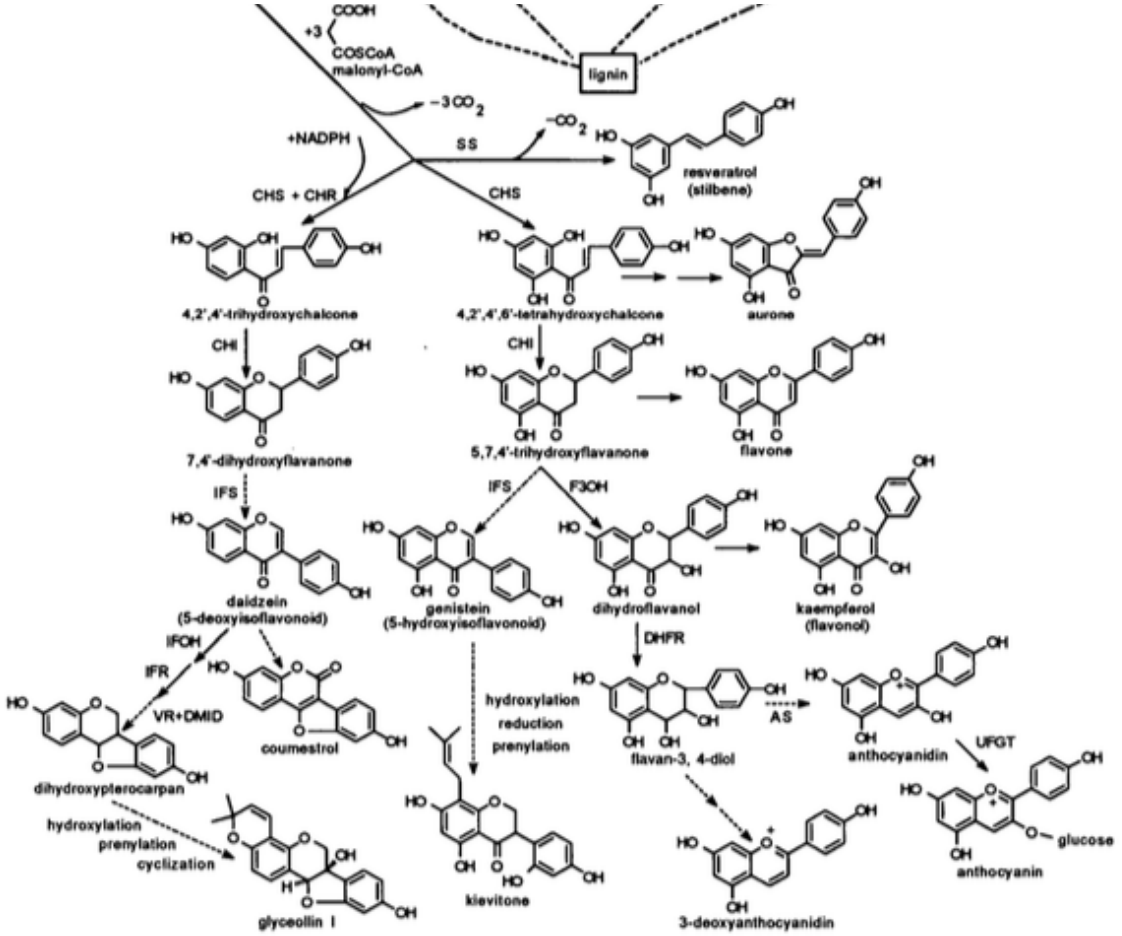
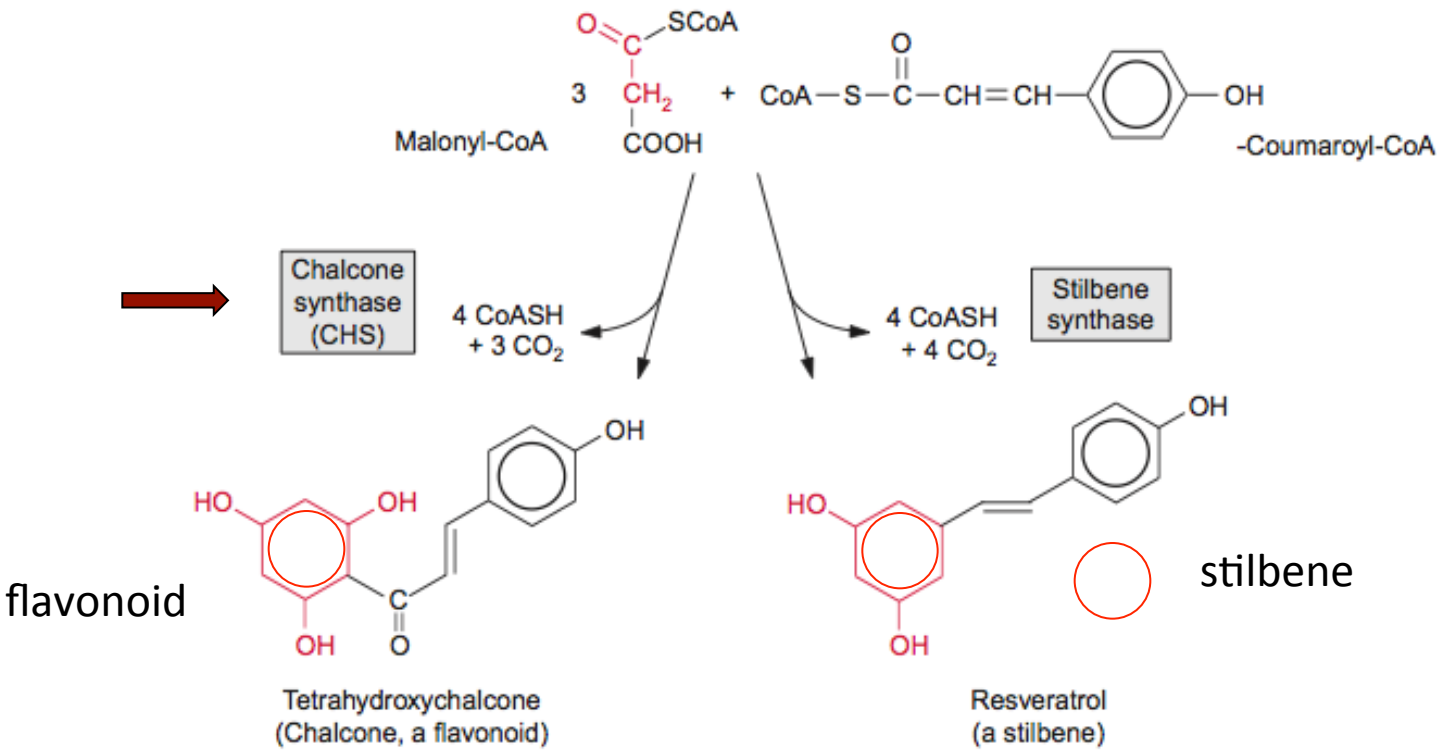
# Roadmap of phenylpropanoids in plants – part 2




