Fish Feeding :
4-Fat

Dr.A.Y.Al-Dubakel

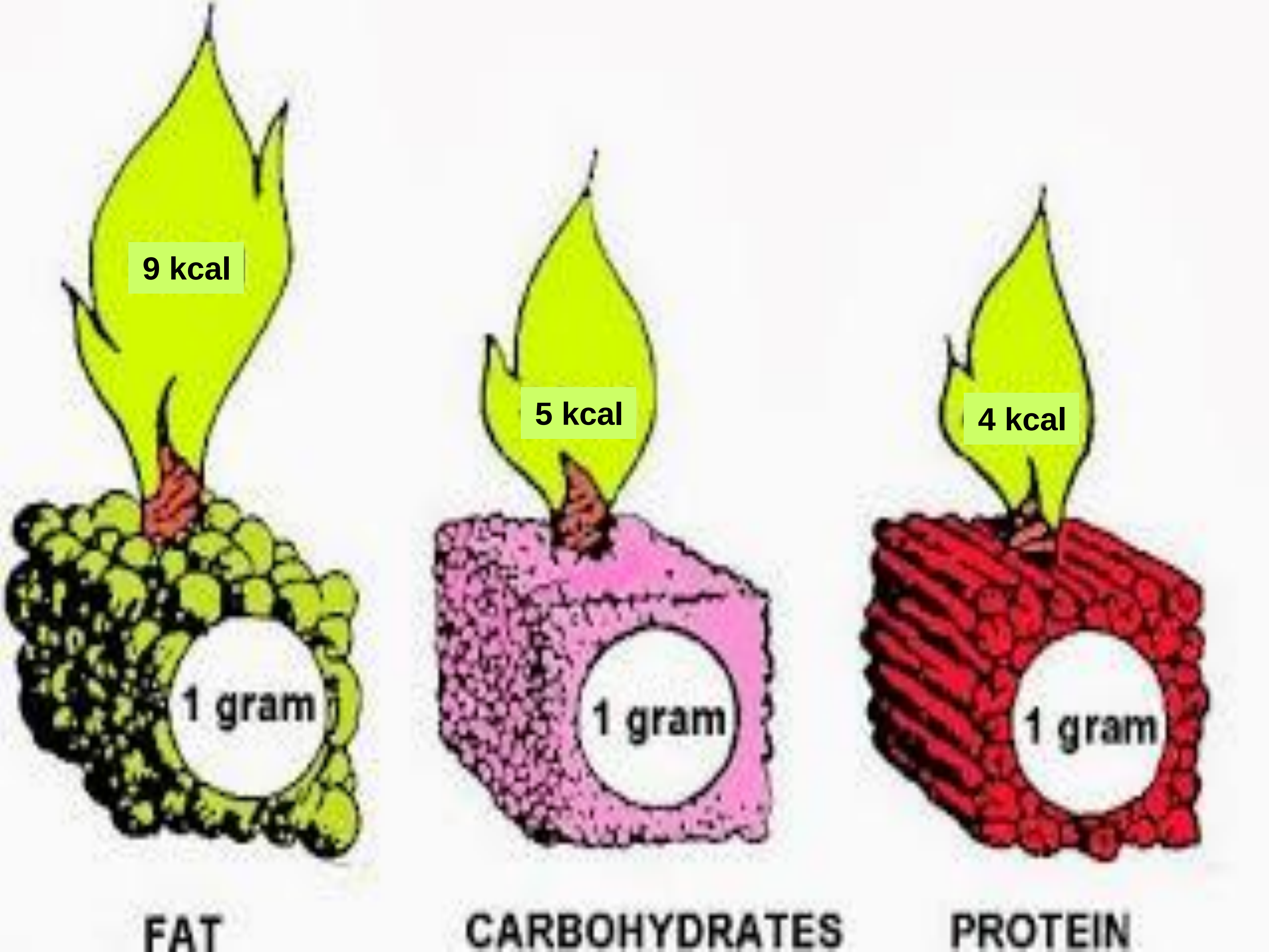
Lipid Characteristics

- Lipid = a compound that is insoluble in water, but soluble in an organic solvent (e.g., ether, benzene, acetone, chloroform)
- "lipid" is synonymous with "fat", but also includes phospholipids, sterols, etc.
- chemical structure: glycerol + fatty acids

Of the major nutrients, lipids are the group most easily digested and metabolised. On a unit -for-unit basis they also provide more energy than carbohydrates or proteins?. Fish also require certain essential fats for the correct structural arrangement of membranes such as cell walls - long-chain polyunsaturated fats are necessary for carnivorous fish, particularly salmonids. Over the years the fat/oil content of diets has steadily increased, from around 6% some 20 years ago, to 10 - 12% 15 years ago, 18 - 21% five or six years ago to current levels of 25 - 33%. These so-called 'high energy' diets have to be given with care as problems can and do occur.

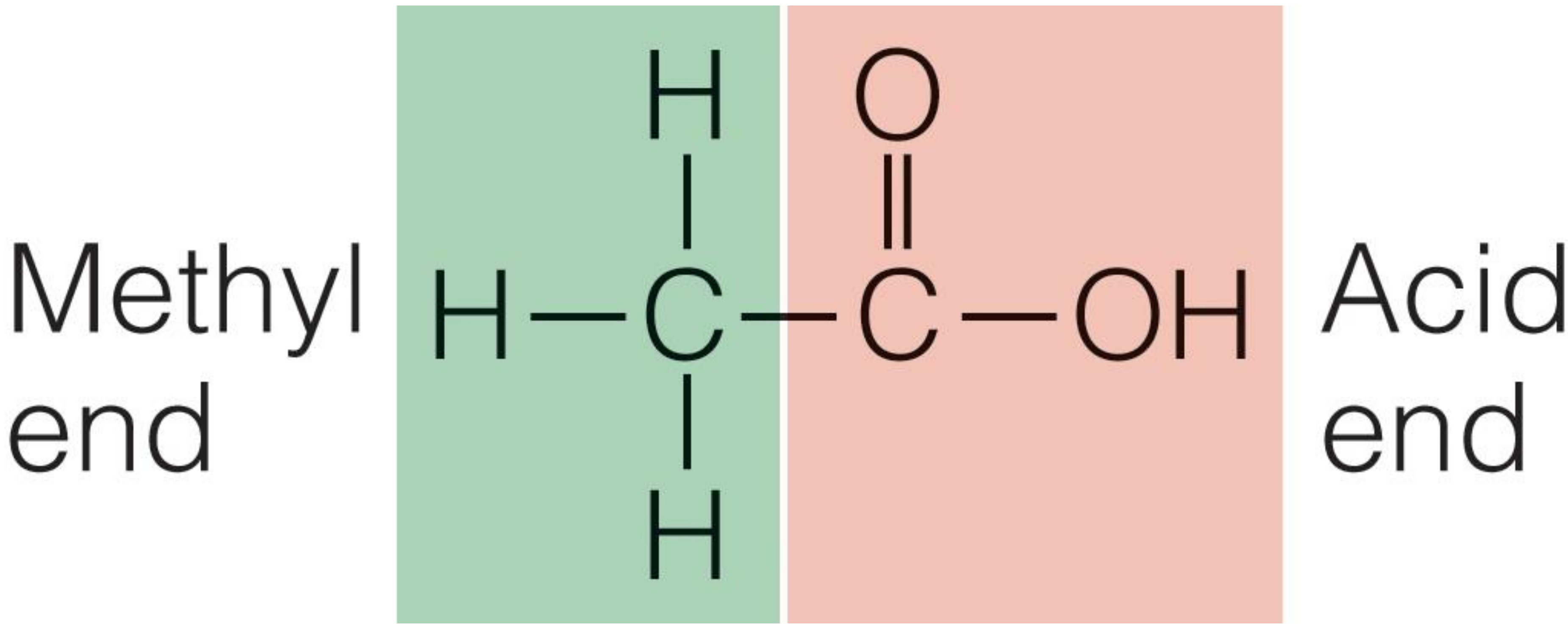
Dietary lipids also serve as carriers for absorption of other nutrients including fat- soluble vitamins and pigments for flesh coloration in salmonids. As with protein, dietary lipids are provided from marine fish oils which are rich in essential fatty acids. Care has to be taken with regard to storage as PUFAs readily oxidise and become rancid.

