
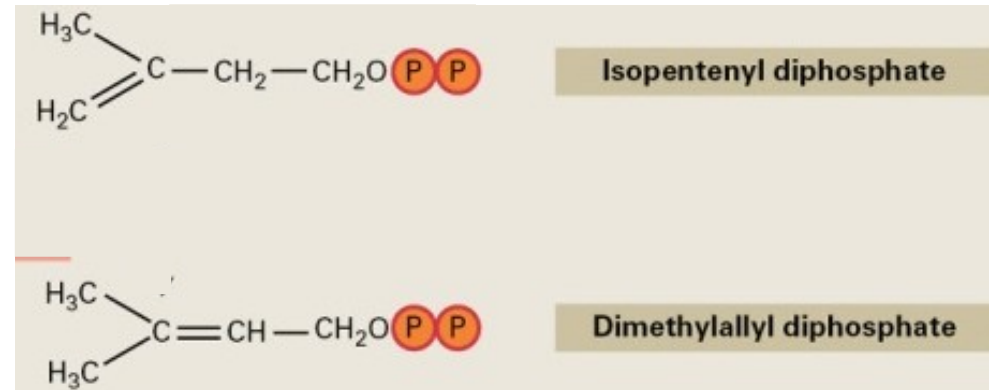
**Pimaric acid**



# 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

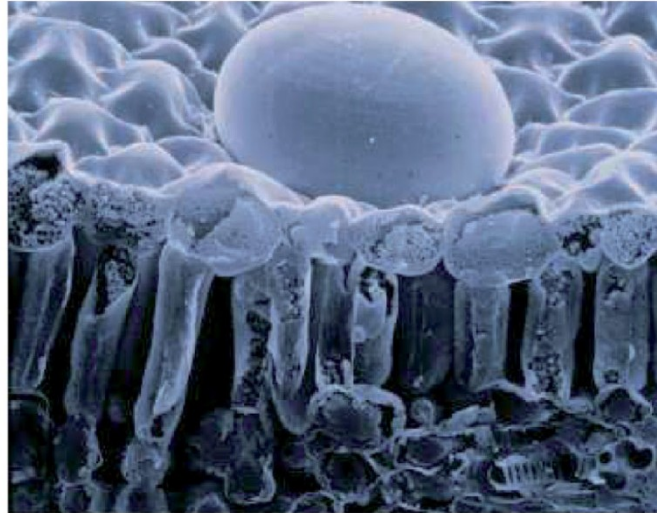


The prenyltransferase reaction

# Terpenoids



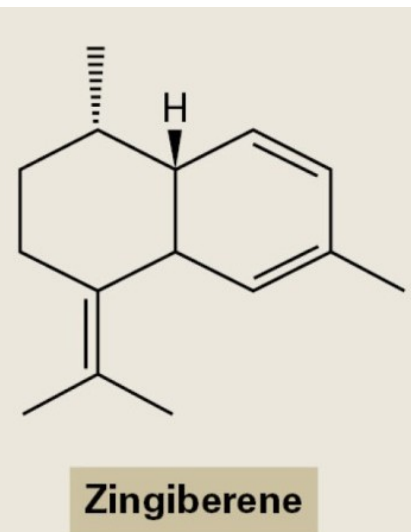
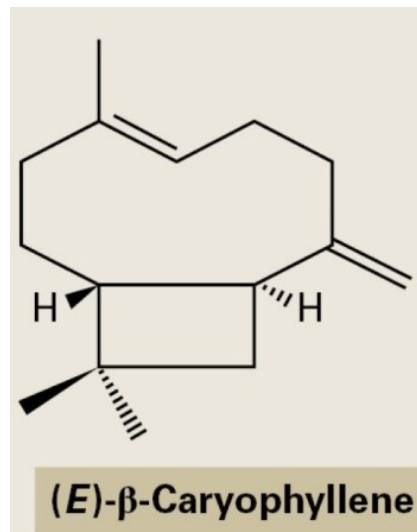
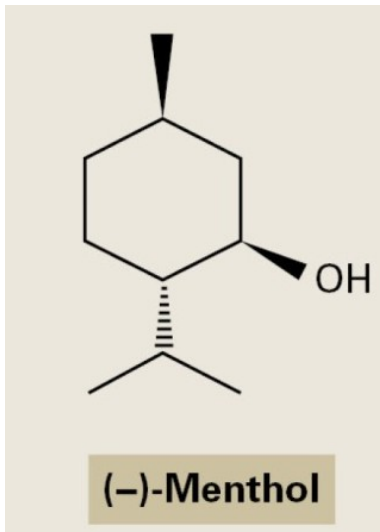
Resin