Paiva & Dixon, P

# Similarity of Stilbene & Flavonoid Synthesis

Fig. 18.11



# Flavonoid Structural Families

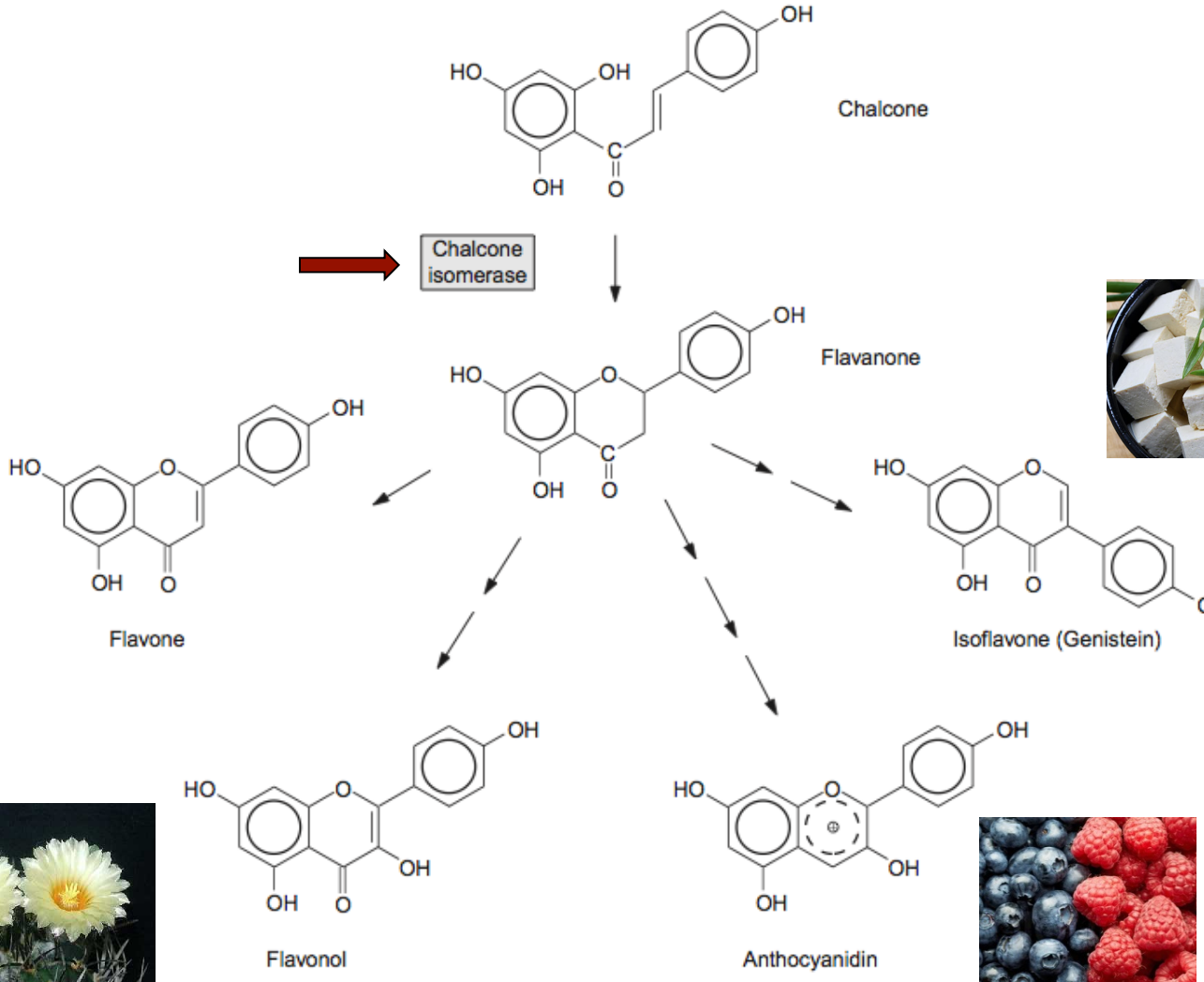





Fig. 18.13

# Flavonoid Structural Families

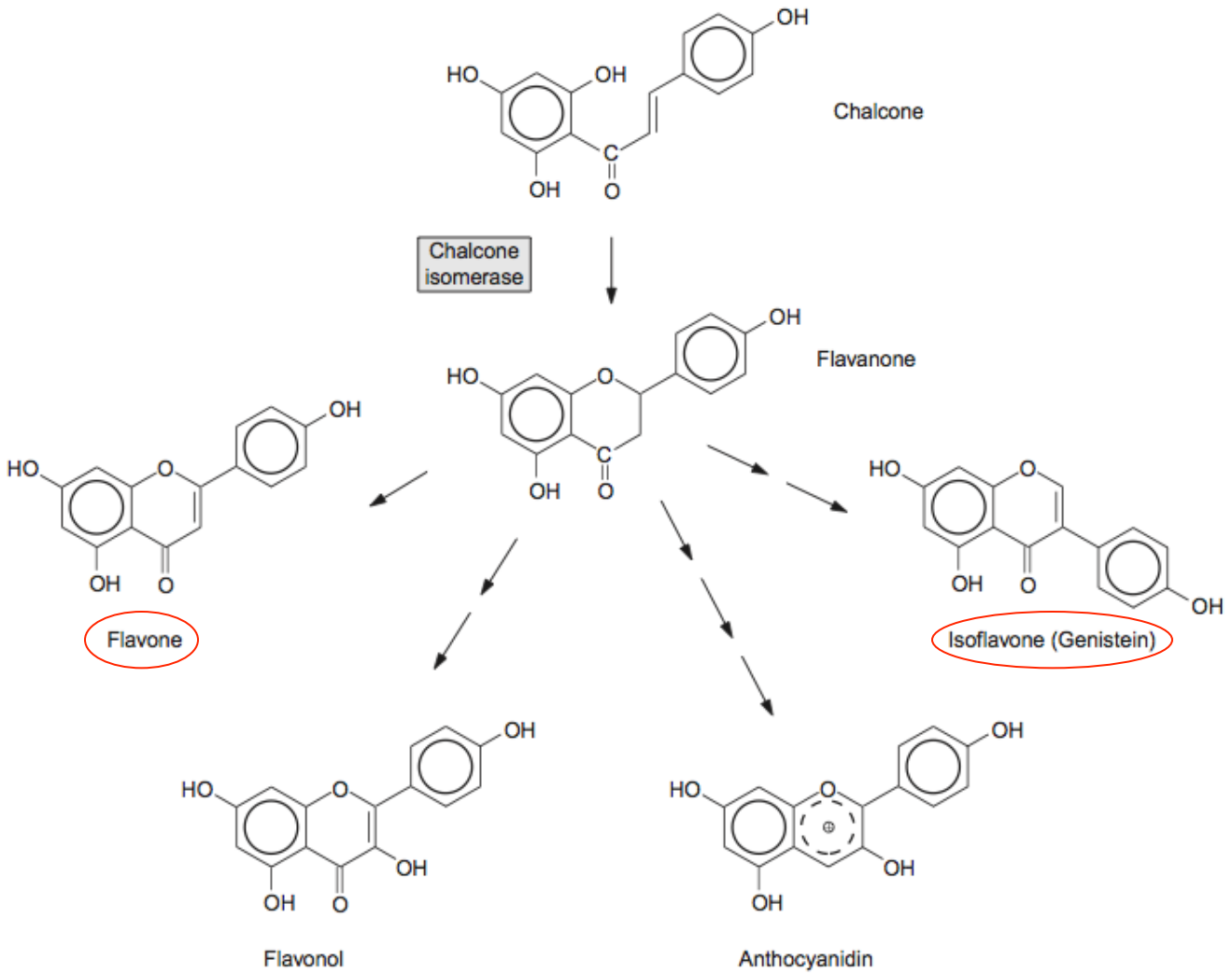
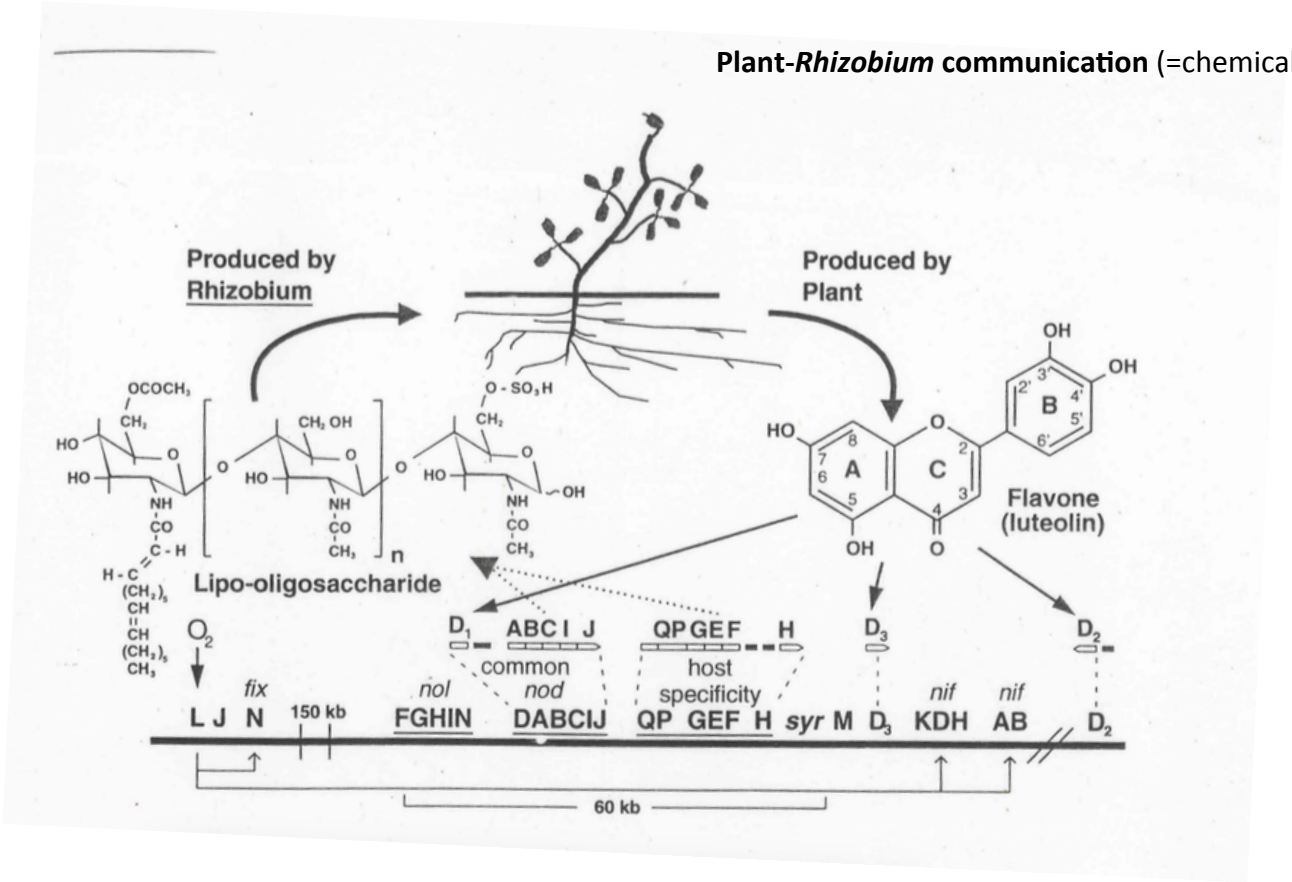



Fig. 18.13

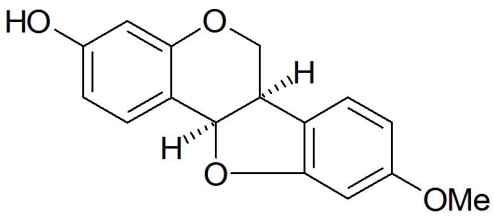
## **i) Flavones** (C4 carbonyl group (and no hydroxyls on C3)

**Plant-*Rhizobium* communication** (=chemical ecology)



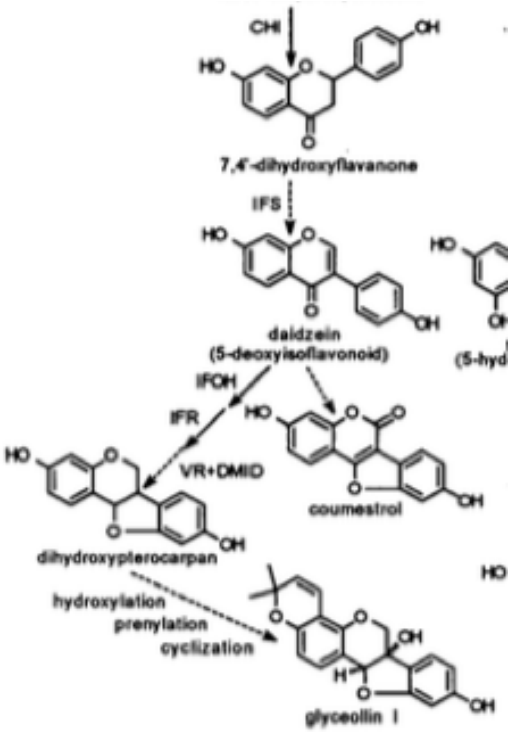
## **ii) Isoflavonoids** (isoflavones and pterocarpans)

