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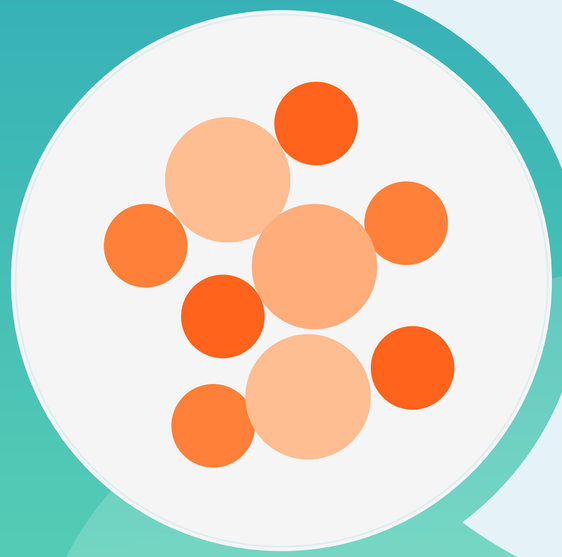
For healthcare professional use only

Simply lipids

A guide to understanding lipids



Abbreviations

ALA Alpha-linolenic acid

ARA Arachidonic acid

BMI Body mass index

DHA Docosahexaenoic acid

EPA Eicosapentaenoic acid

HMO Human milk oligosaccharides

LA Linoleic acid

LCPUFA Long-chain polyunsaturated fatty acids

MCFA Medium-chain fatty acids

MFG Milk fat globules

MFGM Milk fat globule membrane

MUFA Monounsaturated fatty acid

PA Palmitic acid

PUFA Polyunsaturated fatty acids

SFA Saturated fatty acid

TG Triglycerides

WHO World Health Organization

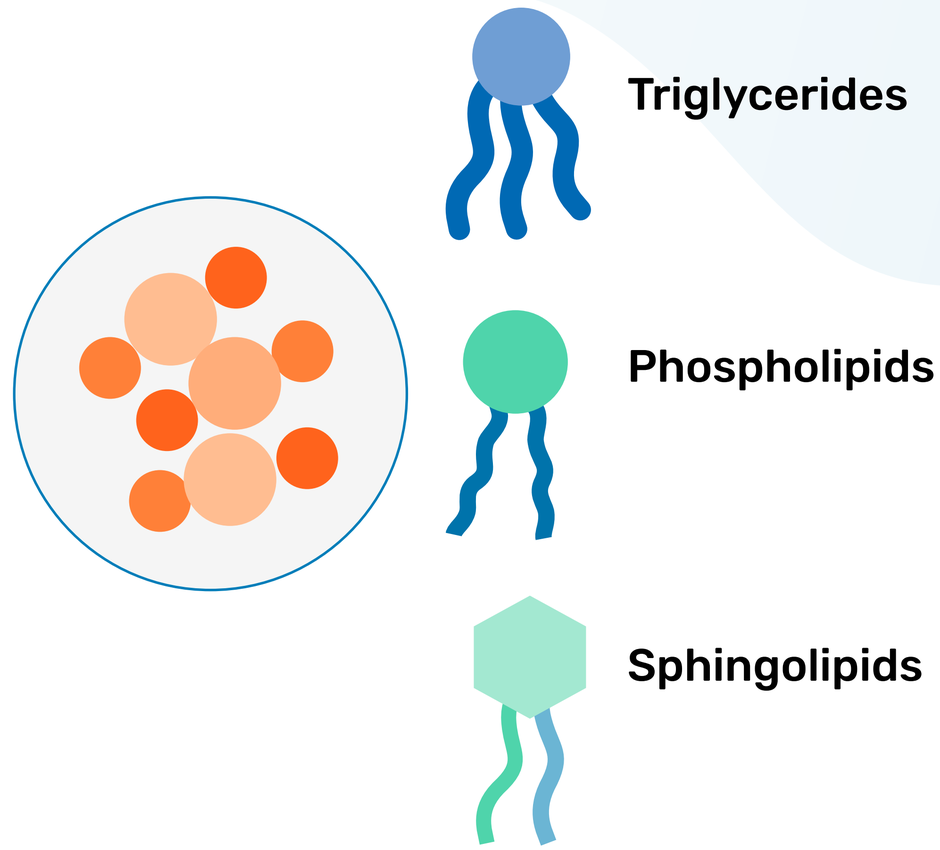
Lipids

What are lipids?

