Development of Functional Foods with Omega-3 Fatty Acids

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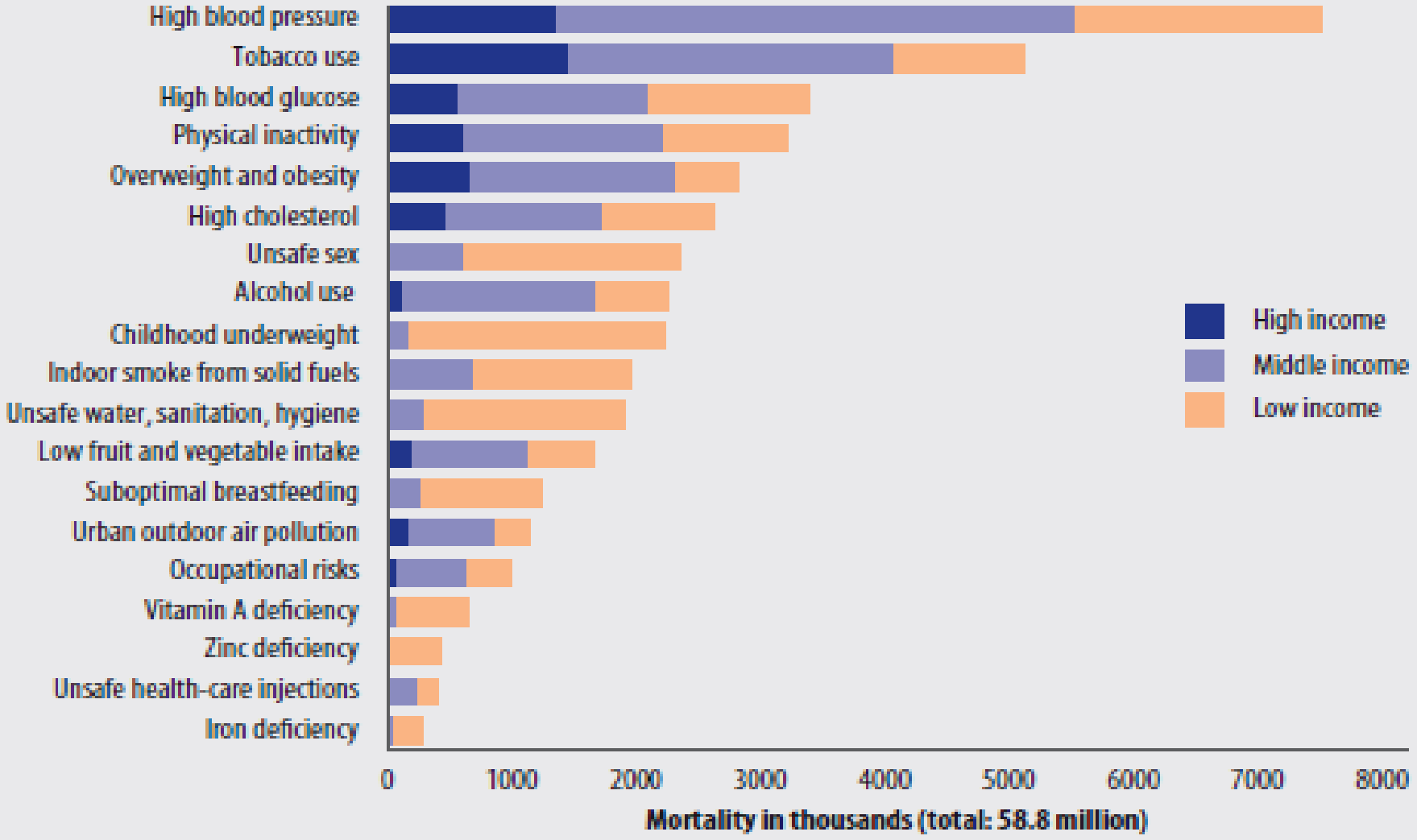
Topics

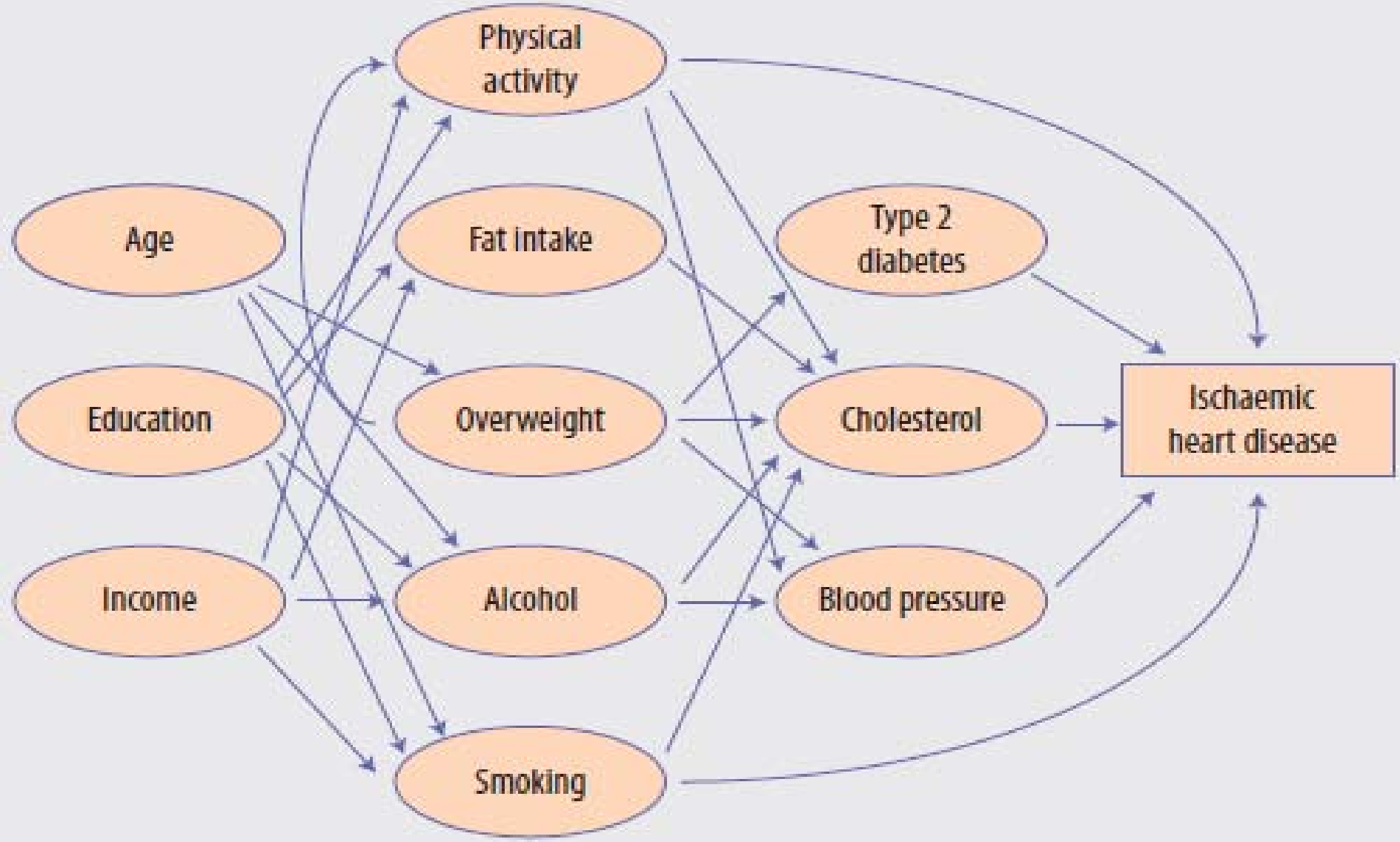
- **Human Health and Diet**
- **Emergence of Functional Foods**
- **Oils and Fats in Perspective: Fatty Acids and it's role in Human Health**
- **Nutritional Lipids: Strategies**
- **Conclusions**

Human Health and Diet: Deaths attributed to 19 leading risk factors, by country income level.