1 gram of carbohydrate	=	17.1 kj
1 gram of protein	=	18.2 kj
1 gram of fat	=	38.9 kj

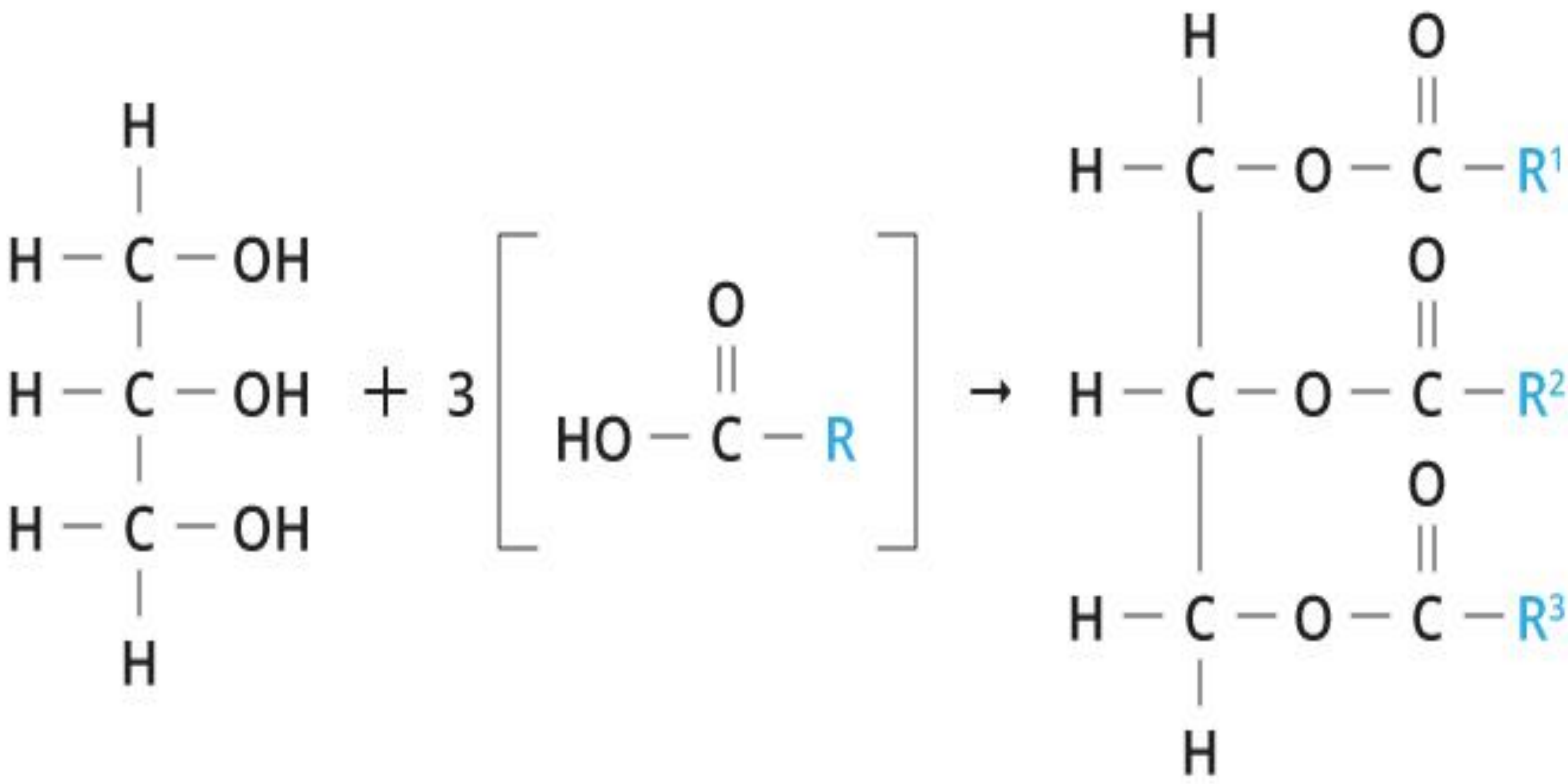

9 kcal
5 kcal
4 kcal
1 gram
1 gram
1 gram
FAT
CARBOHYDRATES
PROTEIN

Fatty Acids

- Organic acid (chain of carbons with hydrogens attached) that has an acid group at one end & a methyl group at the other end



Lipid Molecule



Glycerol 3 Fatty Acids Fat (triglyceride)

