Study Of
Simple Lipids/Neutral Lipids

Triacylglycerols/Triglycerides

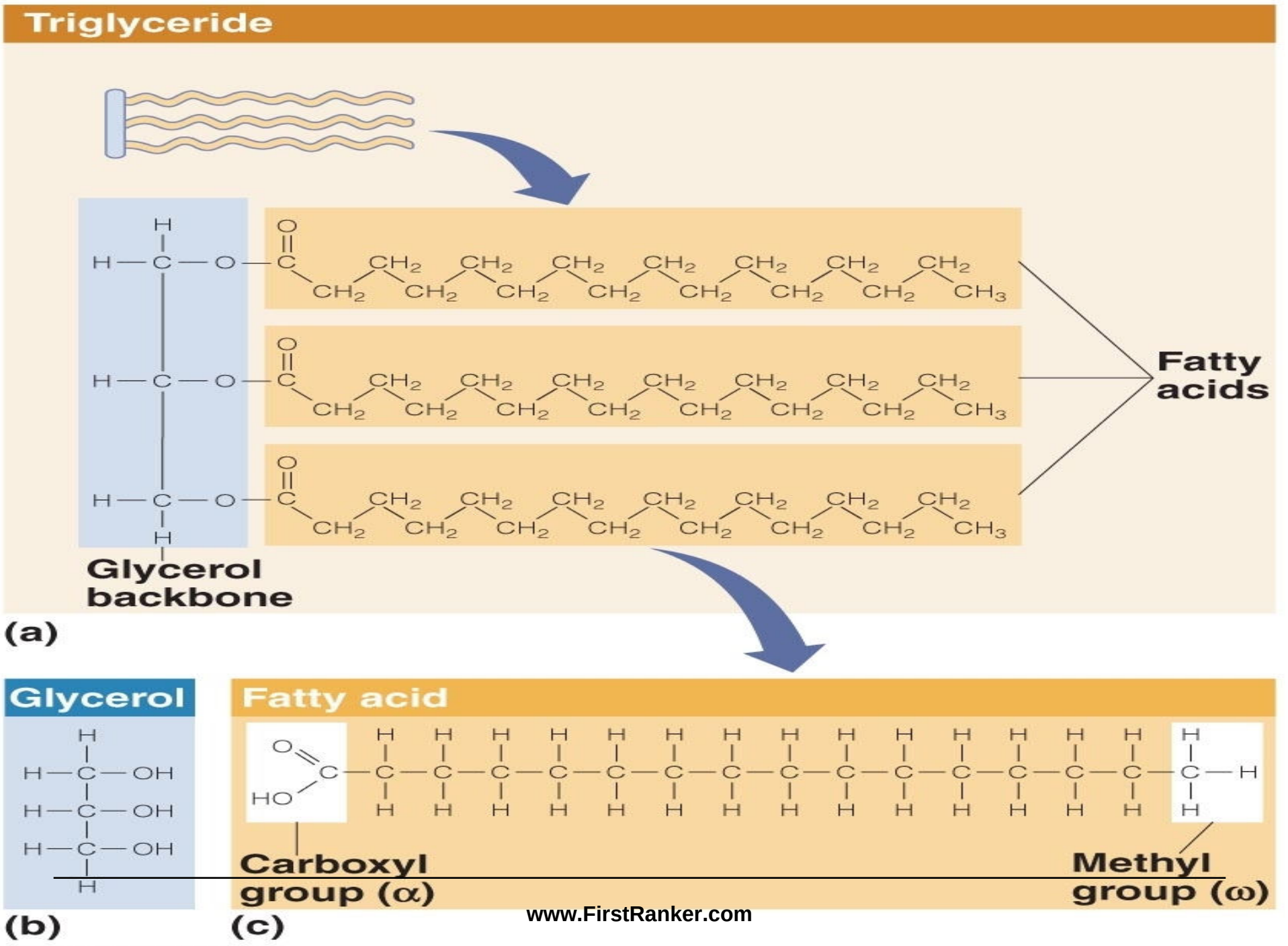
- Chemical name of Fat/Oil is **Triacylglycerol (TAG).**

- **TAG is a Simple, Glycerol based ,Neutral Lipid.**

Chemical Structures Of Triacylglycerol (TAG)

Triacylglycerol/Fats/Oils

- **TAG/Fats/Oils are**
- Chemically **Esters** of
- **Three Fatty acids (Same or Different)**
- **with one Glycerol (Trihydric Alcohol).**



Most Common Fatty Acids in Triacylglycerol

Fatty acid	Carbon:Double bonds	Double bonds
Myristic	14:0	
Palmitic	16:0	
Palmitoleic	16:1	*Cis*-9
Stearic	18:0	
Oleic	18:1	*Cis*-9
Linoleic	18:2	*Cis*-9,12
Linolenic	18:3	*Cis*-9,12,15
Arachidonic	20:4	*Cis*-5,8,11,14
Eicosapentaenoic	20:5	*Cis*-5,8,11,14,17
Docosahexaenoic	22:6	*Cis*-4,7,10,13,16,19

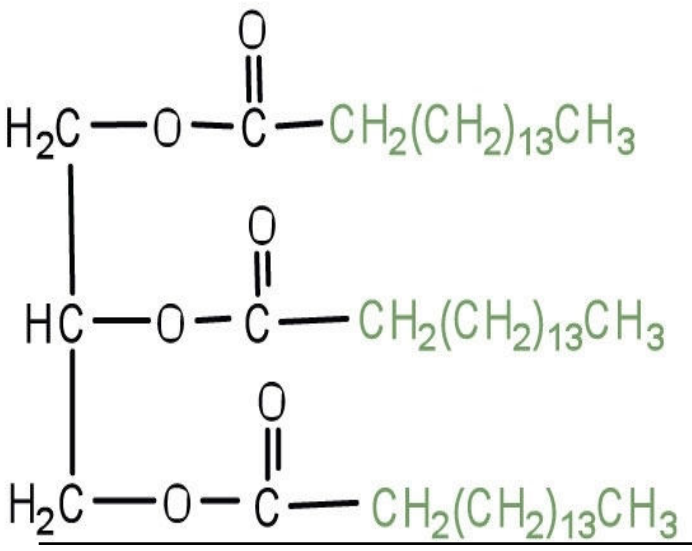
$CH_3(CH_2)_n COOH$

- **TAG is Neutral or Non polar lipid.**
- Since **TAG structure** has **no charged/polar groups** in its structure.