- WHO Report 2010

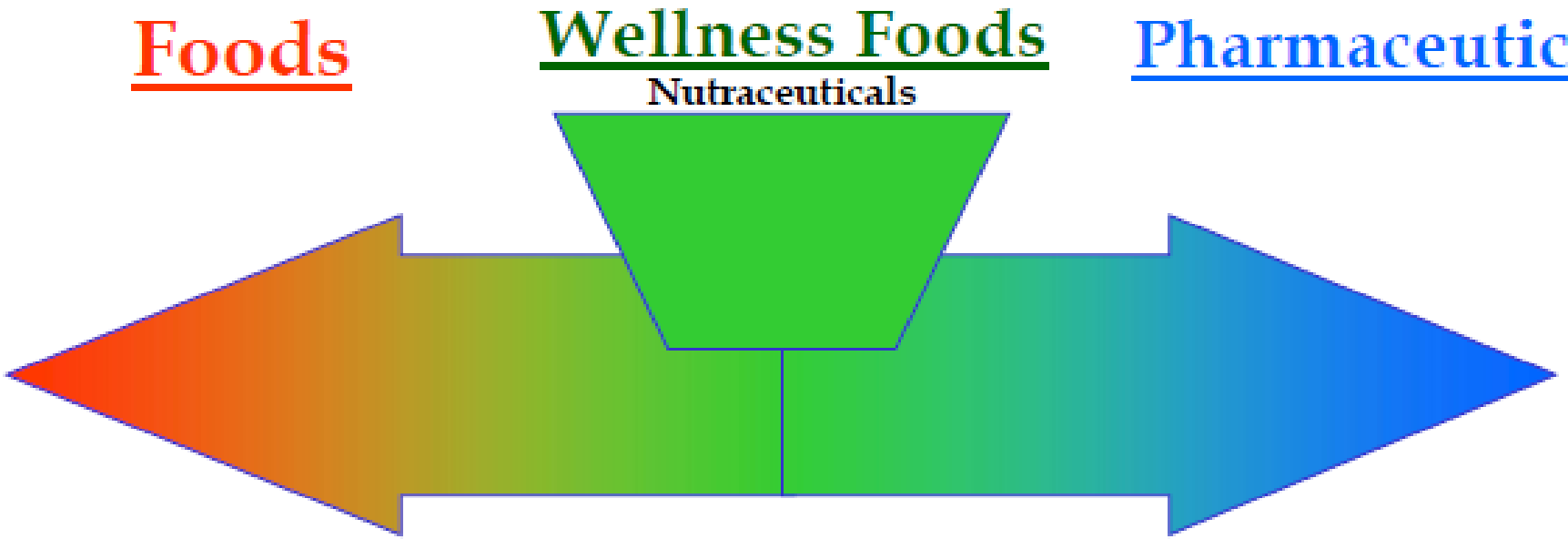
The Causal Chain-Causes of Blood Pressure, Cholesterol, Ischaemic heart Disease



Partial Listing of Lifestyle-related and other Disorders/Diseases where Nutraceuticals/Functional Foods can play a Major Role in Prevention/Management

1. **Cardiovascular Diseases (CVD) and risk factors (blood lipids, b.p., etc.)**
2. **Type 2 Diabetes**
3. **Inflammatory conditions (arthritis, bowel, etc.)**
4. **Osteoporosis**
5. **Mental Health and 'Psychiatric disorders'**
6. **Digestive Problems/Liver Diseases**
7. **Cancers (colon, prostate, breast, others)**
8. **Kidney Disorders**
9. **Others**

Emergence of Functional Foods:
Wellness Food-Drug Interface

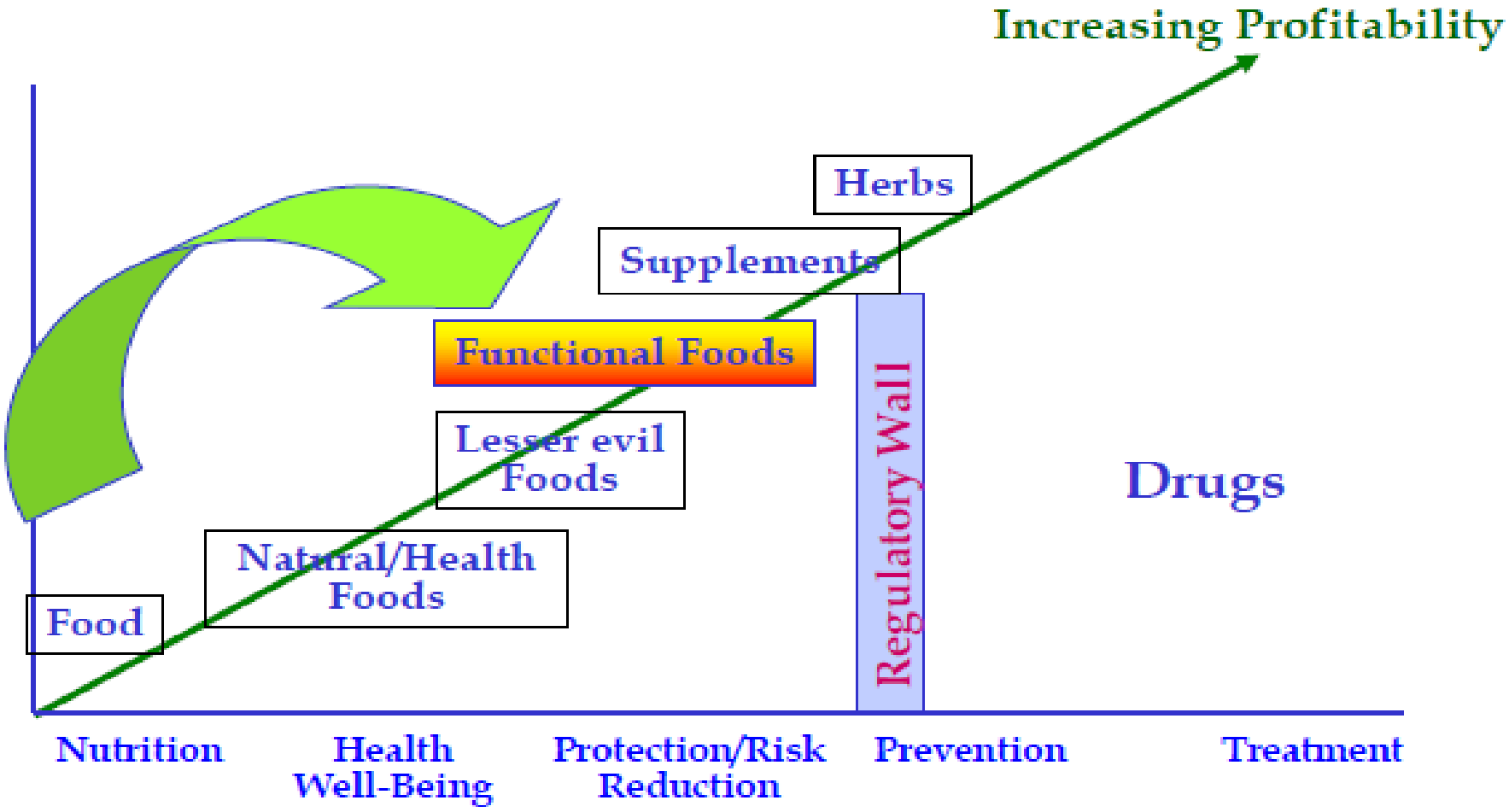


Functional foods fall in the grey area between conventional foods and drugs.

"Functional Foods" are foods or dietary components that may provide a health benefit beyond basic nutrition.

Product Benefit

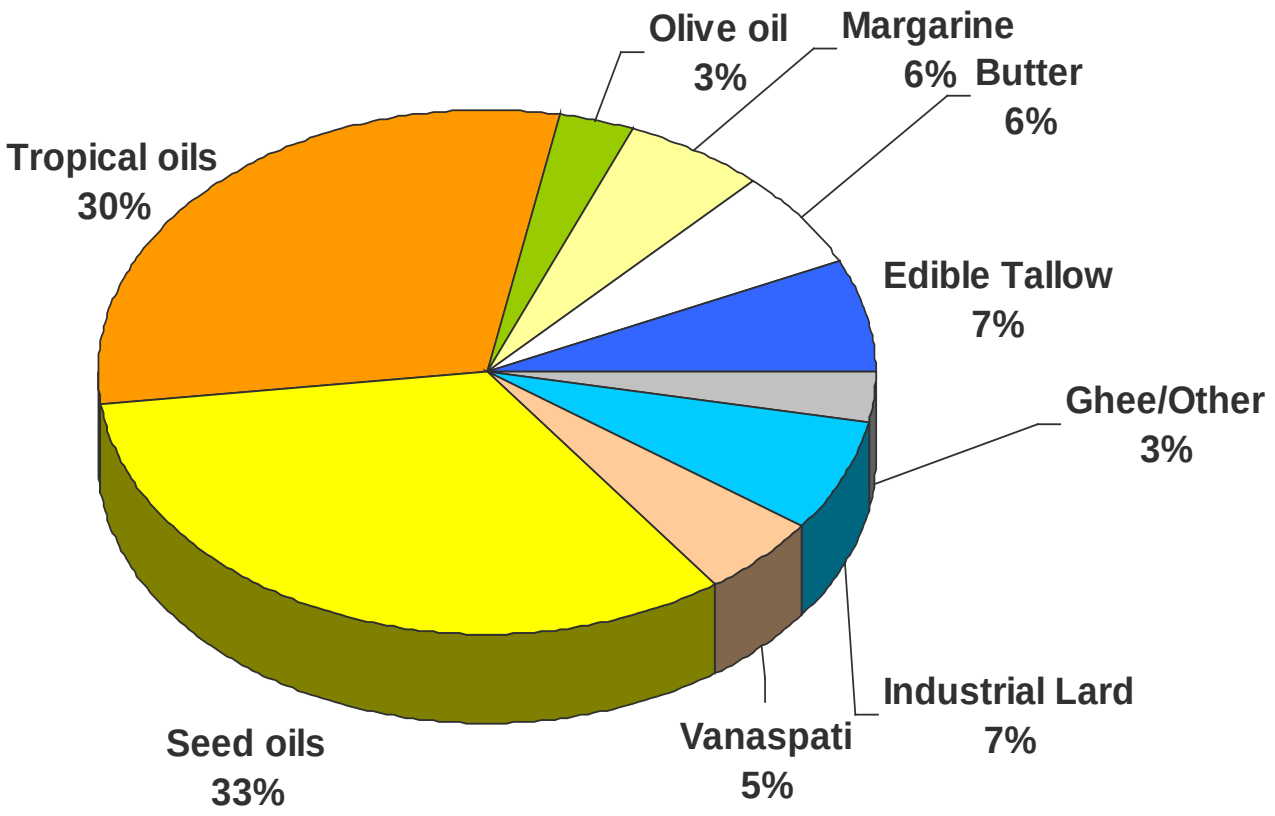
Foods to Drugs….



