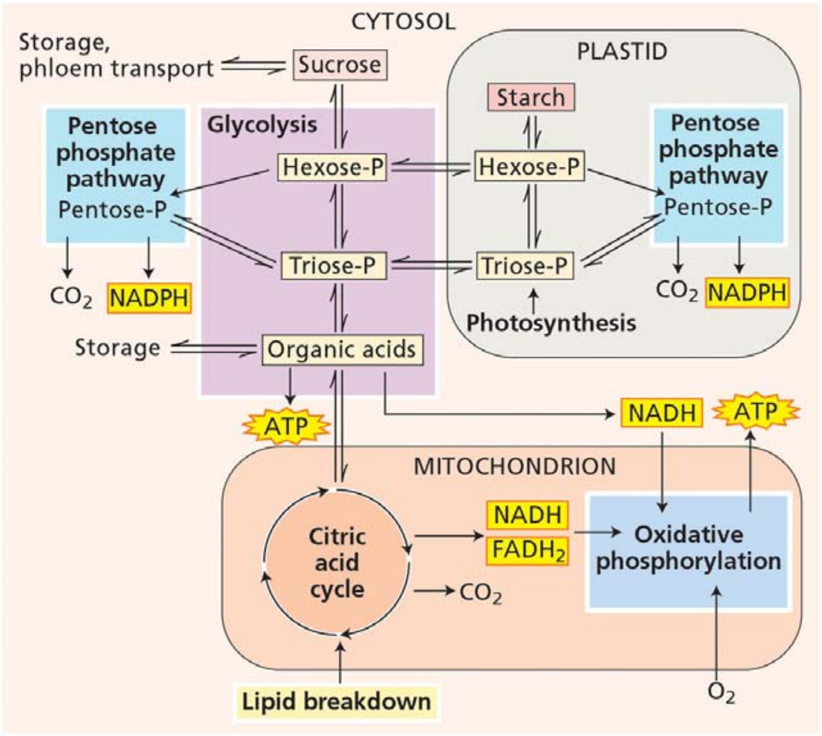
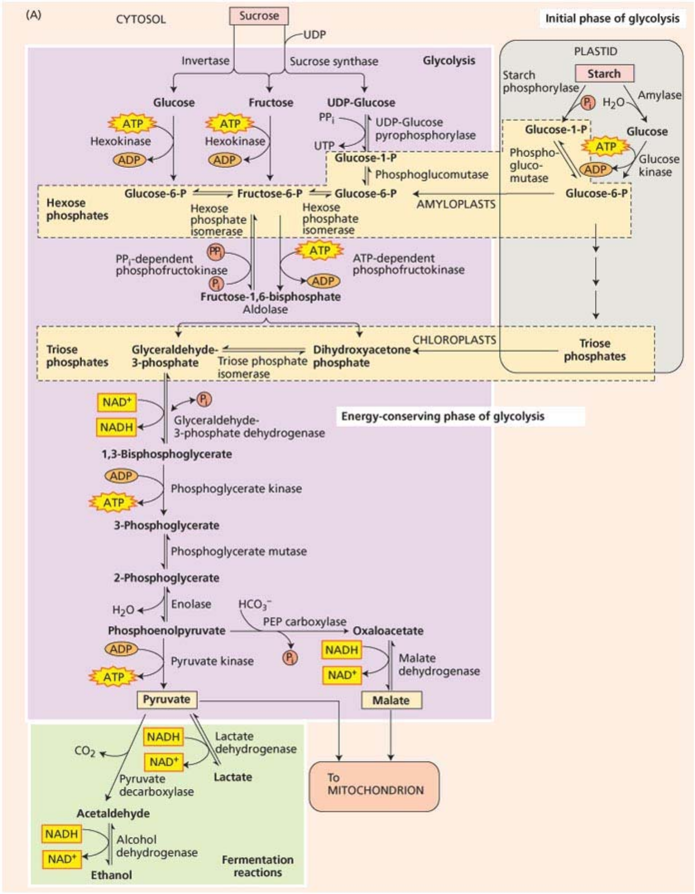
Respiration and lipid metabolism