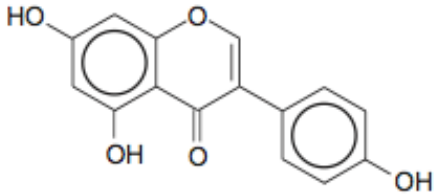
- note B-ring position, other heterocycles
- phytoalexins, phytoestrogens




medicarpin

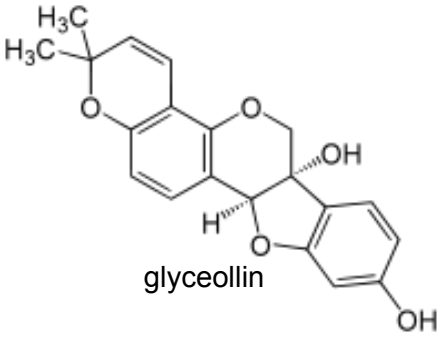
Isoflavonoid synthesis



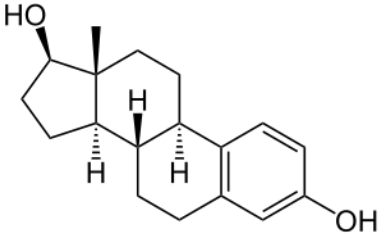




Isoflavone (Genistein)

phytoestrogen = estrogen mimic



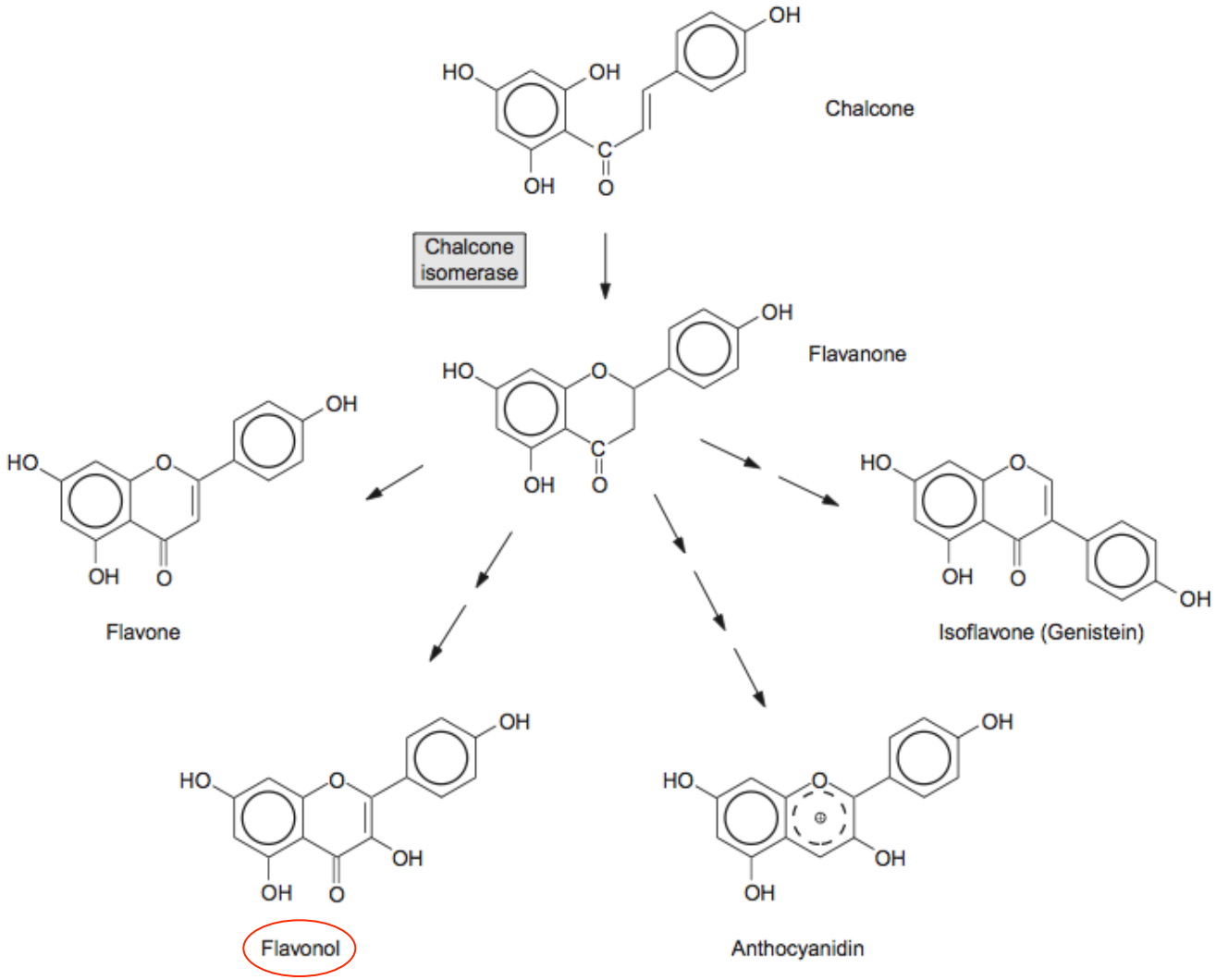

glyceollin




17ß-estradiol – steroid hormone

# Flavonoid Structural Families

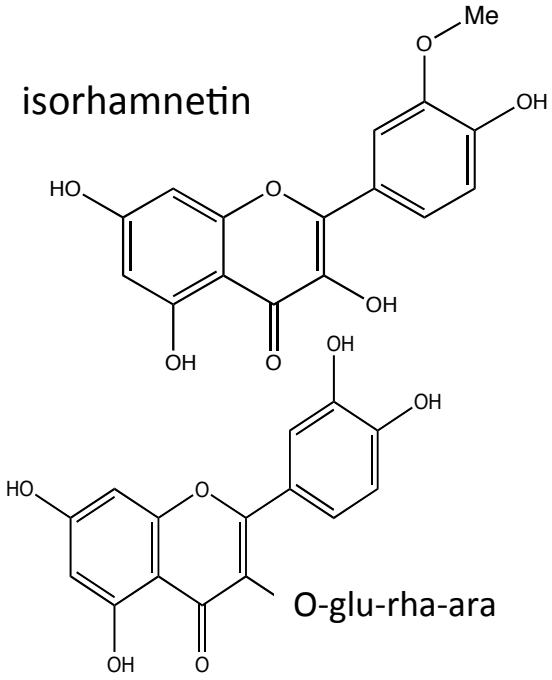
Fig. 18.13



**iii) Flavonols** – 4-carbonyl group and 3-OH

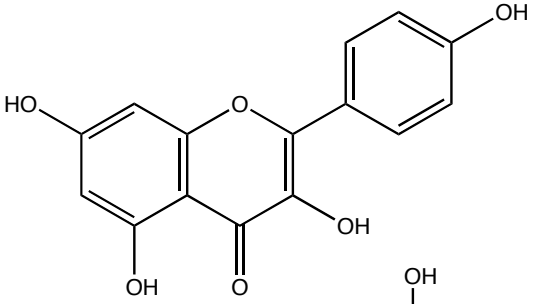
Absorb in UV range of light:

- UV sun screen
- flower color
- dietary antioxidants

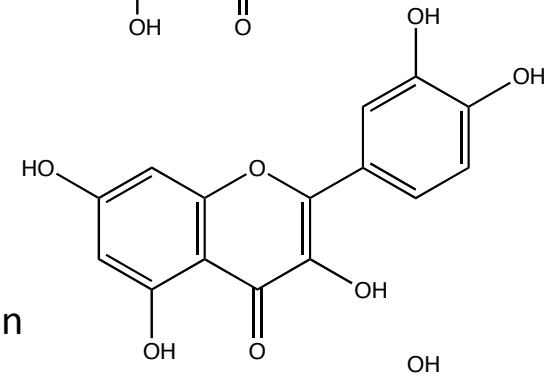



isorhamnetin

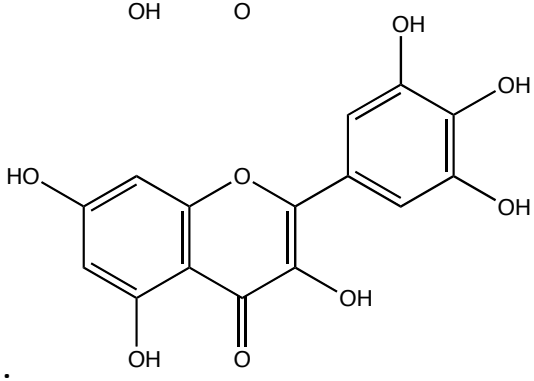
quercetin glycoside




kaempferol

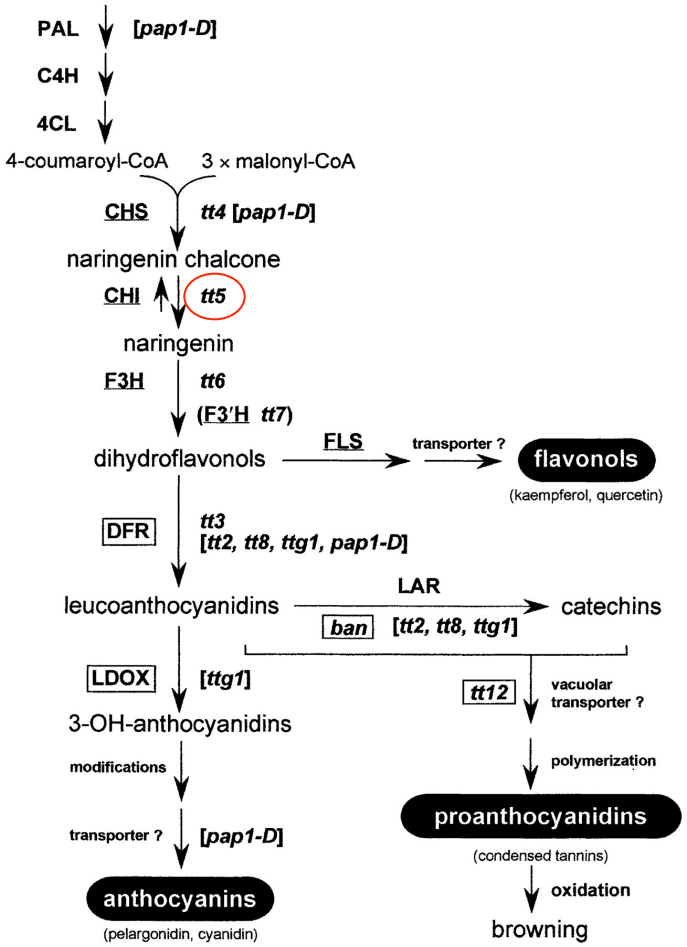



quercetin




myricetin

# Flavonols are often induced by UV-B in WT, but not in ***tt5*** (chalcone isomerase) mutants




Scheme of the Flavonoid Biosynthetic Pathway of Arabidopsis Leading to the Synthesis of Anthocyanins, Flavonols, and Proanthocyanidins