Lipids are a large and varied group of **organic molecules** that are insoluble in water and soluble in non-polar solvents. They are found in every type of **animal** or **plant cell**.

Different types of lipids can be found in the body and are organized in different molecular structures, for example triglycerides, phospholipids and sphingolipids:

- **Fat (Triglyceride)** is stored in the adipose tissue and under the skin. It is mainly used as an energy-storage molecule in the body.
- **Triglycerides** can occur in two different forms; **fats** (solid at room temperature) and **oils** (liquid at room temperature).
- **Phospholipids and sphingolipids** mainly occur in the cell membrane.

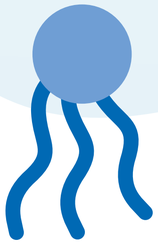


Did you know?

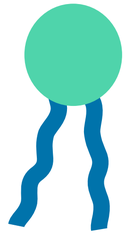
Lipids are named after the Greek word lipos, which means ‘FAT’.

What do lipids and triglycerides look like?

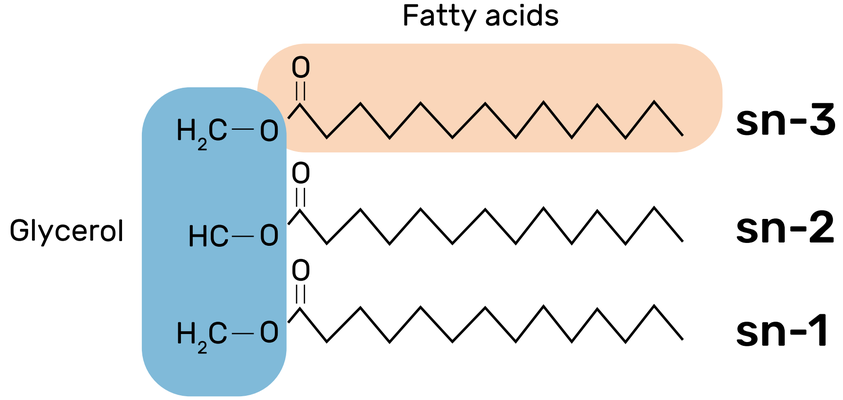
The chemical composition of all lipids includes C (carbon), H (hydrogen) and O (oxygen) forming long hydrocarbon chains.



Triglycerides (98-99%) represent the major form of breastmilk lipids



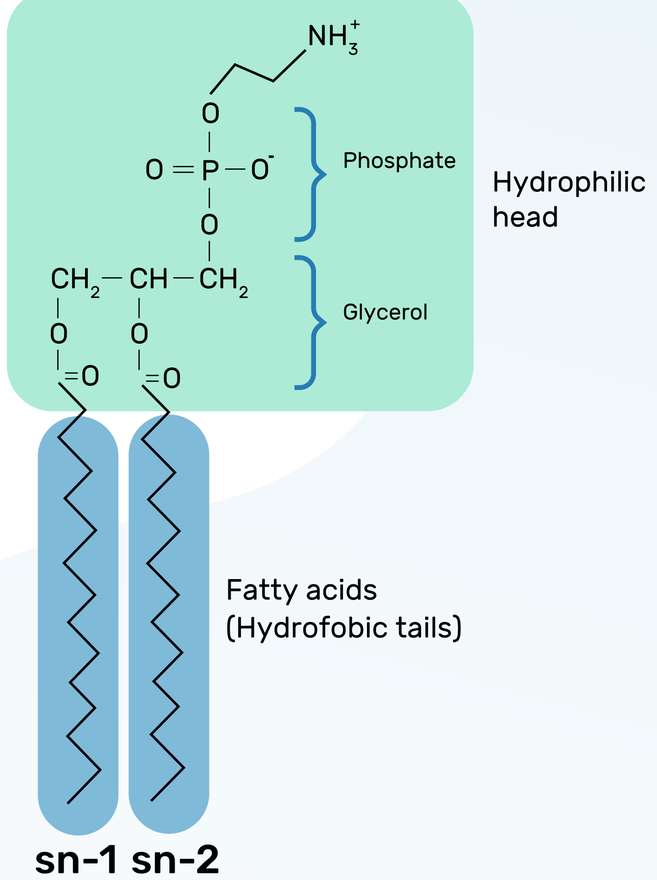
Phospholipids (0.2-2.0%) are found in all plant and animal cell membranes[1]



A **triglyceride (TG)** is an ester derived from:

- **glycerol** (backbone) and
- **three fatty acids** (tails).