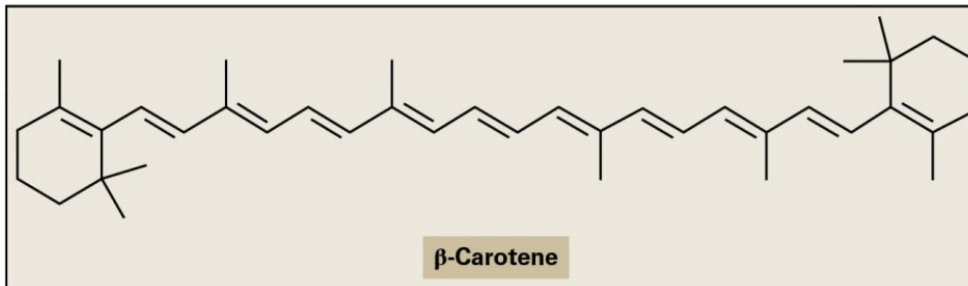
Oil stored in a glandular hair



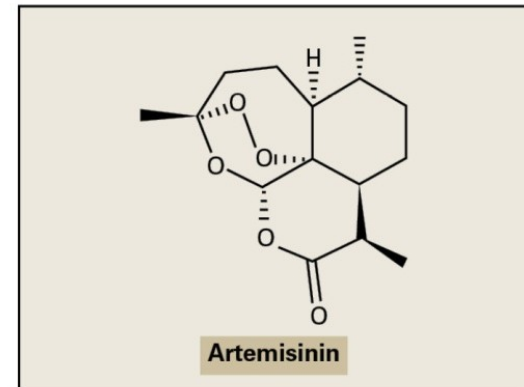
Plant latex



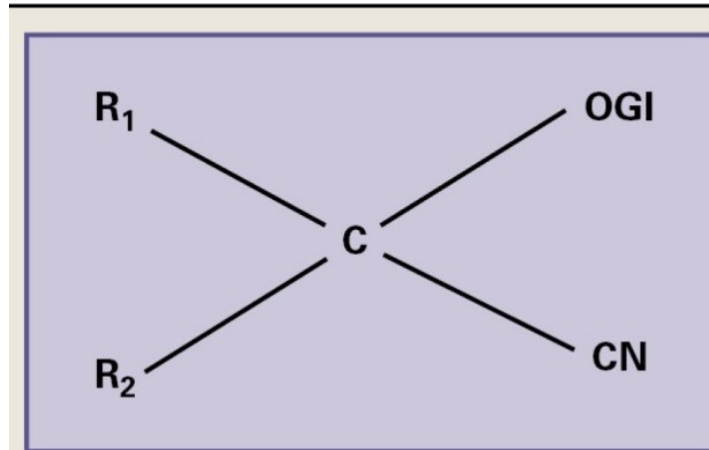
# Terpenoids



A

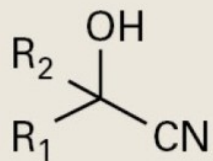


## Cyanogenic glycosides

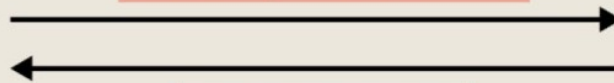


OGlc = glucose residue  
 attached by *O*-β-D-glucosyl linkage  
 CN = nitrile group  
 R<sub>1</sub> = aliphatic or aromatic group  
 R<sub>2</sub> = usually H