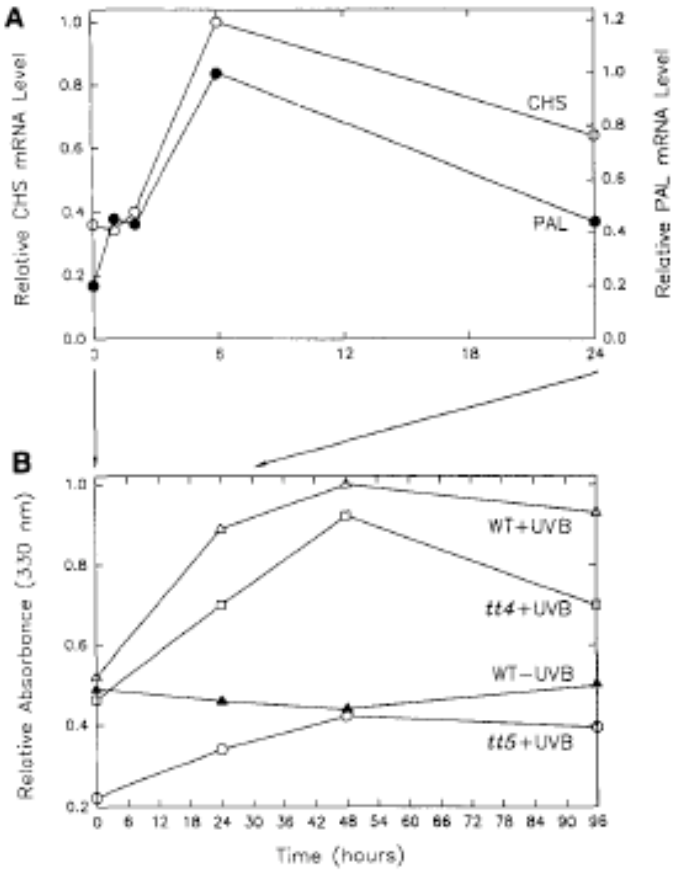
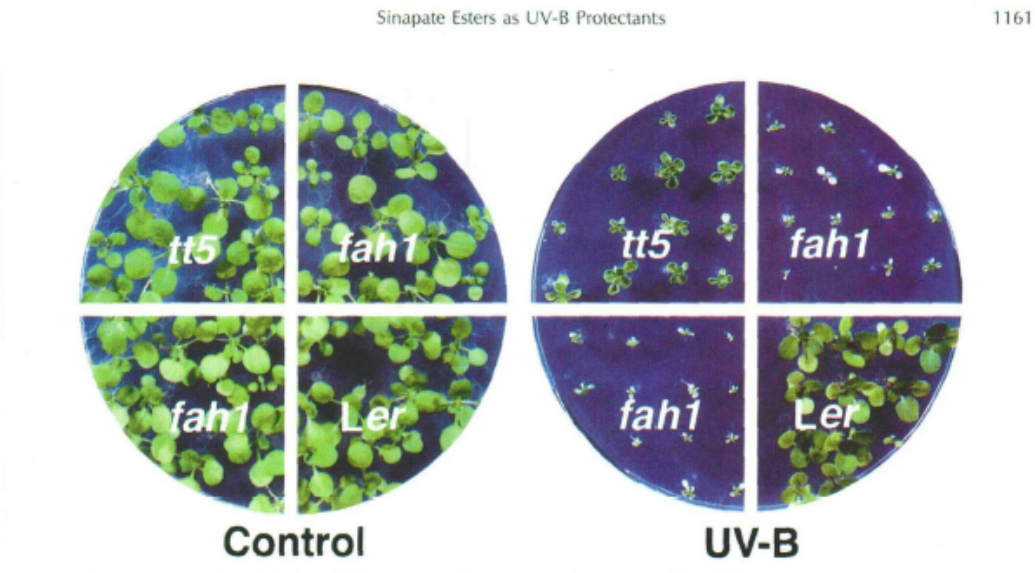


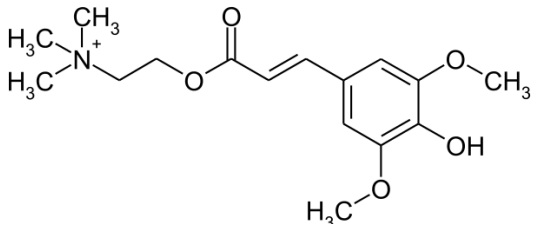

**Figure 2.** Induction of Leaf Phenolic Compound Biosynthes
sponse to UV-B.

Plant Cell, 5: 171-179, 1993

Effect of mutations in **flavonoid** (**tt5**) and **sinapate (fah1)** pathways on UV-B resistance in Arabidopsis seedlings




***(fah1)**=ferulate hydroxylase =coniferaldehyde 5'-hydroxylase)*




sinapine: sinapoyl choline

Flavonols function as pigments / flower guide for insects with UV vision

- Black-eyed Susan (*Rudbeckia* sp.) as seen by humans (A) or honeybees (B)

*Visible light*

(A)

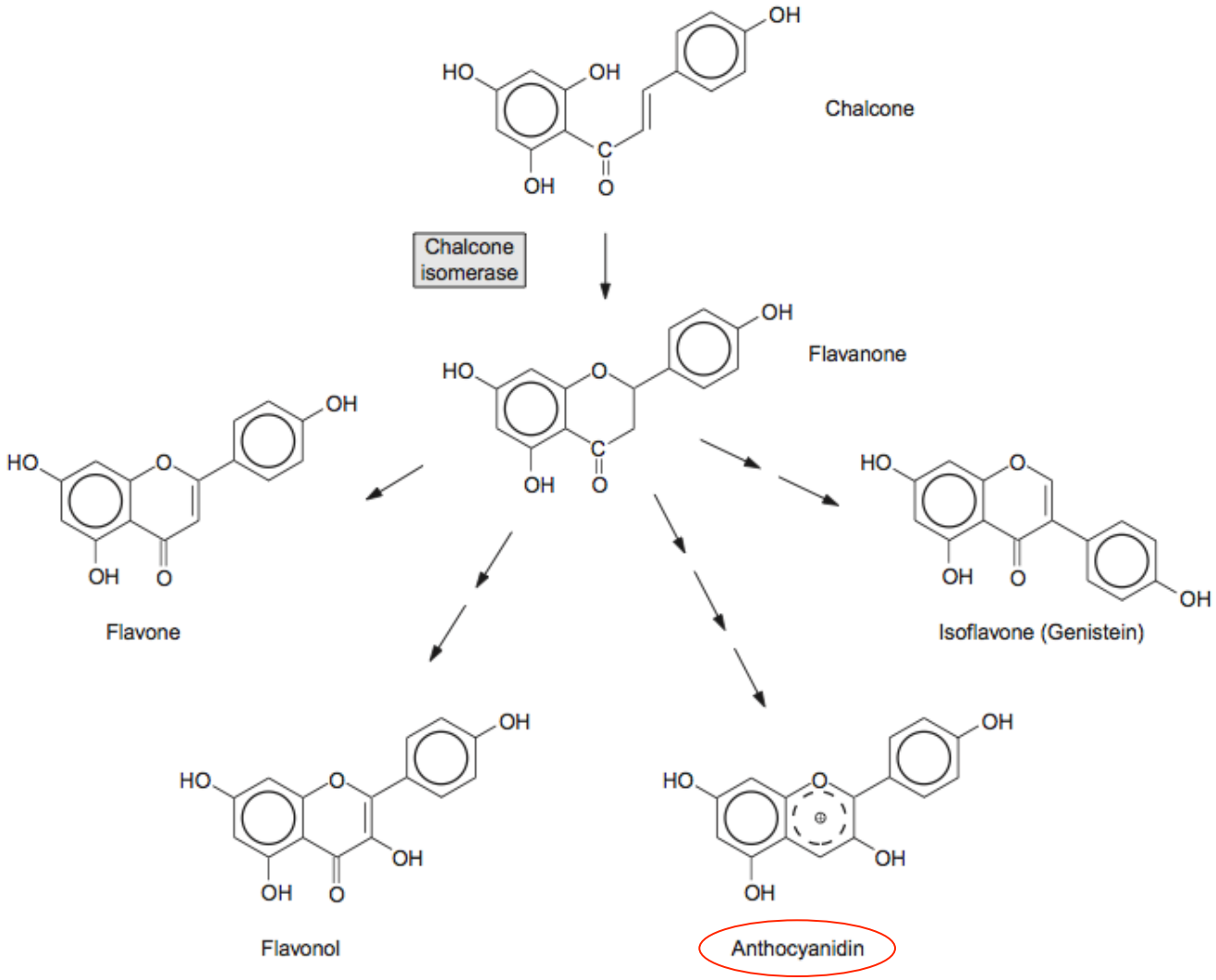
*UV light*

(B)

***PLANT PHYSIOLOGY, Fourth Edition,* Figure 13.14 (Part 2)** 

Flavonoid Structural Families

Fig. 18.13



iv) Anthocyanins function to aid in **seed dispersal and** pollinator attraction)

**anthocyanins** (blue/red/purple/black)

black hollyhock flowers

(**carotenoids**: yellow/orange/red)

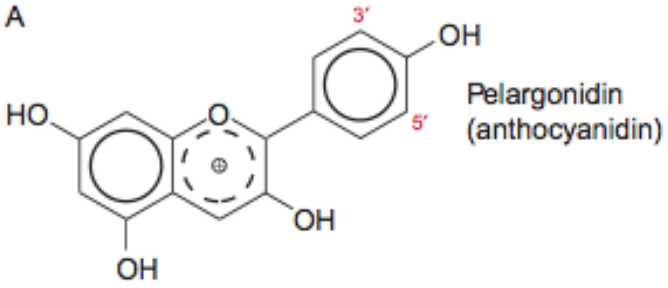
**Anthocyanins** and carotenoids protect photosynthetic apparatus during **senescence** and **juvenile** phases

anthocyanins - young rose leaves

# Anthocyanins – modulation of color

Fig. 18.15

A

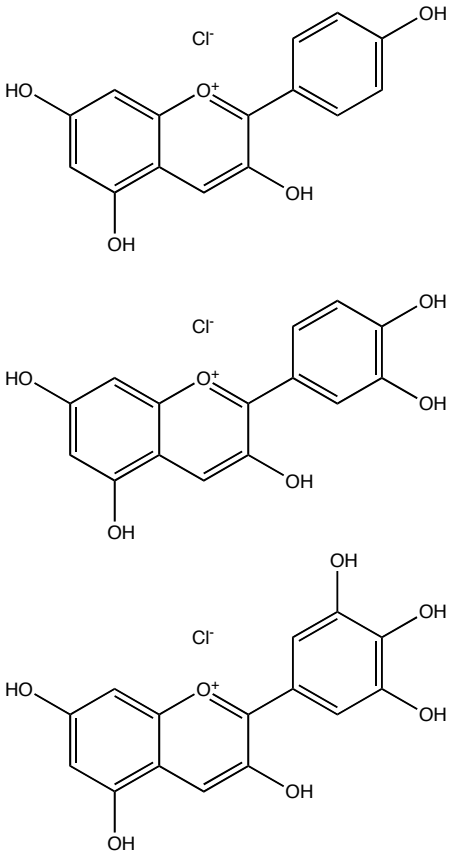



Pelargonidin (anthocyanidin)