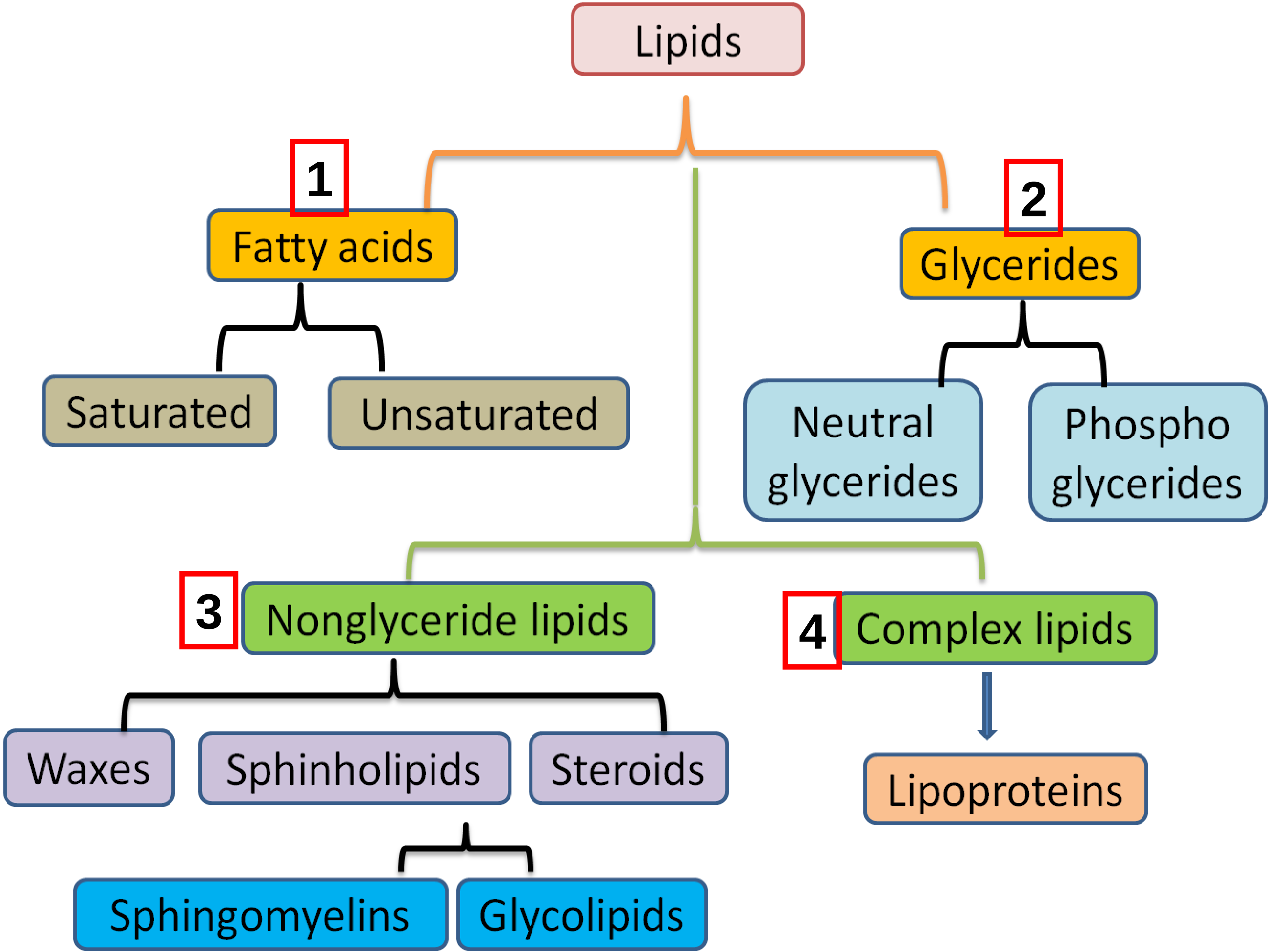
Nutritional Uses of Lipids

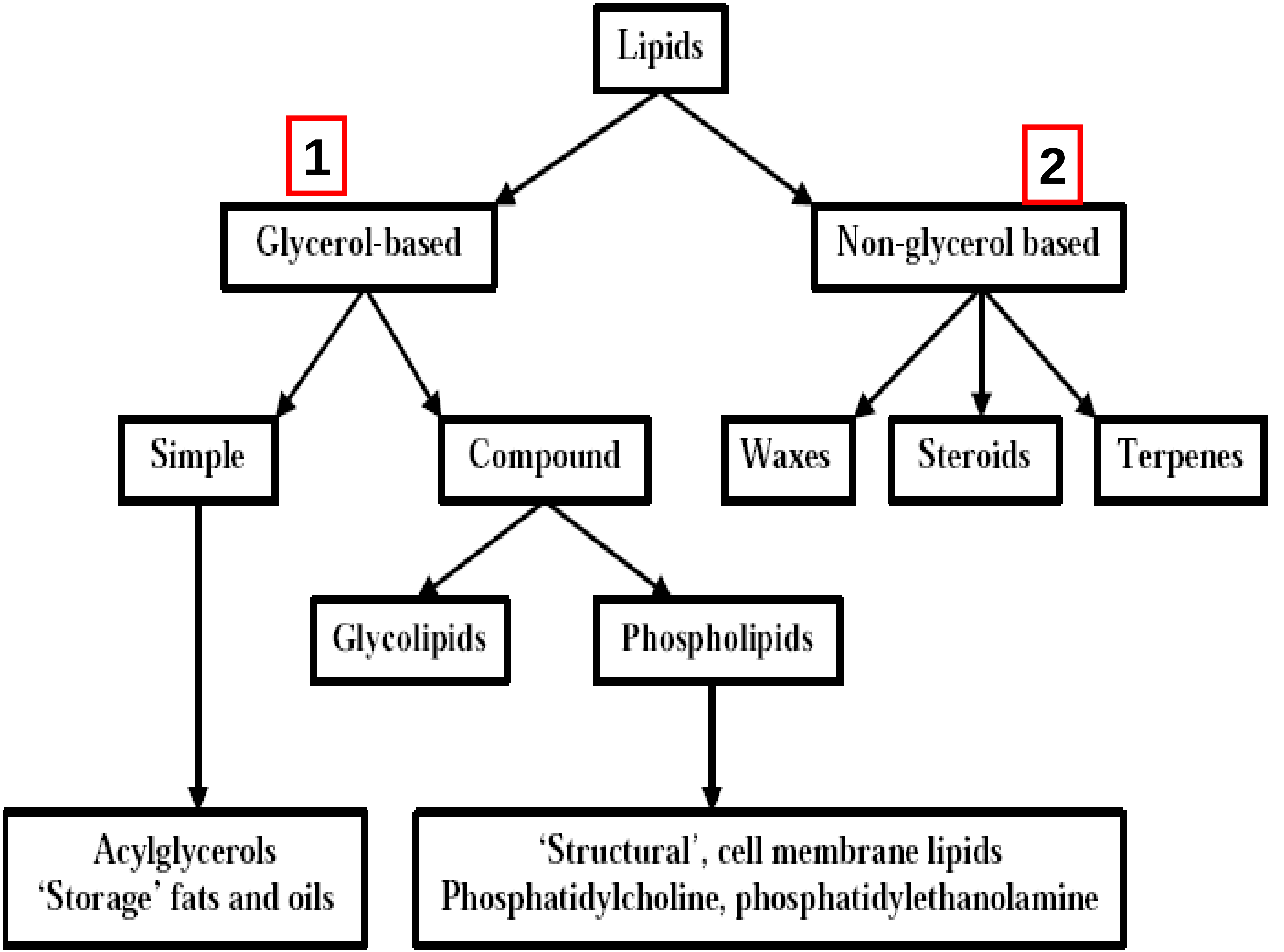
- Lipids are concentrated sources of energy (9.45 kcal/g)
- Provide means whereby fat-soluble nutrients (e.g., sterols, vitamins) can be absorbed by the body
- Structural element of cell, subcellular components
- Components of hormones and precursors for prostaglandin synthesis

