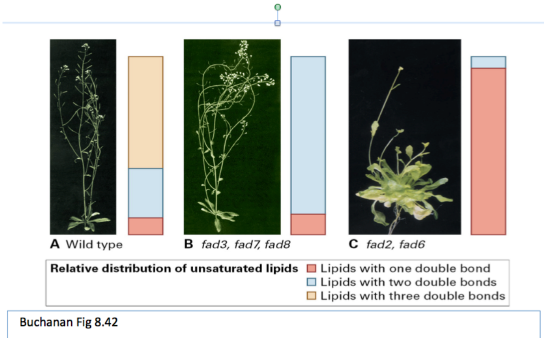
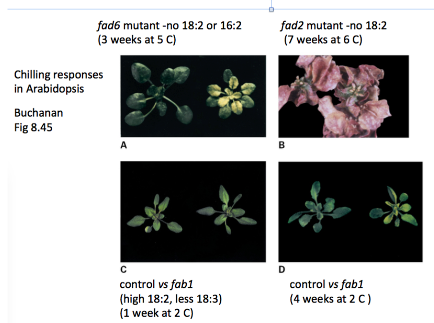
Additional Functions & Features of Plant Fatty Acids

I. Importance of desaturation in photosynthesis, hormone synthesis, and chilling tolerance

- desaturation is required for photosynthetic functions (without 18:2 and 18:3, plants cannot photosynthesize - *Arabidopsis* **fad2**, **fad6** mutants)
- *Arabidopsis* without 18:3 (fad3, fad7, fad8) are male sterile but grow normally
- many plants can develop chilling and freezing tolerance; part of this adaptive response is increased FA **desaturation** in cold temperatures)
- lack of desaturation causes chilling sensitivity (***fad2*** and ***fad6*** mutants)
- desaturation of membrane lipids is only one of many chilling adaptations (see fab1 mutant)





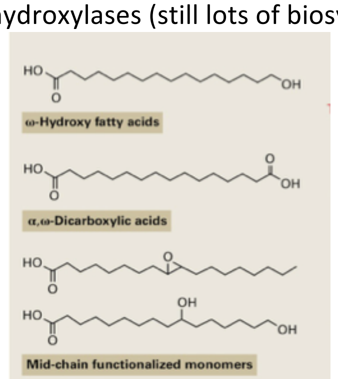
II. Long Chain (C20-C22) and Very Long Chain (C24-C32) Fatty Acids (Waxes and Cutin)

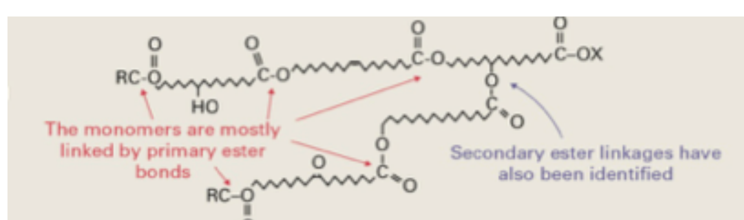
- plants make long fatty acids for multiple functions
- Long chain and VLCFAs are important for waxes, cutin, and suberin, also specialized FAs (erucic a.)
- elongases act on CoA-bound FAs (i.e., linolenoyl-CoA)

i.e. Erucic acid ($C22:1^{\Delta 13c}$) (toxic but useful)
- elongase acts on $C18:1^{\Delta 9c}$), i.e. on **oleoyl-CoA**

i.e. Cuticle (Cutin, Wax) and Suberin
- suberin waterproofs cell walls, important in Casparian strip, and bark and periderm
- waxes waterproof surfaces, and cutin has more structural roles (crystals on wax on plant surface)

Waxes: mixture of esters of long fatty acids and fatty alcohols (plus alkanes)
Cutin: also a mixture, but includes esters with mid-chain hydroxy fatty acids, **dicarboxylic acids**, other groups.
Suberin: Similar to cutin with additional components, longer chains, fatty alcohols, **phenolics**
Key enzymes include **elongases**, **acyl-CoA reductases** to make fatty alcohols, and midchain hydroxylases (still lots of biosynthetic questions).