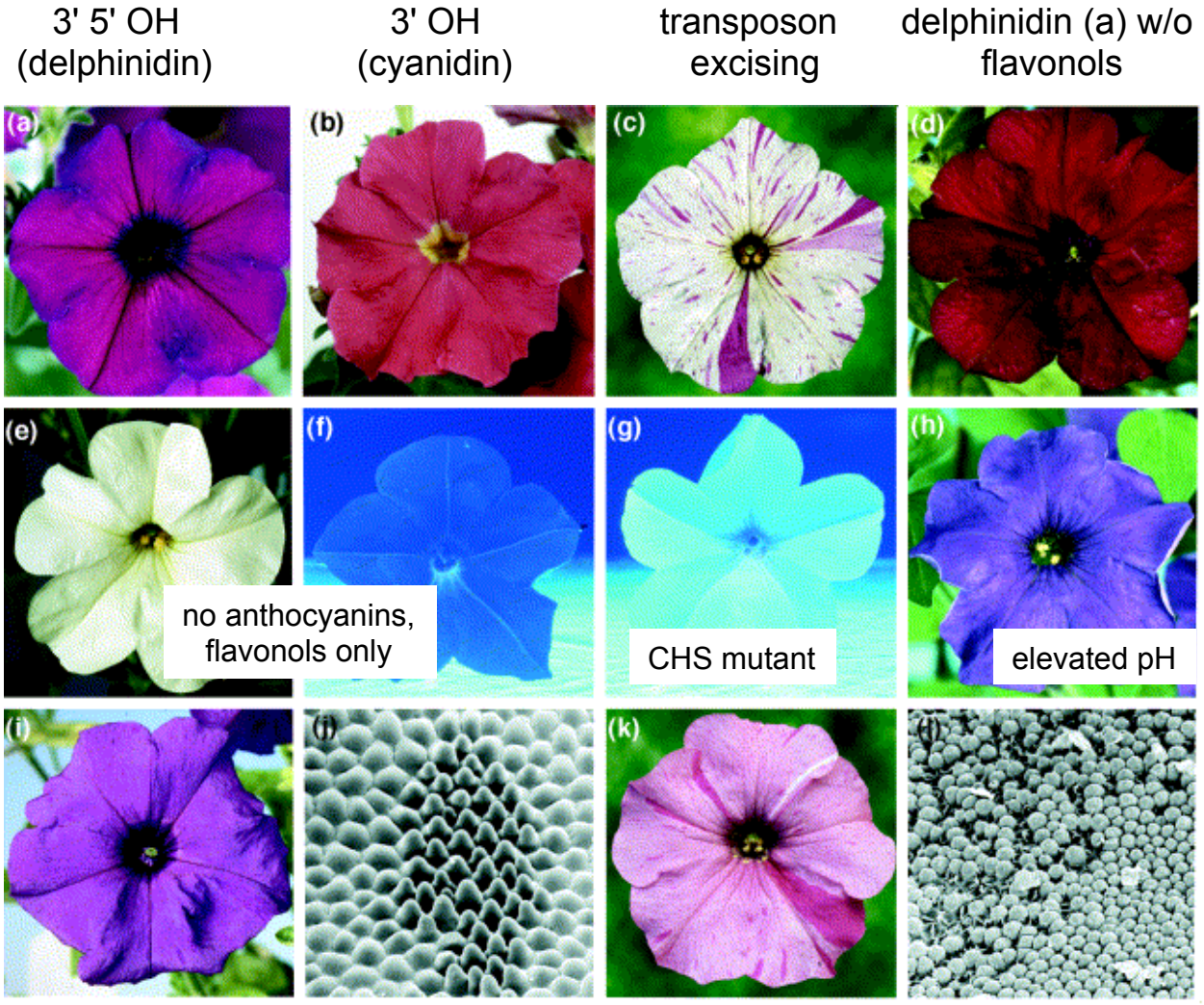
Pelargonin (anthocyan)

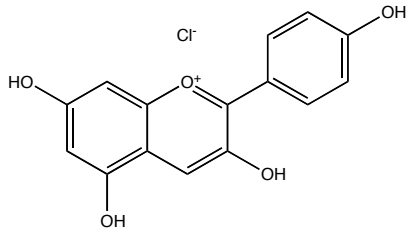
B

| Anthocyanidin | Substituent | Color |
|---|---|---|
| Pelargonidin | — | Orange-red |
| Cyanidin | 3′-OH | Red |
| Peonidin | 3′-$OCH_3$ | Pink |
| Delphinidin | 3′-OH, 5′-OH | Bluish-purple |
| Petunidin | 3′-$OCH_3$, 5′-OH | Purple |
| Malvidin | 3′-$OCH_3$, 5′-$OCH_3$ | Reddish-purple |

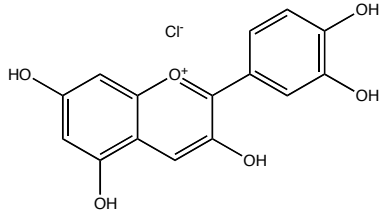


# Anthocyanins and flavonoids are important for flower color

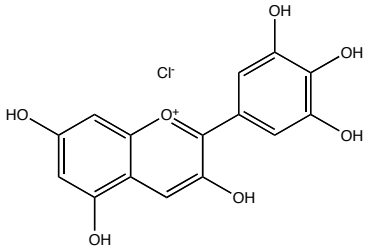



*pelargonidin*



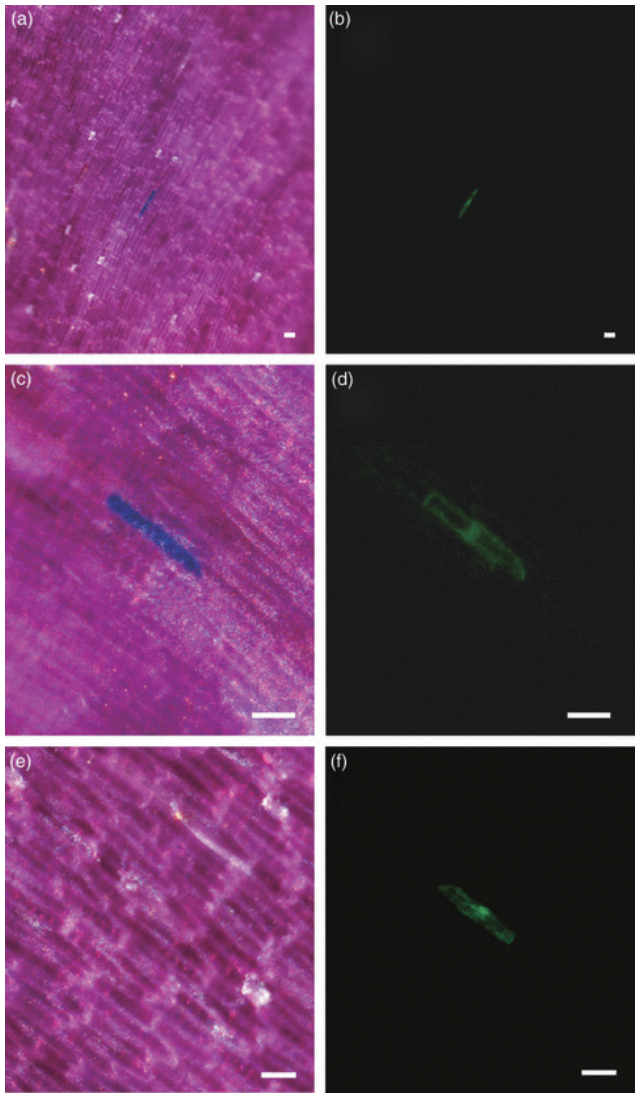

*cyanidin*




*delphinidin*

Impact of iron transport to vacuole on anthocyanin color in tulip

anthocyanins




GFP

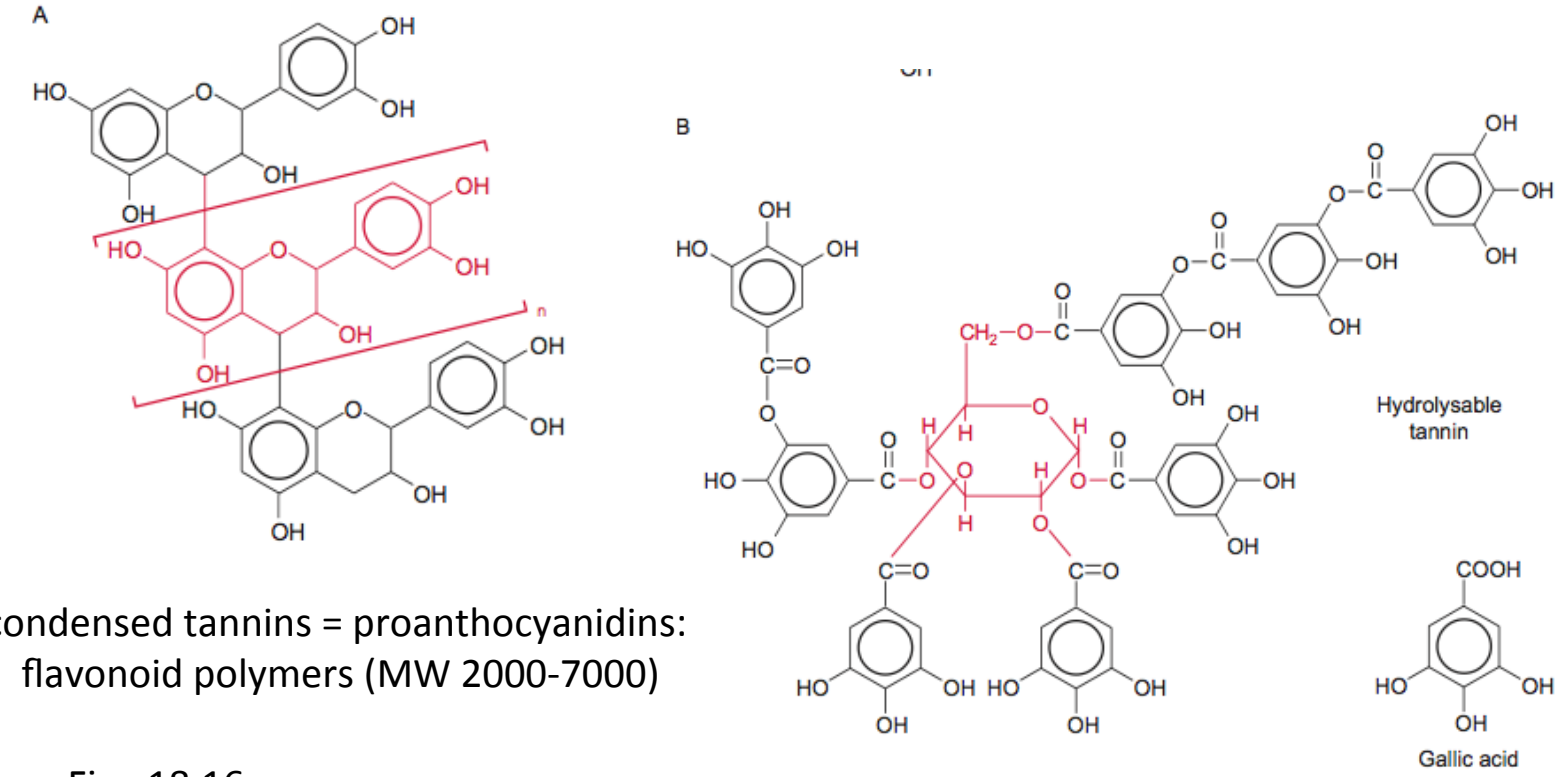
(overexpression of vacuolar iron transport protein)