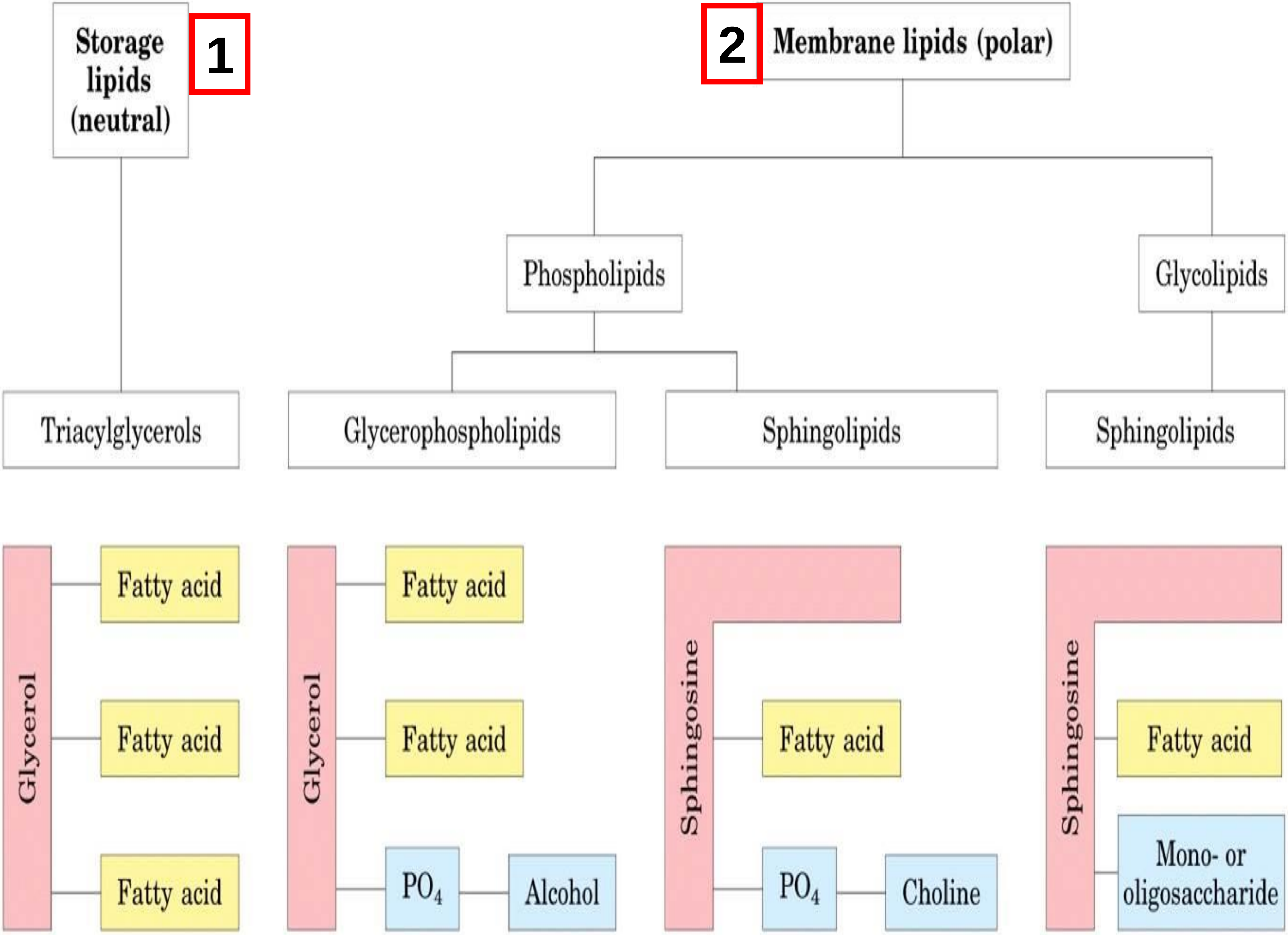
- They are not polymeric substances like proteins, polysaccharides & nucleic acids
- Building block of most of the lipids: Fatty acid
- Lipids that lack fatty acids: Cholesterol

Lipid Classes

- **simple:** FA's esterified with glycerol
- **compound:** same as simple, but with other compounds also attached
- **phospholipids:** fats containing phosphoric acid and nitrogen (lecithin)
- **glycolipids:** FA's compounded with CHO, but no N
- **derived lipids:** substances from the above derived by hydrolysis
- **sterols:** large molecular wt. alcohols found in nature and combined w/FA's (e.g., cholesterol)


Lipids
1
Fatty acids
Saturated
Unsaturated
2
Glycerides
Neutral glycerides
Phospho glycerides
3
Nonglyceride lipids
Waxes
Sphinholipids
Steroids
Sphingomyelins
Glycolipids
4
Complex lipids
Lipoproteins


Lipids
1
Glycerol-based
2
Non-glycerol based
Simple
Compound
Waxes
Steroids
Terpenes
Glycolipids
Phospholipids
Acylglycerols
'Storage' fats and oils
'Structural', cell membrane lipids
Phosphatidylcholine, phosphatidylethanolamine


Storage lipids (neutral)
1
2
Membrane lipids (polar)
Phospholipids
Glycolipids
Triacylglycerols
Glycerophospholipids
Sphingolipids
Sphingolipids
Glycerol
Fatty acid
Fatty acid
Fatty acid
Glycerol
Fatty acid
Fatty acid
PO_4
Alcohol
Sphingosine
Fatty acid
PO_4
Choline
Sphingosine
Fatty acid
Mono- or oligosaccharide