- Production of ATP
- $C_{12}H_{22}O_{11} + 12O_2 \rightarrow 12\ CO_2 + 11\ H_2O$
- 5760 kJ/mol
- 60 ATP



Glycolysis

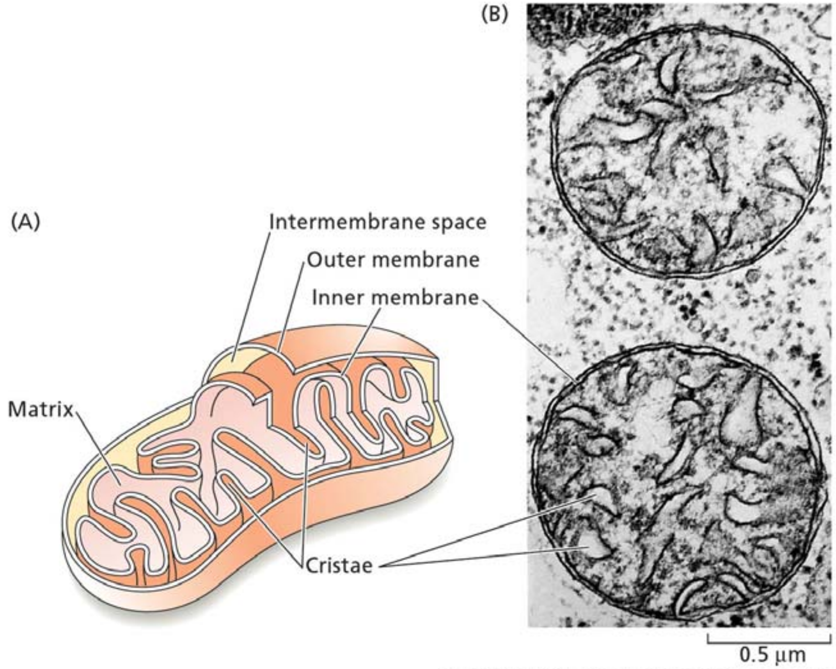
- **Ancient Pathway**
- **In cytoplasm**
- **No oxygen required**
- **Used for energy production**
- **Production of intermediates for other pathways**
- **Fermentation**
- **Fate of pyruvate when no oxygen is available**
- **Recycle NADH to NAD+ to keep glycolysis going**
- **Alcohol/Lactic acid fermentation**



PLANT PHYSIOLOGY, Third Edition, Figure 11.3 (Part 1) © 2002 Sinauer Associates, Inc.