## 7. Tannins (condensed/flavonoid-derived and hydrolyzable)

Definition: *water-soluble high MW polyphenols which precipitate proteins.*

condensed tannins – flavanoid-derived

hydrolyzable tannins –gallic acid derived




condensed tannins = proanthocyanidins: flavonoid polymers (MW 2000-7000)

Fig. 18.16

**Tannins:**

- **large polymeric** polyphenols
- **protein-binding** (& precipitating) ability via aromatic rings (hydrophobic interactions) and hydroxyls (H-bond with amino groups)
- **astringency** in wine and drinks: 'mouth-puckering', 'dry mouth' due to taste receptor interactions
- historically, used for leather -"tanning" ability, based on antimicrobial activity & protein binding
- generally **antimicrobial** compounds (see below)
- health foods (berries, apple, whole grains, nuts) and drinks (beer, wine) contain beneficial tannins
- dietary tannins reduce risk of cardiovascular disease, metabolic syndrome, neurodegenerative disease, others

  -> mechanisms unclear – probiotic? antioxidant?

  (-> only small tannins are absorbed from intestine)

**Tannins: what is their function in ecological systems?**

*i) Herbivore defense against mammals* (high levels, needs acidic gut)

- mechanism of tannin toxicity: bind gut proteins and prevent digestion / absorption
- many mammals have counter-adaptations: **proline-rich proteins** that bind tannins
- work with forest tent caterpillars on aspen showed no effect (!)

*-> Antimicrobial (pathogen defense)*

- poplar tannins reduce poplar rust infection or growth

*-> Modulate soil nutrient dynamics*

- tannins act as microbial inhibitors in soil -> slow **decomposition** and **mineralization**
- favor **mycorrhizae** and plant assimilation or amino acids (organic N)

# Overexpression of Myb134 in poplar leads to tannin accumulation

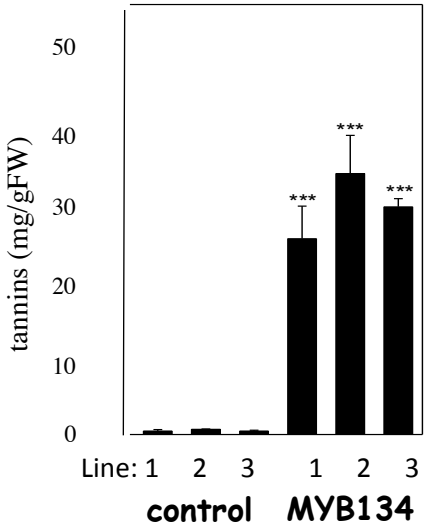
[Constabel Lab Research]

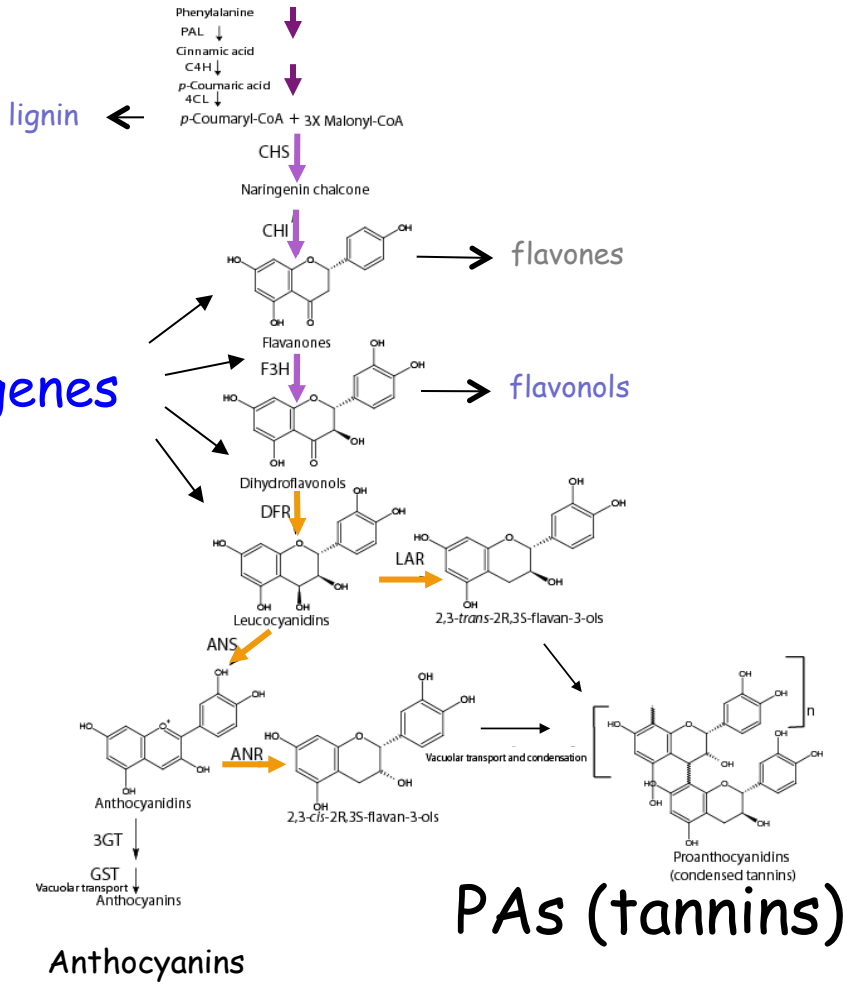
# Overexpression of Myb134 in poplar leads to tannin accumulation [Constabel Lab Research]

High-tannin plants are a unique opportunity to test biological functions of tannins

MYB134 → PA genes

MYB134 overexpressing Transgenic poplar




Anthocyanins

PAs (tannins)

*MYB134-overexpressing poplars show no visible phenotypic abnormalities despite 50-fold higher tannin levels*

*P. tremula x alba* (INRA 717-IB4)

*P. tremula x tremuloides* (INRA 353-38)

# Does Myb134 overexpression and high tannin levels lead to deterrence of lepidopteran insect pests?

*Malacosoma disstria* (Forest Tent Caterpillar)

- oligophagous, prefers *P. tremuloides*

*Lymantria dispar* (Gypsy Moth)

- polyphagous, generalist for woody plants

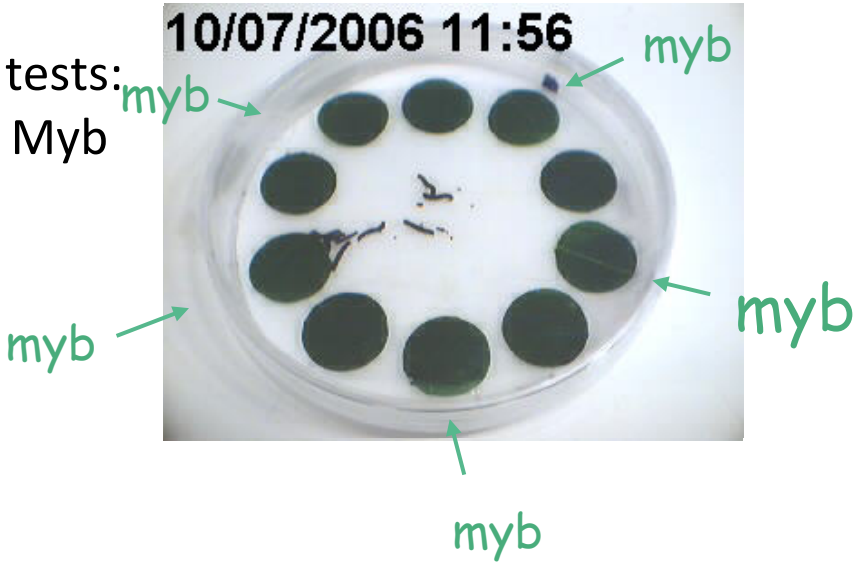
no choice assay

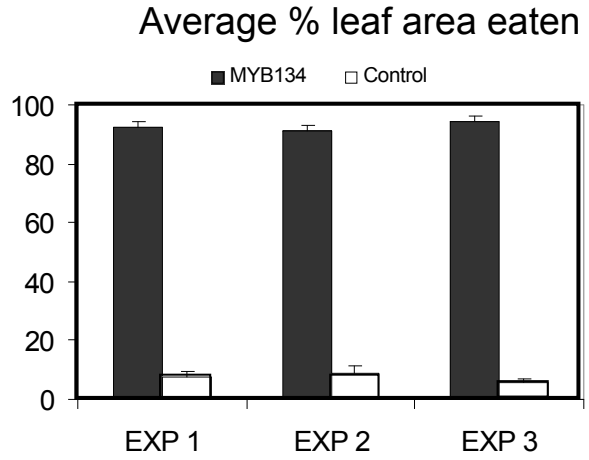
choice assay

Does Myb134 overexpression and high tannin levels lead to deterrence of lepidopteran insect pests?