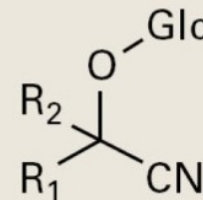
### α-Hydroxynitrile



Glucosyltransferase



### Cyanogenic glucoside



β-Glucosidase



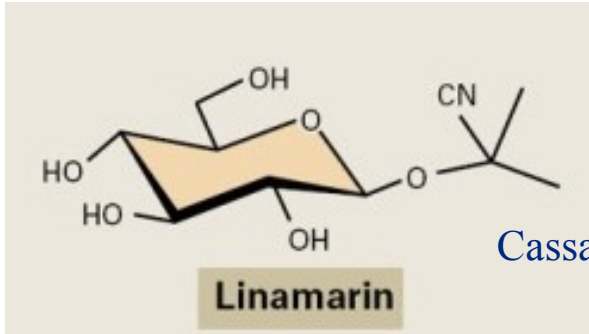
α-Hydroxynitrilases



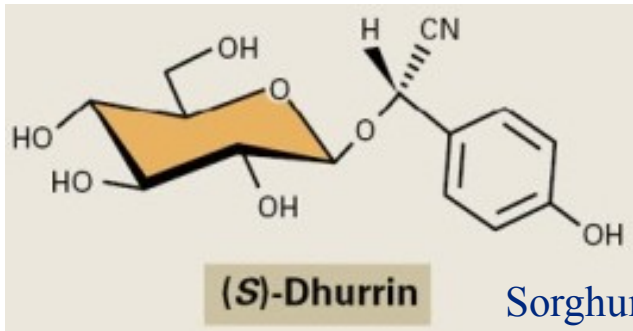
Insect defense compounds



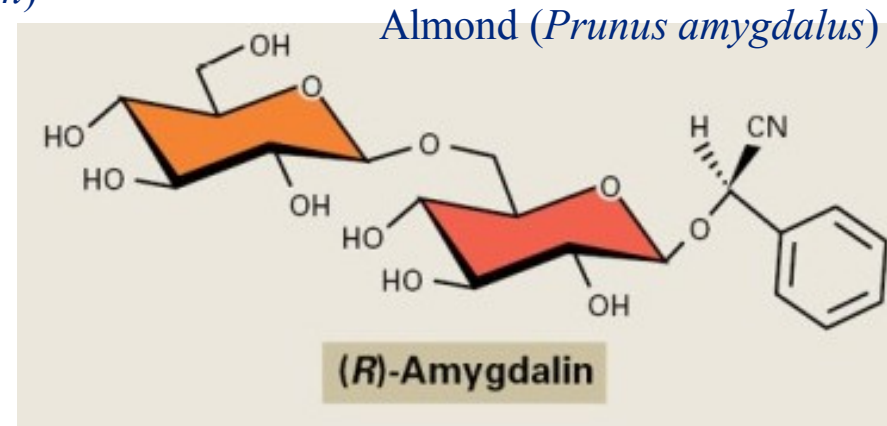
## Cyanogenic glycosides



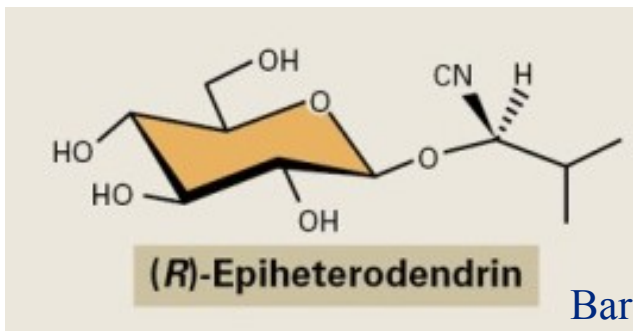
Cassava (*Manihot esculentum*)



Sorghum (*Sorghum bicolor*)