Functional food market developed in a way to reduce the high health costs derived from a population with high life expectations

Oils and Fats in perspective

6.5 b people consume about 120 m tons pa
That is almost 20 kg per capita

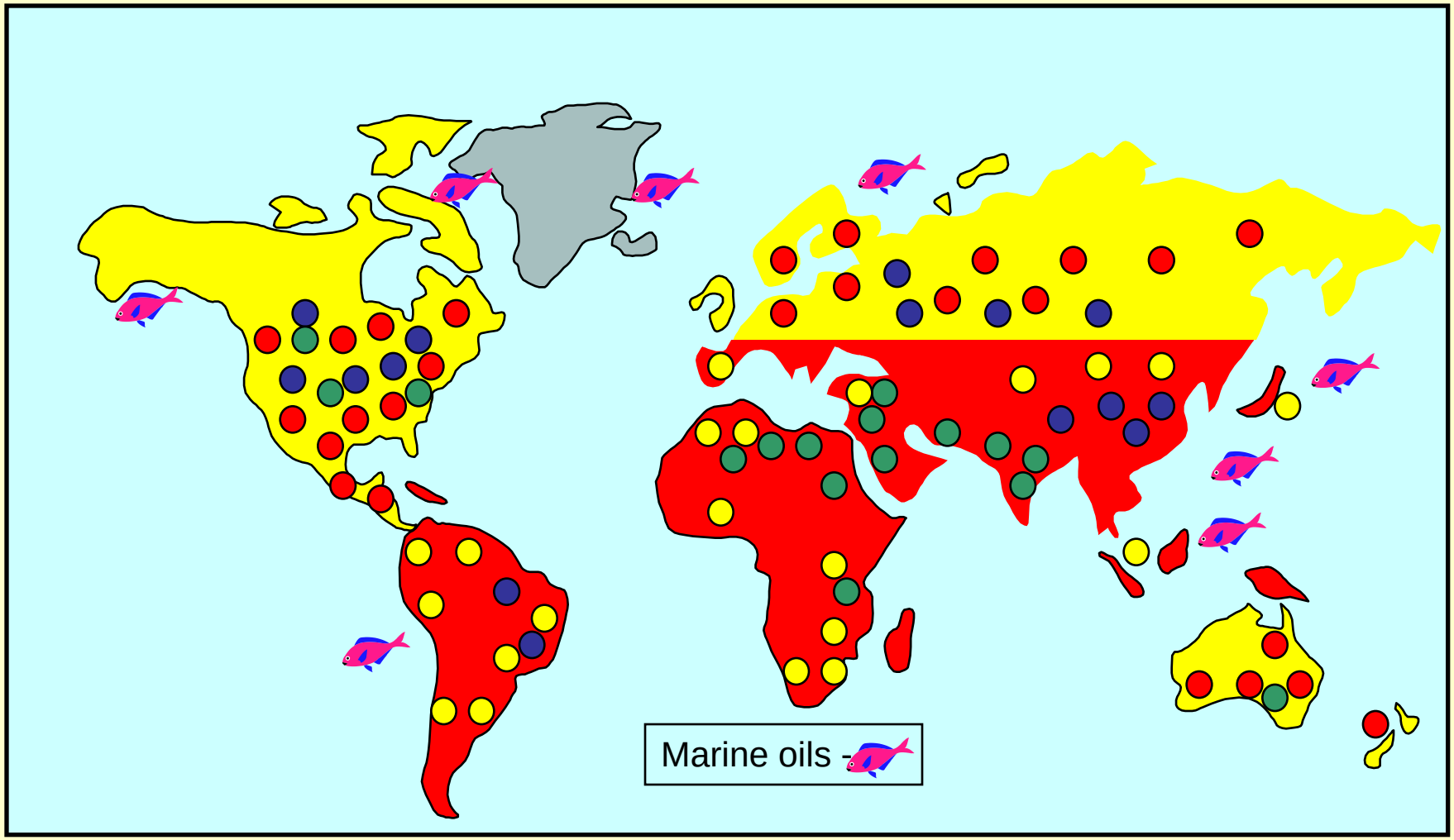


Annual value of oils and fats market over €120b

Seed oil (soybean, sunflower seed, rapeseed, mustard, etc.) Tropical oil (palm, coconut, palm kernel, etc.)

Ann Nutr Metab 2009; 54(suppl 1):15–24

Regional Consumption Patterns



Ann Nutr Metab 2009;54(suppl 1):15–24

Many Different Fat-Rich Products

- **Primary:**
  - **Vegetable/plant oils**
  - **Butter/milk fats**
  - **Lard/tallow (derived from animals)**
  - **Marine**

- **Secondary: (made from one or more of the above)**
  - **Margarines, Reduced fat spreads**
  - **Ghee**
  - **Vanaspati**
  - **Cooking fats/white fats/shortenings**
  - **Mayonnaise**

Main Dietary Sources of Fat

- Major contributors to intake of saturated fat
  - Dairy (Ghee, Butter, Milk, Cheese)
  - Meat
  - Baked/Fried foods and snacks
  - Cooking fats/oils (Coconut, Palm, Olive)

Major contributors to intake of polyunsaturated fat

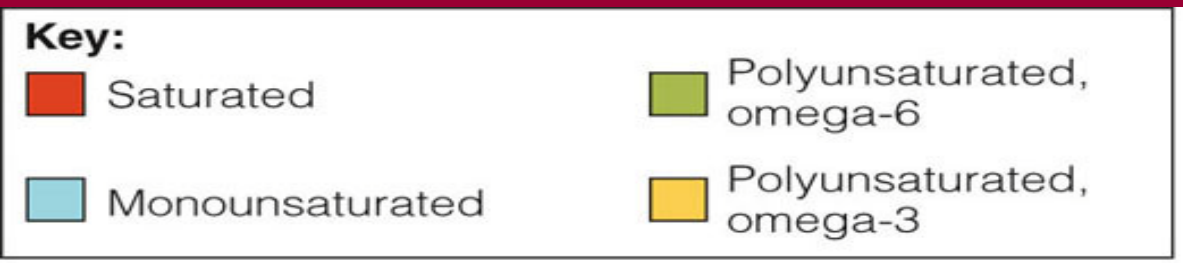
- Vegetable oils (Canola, Soyabean, Peanut, Sunflower, Rapeseed)
- Margarines and mayonnaise

Fatty acid composition (%) of some common vegetable oils

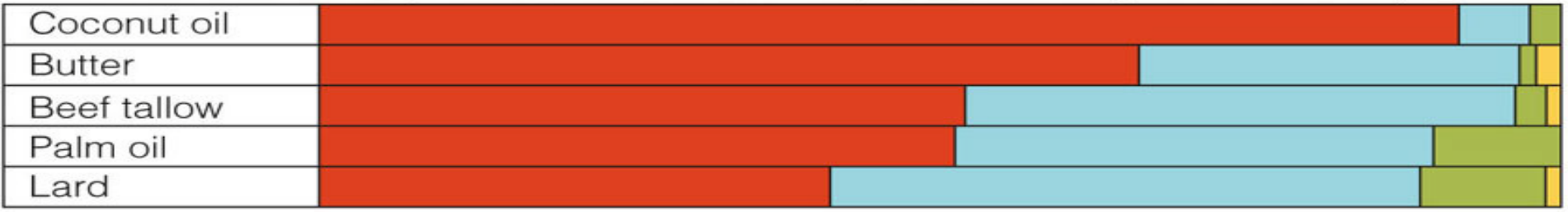
Adapted from:Chow, C. K. (1992). Fatty acids in foods and their health implications, Marcel Dekker