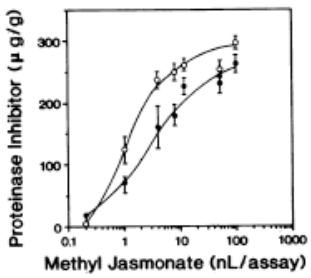


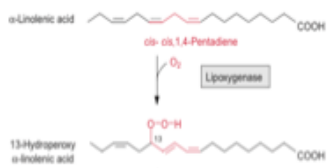


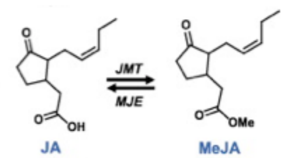
III. Unexpected Functions of Fatty Acids: FA-derived Stress Signals and Hormones (jasmonates and green leaf volatiles)

Methyl Jasmonate and **Jasmonic Acid**

- Methyl jasmonate (MeJa) was discovered as potent inducer of plant defense (**proteinase inhibitors**: paradigm of **induced defense**)
- while MeJa is unlikely to be an actual volatile signal for plant-plant communication, jasmonic acid (JA) and related jasmonates (JA-Ile, others) are now known to be important defense signals
- JA-Ile and jasmonates are the **systemic** defense signal
- JA is also required for pollen development (developmental function).
- jasmonates are derived from linolenic acid (18:3) [key enzymes: 13-*lipoxygenase*, *cyclase]*
- JA synthesis mutant tomatoes are unable to induce defenses against caterpillars and other herbivores







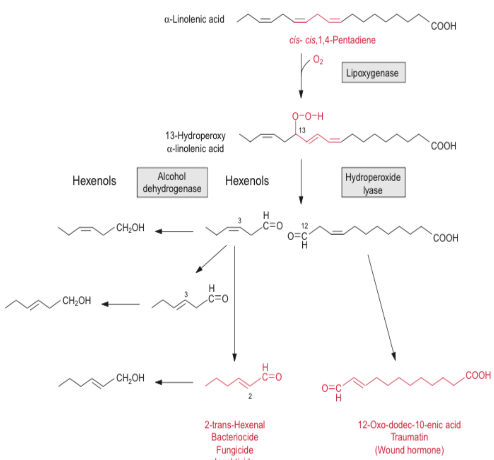
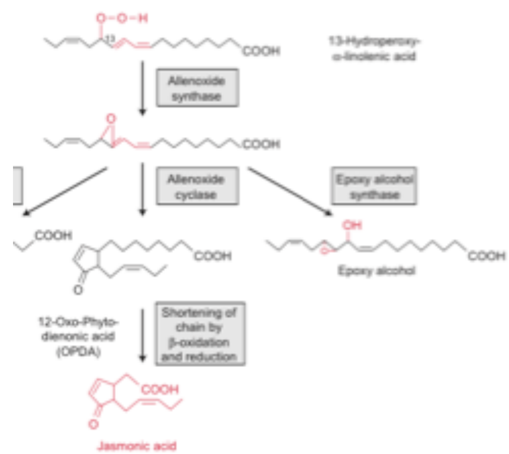


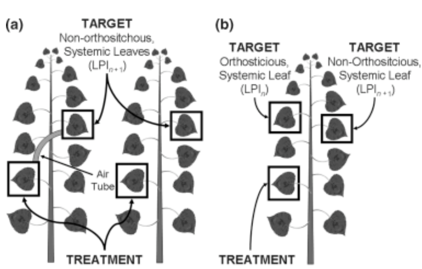
Figure 15.29 By reaction with O_2, lipoxygenase catalyzes the introduction of a



Green Leaf Volatiles (hexenols and hexenals) are made from linolenic acid via a parallel pathway

key enzymes: 13-*lipoxygenase*, *hydroperoxide lyase, alcohol dehydrogenase*

- these are small volatile lipids: *trans*-2-hexenal, *cis*-3-hexenol = "cut lawn" smell
- can **prime** inducible defenses: enhanced response to later attacks (intra-plant signals)



IV. Fatty Acids in Seed Oils of Several Crop Plants Can Be Genetically Engineered

Why? Improved FA profiles for better human health, or as a source of industrial chemical feedstocks

- for food, oils high in 18:1 (and not too much 18:3) are optimal as dietary fats (part of Mediterranean diet). Saturated fats are linked to cardiovascular disease (animal fats)
- FAs found in crop species have value for chemical industry (polymers, lubricants, detergents), for example flax seed, rapeseed/canola, palm kernel.
- novel FAs in some specialty plants are very valuable feedstocks (but may be hard to grow)
- since oil seed plants (canola in particular) can be genetically modified, plants with customized seed oils could be generated in crop plants, with good agronomic and processing systems
- such higher value crops would be good for agriculture, and would reduce reliance on petroleum. [*Note: canola is low erucic acid, derived by conventional breeding (crossing and selecting). It is also low in glucosinolates (mustard oils) and sinapyl choline in seed.]*