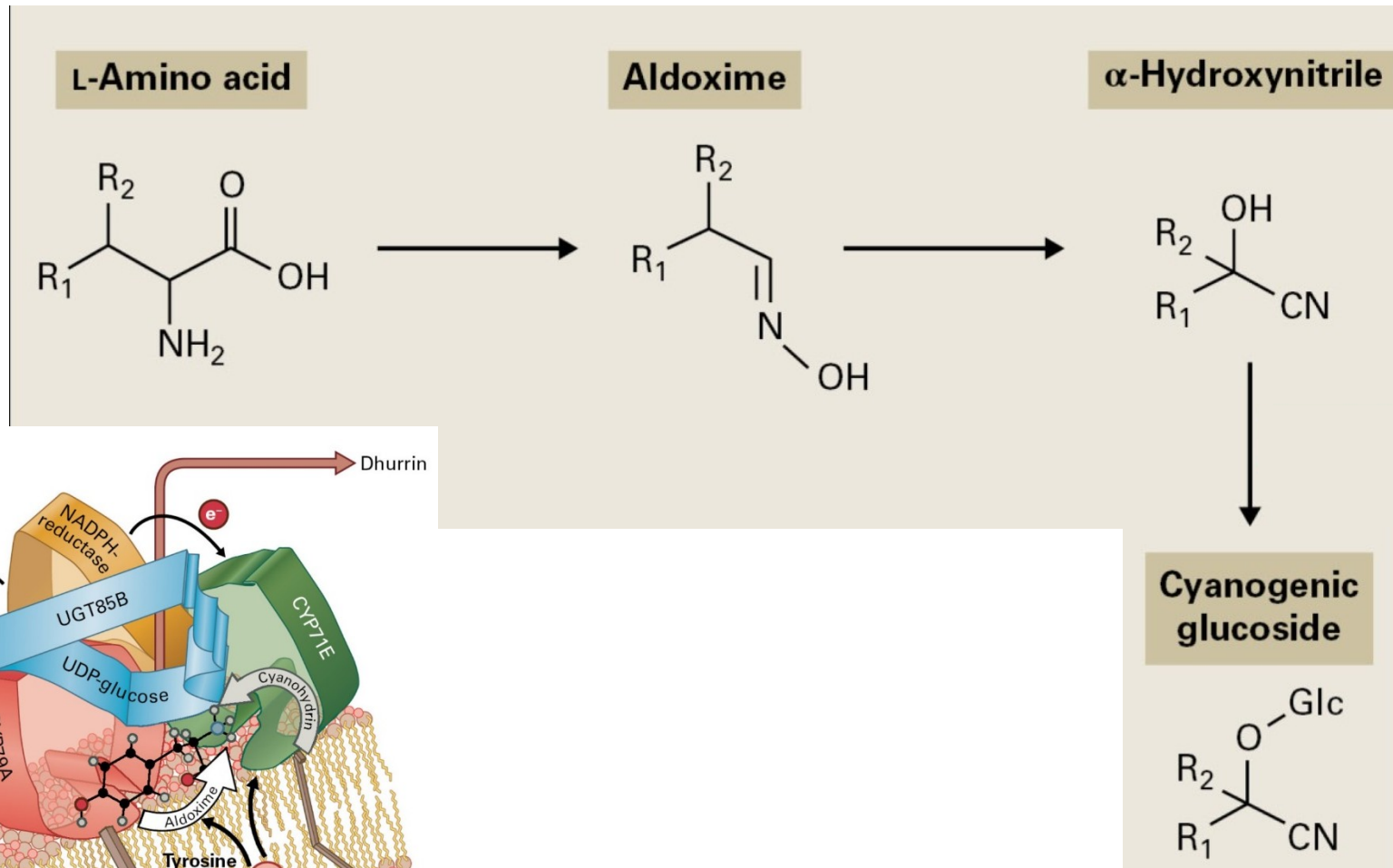


Almond (*Prunus amygdalus*)