Fatty acids	Coconut Oil	Palm kernel oil	Palm oil	Oilve oil	Peanut oil	Sunflower oil	Soybean oil	Linseed oil	Rapeseed oil
8:0	8.0	3.9	-	-	-	-	-	-	-
10:0	6.4	4.0	-	-	-	-	-	-	-
12:0	48.5	49.6	0.3	-	-	-	-	-	-
14:0	17.6	16.0	1.1	-	-	-	-	-	-
16:0	8.4	8.0	45.1	13.7	11.6	11.0	11.0	4.8	2.8
18:0	2.5	2.4	4.7	2.5	3.1	4.7	4.0	4.7	1.3
18:1	6.5	13.7	38.8	71.1	46.5	18.6	23.4	19.9	23.8
18:2	1.5	2.0	9.4	10.0	31.4	68.2	53.2	15.9	14.6
18:3	-	-	-	0.6	-	0.5	7.8	52.7	7.3
20:0	-	-	-	0.9	1.5	0.4	0.3	-	0.7
20:1	-	-	-	-	1.4	-	-	-	12.1
20:2	-	-	-	-	-	-	-	-	0.6
22:0	-	-	-	-	3.0				0.4
22:1	-	-	-	-	-	-	-	-	34.8
24:0	-	-	-	-	1.0	-	-	-	1.0

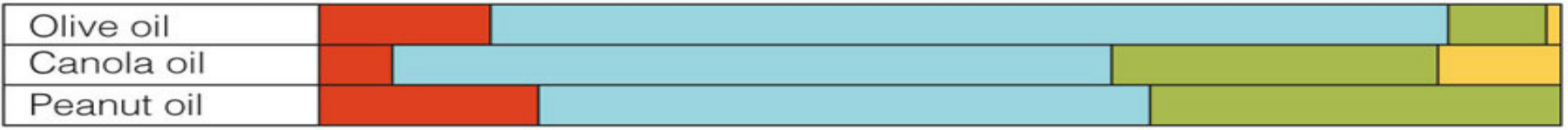
Comparision of Dietary Fats and Oils



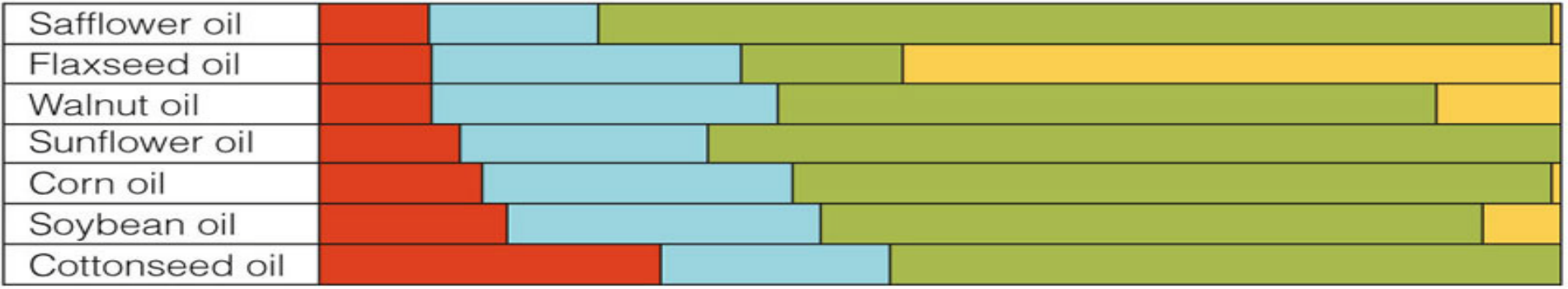
Animal fats and the tropical oils of coconut and palm are mostly **saturated** fatty acids.



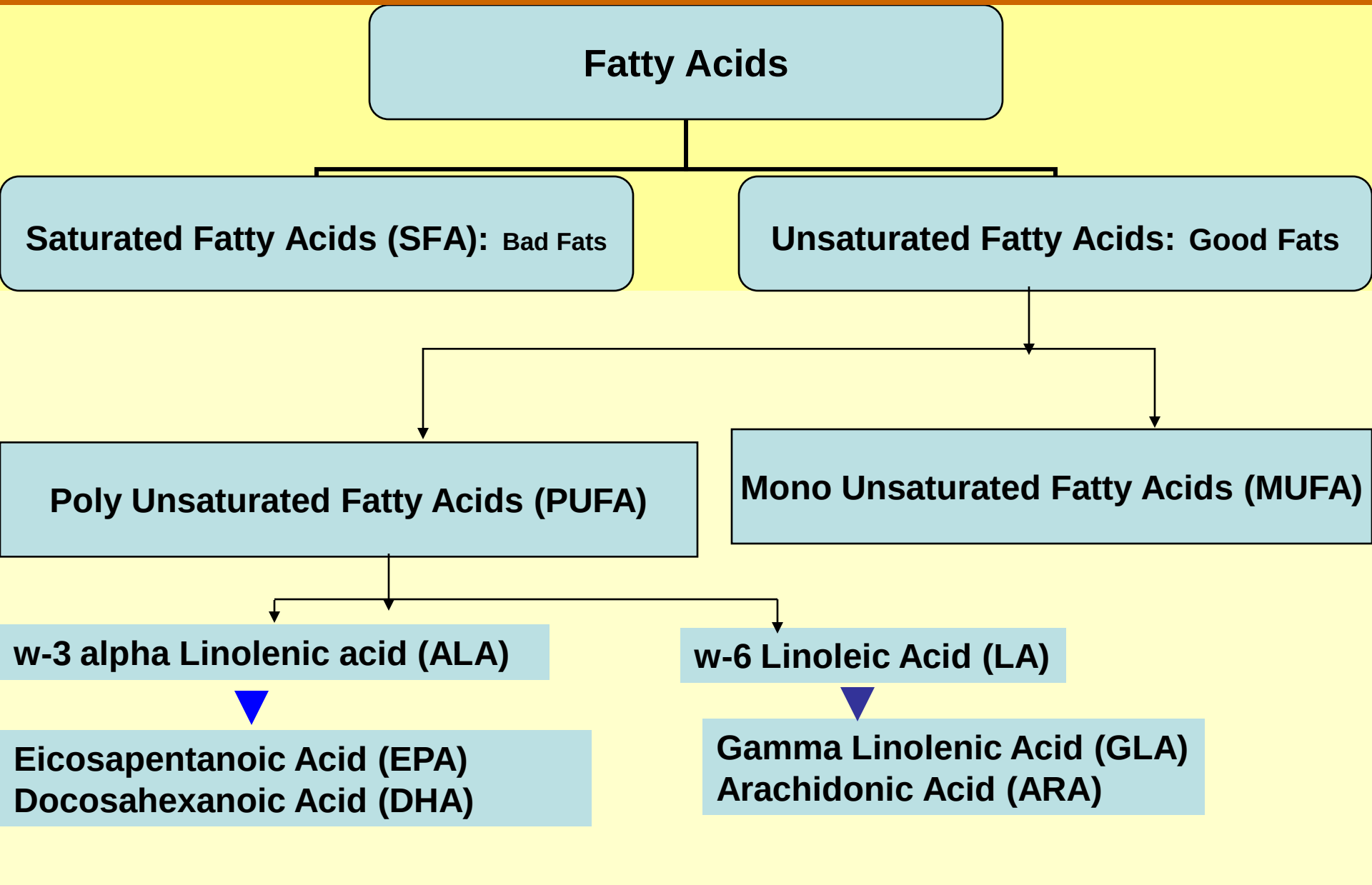
Some vegetable oils, such as olive and canola, are rich in **monounsaturated** fatty acids.



Many vegetable oils are rich in **polyunsaturated** fatty acids.