Linolenic acid: 18:3n-3

1 2 3 4 5 6 7 8 9 10 11-17 18

$$CH_3-CH_2-CH=CH-CH_2-CH=CH-CH_2-CH=CH-(CH_2)_7-COOH$$

1 2 3

Linoleic acid: 18:2n-6

1 2-5 6 7 8 9 10 11-17 18

$$CH_3(CH_2)_4-CH=CH-CH_2-CH=CH-(CH_2)_7-COOH$$

1 2

Arachidonic acid: 20:4n-6

1 2-5 6 7 8 9 10 11 12 13 14 15 16 17-19 20

$$CH_2(CH_2)_4-CH=CH-CH_2-CH=CH-CH_2-CH=CH-CH_2-CH=CH(CH_2)_3-COOH$$

1 2 3 4

Saturated vs. Unsaturated Fatty Acids

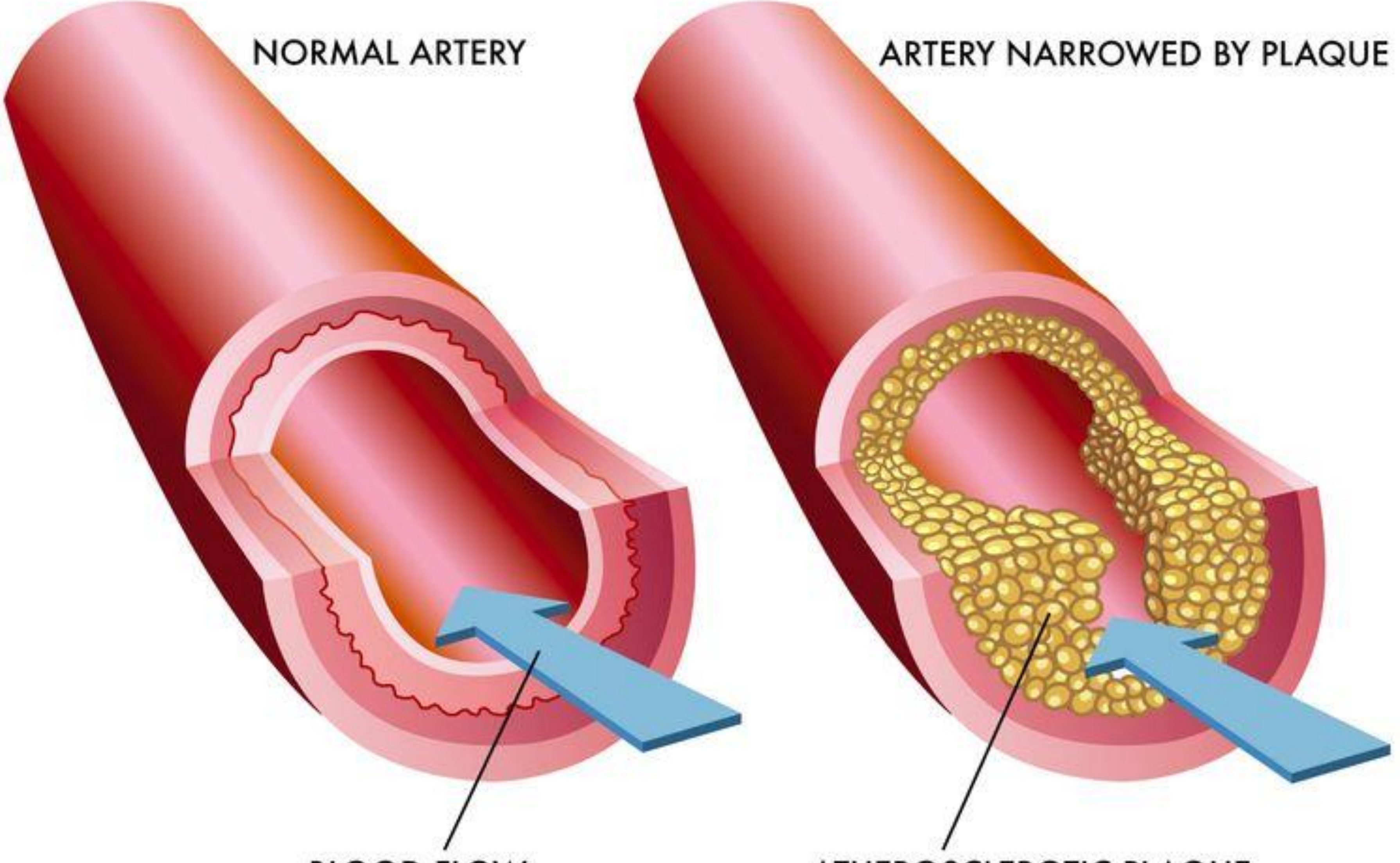
- **saturated**: the SFA's of a lipid have no double bonds between carbons in chain
- **polyunsaturated**: more than one double bond in the chain
- most common polyunsaturated fats contain the polyunsaturated fatty acids (PUFAs) oleic, linoleic and linolenic acid
- unsaturated fats have lower melting points
- stearic (SFA) melts at 70°C, oleic (PUFA) at 26°C

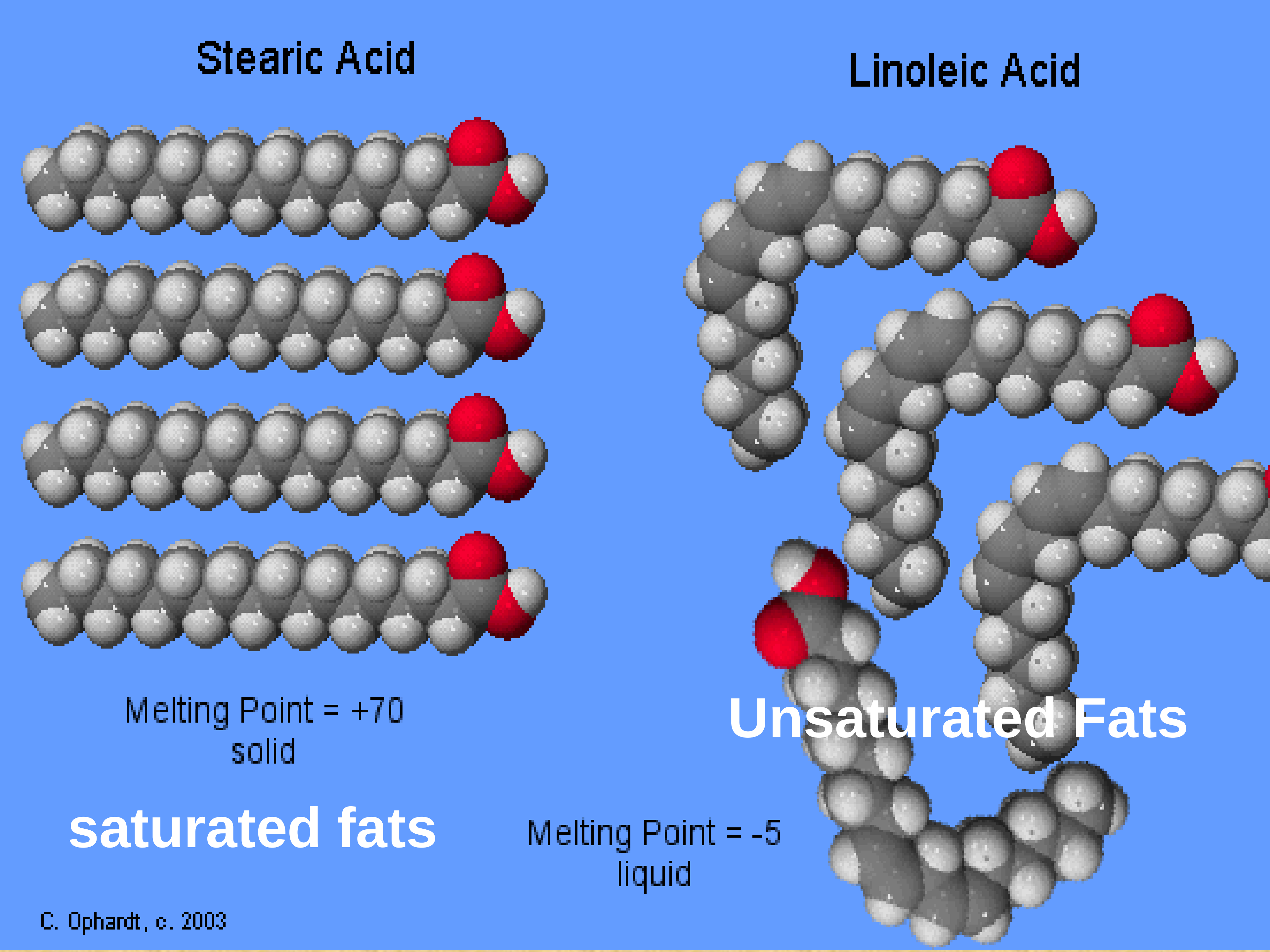
Trivial name (scientific designation)	Number of carbon atoms	Number of double bonds	Fatty acid series	Shorthand notation
Saturated fatty acids (SFAs)				
Lauric (dodecanoic)	12	0		12:0
Palmitic (hexadecanoic)	16	0		16:0
Stearic (octadecanoic)	18	0		18:0
Monounsaturated fatty acids (MUFAs)				
Palmitoleic (hexadecenoic)	16	1	n-7	16:1 n-7
Oleic (octadecenoic)	18	1	n-9	18:1 n-9
Erucic (docosenoic)	22	1	n-9	22:1 n-9
Polyunsaturated fatty acids (PUFAs)				
Linoleic (octadecadienoic)	18	2	n-6	18:2 n-6
γ-Linolenic (octadecatrienoic)	18	3	n-6	18:3 n-6
α-Linolenic (octadecatrienoic)	18	3	n-3	18:3 n-3
Highly unsaturated fatty acids (HUFAs)				
Arachidonic (eicosatetraenoic)	20	4	n-6	20:4 n-6
EPA (eicosapentaenoic)	20	5	n-3	20:5 n-3
DHA (docosahexaenoic)	22	6	n-3	22:6 n-3