Citric Acid cycle

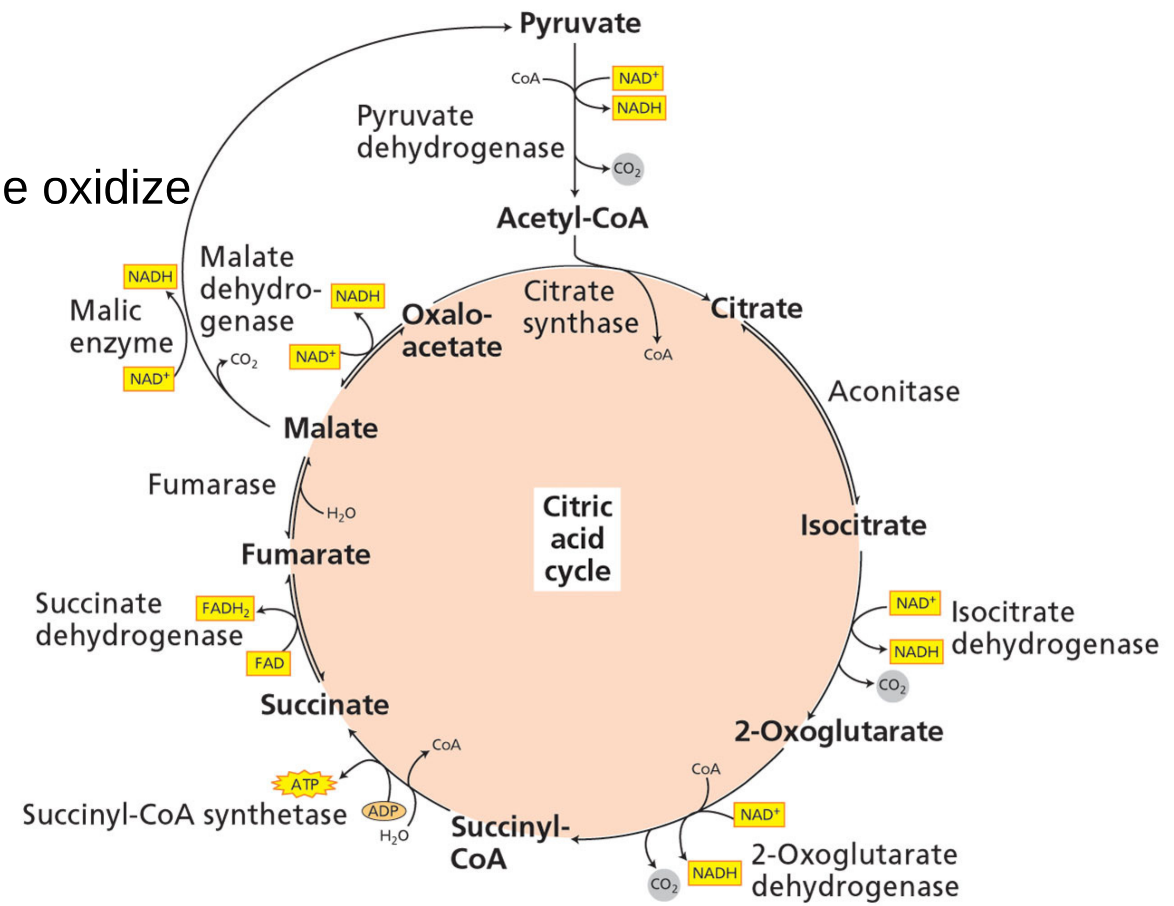
- In Mitochondria
- Complete oxidation of sucrose (other sugars) when O_2 is present
- Releases CO_2
- Produce NADH, FADH, and ATP