Classification of Fatty Acids



Classification of Fatty Acids

Saturated fat

Solid or plastic fats:

shortening, butter, lard or any solid fat

usually solid at room temperature

except palm & coconut oils

Unsaturated Fatty Acids

Poly unsaturated

Sunflower, sesame seed, cottonseed, canola, rapeseed, soy oil, marine fish oil

Mono unsaturated

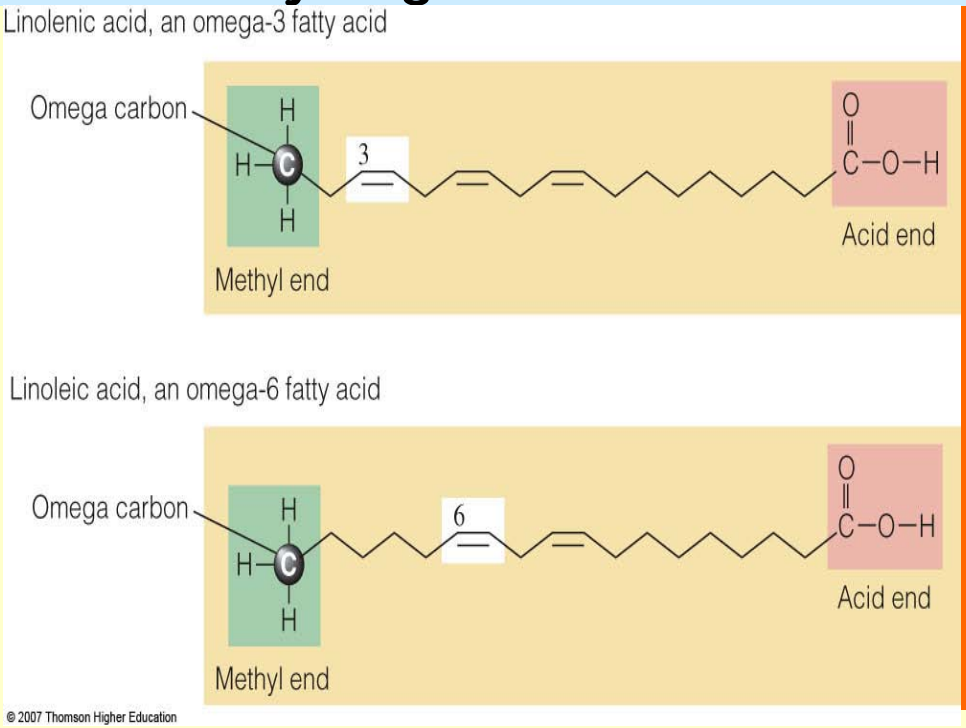
olive oil, canola oil, nuts, seeds * cashews

Trans Fatty Acids are formed during hydrogenation of oil

Purpose of hydrogenation: to prevent rancidity and increase shelf life

Impact of Unsaturation

- Stability
  - **Saturated fat** is more resistant to oxidation.
  - **Monounsaturated fat** is slightly less susceptible to spoilage.
  - **Polyunsaturated fat** spoils most readily.
  - Protection from rancidity
    - Sealed in airtight containers away from light
    - Add antioxidants
    - Hydrogenation



- **Types of PUFA**
- An **omega-3 fatty acid** has the location of the double bond in the third position. An example is linolenic acid.
- An **omega-6 fatty acid** has the location of the double bond in the sixth position. An example is linoleic acid.

Good Fats / Bad Fats

GOOD

- lower total cholesterol
- lower LDL “bad” cholesterol

Monounsaturated

Sources: Nuts, canola, olive oil

Polyunsaturated

Sources: Seafood (Animal), Corn, soy, safflower, sunflower, rapeseed (Plant)

Omega 3’s = polyunsaturates

☹ **BAD**

- raise LDL
- lower HDL "good“ cholesterol

Saturated

Sources: Meat, dairy, and eggs (Animal); coconut, palm oil (Plant)

Trans

Sources: Fried foods, processed foods with hydrogenated oils

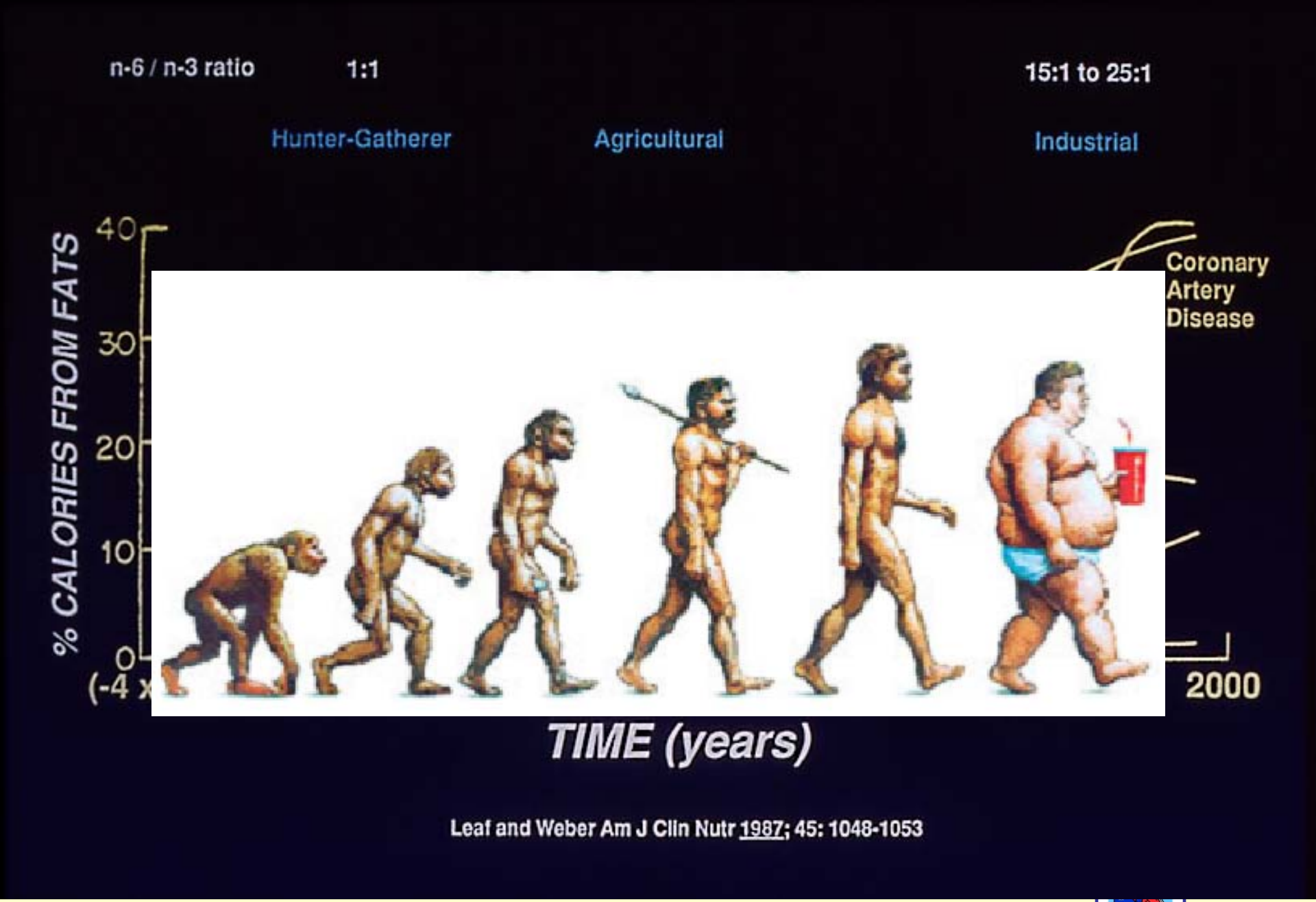
Trans Fat Is More Dangerous than Saturated Fat