The **position** occupied by these FA are numbered relative to their stereospecific numbering (sn) as **sn-1**, **sn-2** and **sn-3**.



Zooming into Long-Chain Polyunsaturated fatty acids DHA and ARA

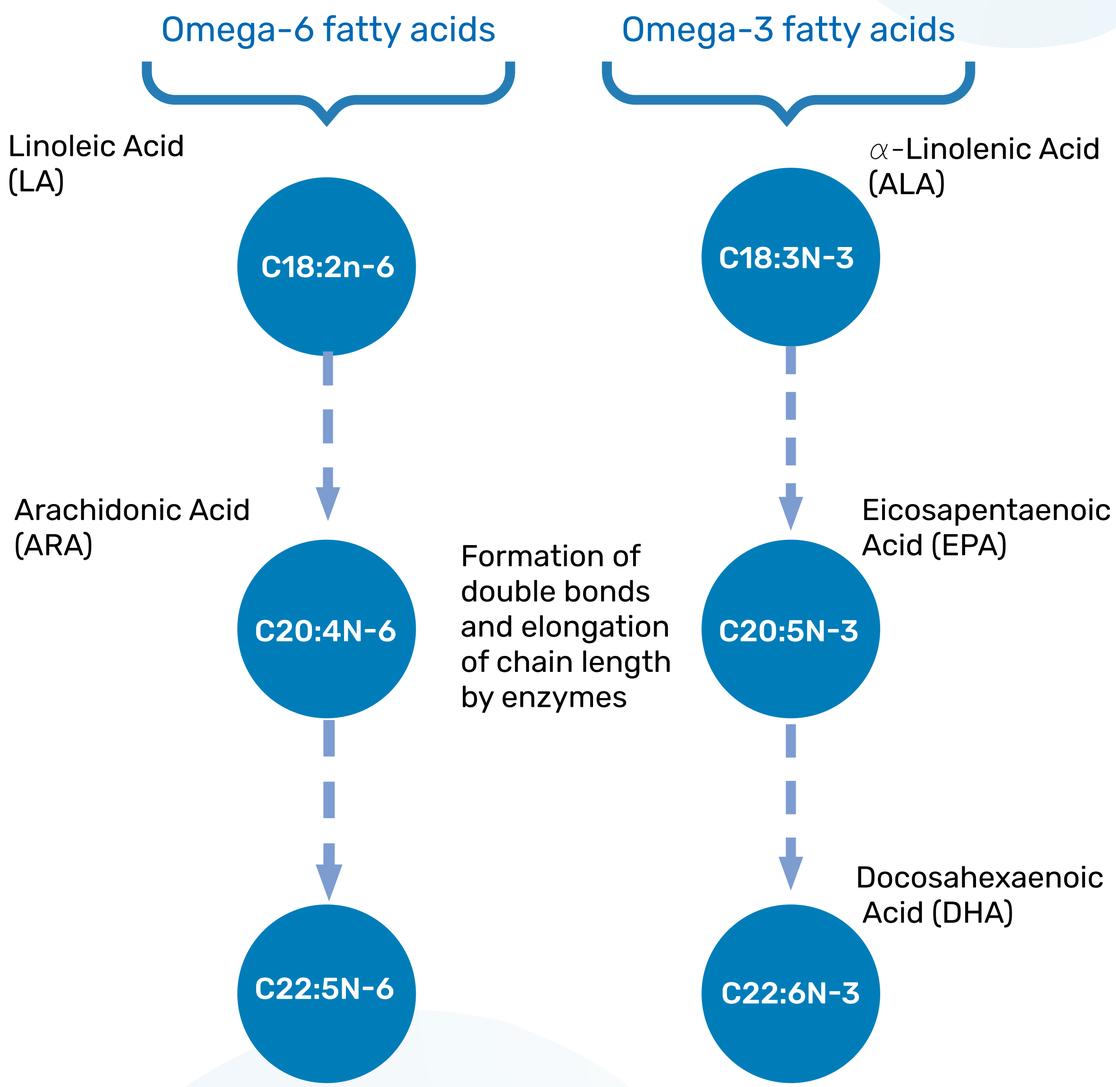
There are **two types of biologically important, essential PUFAs** known for humans:[2]