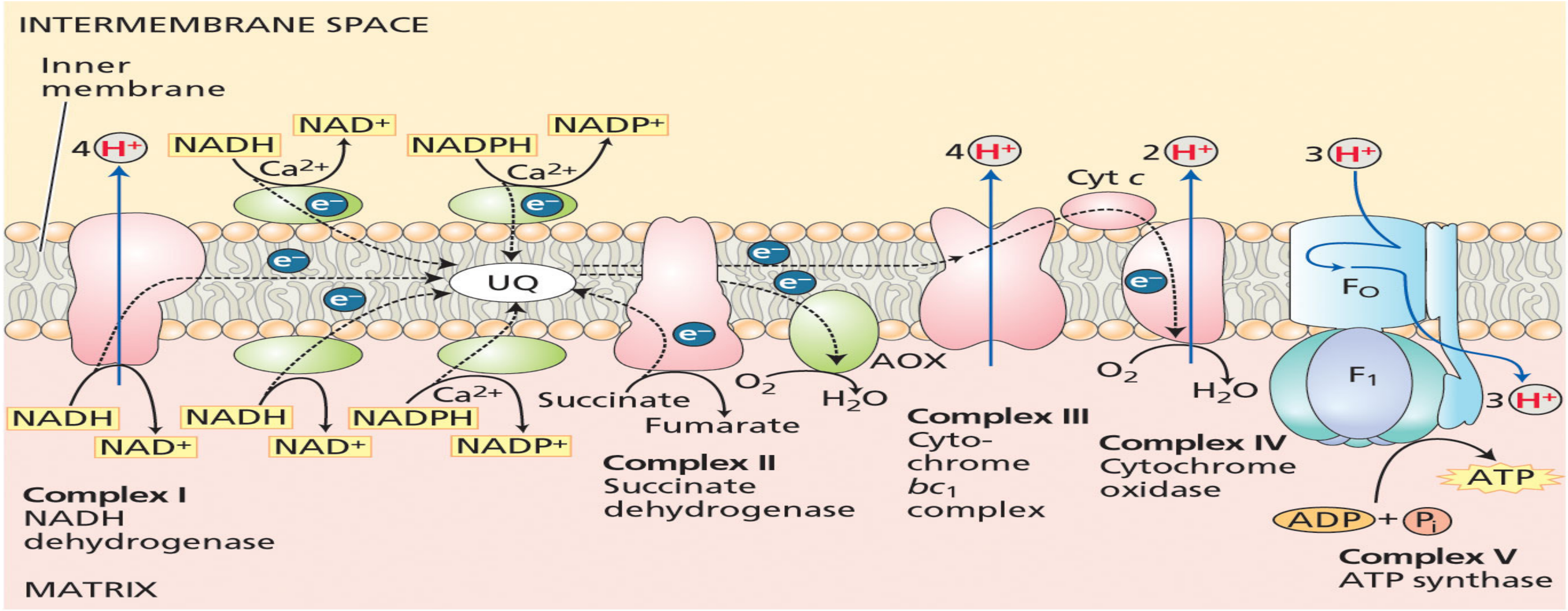
PLANT PHYSIOLOGY, Third Edition, Figure 11.5 © 2002 Sinauer Associates, Inc.

Citric acid cycle

Malic enzyme oxidize
Malate



Electron Transport



PLANT PHYSIOLOGY, Third Edition, Figure 11.8 © 2002 Sinauer Associates, Inc.

- NADH and FADH from TCA cycle
- NADH from glycolysis
- Reduction potential
  - 0.32V for NADH to NAD+
  - 0.82V for O2 to H2O
- Two electron change

Alternate pathways

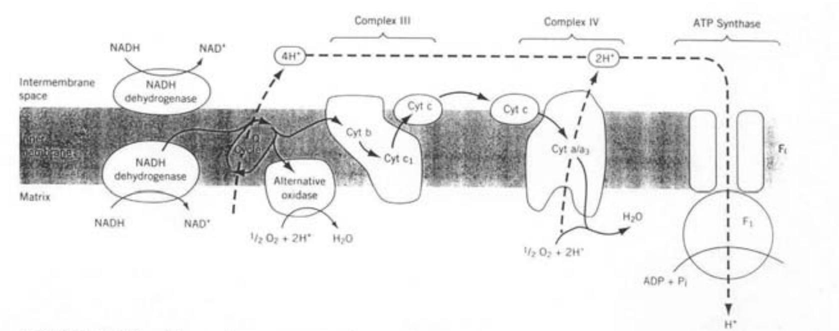
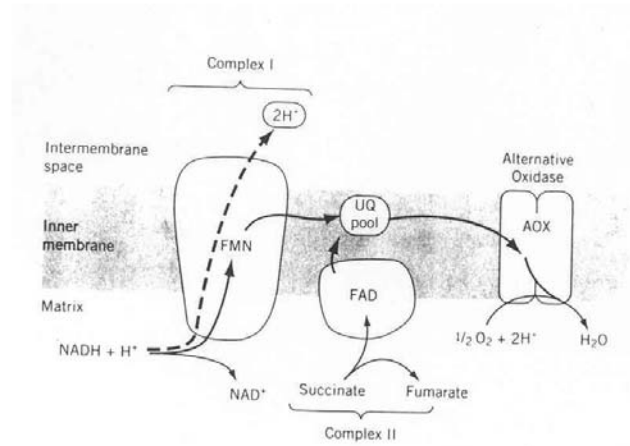


FIGURE 12.11 Alternate electron transport pathways in plant mitochondria.