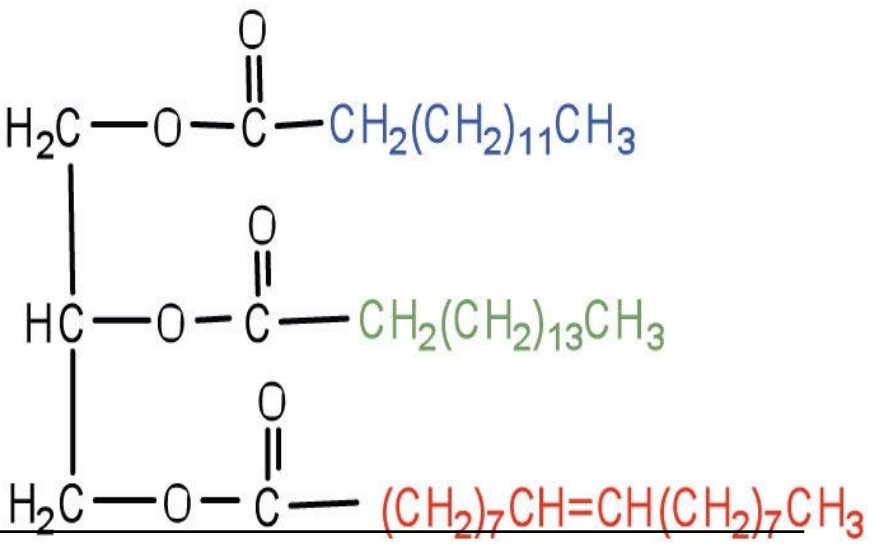
Types Of Triacylglycerol

Based On Nature Of Fatty Acid

- Simple TAG
- Mixed TAG



Tristearin



- **Simple TAG: Three same Fatty acids** are esterified to Glycerol to form simple TAG.
- **Examples of Simple TAG:**
  - –TriPalmitin
  - –TriStearin
  - –TriOlein

- **Mixed TAG:**

- The **3 different Fatty acids** esterified to Glycerol to form a mixed TAG.

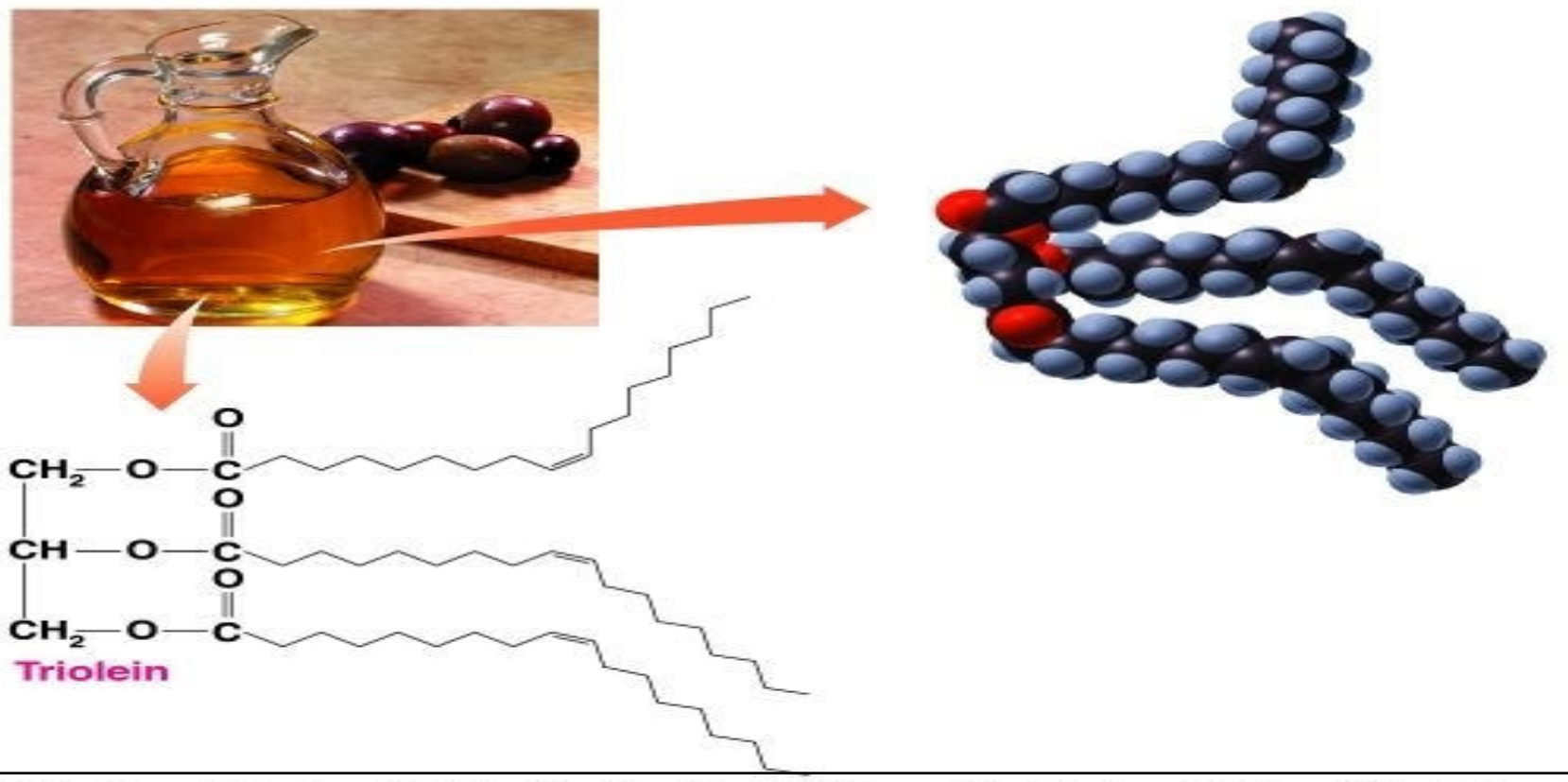
- Mixed TAG's are **more predominant in nature**.

- **In a Mixed TAG**

- **First Carbon C1** -has **Saturated Fatty acid**
- **Second position C2-**has **Unsaturated Fatty acid-PUFA**
- The **3 rd position C3 Fatty acid** in TAG has - **either Saturated/Unsaturated fatty acid**

Olive Oil Rich In Simple TAG

- Olive oil contains mostly TAG as **Triolein, which has three Oleic acids.**



Sources OF Triacylglycerol To Human Body

- Exogenesis source of TAG :
  - Dietary Fats/Oils
- Endogenous source of TAG :
  - Liver Lipogenesis in well fed condition
  - Using Glucose product Acetyl-CoA.