*Choice test of MYB134 transgenics forest tent caterpillar*

choice tests:
Con vs Myb



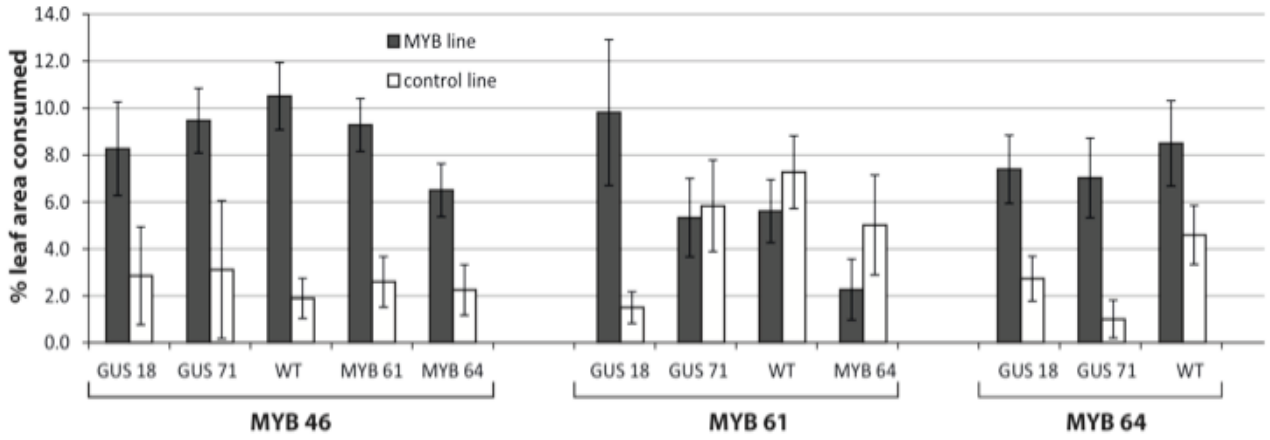




High tannin (MYB) foliage is preferred!

➔ also seen with generalists such as gypsy moth (*Lymantria dispar)*

# Gypsy moth (*Lymantria dispar*) also shows preference for high-tannin MYB-overexpressors (but not line 61)

(Sybille Unsicker, Andi Boeckler & Jonathan Gershenzon,
MPI for Chemical Ecology, Jena)

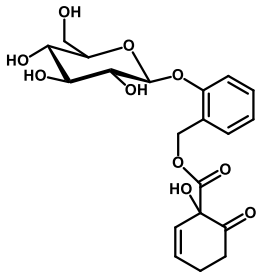



preferred

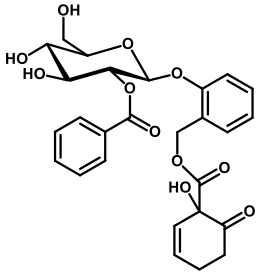
**no preference (line MYB61)**

preferred

Caveat: Myb134 overexpression leads to high tannin levels and **reduced** phenolic glycosides (salicortin, tremulacin)

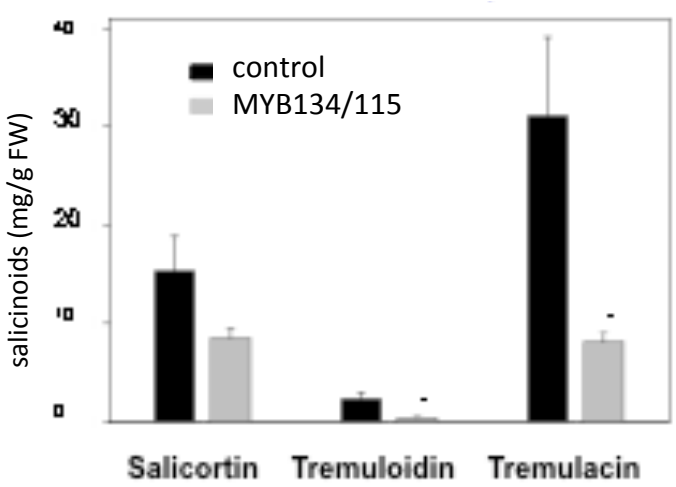


salicortin



tremulacin

*Phenolic glycosides are reduced in MYB plants*

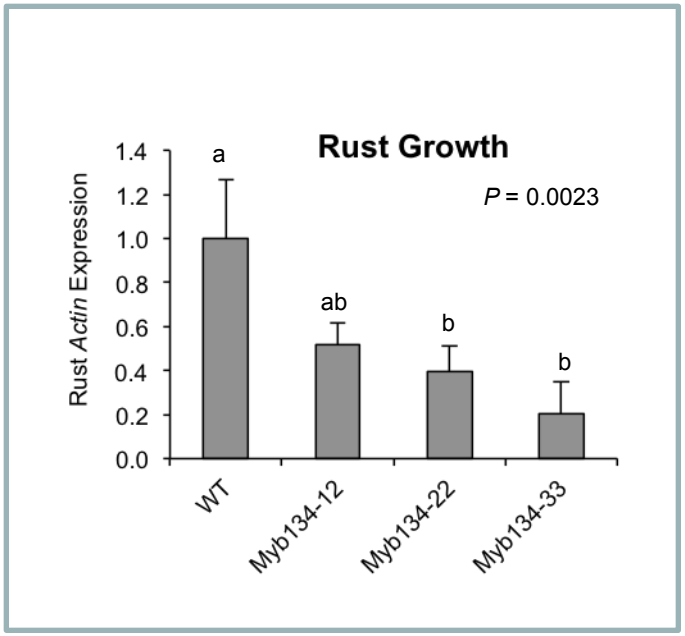


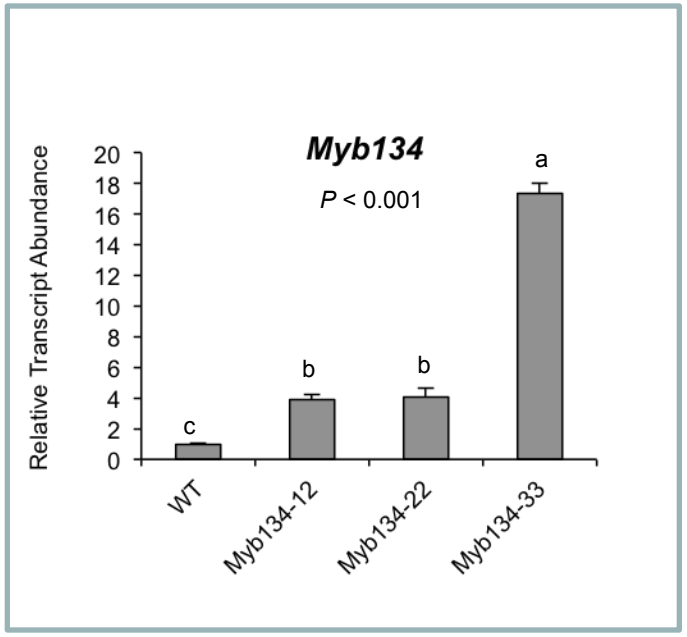

Two hypotheses:

i) is condensed tannin a feeding stimulant?

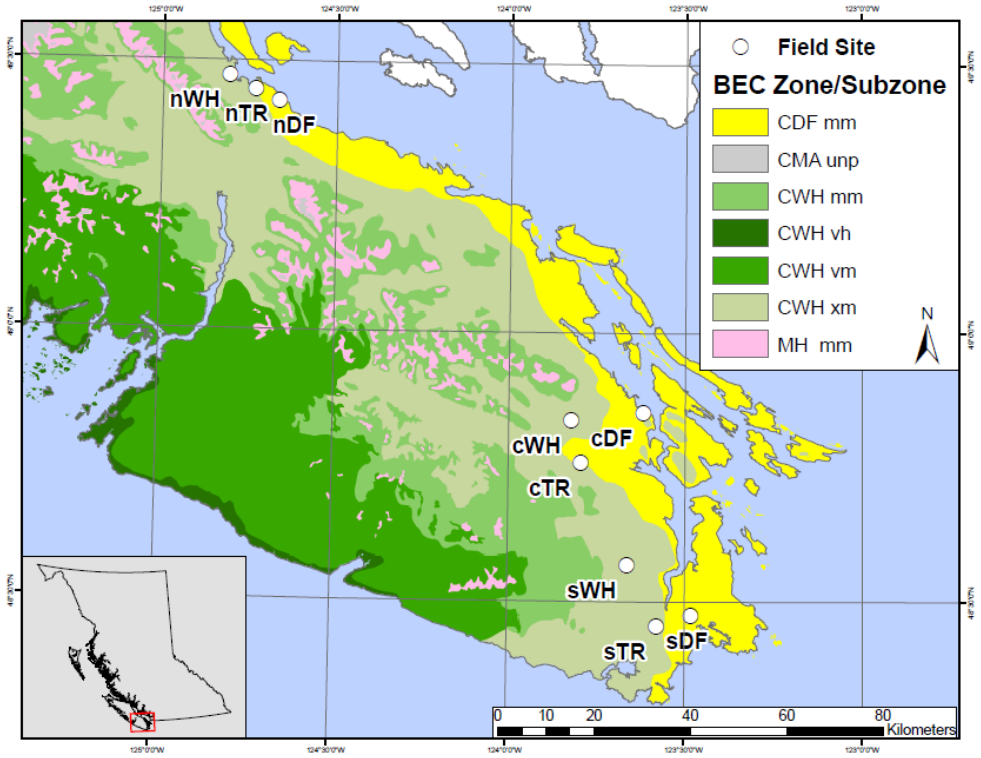
ii) do reduced salicortin & tremulacin make leaves more preferred?

ii) *Antimicrobial (pathogen defense)* - poplar tannins reduce poplar rust infection /growth