Trans fat

Saturated fat

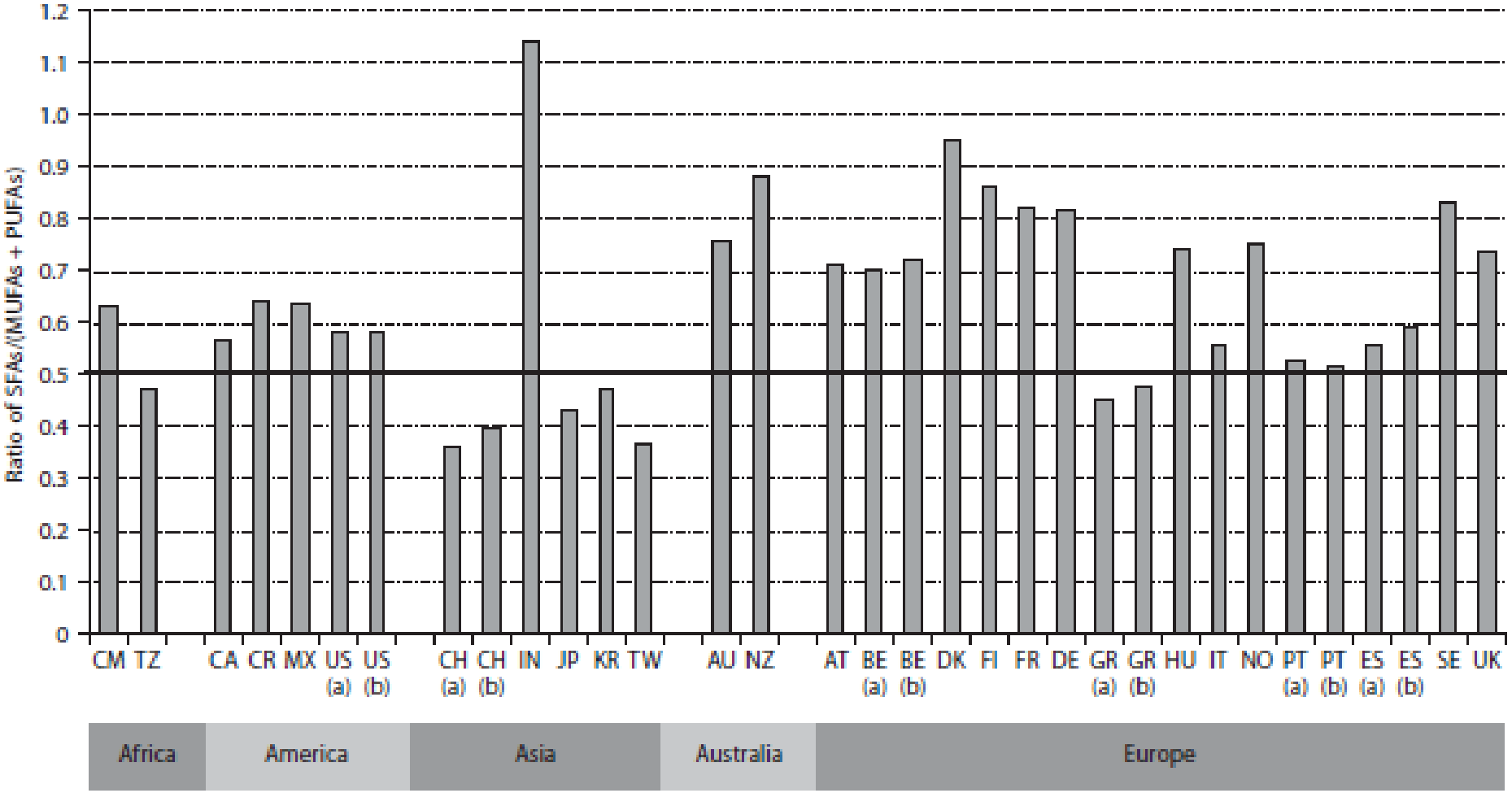
Good (HDL) Cholesterol ↓ ↑

Bad (LDL) Cholesterol ↑ ↑



Simopoulos AP. Am J Clin Nutr. 1999;70:560-9S.

Ratio of SFAs/(MUFAs + PUFAs) in the diet in different regions.



Elmadfa I. and Kornsteiner M.2009. Dietary Fat Intake – A Global Perspective. Ann Nutrition and Metabolism. 54(suppl 1):8–14.

Drivers of Nutritional Improvements for Oil/Fat Based Food Industry

- **Replace SFA by MUFA or preferably PUFA**
- **Practically eliminate TFA**
- **Ensure delivery of essential Omega 3 and 6**
- **Fortify with fat soluble vitamins A and D**
- **Preserve natural antioxidants (e.g. vit E)**

- **WHO Recommendations on the quality of fat in the diet are made for optimal health across the life course worldwide, from an age of about 2 years onwards:**

- **Fat may provide up to 15–35% of the daily energy intake (at least 15%);**
- **Saturated fat should provide no more than 10% of the daily energy intake;**
- **Essential PUFA (w–6 and w–3) should contribute 6–10% of the daily energy intake;**
- **Trans fats should be less than 1% of the daily energy intake, and**
- **The remaining of the energy from fat can be provided by monounsaturated fats**
- **The ratio of linoleic to alpha-linolenic acid in the diet should be between 5:1 and 10:1. Individuals with a ratio in excess of 10:1 should be encouraged to consume more w-3 rich foods such as green leafy vegetables, legumes, fish and other seafood.**

Greenland Eskimo Study

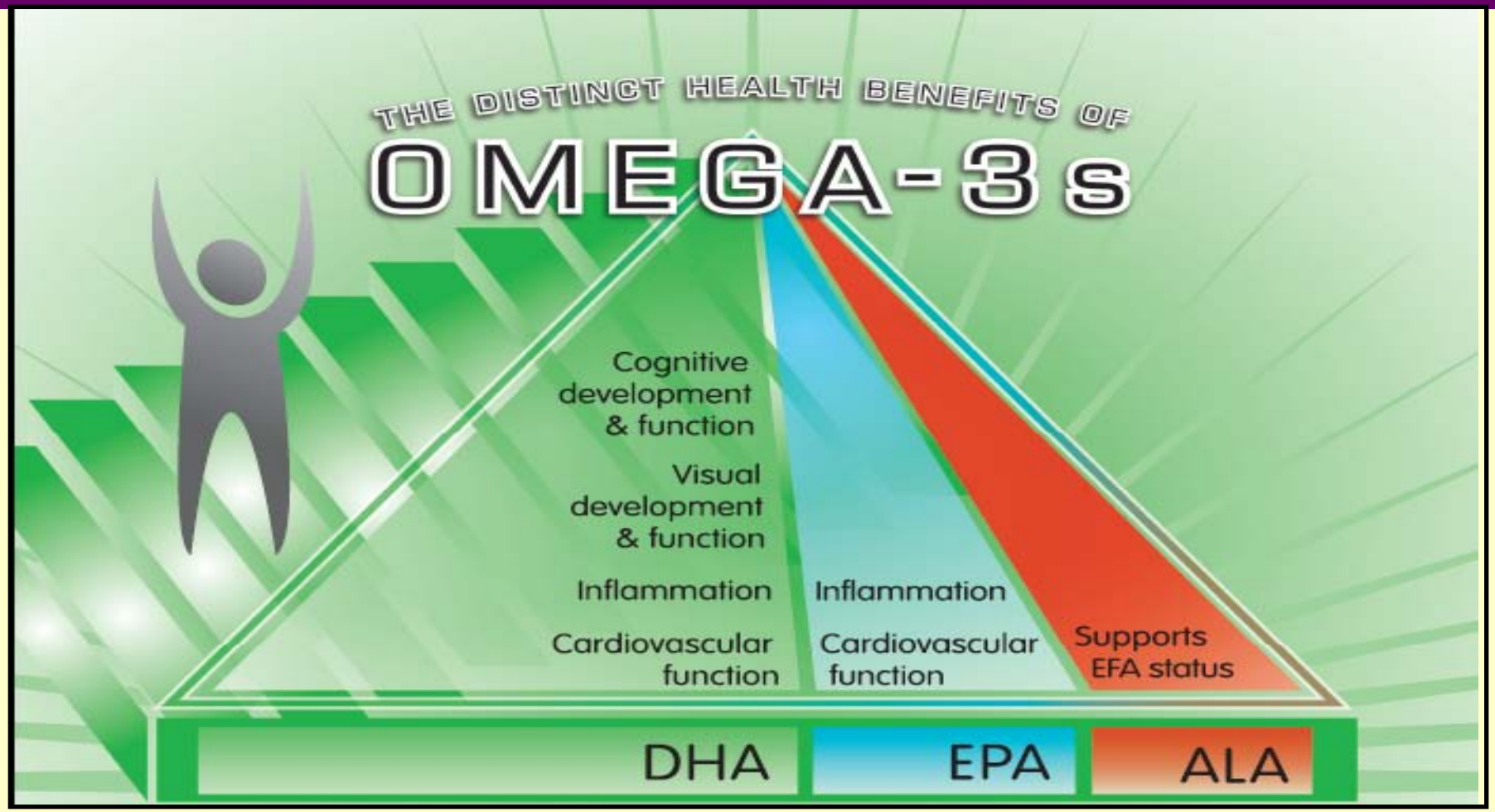
- **“Eskimo paradox”**
  - **traditional diet - high in fat and protein, low in fruit, fiber and leafy green vegetables**
  - **little evidence of heart disease and low blood cholesterol levels.**
- **Greater intake of seal, whale and fish (all contain high levels of DHA and EPA)**
- **Lower intake of omega-6 fatty acids**
- **Lead to interest in omega-3 fatty acids in fish oil for prevention of Cardio Vascular Disease (CVD)**