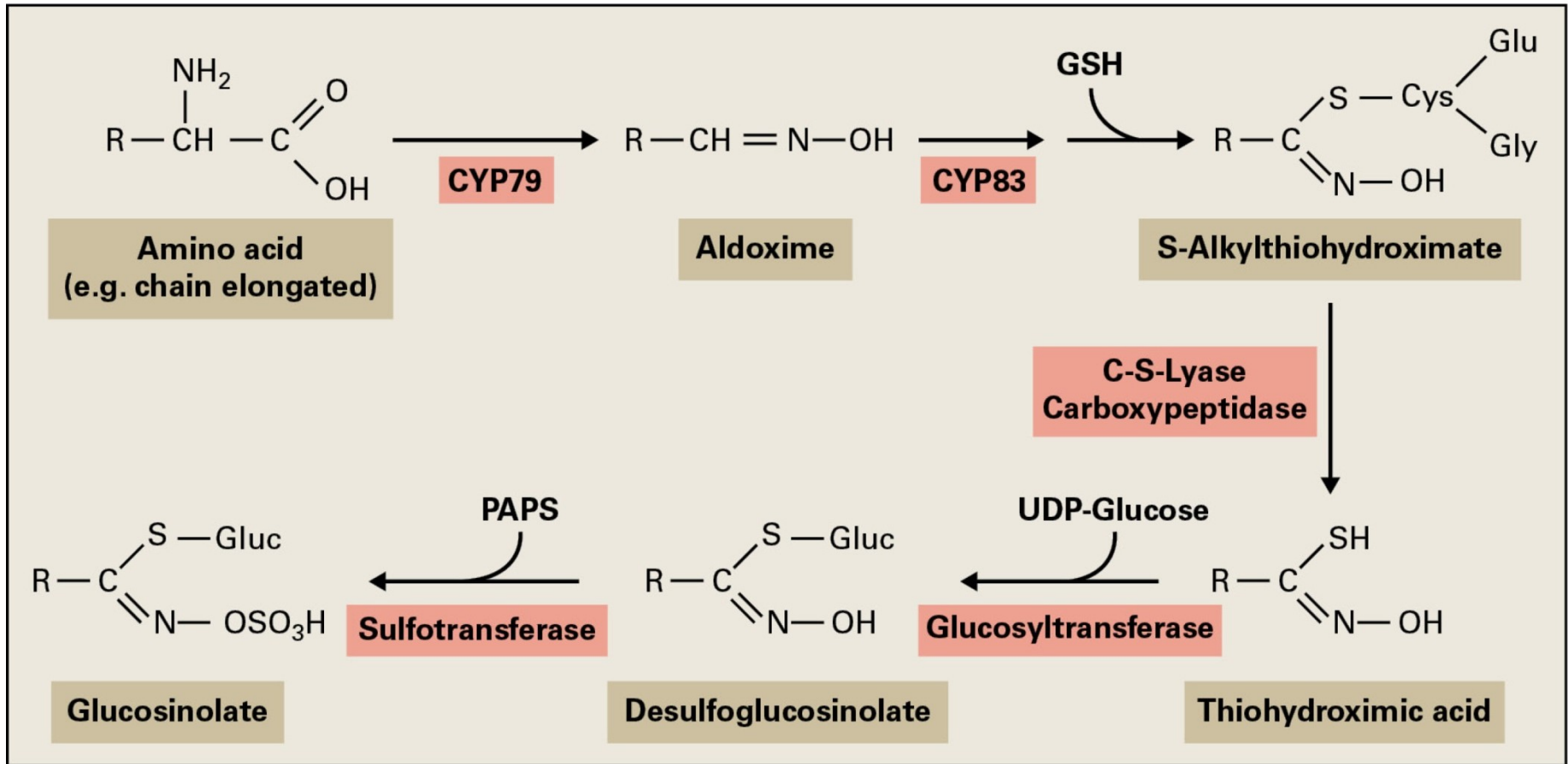
Barley (*Hordeum vulgare*)

# Cyanogenic glycosides





# Glucosinolates

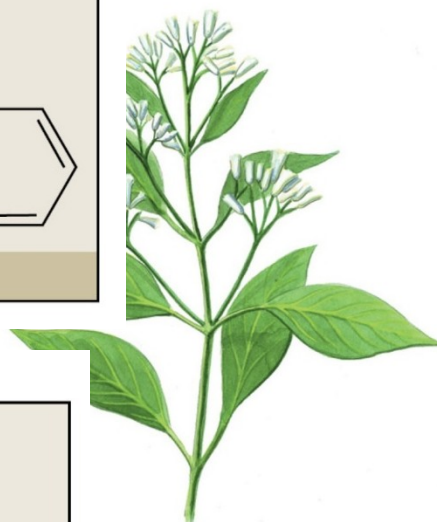
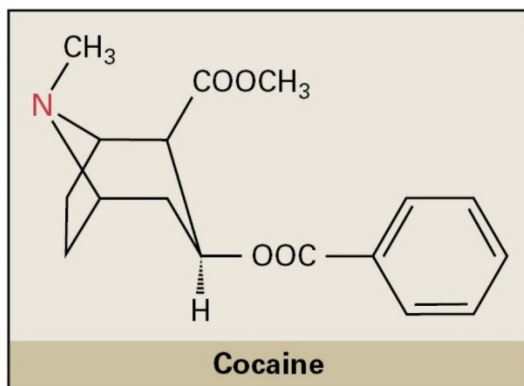