Dietary Sources Of TAG

- Animal Fat (Solid)
- Plant Oils (Liquid)

Fats (solid Triacylglycerol)
Oil (a liquid Triacylglycerol)

Occurrence/Distribution Of TAG

- **TAG is a most widely distributed abundant natural lipid.**

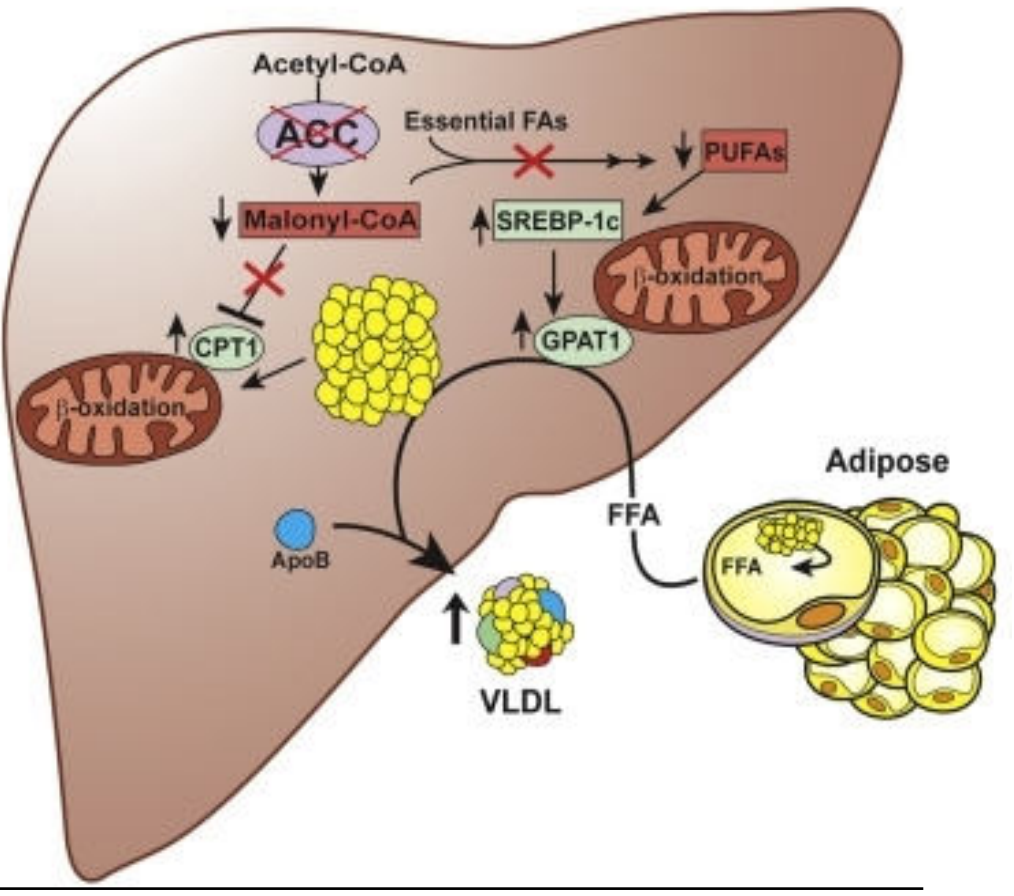
TAG Major Lipid Form Of Human Body

–**Predominant Lipid ingested** in **Human diet** is **TAG 98%.**

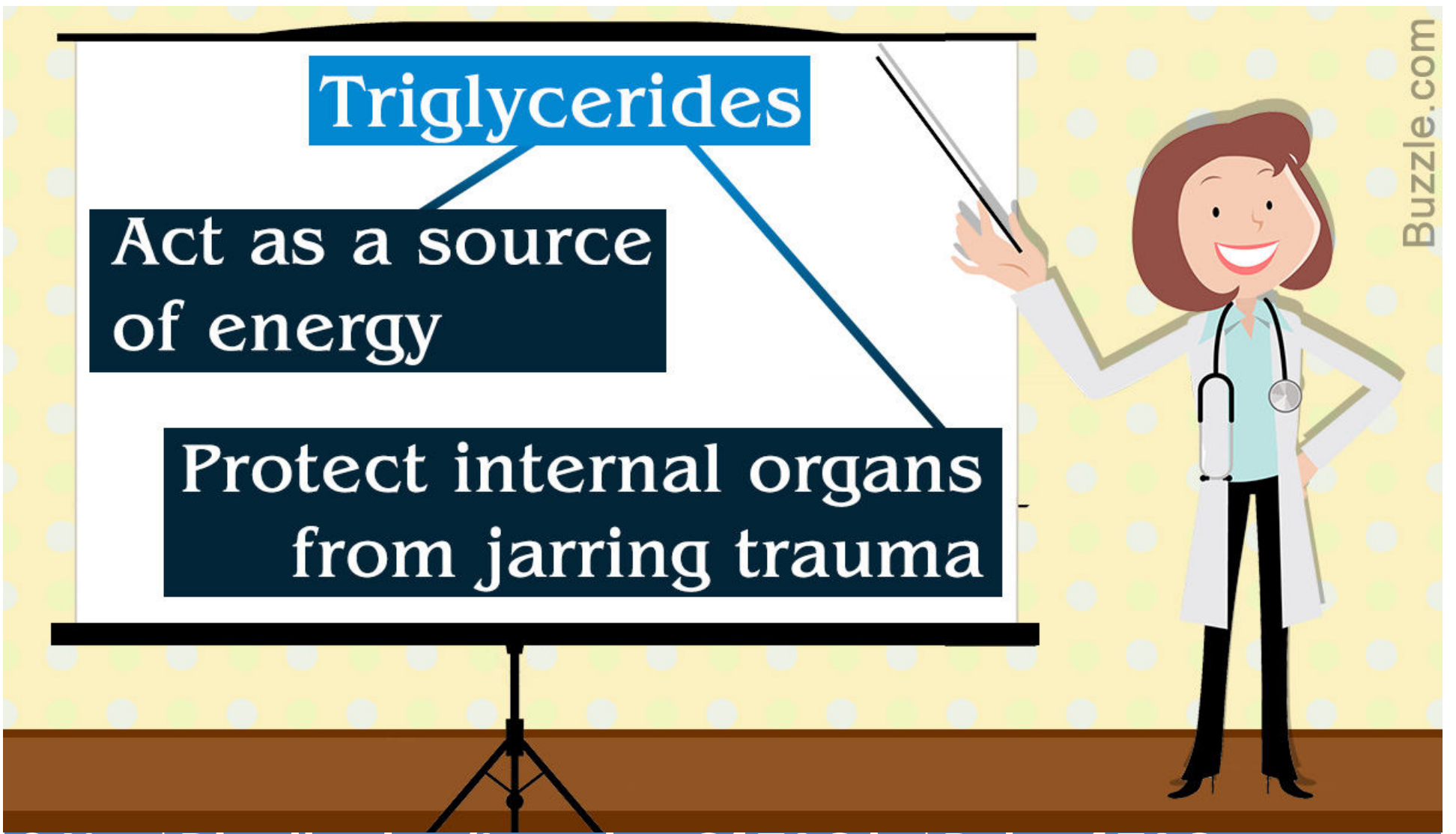
–**Abundant Lipid of human body Lipid** is **TAG 95 %.**

Transportation Of TAG in blood is By Lipoproteins

- **Chylomicrons** :
- Transports exogenous dietary TAG
- **VLDL:**
- Transports endogenous TAG



Biomedical Importance Of TAG



S.No	Distribution/Location Of TAG in Human Body	Role of TAG
1	Predominant Dietary Form of Lipid Ingested in GIT	**Dietary and Calorific Value- Secondary Source of Energy**
2	Adiposecytes/Depot Fat- Exclusively TAG	**Reservoir of Energy**
3	Subcutaneous layer /Below Skin	**Insuating Effect**, Regulates Body Temperature
4	Fat Pad around Internal Soft Visceral Organs	Mechanical Shock absorbers

1.TAG Serves As Source Of Energy

- TAG has **high calorific value (9Kcal/gram)** more than Carbohydrates (4 Kcal/gram).