Ref.: Rosenberg. Fish-food to claim the Heart-Perspective- N. Engl.J.Med., 2002: Vol 346: No.15:1102-03

Synthesis of Essential Fatty Acids

w-6 fatty acids		Enzymes	w-3 fatty acids	
Linoleic (LA)	18:2		α-Linolenic (ALA)	18:3
↓		Δ 6-desaturase	↓	
γ-Linolenic (GLA)	18:3		Octadecatetraenoic	18:4
↓		elongase	↓	
Dihomo-γ-linolenic	20:3		Eicosatetraenoic	20:4
↓		Δ 5-desaturase	↓	
Arachidonic (ARA)	20:4		Eicosapentaenoic (EPA)	20:5
↓		elongase	↓	
Adrenic	22:4		Docosapentaenoic	22:5
↓		elongase	↓	
Tetracosatetraenoic	24:4		Tetracosapentaenoic	24:5
↓		Δ 6-desaturase	↓	
Tetracosapentaenoic	24:5		Tetracosahexaenoic	24:6
↓		β-oxidation	↓	
Docosapentaenoic (DPA)	22:5		Docosahexaenoic (DHA)	22:6

Omega-3 Fatty Acids Are Not The Same



- **Because of critical role in normal retinal and brain development in the human, DHA should be considered conditionally essential during early development. Similarly, EPA+DHA might be considered conditionally essential for life-long health considering intakes required for the prevention of CVD.**

Role of w-6 Fatty Acids

- **Linoleic acid (LA C18:2) and gamma-linolenic acid (GLA C 18:3) : Leafy vegetables and unhydrogenated vegetable oils such as corn oil, peanut oil, cottonseed oil, soybean oil**

- **Arachidonic acid (ARA;C20:4): is obtained from meats, eggs and dairy products.**

- ***Conjugated Linoleic Acid:*** **no sufficient evidence to demonstrate that the intake of CLA has a positive effect on weight and body composition in humans**

- **Excessive amounts of omega-6 (PUFA) and a very high omega-6/omega-3 ratio has been shown to promote the pathogenesis of many diseases: -cardiovascular disease**

  -cancer

  -Inflammatory and autoimmune diseases

- **Salas-Salvadó, J. , Márquez-Sandoval, F. and Bulló, M.(2006) 'Conjugated Linoleic Acid Intake In Humans: A Systematic Review Focusing on Its Effect on Body Composition, Glucose, and Lipid Metabolism', Critical Reviews in Food Science and Nutrition, 46: 6, 479-488.**

Omega-3 fatty acids may have positive effects on:

- High blood pressure
- Body TAG and cholesterol
- Abnormal blood clotting (thrombosis)
- Reduced Fat deposition (atherosclerosis)
- Cardiovascular diseases
- Brain growth and development
- Eye Function

Instability of Omega-3 Oils

- **Prone to oxidation**

	primary	secondary
EPA/DHA →	***peroxides*** →	***aldehydes ketones, etc***
Indicators:	Peroxide Value	p-Anisidine Value

- **Oxidation results in:**
  - Loss of EPA% and DHA%
  - Off fishy odor and/or taste
  - Off fishy odor and/or taste

Omega 3 Fatty Acids are sensitive to oxidative damage as well as possessing adverse taste and flavour

Intake Recommendations for w-3 Fatty Acids

- FDA – Should not exceed 3 g per person per day from conventional food and dietary supplement sources
- Simopoulos (1997) recommended daily intakes for EPA + DHA at 650 mg, with at least 222 mg for both EPA and DHA, and 2.22 g/d for ALA.

Ref.: A.P.Simopolous., A.Leaf, N.Salem Jr., Workshop statement on the essentiality of recommended dietary intakes for omega-6 and omega-3 fatty acids., Prostaglandins, Leukotrienes and Essential Fatty acids. 2000;63(3),119-121.

American Heart Association®

Fighting Heart Disease and Stroke

Scientific Statement

TABLE 5. Summary of Recommendations for Omega-3 Fatty Acid Intake

Population	Recommendation
Patients without documented CHD	Eat a variety of (preferably oily) fish at least twice a week. Include oils and foods rich in α-linolenic acid (flaxseed, canola, and soybean oils; flaxseed and walnuts)
Patients with documented CHD	Consume $\approx$1 g of EPA+DHA per day, preferably from oily fish. EPA+DHA supplements could be considered in consultation with the physician.
Patients needing triglyceride lowering	Two to four grams of EPA+DHA per day provided as capsules under a physician's care

Kris-Etherton PM, Harris WS, Appel LJ. Circulation 2002; 106:2747-57

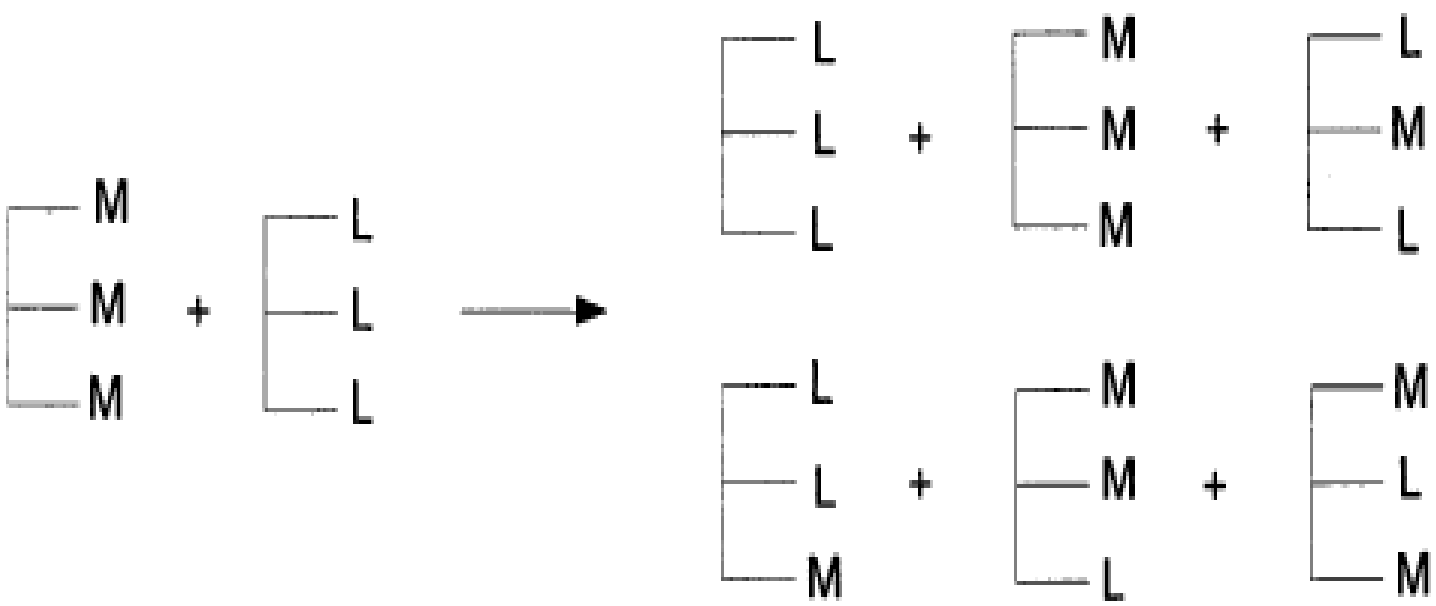
Improvement on the Nutritional Profile of Fat Based Food Products

- **Nutritional Lipids:**
- **Structuring Edible Oils: (Chemical and enzymatic inter-esterification)**
- **Genetic Modification of Oilseed Crops**
- **Feeding Animals with PUFAs for PUFA enriched Foods**
- **Polyunsaturated Fatty Acid Production and Delivery:**
  - **Production of PUFAs by Microorganisms**
  - **Production and Extraction of PUFAs from Fish Oil**
  - **Micro-encapsulation of PUFAs**
    - **(Spray drying, Extrusion, Gelation, Emulsion, Coacervation)**

Structuring Edible Oils

Chemical and Enzymatic Esterification:

Potential TAG species from a 1,3-specific lipase-catalyzed trans-esterification reaction between a medium-chain TAG and a long chain TAG.



Selective Enrichment of DHA and EPA Using Lipases Possessing Fatty Acid Specificity

PUFA in Marine Fish Muscle

The Approximate Content of n-3 Polyunsaturated Fatty Acids (PUFA) in Seafood[a]

Seafood	g n-3 PUFA/100 g
Mackerel	1.8–5.3
Herring	1.2–3.1
Salmon	1.0–2.0
Trout	0.5–1.6
Tuna	0.5–1.6
Halibut	0.5–1.0
Shrimp	0.2–0.4
Cod, plaice, flounder	~0.2

[a]Depends on variables such as season and place of capture.