- Two NAD(P)H dehydrogenase outer surface of inner membrane
- Rotenone insensitive NADH dehyrdrogenase
- Alternative oxidase insensitive to CN (10-25%) of total levels
- Inhibited by salicyhydroxamic acid (SHAM)
- Produce heat (Arum family), volatize chemicals to attract pollinators
- Energy overflow
- Reduce Ub over reduction
- Rotenone insensitive: proton pumping bypass

Oxidative phosphorylation

- Production of ATP
- Proton motive force
- Two components
  - membrane potential
  - pH gradient
- ATP synthetase in inner membrane
- 2.5 ATP/NADH
- 1.5 ATP/FADH

TABLE 11.1
Theoretical and experimental ADP:O ratios in isolated plant mitochondria

Substrate	ADP:O ratio Theoretical[a]	Experimental
Malate	2.5	2.4–2.7
Succinate	1.5	1.6–1.8
NADH (external)	1.5	1.6–1.8
Ascorbate	1.0[b]	0.8–0.9

[a]It is assumed that complexes I, III, and IV pump 4, 4, and 2 H^+ per 2 electrons, respectively; that the cost of synthesizing one ATP and exporting it to the cytosol is 4 H^+ (Brand 1994); and that the nonphosphorylating pathways are not active.

[b]Cytochrome *c* oxidase pumps only two protons when it is measured with ascorbate as electron donor. However, two electrons move from the outer surface of the inner membrane (where the electrons are donated) across the inner membrane to the inner, matrix side. As a result, 2 H^+ are consumed on the matrix side. This means that the net movement of H^+ and charges is equivalent to the movement of a total of 4 H^+, giving an ADP:O ratio of 1.0.

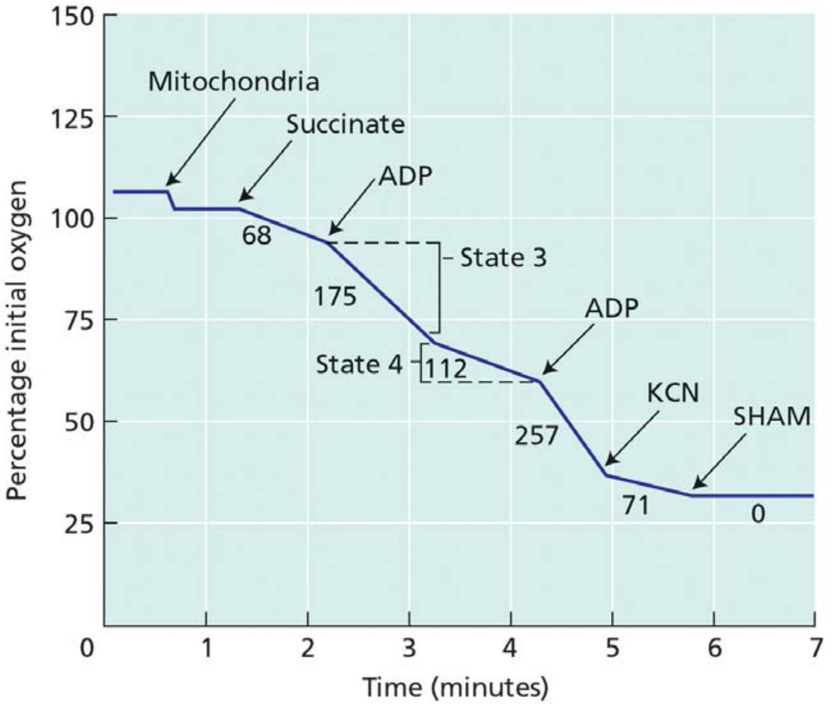
TABLE 11.2
The maximum yield of cytosolic ATP from the complete oxidation of sucrose to CO_2 via aerobic glycolysis and the citric acid cycle