Table 15.4: Industrial utilization of fatty acids from vegetable oils

	Main source	Utilization for
Lauric acid (12:0)	Palm kernel, coconut	Soap, detergents, cosmetics
Linolenic acid (18:3)	Flax seed	Paints, lacquers
Ricinoleic acid (18:1, Δ9, 12-OH)	Castor bean	Surface protectants, lubricant
Erucic acid (22:1, Δ13)	Rape seed	Tensides Foam control for detergents, lubricant, synthesis of artificial fibers

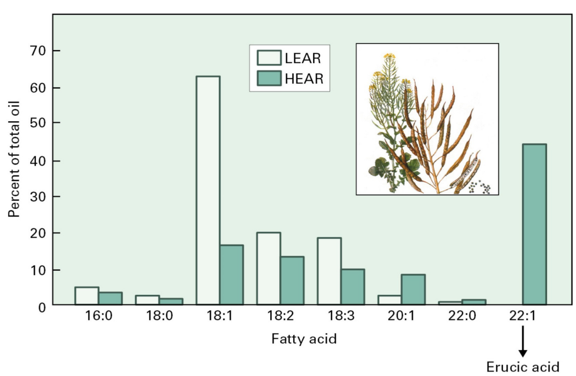
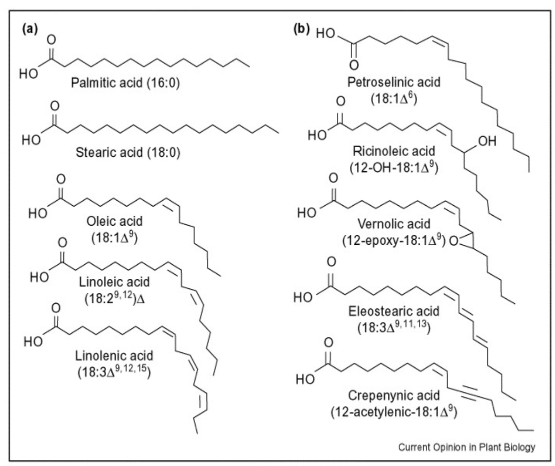
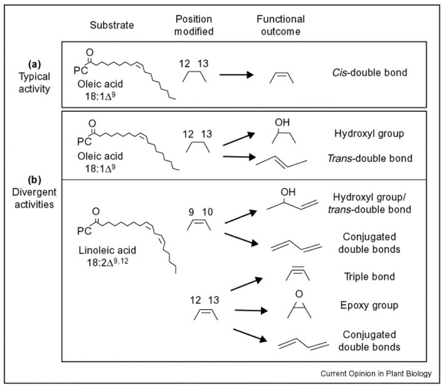


FIGURE 8.67 *Fatty acid composition of seed oil from high and low-erucic acid rapeseed (HEAR and LEAR, respectively) varieties. Additional improvements by plant breeding have reduced the 18:3 content of the most recent cultivars to a small percentage of the total fatty acids, with corresponding increases in the 18:1 content. Rapeseed is the major oilseed crop of Europe, Canada, and many countries with short growing seasons. After soybean and oil palm, it is the world's third largest source of vegetable oils. Varieties that have been bred to contain low amounts of erucic acid are referred to as canola. Because of its high oil content (45% of seed weight) and relative ease of transformation, canola has become the first crop genetically engineered to produce new oils.*



Biochemistry & Molecular Biology of Plants, Second Edition. Edited by Bob B. Buchanan, Wilhelm Gruissem, and Russell L. Jones.
© 2015 John Wiley & Sons, Ltd. Published 2015 by John Wiley & Sons, Ltd.
Companion website: www.wiley.com/go/buchanan/biochem
WILEY Blackwell



Enzymes which create the novel, modified FAs can be identified and cloned from the corresponding species. Modified 12DES (also FAD2-like) have evolved to take on these functions.

Strategies for altering the FA profile of plants via genetic engineering
(Class Discussion or Thinking Questions)

1) Can you genetically engineer soya bean to be high in oleic acid (C:18:1)? How?

2) How could one engineer canola or soybean to make lauric acid (C12:0)? What enzyme would you have to insert or modify?

3) Can canola plants be created make ricinoleic acid (18:1, 12-OH) in their storage oils? WHat is the strategy that you might propose.

4) Assuming you can make transgenic canola that expresses the enzymes that synthesize **crepenynic acid**, what other factors would you hvae to take into consideration? Are novel fatty acids easily incorporated into in seed oils of crop plants? What would you do to additionally prevent unintended side effects?

6) How and why do plants make these novel fatty acids?