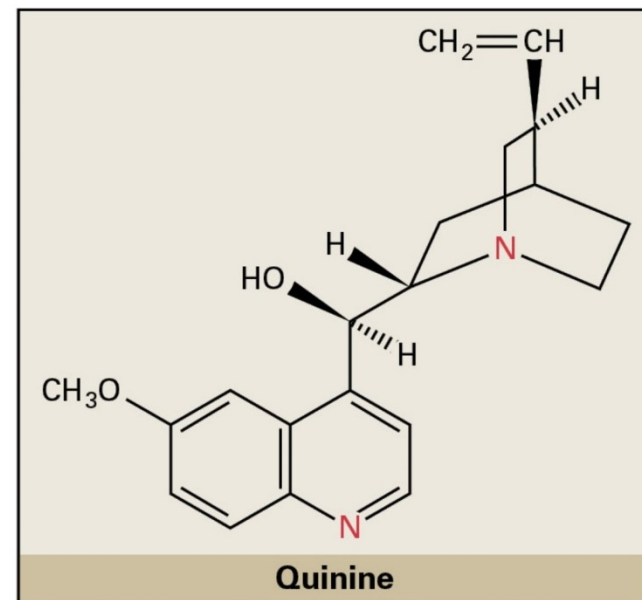
# Alkaloids



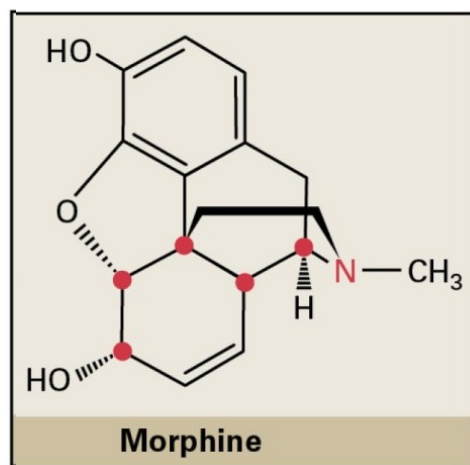
*Erythroxylum coca*



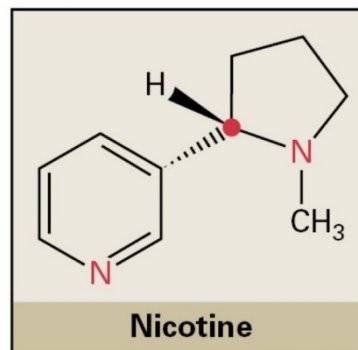
*Cinchona officinalis*