Part reaction		ATP per sucrose[a]
Glycolysis		
4 substrate-level phosphorylations		4
4 NADH	4 × 1.5	6
Citric acid cycle		
4 substrate level phosphorylations		4
4 $FADH_2$	4 × 1.5	6
16 NADH	16 × 2.5	40
Total		60

Source: Adapted from Brand 1994.
Note: Cytosolic NADH is assumed oxidized by the external NADH dehydrogenase. The nonphosphorylating pathways are assumed not to be engaged.
[a]Calculated using the theoretical values from Table 11.1

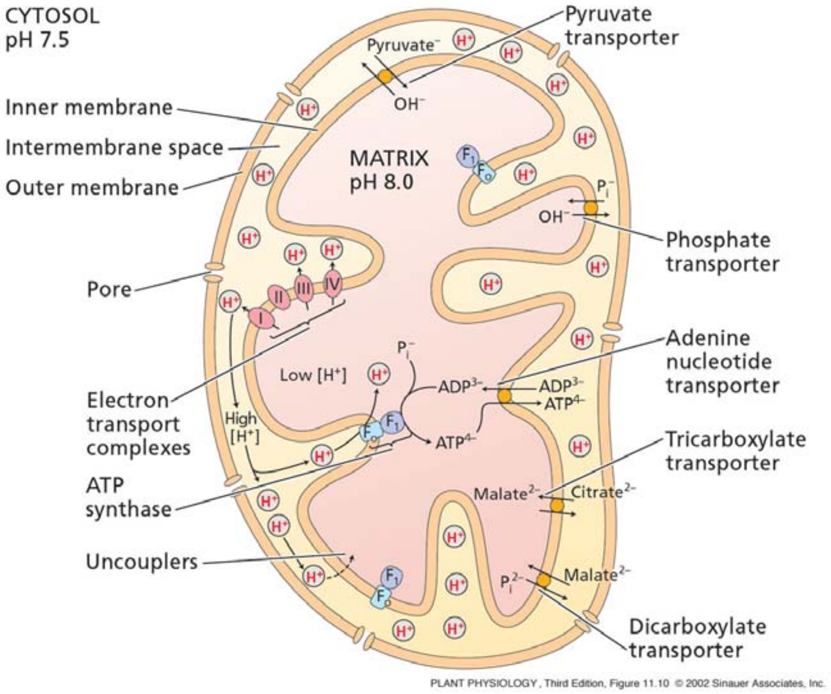
Respiration rates

- O_2 consumption versus time
- Addition of ADP needed
- calculate P/O ratio of different compounds
- Uncouplers and their effect
- DNP
- vallinomycin
- gramicidin
- SHAM
- CN



Transport

- Transport of ATP
- ATP/ADP exchange
- Pi/OH- exchange



Whole plant respiration

- Many factors effect respiration
- Oxygen
- Water saturation
- Temperature
- CO_2 concentration

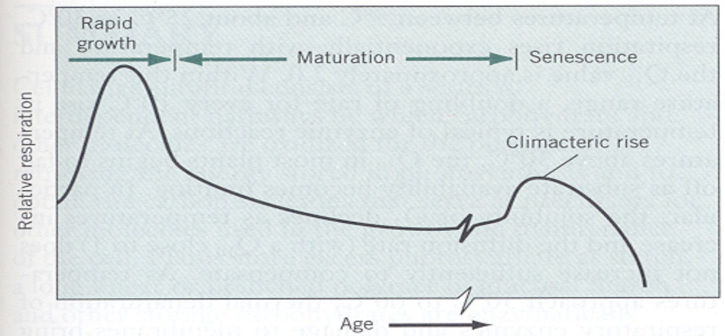


FIGURE 7.15 Respiratory rate as a function of age. This type of curve applies generally to most herbaceous plants, tissues, and organs. The magnitude of the climacteric will vary—some organs exhibit little or no climacteric rise.