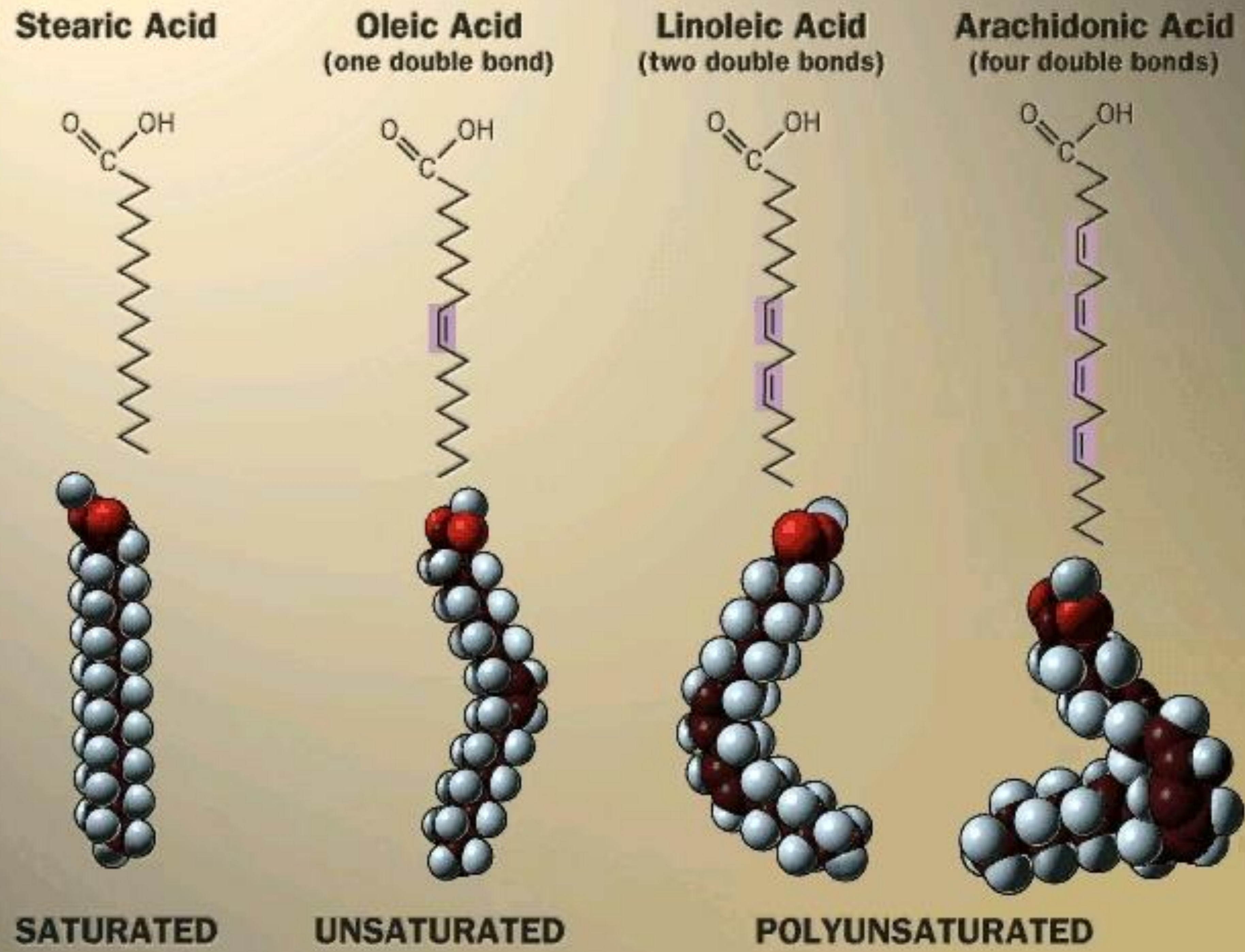
Saturated vs. Unsaturated Fats

- saturated fats tightly packed, clog arteries as **atherosclerosis**
- because of double bonds, polyunsaturated fats do not pack well -- like building a wall with blocks (sat.) vs. irregular-shaped objects (unsat.)
- plant fats are much higher in PUFA's than animal fats

ATHEROSCLEROSIS




Stearic Acid
Linoleic Acid
Melting Point = +70
solid
Unsaturated Fats
saturated fats
Melting Point = -5
liquid
C. Ophardt, c. 2003