2.TAG Reservoir Of Energy

Storage form of **Lipid** in human body is **TAG.**

Triacylglycerols In Its Structure

Links and Stores Fatty acids

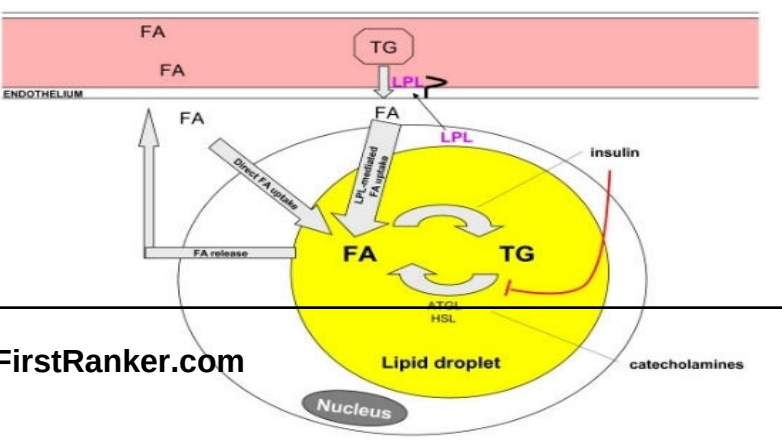
- **Fatty acids** are **not stored in free form** in living beings.
- **Fatty acids** are **stored** in **bound form** as **TAG.**
- Thus **TAG** is a **storage form of Fatty acids** .

Criteria's For TAG To Be Chosen As Reservoir of Energy

- TAG is **highly reduced and anhydrous** form.

- Hence **chosen as energy reserve** of the body.

- **Because of insolubility of TAG in aqueous phase:**
- Body TAG are mostly found in **isolated compartments as droplets.**
- **TAG in anhydrous form** is packed in **Adipocytes (Depot Fat)**



3.Store House Of TAG is High In Comparison To Glycogen Stores

- **More content** of **energy** can be stored by TAG in **comparison to Glycogen stores.**

- **1 gm** of **anhydrous TAG stores more than 6 times** as much as **energy** as **1 gm of hydrated Glycogen.**

  - **Hydrated molecules requires more space.**

- **TAG stored in anhydrous** form requires **less space.**

- In contrast **Glycogen being hydrated** requires more space.

(1 gm of Glycogen binds with 2gm of water)

- **TAG When excess serves** as an **energy reservoir stored in Adipocytes** as :
  - **Anhydrous form**
  - **Concentrated**
  - **Unlimited amount**

- Stores of TAG are utilized in **between meals** and **starvation phase**.

- A **good storage of depot Fat** can suffice for **2-3 months** in **starvation condition.**

- The stored TAG is used as **long term energy source for body activities.**

- In **long marathon race** energy for muscle activity is provided by the **hydrolysis of depot TAG.**

4. TAG Regulates Body Temperature

- The **subcutaneous Fat** layer is a TAG
- TAG is a **bad conductor of heat and electricity** and serves as a **thermal and electrical insulator.**
- Which prevents loss of heat from the body and plays important role in **regulating body temperature.**

5.TAG Protects Internal Visceral Organ and Systems

- A presence of **Fatty** (TAG) **pad** around the **soft delicate** internal **visceral organs**
- **Protects from mechanical trauma or injury** by **acting as a shock absorber.**

- TAG **provides shape to body and**
- **Keep skin smooth and supple.**

Remember TAG is not associated to biomembranes.

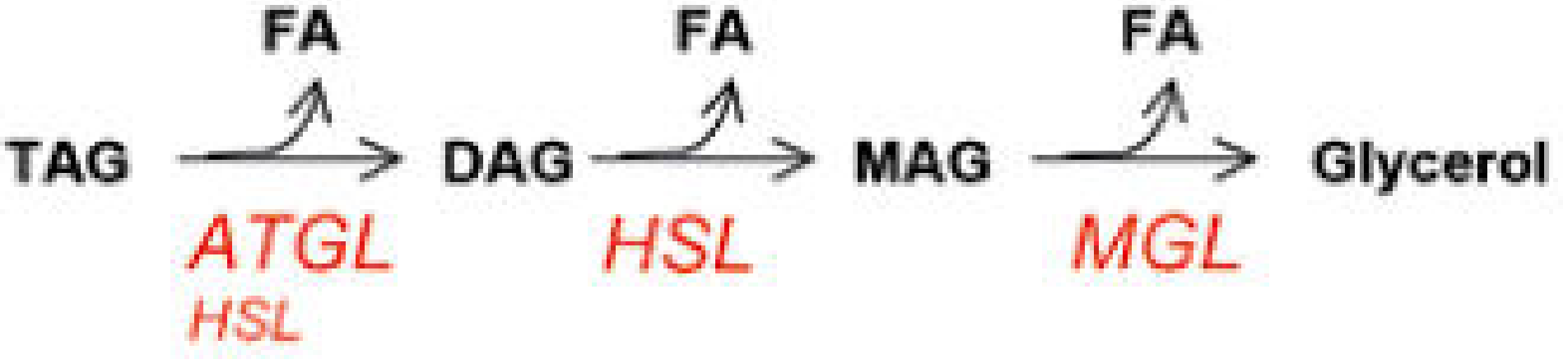
- **MAG and DAG are derived Lipids.**

- **Monoacylglycerol** and **Diacylglycerol** are hydrolytic products of **Triacylglycerol.**
- These are produced during **TAG metabolism** in the body.

– **Monoacylglycerol (MAG) /(Monoglycerides):** A Glycerol esterified with one fatty acid.

– **Diacylglycerol (DAG) (Diglycerides):**

– A Glycerol esterified with two fatty acids.