TABLE 7.2 Approximate specific dark respiration rates at 20°C for crop species, deciduous foliage, and conifers.

	Specific Respiration Rate μmol CO_2 evolved $\cdot$ g^{-1} dry mass $\cdot$ h^{-1}
Crops	70–180
Deciduous foliage	
(sun leaves)	70–90
(shade leaves)	20–45
Conifers	4–25

Hopkins & Huner

Lipid metabolism

- **Nomenclature**
- **saturated: palmitate, stearate, no double bonds**
- **unsaturated: palmitoleate, Oleate: double bond at cis 9 position**
- **polyunsaturated**
- **Melting points: saturated vs unsaturated**

TABLE 11.3
Common fatty acids in higher plant tissues

Name[a]	Structure
Saturated Fatty Acids	
Lauric acid (12:0)	$CH_3(CH_2)_{10}CO_2H$
Myristic acid (14:0)	$CH_3(CH_2)_{12}CO_2H$
Palmitic acid (16:0)	$CH_3(CH_2)_{14}CO_2H$
Stearic acid (18:0)	$CH_3(CH_2)_{16}CO_2H$
Unsaturated Fatty Acids	
Oleic acid (18:1)	$CH_3(CH_2)_7CH{=}CH(CH_2)_7CO_2H$
Linoleic acid (18:2)	$CH_3(CH_2)_4CH{=}CH{-}CH_2{-}CH{=}CH(CH_2)_7CO_2H$
Linolenic acid (18:3)	$CH_3CH_2CH{=}CH{-}CH_2{-}CH{=}CH{-}CH_2{-}CH{=}CH{-}(CH_2)_7CO_2H$

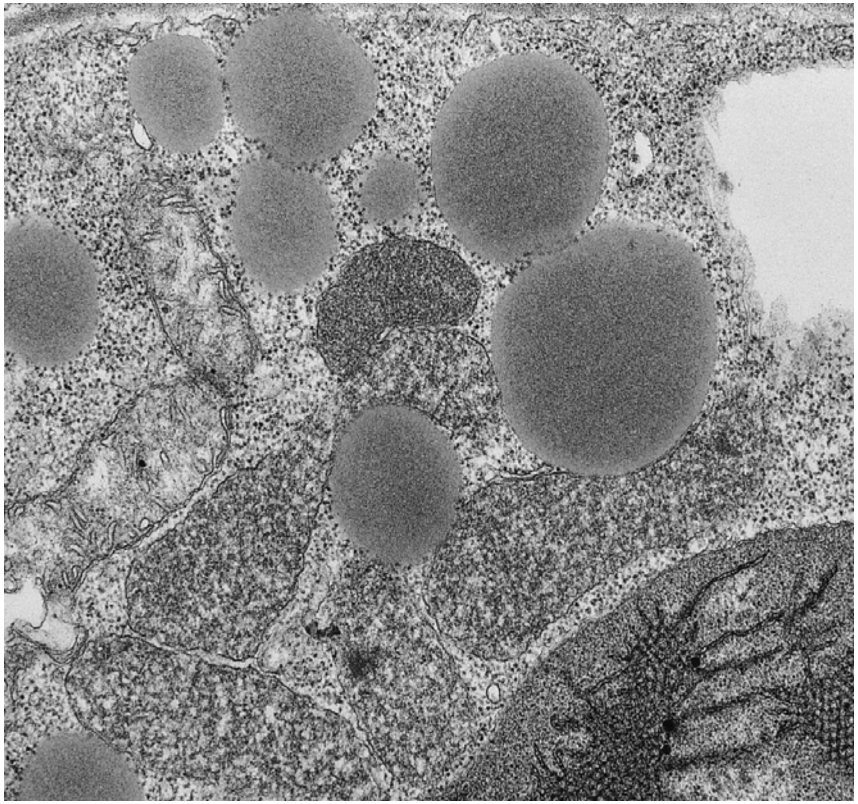
[a]Each fatty acid has a numerical abbreviation. The number before the colon represents the total number of carbons; the number after the colon is the number of double bonds.