Stearic Acid
Oleic Acid
(one double bond)
Linoleic Acid
(two double bonds)
Arachidonic Acid
(four double bonds)
O
OH
C
SATURATED
UNSATURATED
POLYUNSATURATED

The essential fatty acid (EFA) requirements

a) **Aquatic animals** have a **higher** requirement for the **n-3 series** of fatty acids than **terrestrial animals**, for which the **n-6 series** is more **important**;

b) **EFA deficiencies** are more noticeable in **seawater** than in **freshwater** conditions (for trout). Thus **salinity affects EFA requirements**;

c) **Marine fish** appear to have a **greater** requirement for **HUFA's** than **freshwater** or **anadromous** species. It is **not yet known** whether they can utilize the **n-6** series as well as they can the **n-3** series;

d) **Coldwater** species appear to have a **greater** requirement for the **n-3 series** fatty acids than **warmwater** species;

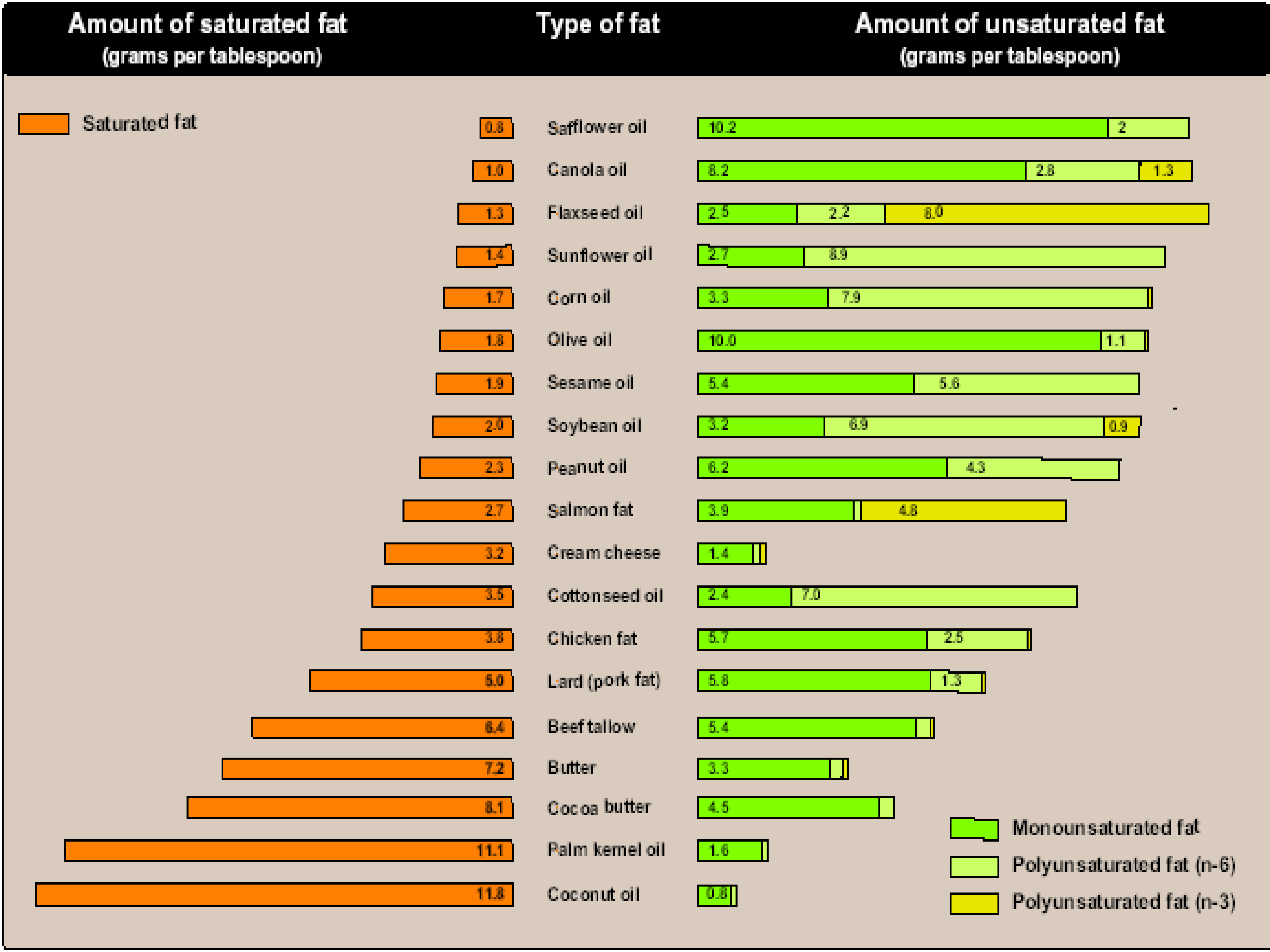
The essential fatty acid (EFA) requirements

e) **Shrimp** and prawns have a requirement for the **n-3 series** and the **n-3:n-6 ratio** is **important**;

f) The levels of either type of **PUFA's** can be detrimentally high in a feed. Knowledge of the specific requirements of a species is therefore constantly being sought to optimize formulation practice.

g) Although many **vegetable** lipids (but not those of palm, olive or coconut) are **high** in **PUFA's**, the **best sources** (and the **most expensive**) sources of the **n-3 HUFA's** are **marine lipids**. **Vegetable** oils tend to have **high** levels of the **n-6 series** (**linoleic series**). **Beef** tallow have **low** total levels of **PUFA's**.

The necessity of high dietary levels of PUFA's in aquatic animal diets makes the possibility of fats becoming **rancid** very real. These may be **toxic** or **growth depressive**.



Amount of saturated fat (grams per tablespoon)
Type of fat
Amount of unsaturated fat (grams per tablespoon)
Saturated fat
0.8 Safflower oil 10.2 2
1.0 Canola oil 8.2 2.8 1.3
1.3 Flaxseed oil 2.5 2.2 8.0
1.4 Sunflower oil 2.7 8.9
1.7 Corn oil 3.3 7.9
1.8 Olive oil 10.0 1.1
1.9 Sesame oil 5.4 5.6
2.0 Soybean oil 3.2 6.9 0.9
2.3 Peanut oil 6.2 4.3
2.7 Salmon fat 3.9 4.8
3.2 Cream cheese 1.4
3.5 Cottonseed oil 2.4 7.0
3.8 Chicken fat 5.7 2.5
5.0 Lard (pork fat) 5.8 1.3
6.4 Beef tallow 5.4
7.2 Butter 3.3
8.1 Cocoa butter 4.5
11.1 Palm kernel oil 1.6
11.8 Coconut oil 0.8
Monounsaturated fat
Polyunsaturated fat (n-6)
Polyunsaturated fat (n-3)