Healthy TAG In Human Body

- Ingesting Natural Mixed Form – PUFAs and Short chain FAs
- Avoiding Trans Fats
- Balanced/Moderate ingestion
- No excess or deficient TAG stores
- Normal serum TAG levels < 150 mg%

Disorders Associated To TAG

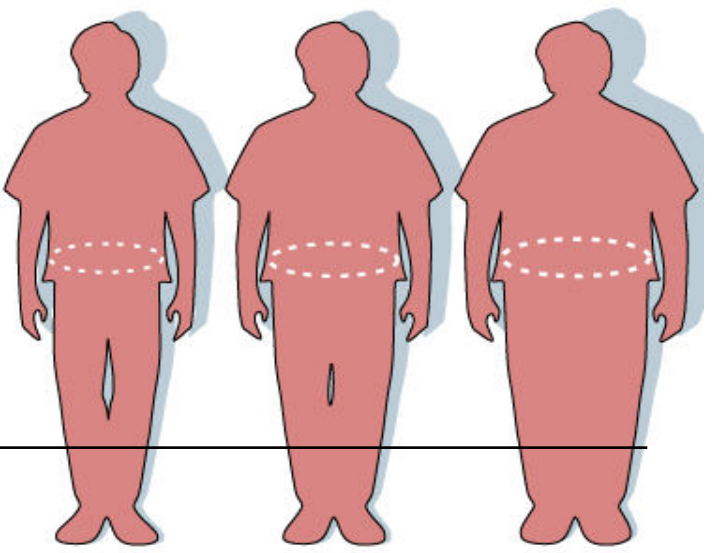
Triglyceride Levels

Normal, Borderline, High, Very High

Interpretation	Level mg/dL	Level mmol/L
Normal range, low risk	<150	<1.69
Borderline high	150-199	1.70-2.25
High	200-499	2.26-5.65
Very high: high risk	>500	>5.65

Bad About : TAG/ Fats and Oils

- Excess Fat leads to **Obesity**
- Increases risk for **Diabetes Mellitus**
- Leads to Coronary Artery disease
- MI, Stroke
- **Susceptible to Cancer**



Disorders Related To TAG

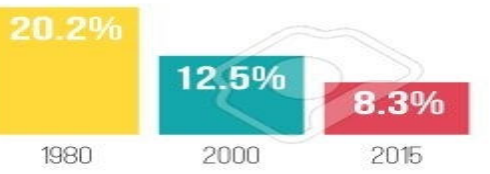
- **Normal Fat content of adult:**
  - **Men 21%**
  - **Women 26%**
- If the **Fat** content of an adult body goes **above the normal** content the condition is termed as **Obesity.**

JUNK FOOD & OBESITY INFOGRAPHIC

80% PEOPLE
EAT JUNK FOOD ON A DAILY BASIS

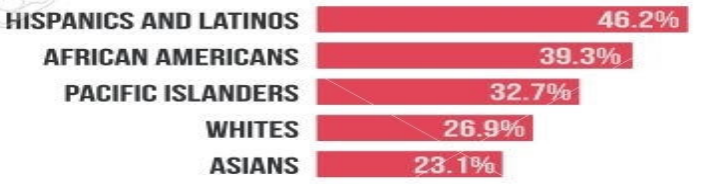
360 000 AMERICANS
DIE EACH YEAR FROM DISEASES DIRECTLY RELATED TO OBESITY AND AN UNHEALTHY LIFESTYLE

CHILDREN WALKING TO SCHOOL BY FOOT



ONLY 19% OF PEOPLE
GET THE RECOMMENDED AMOUNT OF PHYSICAL ACTIVITY

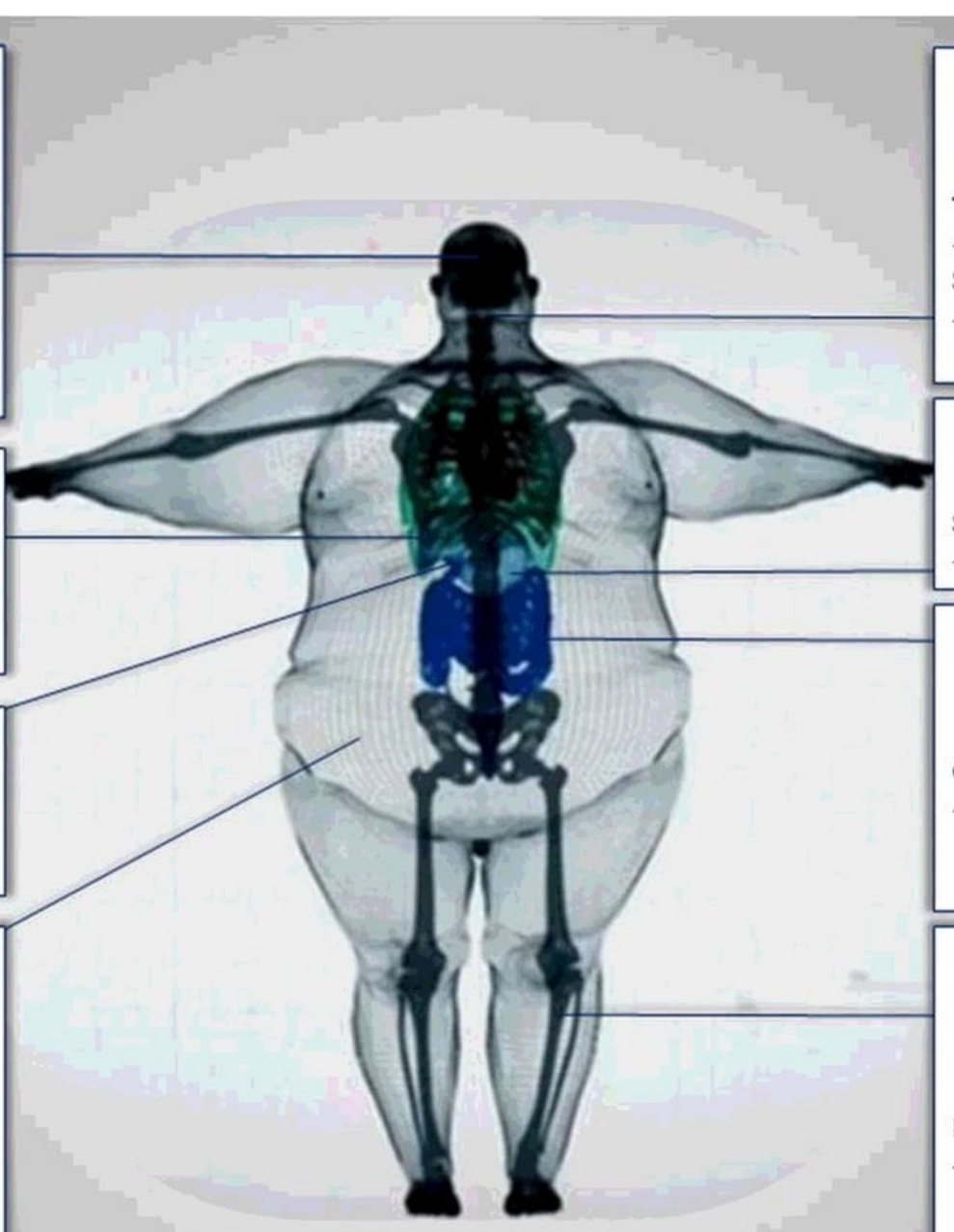
OVERWEIGHT BY ETHNICITY/RACE



CALORIES CONSUMED PER DAY BY ADULTS

MAIN SOURCES OF EMPTY CALORIES

EVERY 5TH CHILD IN THE WORLD IS OVERWEIGHT OR OBESE



Central Nervous System
- Disturbed brain development
- Leptin-Melanocortin Pathway
- Impaired energy homeostasis
- Neural transmission
- Impaired appetite regulation
- Food preference changes