EPA and DHA content (% of total fatty acids) in various fish

Fish	EPA (%)	DHA (%)
Sardine	3	9–3
Pacific anchovy	18	11
Mackerel	8	8
Capelin	9	3
Herring	3–5	2–3
Freshwater fish	5–13	1–5

Adapted from: Newton and Snyder (1997).

- **Increasing fish consumption is challenging and may not be possible.**
  - **Difficult to eat amount of fish needed**
  - **Vegetarians/People with fish allergies/Those who don't like fish**
  - **Contamination with metals**
- **Food fortification with w-3 Fatty Acid is convenient and efficient**
  - **Allows one to eat foods fortified with Omega-3 fatty acids**

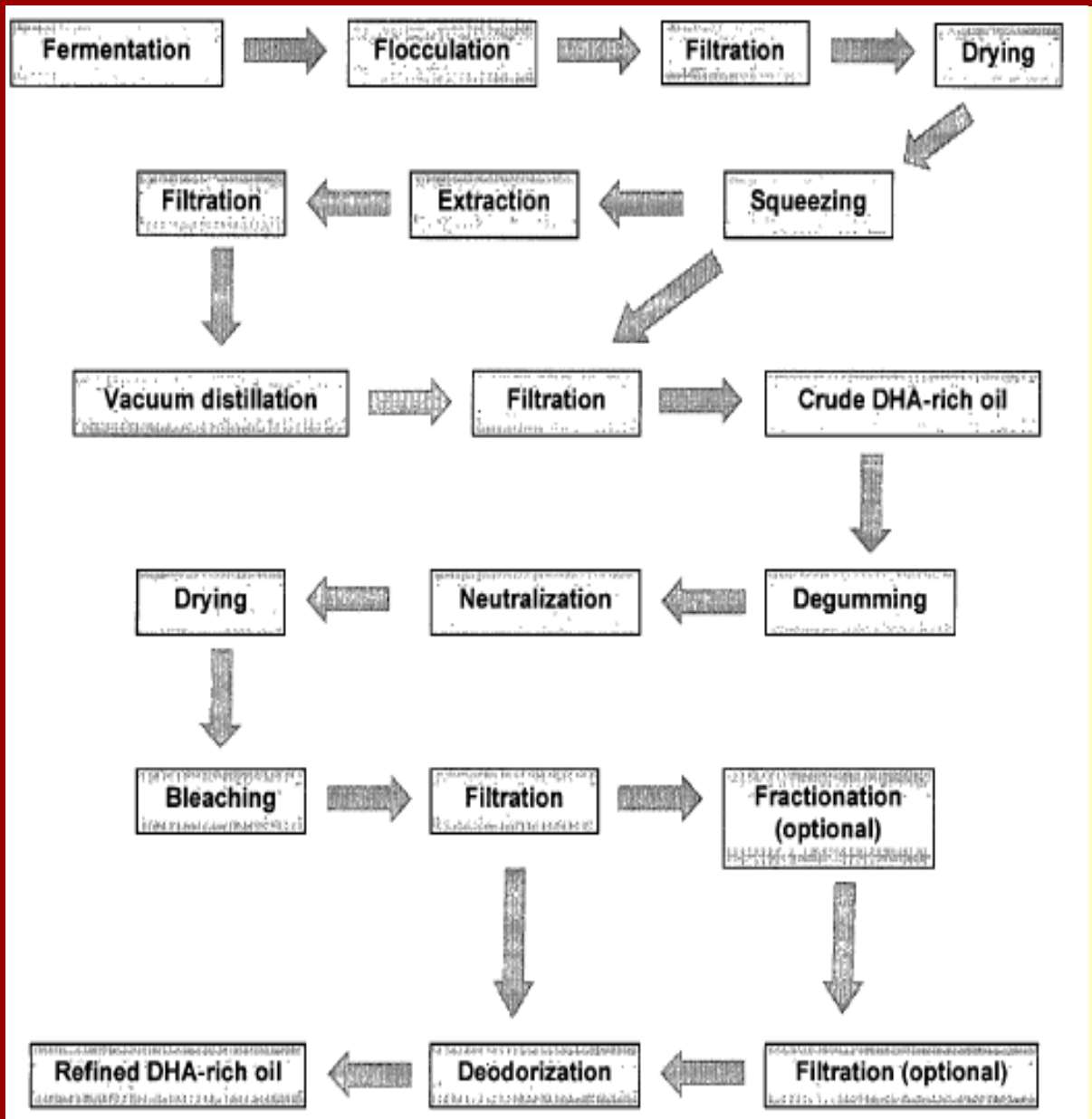
Production of PUFA (DHA) by Microorganisms

PUFA producing Microbes

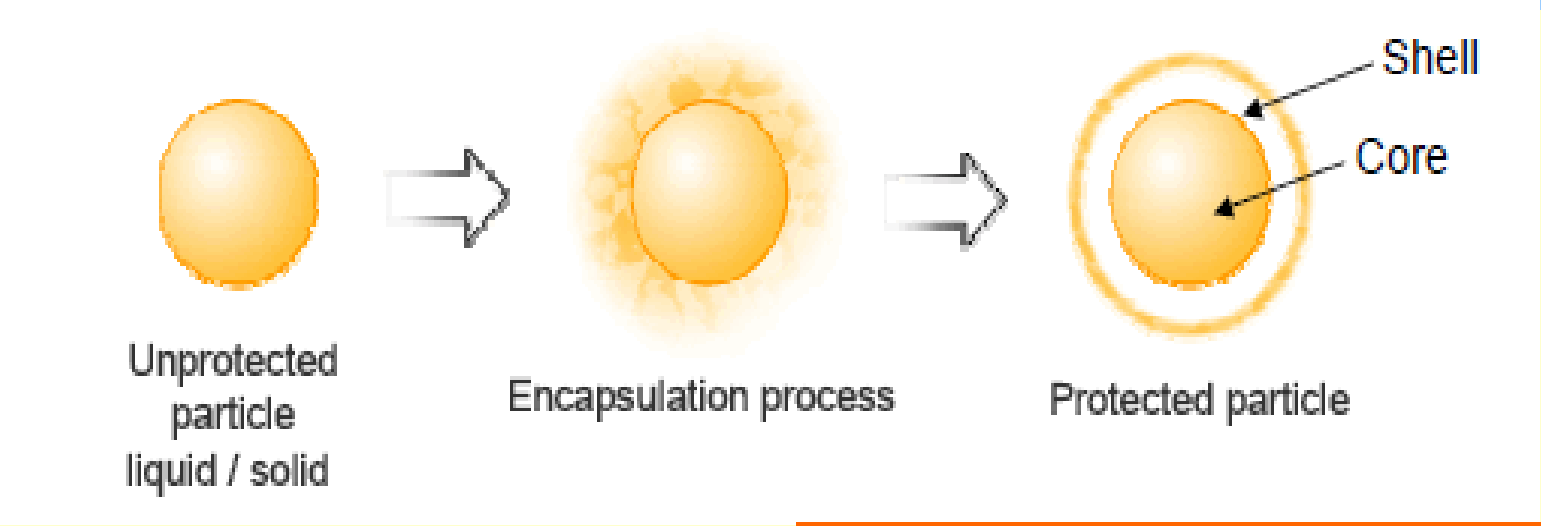
- ***Phaeodactylum tricornutum***
- ***Isochrysis galbana***
- ***P. tricornutum***
- ***Monodus subterraneus***
- **P. ultimum (Fungi)**

Feasibility of large scale production

Biotechnology Advances, Vol. 16, No. 3, pp. 517-580, 1998



Micro-encapsulation offers ability to develop innovative food products



Spray Drying
Emulsion
Coacervation
Polymerization

Stabilising Shelflife
Prevents oxidation
Provides stable Matrix
Controlled/delayed release of active ingredients

- **Encapsulation matrix**
- **Effects of antioxidants on stability of EPA and DHA**

Omega 3 FA have been added to commercial products including milk, cheese, yogurt, bread and juice.

Global Omega-3 Fatty Acid Market (Frost & Sullivan 2005)

Frost And Sullivan Report (2005). CASE STUDY: The Omega-3 Fatty Acid Market.

Conclusions: Functional Food Development using w-3 Fatty Acids

Critical Factors

- Improvement Of Ratio Of Saturated Fatty Acid To Unsaturated Fatty Acids and w-3:w-6 Fatty Acid Ratio In The Diet
- Development Of w-3 Fatty Acid Supplemented Food Products With Optimal Taste And Functional Properties
- Technology Know-how
- Nutritional And Clinical Scientific Evidence
- Product And Process Development

Thank You for Your Attention.