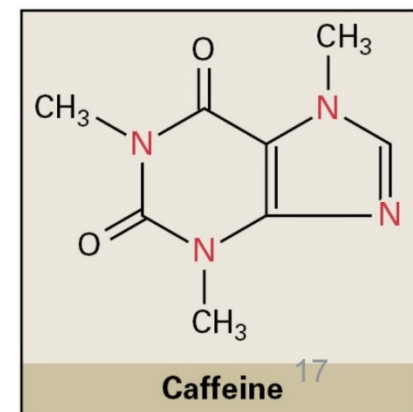
*Papaver somniferum*



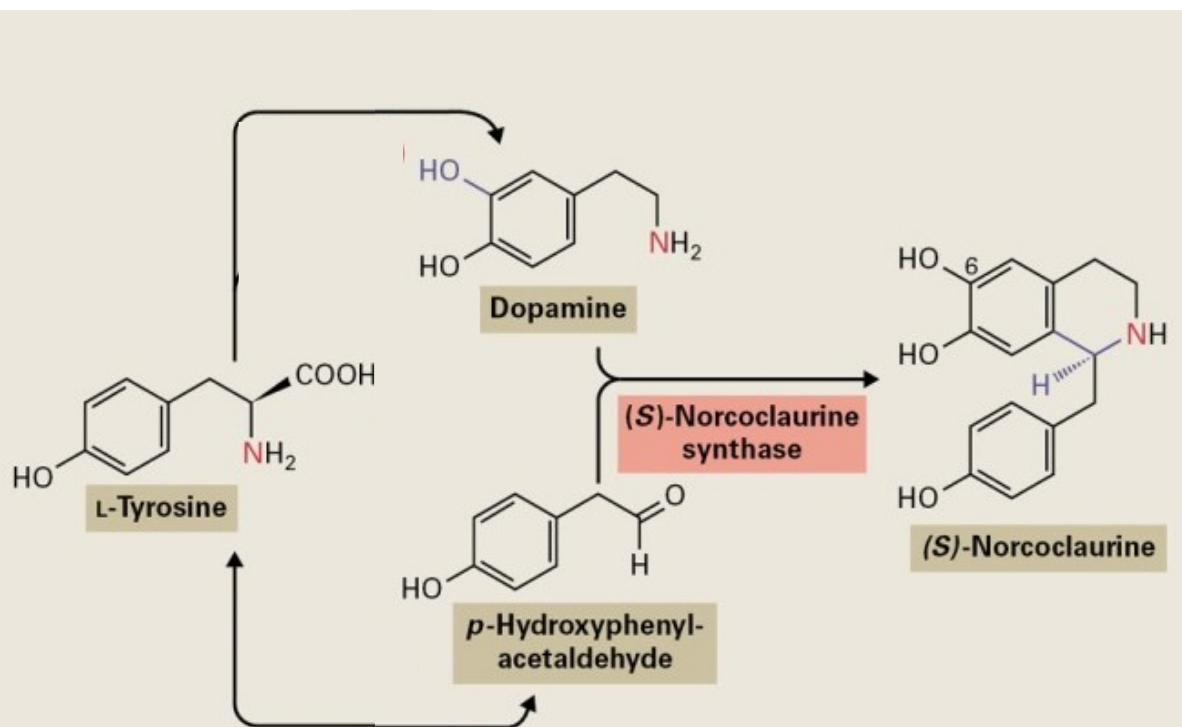
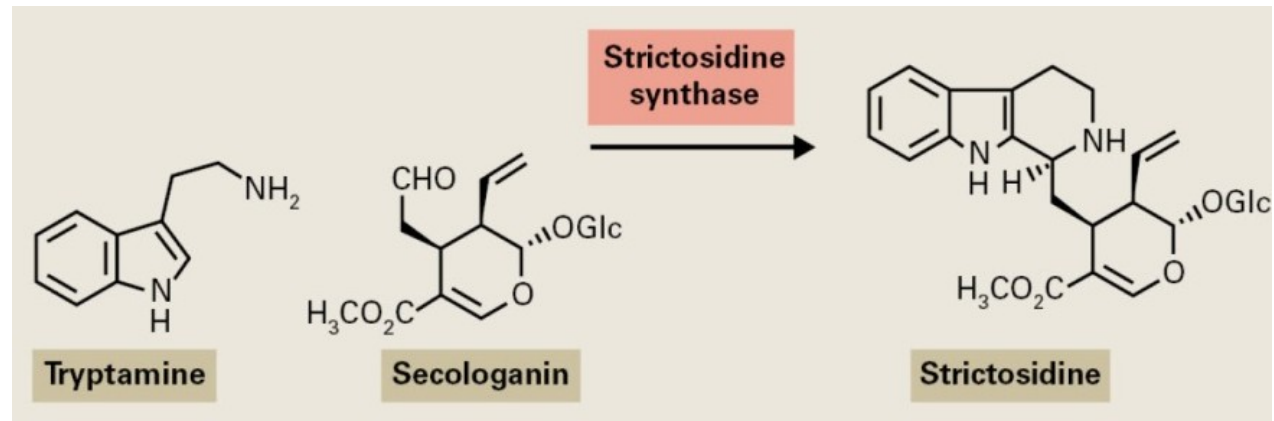
*Nicotiana tabacum*