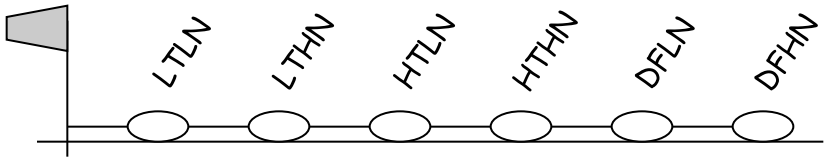


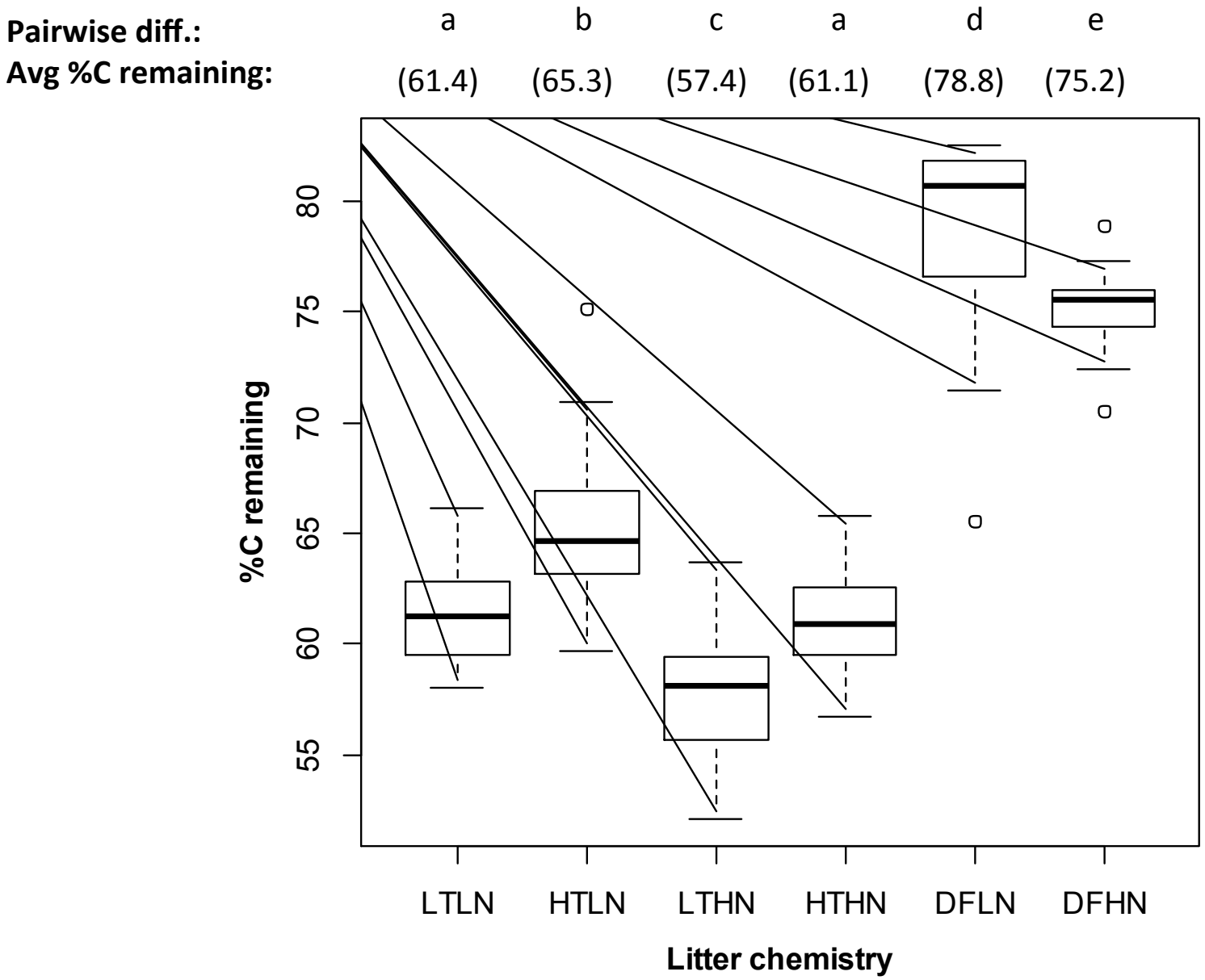

# Condensed tannin content slows poplar litter decay *in situ*



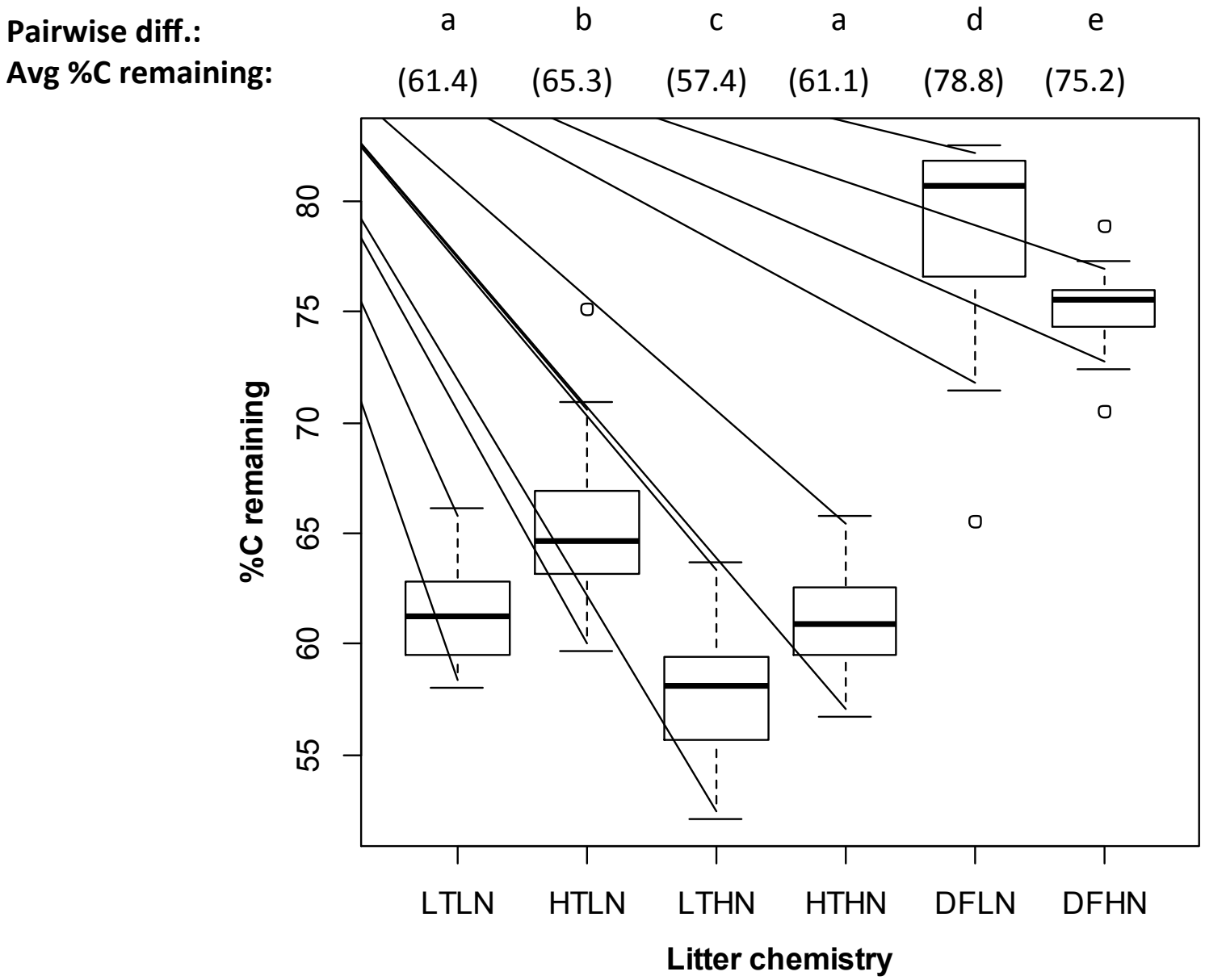

Philip-Eduoard Shay

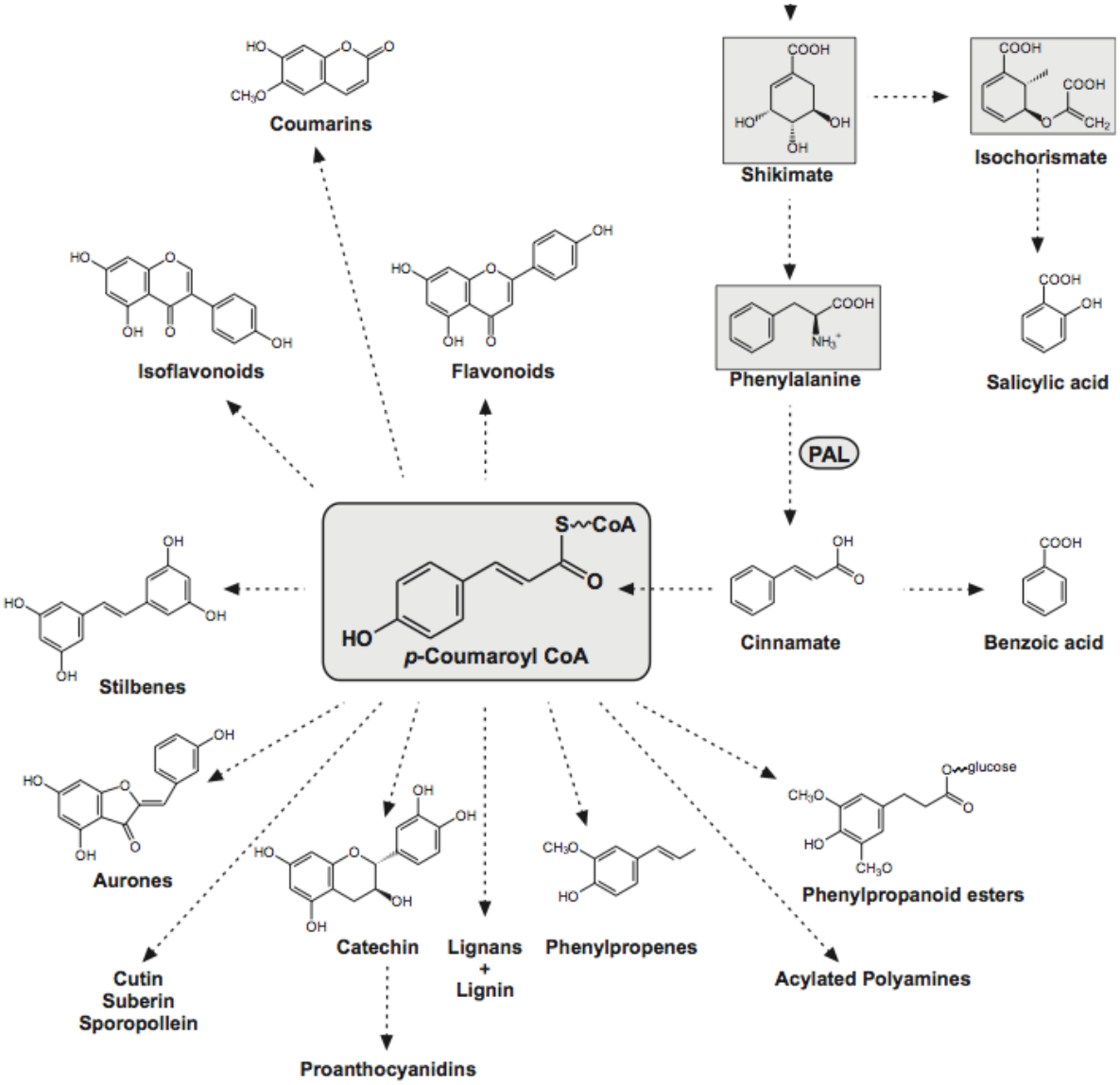



# Carbon remaining in litter at 0.5 - 1yr is affected by tannin content



Carbon remaining in litter at **0.5 - 1yr** is affected by tannin content




Coumarins
Shikimate
Isochorismate
Isoflavonoids
Flavonoids
Phenylalanine
Salicylic acid
PAL
p-Coumaroyl CoA
Stilbenes
Cinnamate
Benzoic acid
Aurones
Catechin
Lignans
+
Lignin
Phenylpropenes
Phenylpropanoid esters
Cutin
Suberin
Sporopollein
Proanthocyanidins
Acylated Polyamines