Liver
- ↑ insulin resistance
- Impaired lipid metabolism
- ↑Inflammation

Pancreas
- ↑ beta cell mass
- ↑ beta cell function

Adipose Tissue
- ↑ leptin, ↑ or ↓adiponectin
- ↑ browning of WAT
- Impaired thermogenesis
- Impaired adipocyte homeostasis
- ↑ insulin resistance
- ↑ inflammation

Taste Receptor
- Impaired fatty acid sensing

Salivary Glands
- Amylase and carbohydrate metabolism

Stomach
- Lactose digestion

Gut Microbiota
- Disruption in Proportion of Bacteroidetes to Firmicutes population

Musculoskeletal System
- Skeletal growth abnormalities
- Impaired glucose transport in muscles & ↑ lipid use in muscles
- ↑ insulin resistance

- Obesity has **excess fat depots.**
- **Truncal/central obesity** is a risk factor for heart attack.

- **Obesity** has abnormal Lipid metabolism.
- Increased Blood Cholesterol and Lipoproteins.

- **Obese persons** has **high risk of**
- **Diabetes mellitus**
- **Atherosclerosis and CVD**
- **Consequently lead to Metabolic Syndrome**

Problems related to obesity :

Prevent Obesity

AVOID STRESS

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EAT MORE FRUITS AND VEGETABLES

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GET ENOUGH SLEEP

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GET RID OF BAD HABITS

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STOP EATING FAST FOOD

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DRINK ENOUGH WATER

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DO PHYSICAL EXERCISES

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LESS TV

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Properties Of Triacylglycerol

Lipid Peroxidation
(autoxidation)

Lipid Peroxidation
Is a source of Higher Free Radicals

- During **Oxygen metabolism in body.**

- **Oxygen derived free radicals** (RO.,OH.,ROO.) with **unpaired electrons are released.**

- **These Reactive Oxygen Species (ROS) , Free radicals interact and oxidize double bonds of PUFAs** leads to chain reactions of lipid peroxidation.

- **Steps of Lipid peroxidation reaction:**
  - **Initiation**
  - **Propagation**
  - **Termination**

- **PUFAs are more prone for peroxidation.**

- **Lipid peroxidation Provide** continuous **Free radicals.**

- Thus has potentially **devastating effects in the body**

- **In vitro peroxidation of Lipids deteriorates the quality of Fats and Oils**

- Makes the Fat/Oil **rancid and in edible.**

- Fat/oil has **bad taste and odor**

- **Decreases the shelf life** of Fats and Oils.

- **In vivo peroxidation of**

membrane Lipids damages cells & tissues

- Lipid peroxidation has devastating effects on body Lipids.
- Increases risk of Inflammatory diseases
- Ageing
- Cancer

- **Antioxidants** control and **reduces**

In vivo and **In vitro Lipid peroxidation.**

- **Naturally occurring antioxidants** are :
  - **Vitamin E**
  - **Vitamin C**
  - **Beta Carotene**

- **Body Enzymes as Antioxidants:**
  - **Catalase**
  - **Glutathione Peroxidase**
  - **Superoxide Dismutase**

- **Other Substances as Antioxidants:**
  - **Urate**
  - **Bilirubin**

- **Food Additives as Antioxidants:**
  - Alpha Naphtol
  - Gallic Acid
  - Butylated Hydroxy Anisole (BHA)
  - Butylated Hydroxy Toluene (BHT)

- **Preventive Antioxidants:**

- Reduces rate of Chain initiation of Lipid peroxidation
  - **–Catalase**
  - **–Peroxidase**
  - **–EDTA**
  - **–DTPA**

- **Chain Breaking Antioxidants:**

- Interferes the chain propagation of Lipid peroxidation.
  - –Vitamin E
  - –Urate

Rancidity Of Fats/Oils

Rancidity

- Rancidity is a **physico chemical phenomenon**
- Which **deteriorates Fats and Oils**
- Resulting in an **unpleasant taste ,odor and color of Fat/Oil (Rancid Fat/oil)**

- Rancid Fat is **inedible**

Factors Causing Rancidity

- **Double bond** containing /Unsaturated Fatty acids are **unstable** and **ready** for **peroxidation and rancidity.**

- **Single bond** containing/Saturated Fatty acids are **stable and less peroxidized and made rancid**.

PUFAs are more prone to Rancidity

Since Double bonds are more susceptible to Lipid peroxidation

Causes Of Rancidity

- Fats and Oils get **Rancid on Ageing**.
- Various **Factors aggravates rancidity** of Oils and Fats:
- **Improper handling by an exposure to:**
  - **Light**
  - **Air (Oxygen)**
  - **Moisture**
  - **Microbes**

Types and Mechanism Of Rancidity

Types Of Rancidity

- **Oxidative Rancidity**
- **Hydrolytic Rancidity**
- **Ketonic Rancidity**

• Oxidative Rancidity:

- PUFAs having **double bonds** are easily oxidized to form its peroxides.
- By the action of **Oxygen Derived Free radicals (ODFR).**

- The **cellular Lipids** are also likely to **get peroxidized** by **Free radical action** causing damage to biomembranes.

- **Hydrolytic Rancidity:**

- Long Chain Saturated fatty acids are **hydrolyzed** by **Bacterial Enzymes .**
- To produce **Dicarboxylic acids, Aldehydes**, **Ketones** etc which make a Fat rancid.

Ketonic Rancidity

- It is due to the **contamination** with certain **Fungi** such as **Asperigillus Niger on Oils** such as Coconut oil.
- **Ketones, Fatty aldehydes, short chain fatty acids** and **fatty alcohols** are formed.
- **Moisture accelerates Ketonic rancidity.**

- Rancidity gives bad odor and taste to rancid Fats/oils.
- **Due to Dicarboxylic acids ,Ketones , Aldehydes** Produced during the process of

Prevention of Rancidity of Fat/Oil By :

- Good storage conditions
- Less Exposure to light
- Low Oxygen, moisture
- No very High temperatures
- No Bacteria or fungalcontamination
- Addition of Antioxidants

Prevention Of Rancidity

- **Rancidity can be prevented by proper handling of oils**
  - **By keeping fats or oils in well closed containers in cold, dark and dry place.**

Prevention Of Rancidity

- **Avoid** exposure to **direct sunlight, moisture and air.**

- **Avoid over** and **repeated heating** of oils and fats.