*Coffea arabica*



# Alkaloids



# Alkaloids

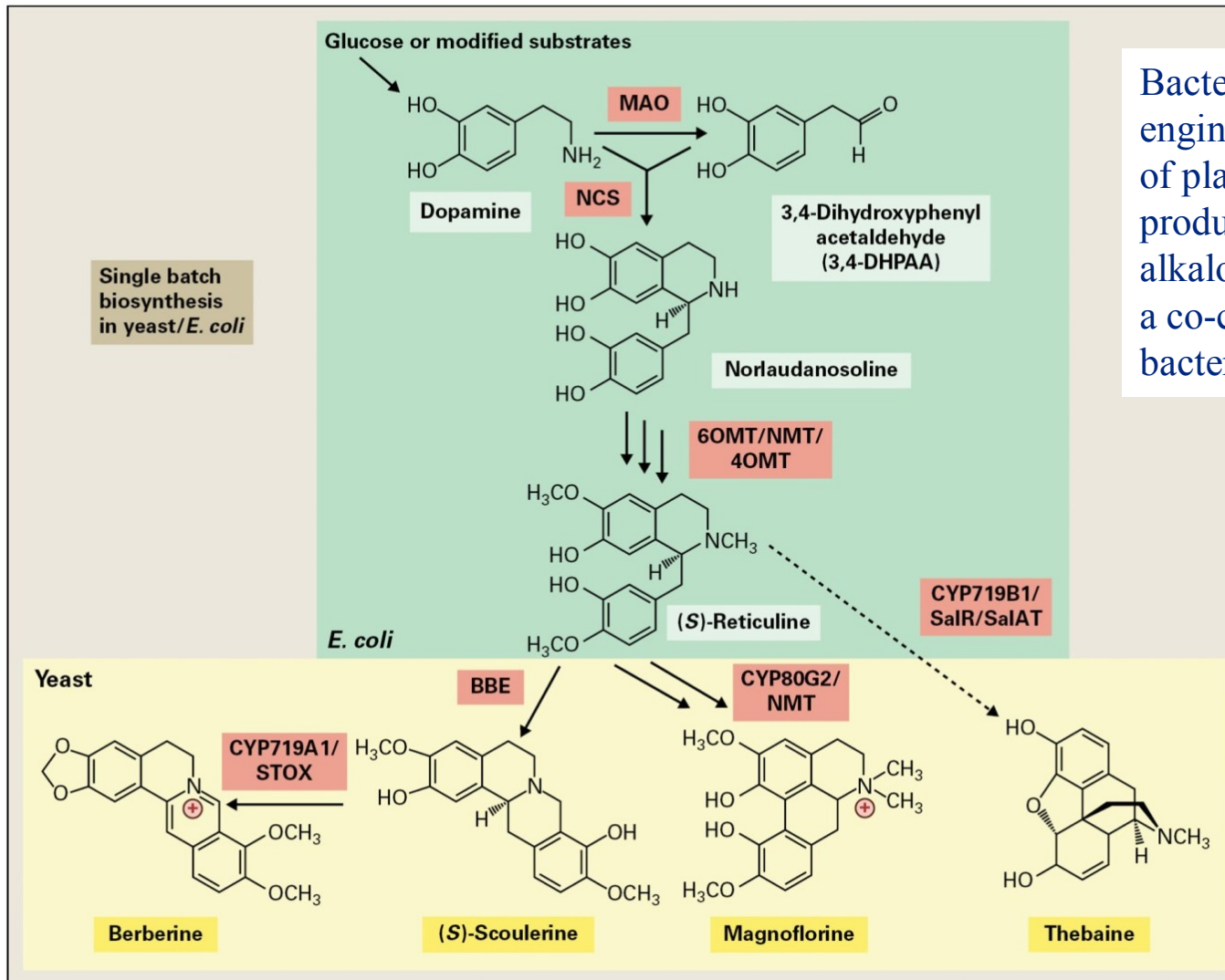


*℥ Trochiscorum Stiliticorum ℥ xij .*  
*Viperinorum ,*  
*Magnatis Hedycroi ,*  
*Piperis longi ,*  
*Opy Toctiaci ana ℥ v j ,*  
*Rosarum rubrarum ,*  
*Iridis ,*  
*Succi Glycyrrhiza ,*  
*Seminis Buniadis ,*  
*Scordij ,*  
*Opopalij ana ℥ iij ,*  
*Cinnamonij ,*  
*Acetici ana ℥ iij ,*  
*Coffi ,*  
*Nardi Indica ,*  
*Diacardij Celtici ,*  
*Rhizomatis*  
*Radicis Pentaploidi ,*  
*Zinziberis ,*  
*Praij albi ,*  
*Stachadis Arabica ,*  
*Schamantbi ,*  
*Seminis Petroselini Macedonici ,*  
*Calamintha montana ,*  
*Cassie lignea ,*  
*Croci .*  
*Piperis albi ,*  
*Miris Theophrasti ,*  
*Thuris confecti ,*  
*Theriacina Chia , ana ℥ i β ,*  
*Radicem Gentiana ,*  
*Asoni Feri ,*  
*Melu Athamantici ,*  
*Valeriana majoris ,*  
*Nardi Celtica ,*  
*Amomi Taurini ,*  
*Chamaeyrosos ,*  
*Camis Hyperici ,*  
*Seminis Amicos ,*  
*Thlaspedos ,*  
*Anisi ,*  
*Feniculi ,*  
*Sylvestris Mastichionis ,*  
*Ceraimonis minoris ,*  
*Malabathri*  
*Come Polymontani ,*  
*Chamaedrys ,*  
*Carpobalsami*  
*Succi Hypocistidis ,*  
*Gummi Arabici ,*  
*Styracis Calamiae ,*  
*Terra Lemnia ,*  
*Chalcitidis ,*  
*Sagapeni anatica ,*  
*Radicem Aristolochiatennis ,*  
*Come Centaurij minoris ,*  
*Seminis Druaci Cretici ,*  
*Opoponaci ,*  
*Galbani ,*  
*Bisbituminis Iudaeici ,*  
*Castorei albi ℥ β .*  
*Mellis optimi despumati 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.