Essential fatty acid requirement

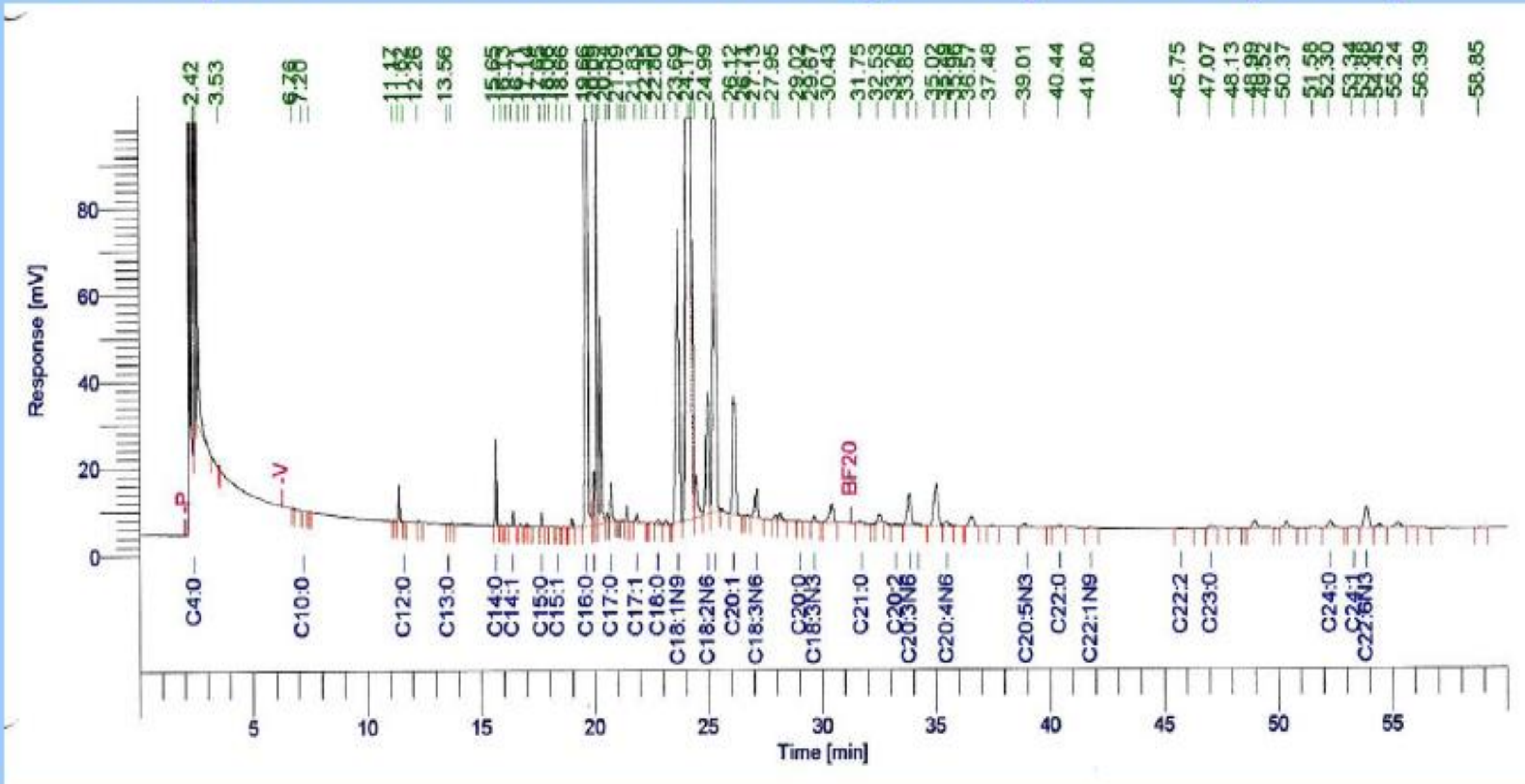
In view of the inability of animals to synthesize de novo fatty acids of the n-6 and n-3 series, these fatty acids must be supplied in a ready made form within the diet. For land animals, the linoleic (n-6) series has been found to have the highest essential fatty acid (EFA) activity, with the linolenic (n-3) series having only partial EFA activity. It follows, therefore, that the predominant fatty acids (PUFA) in the tissues of land animals belong to the linoleic series, namely 18:2n-6 (linoleic acid) and 20:4 n-6 (Arachidonic acid).

By contrast, the predominant PUFA in the tissues of fish and shrimp belong to the linolenic (n-3) series, and this applies to freshwater and marine fish alike. The concentration of n-6 PUFA in the tissues of fish is generally low, although higher levels are reported in freshwater fish species. This is perhaps not surprising if one considers that the diet of freshwater fish contains a component derived from terrestrial sources, and consequently rich in n-6 series fatty acids. It is generally believed that the n-3 series fatty acids permit a greater degree of unsaturation - a requirement for greater membrane fluidity, flexibility and permeability at low temperatures. In fact, it is generally believed that the dietary requirement (preferential) of fish for n-3 series EFA, over n-6 series, is fundamentally due to the low water temperature of their aquatic environment (as compared with mammals). In fact, the lower the water temperature, the greater the incorporation of n-3 series PUFA in the tissues. Apart form the differences in n-6 PUFA content of the tissues of freshwater and marine fish species, freshwater fish also generally have higher tissue concentrations of the shorter chain PUFA n-3 series.

With the exception of strict carnivorous fish species, fish are able to chain elongate and further desaturate 18:2 n-6 or 18:3 n-3 (depending on the fish species) to the corresponding highly unsaturated fatty acid (HUFA): 20:4 n-6 in the case of the n-6 series, and 20:5 n-3 or 22:6 n-3 in the case of the n-3 series. It is generally believed that these HUFA are responsible for the key metabolic functions ascribed to the EFA. In fact, for most fish species, HUFA have greater EFA activity than the corresponding basic unit (18:2 n-6 or 18:3 n-3).

In general, cold water freshwater fish have an exclusive requirement for n-3 series PUFA (18:3 n-3, 20:5 n-3, 22:6 n-3) in their diet (i.e. salmonids), while warm freshwater fish have either a requirement for both the n-3 series and n-6 series PUFA (i.e. carps, and channel catfish), or for the n-6 series alone (i.e. Tilapias). In the case of marine carnivorous fish species (i.e.black sea bream ,yellow tail , plaice, gilthead bream, turbot), since the food organisms consumed are rich in 22:6 n-3 and 20:5 n-3, they have lost ability to chain elongate and further desaturate 18:3 n-3 to the corresponding HUFA. Marine carnivorous fish must, therefore, be supplied with 22:6 n-3 or 22:5 n-3 in a ready made form .

Gas Chromatogram of Fatty Acids Composition in *Clarias gariepinus* (*Keli*)



% Fatty Acids	Omega-6	Omega-3		
	C18:2n6	C18:3n3	C20:5n3	C22:6n3
Keli	11.12	0.07	0.08	0.38