- **Removal** of catalysts such as **Lead** and **Copper** from Fat/Oils that **catalyzes rancidity** prevents rancidity.

Antioxidants Prevent Rancidity

- Antioxidants are **chemical agents** which **prevent peroxidation** and **Hydrolysis of Fats/Oils**.

- **Examples Of Antioxidants:**

- Tocopherol(Vitamin E)
- Vitamin C
- Propyl Gallate
- Alpha Napthol
- Phenols
- Tannins
- Hydroquinone's.
- Butylated Hydroxy Anisole(BHA)
- Butylated Hydroxy Toluene (BHT)

- **The most common natural antioxidant is vitamin E that is important in vitro and in vivo.**

- **Vegetable oils** are associated with **high content** of **natural antioxidants (Vitamin E),**
- Hence **oils do not undergo rancid rapidly**
- As compared to **animal fats** which are **poor in naturally** associated **antioxidants .**

- Rancidity of Fats and Oils is prevented by adding Antioxidants.
- **Thus addition of Antioxidants increases shelf life of commercially synthesized Fats and Oils**.

Hazards of Rancid Fats:

1. Rancidity **destroys the content of polyunsaturated essential fatty acids.**
2. Rancidity causes **economical loss** because **rancid fat is inedible.**
3. The products of rancidity are **toxic,** i.e., **causes food poisoning and cancer.**
4. Rancidity **destroys the fat-soluble vitamins** (vitamins A, D, K and E associated with it.

Others Properties Of TAG

Depends On Nature Of Fatty Acids

Chain Length Of Fatty acids Of TAG affects Melting Point

- **"Hardness"** of the Fat/TAG depends on chain length.
  - **< 10 carbons** in Fatty Acid = **liquid**
  - **>20 carbons** in Fatty Acid = **solid**

Acetic Acid (2 C)	**Vinegar**	**Liquid**
Stearic Acid (18 C)	**Beef Tallow**	**Solid**
Arachidic Acid (20 C)	**Butter**	**Solid**

Differences In Fat and Oil

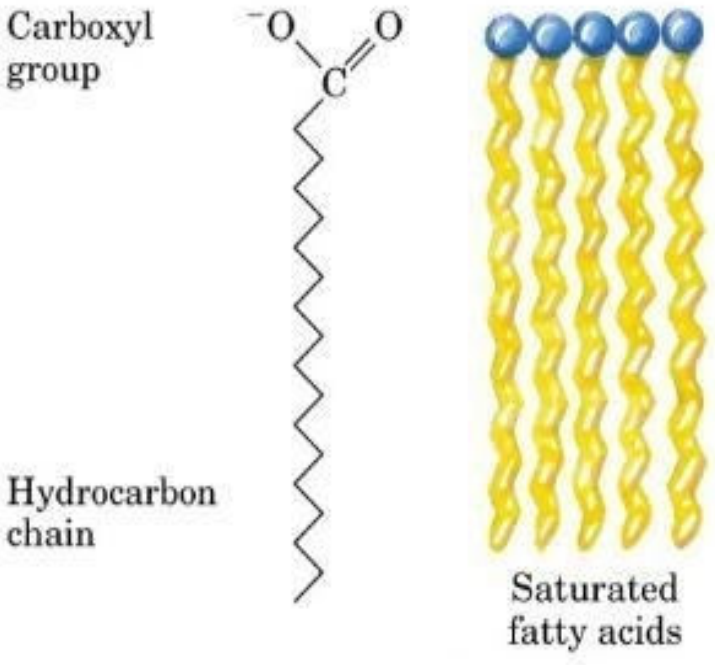
- Fat and Oils are **different** in **Physical Characteristics**

- **Fat is solid at room temperature.**
- **Oil is liquid at room temperature.**

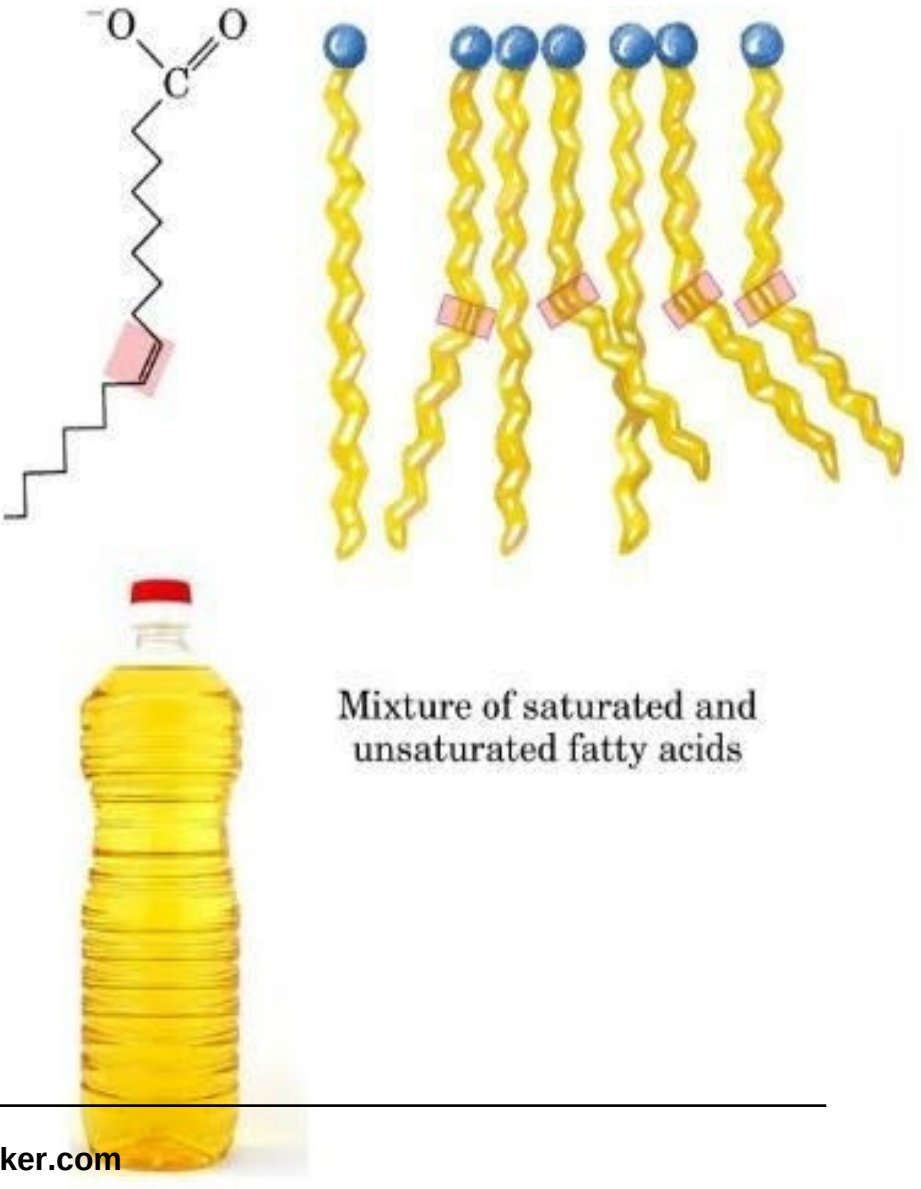
- **TAG of Fat is solid** since chemically composed of **long and saturated fatty acids**.
- **Source of Fat is Animal foods**.