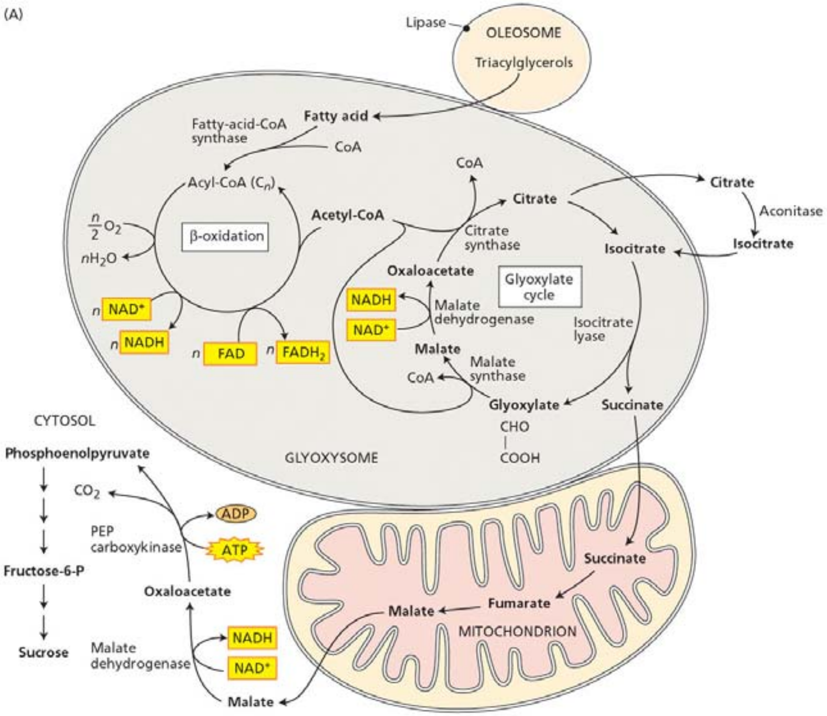
Lipid content of seeds

TABLE 12.1 Approximate lipid content of selected seeds.

Species		Oil Content (% dry weight)
Macadamia nut	*Macadamia ternifolia*	75
Hazel nut	*Coryllus avellana*	65
Safflower	*Carthmus tinctoris*	50
Oil palm	*Elaeis guineensis*	50
Canola	*Brassica napus*	45
Castor bean	*Ricinus communis*	45
Sunflower	*Helianthus annum*	40
Maize	*Zea mays*	5

Glyoxylate cycle





PLANT PHYSIOLOGY, Third Edition, Figure 11.18 © 2002 Sinauer Associates, Inc.

- net conversion of fat into carbohydrates
- found in bacteria, algae, plants
- usually in germinating seeds
    - sunflower, castor bean, peanuts, kale

Membrane lipids

TABLE 21.2 Ratio of unsaturated/saturated fatty acids of membrane lipids of mitochondria isolated from chilling-sensitive and chilling-resistant tissues.

Chilling-sensitive tissues		
Phaseolus vulgaris (bean)	shoot	2.8
Ipomoea batatas (sweet potato)	tuber	1.7
Zea mays (maize)	shoot	2.1
Lycopersicon esculentum (tomato)	green fruit	2.8
Chilling-resistant tissues		
Brassica oleracea (cauliflower)	buds	3.2
Brassica campestris (turnip)	root	3.9
Pisum sativum (pea)	shoot	3.8

From data of J. M. Lyons et al., *Plant Physiology* 39:262, 1964.