- **TAG of Oil is liquid** as composed of **short and unsaturated fatty acids.**
- **Source of Oil is plant**.

Fat



Oil



Hydrogenation Of Fat/Oil

- **Treatment of Oils(TAG) rich in PUFAs with Hydrogen gas, ($H_{2)}$.**
- **Catalyst required (Nickel).**
- **Adding Hydrogen at double bonds of PUFAs.**
- **It is also called "Hardening of Oils"**
- **Hydrogenation converts PUFAs with cis form to trans form.**
- **Margarine**
  - **Vanaspati Dalda Crisco, Spry, etc.**

Advantages and Disadvantages Of Hydrogenation Of Fat /Fatty acids

Advantages Of Fat Hydrogenation

- Hydrogenation transforms **unstable ,unsaturated , liquid TAGs**:
  - **To stable, saturated, solid TAGs**
  - **Reduces risk of Rancidity**
  - **Increases shelf life and business.**
  - Example : Vanaspati Dalda ,Margarine.

Disadvantages Of Hydrogenation Of Fat/Fatty acids

Trans Fats increases the risk of Atherosclerosis and CVD.

- Hydrogenated **trans Fats** are **more stable.**
- Body has **no enzyme system** to oxidize and **metabolize trans fatty acids.**

- **Remember Hydrogenated Fats are Bad for Health.**

- **Summary Of Fat Hydrogenation:**

- **Hydrogen atoms are added** to unsaturated Fatty acids
  - **Make liquid oils more solid and more saturated.**
  - Create ***trans*** **fatty acids**.
  - **Reduces peroxidation of Fatty acids**.
  - **Resists rancidity**
  - **Reduces metabolism**
  - **Increases retention**
  - **Increase risk of cardiovascular disease.**

- **Note**

- Try eat more natural TAGs.
- Avoid Processed Fats.

Tests To Check Purity Of Fat and Oil

- Several laboratory tests are employed to:
  - **Check the purity**
  - **Degree of adulteration**
  - **Biological value of Fat and Oils.**

Tests to Check Purity of Oils and Fats

Tests To Check Purity of Oils	Importance/Significance
Iodine Number	**Index of unsaturation** and **content of unsaturated fatty acids**
Saponification Number	To know **Chain Lengths of Fatty acids**
Acid Number	Checks **purity of Refined oils**
Reichert Meissl (RM) Number	**Useful in testing the purity of butter**

Iodine Number

- Iodine number is **Grams/Number of Iodine absorbed by 100 gram of Fat /Oil .**
- Iodine Number is calculated by method of **Iodometry.**

Use Of Iodine Number

- Iodine number is useful to know
- The **index of unsaturation** and **content of unsaturated fatty acids** present in the Fat/Oil.

- Iodine number is **directly proportional** to **unsaturated bonds of PUFAs** in a Fat/Oil.

- **High value of Iodine number** of oil **indicates more content of Unsaturated Fatty acids** in it.

Name Of Oils	Iodine Number
Coconut Oil	7-10 **(Least)**
Butter	25-28
Ground Nut Oil	85-100
Sunflower Oil	125-145
Soya bean Oil	135-150
Linseed Oil /Flax seed Oil	175-200 **(Highest)**

- Determination of Iodine number **helps in knowing the degree of adulteration** of tested oil sample.

- If **Linseed oil is adulterated** with an oil whose content is high in **saturated fatty acids** will **give lower Iodine number than the reference values.**

Saponification Number

- Saponification number is **milligram/number of KOH molecules required to hydrolyze and saponify one gram of Fat/Oil**.

- Saponification number gives the **idea of molecular size/chain length of Fatty acids** present in 1 gram of Fat.
- 1 gram of Fat/oil with **long chain fatty acids** has **lower saponification number.**
- 1 gram of oil containing **short chain fatty acids has high Saponification number.**

- 1 gram Oil with **short chain fatty acids** has **higher saponification number.**
- Since it has **more COOH groups for KOH reaction.**

- 1 gram **Fat/Oil with long chain fatty acids has low saponification** number.
- Since in 1 gram of Fat has **few -COOH groups of fatty acids to react with KOH.**

Oils	Saponification Number
Coconut Oil	250-260
Butter	230-250
Jojoba Oil	69- 80
Olive Oil	135-142

Acid Number

- Acid number is **milligram of KOH required for complete neutralization** of **free fatty acids present in one gram of Fat/Oil.**
- Acid number checks the **purity of Refined oils.**

- Refined oils are free from free fatty acids and has zero Acid number.
- Increased Acid number of refined oil suggests bacterial/chemical contamination and unsafe for human consumption.

Reichert Meissl (RM)Number

- RM number is **0.1 N KOH required for complete neutralization of soluble volatile fatty acids distilled from 5 gram of Fat .**

- **R.M Number** of Butter is 25-30.

- The R.M number of other **edible oils is less than 1.**

- **R.M number is useful in testing the purity of butter**
- Since it **contains good concentration of free volatile fatty acids** viz: **Butyric, Caproic and Caprylic acid.**

- **Adulteration of butter reduces its R.M number.**

Differentiation Between Fats And Oils

Fats	Oils
Fats are TAGs composed of **Long** and **Saturated Fatty acid.**	**Oils** are TAGs composed of **short** and **Unsaturated Fatty acids.**
Fats solid at room temperature Fat has **high melting point**	**Oils liquid** at room temperature Oils have **low melting point**
Fats -animal In Origin **Example: Lard (pork Fat)**	**Oils -Plant in Origin** **Example: Safflower Oil**
Fats **has low antioxidant content** and **get easily Rancid**	Oils have **high antioxidant** content and **do not get easily Rancid**
Fats are **more stable** Fats are **less metabolizable** in body.	Oils **are less stable** Oils are **readily metabolizable** in the body.
High content of dietary **Fats has high risk for Atherosclerosis.**	Oils have **low risk for Atherosclerosis.**