- 1) **Linoleic acid** (LA, ω-6 family), and 2) **alpha-linolenic acid** (ALA, ω-3 family).[2]
- Humans are able to synthesize arachidonic acid (ARA, ω-6 family) from LA and docosahexaenoic acid (DHA, ω-3 family) and eicosapentaenoic acid (EPA, ω-3 family) from ALA. However, in infants this capacity is limited.[2]
- Hence, human milk which is rich in ARA and DHA, is crucial in providing these lipids to the developing infant.[3]

Did you know?

Between infant genders: some studies have suggested that the milk produced for sons contains more fat than the milk produced for daughters.[4,5]

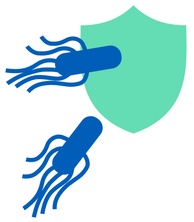
LA & ALA can be converted to LCPUFAs, including ARA & DHA, by enzymes



Zooming into DHA, ARA, LA and ALA

The amount and balance of dietary LA and ALA intake as well as the preformed n-6 and n-3 LCPUFAs in early life nutrition have the potential to affect LCPUFA status of the infant. This has an **impact on the early life development and function of**:

Immune system



PUFAs are important for the development of the early **immune system**, including the modulation of **anti-inflammatory** responses.[6]

Brain

PUFAs have also been linked to **infant vision** and **neurodevelopment**.[2]

Adipose tissue

Growth

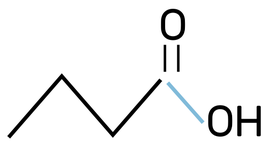
Preformed DHA is considered 'conditionally essential' for infants. This is because the need for DHA is extremely high to support structural and functional maturation of key organs, for example the brain, but endogenous synthesis capacity is too low. Consequently, DHA is mandatory in infant formula.

How are fatty acids classified?

Fatty acids can be classified in different ways[7]

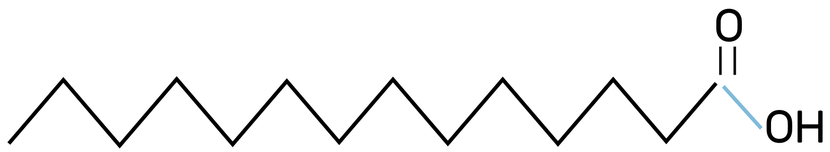
Based on length

The number of carbon atoms



Short chain (<6 carbon atoms)

Medium chain (6–12 carbon atoms*)



Long chain (>12 carbon atoms*)

* some publications indicate that C14 is also a medium chain fatty acid.

Fatty acids can be classified in different ways[7]

Based on saturation

The number and position of double bounds present in a fatty acid

Saturated (also called SFAs)

Single bond = saturated
Double bond = unsaturated

Mono-unsaturated (also called MUFAs)

Poly-unsaturated (also called PUFAs)

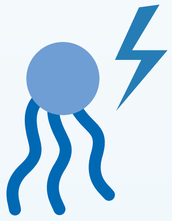
Some examples of poly-unsaturated fatty acids are the omega-3 Docosahexaenoic acid (DHA) and the omega-6 Arachidonic acid (ARA)

Omega-3 and Omega-6 are also called n-3 and n-6 respectively

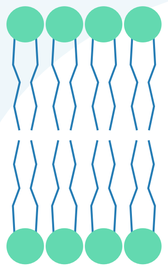
* some publications indicate that C14 is also a medium chain fatty acid.

What are the functions of lipids?

Lipids have a variety of functions, including:



Providing, transporting and storing **energy**, mostly as triglycerides.



Structural components of **biological cell membranes** (different types of lipids and fatty acids in the membrane affect membrane function).

Being a precursor of **vitamins** and **hormones**.

Functioning as **signaling molecules**.

In addition, fat in the body is neccessary for:

Mechanical protection.

Thermal insulation.

Electrical insulation of nerves and receptors in nerve ending membranes.

Breastmilk

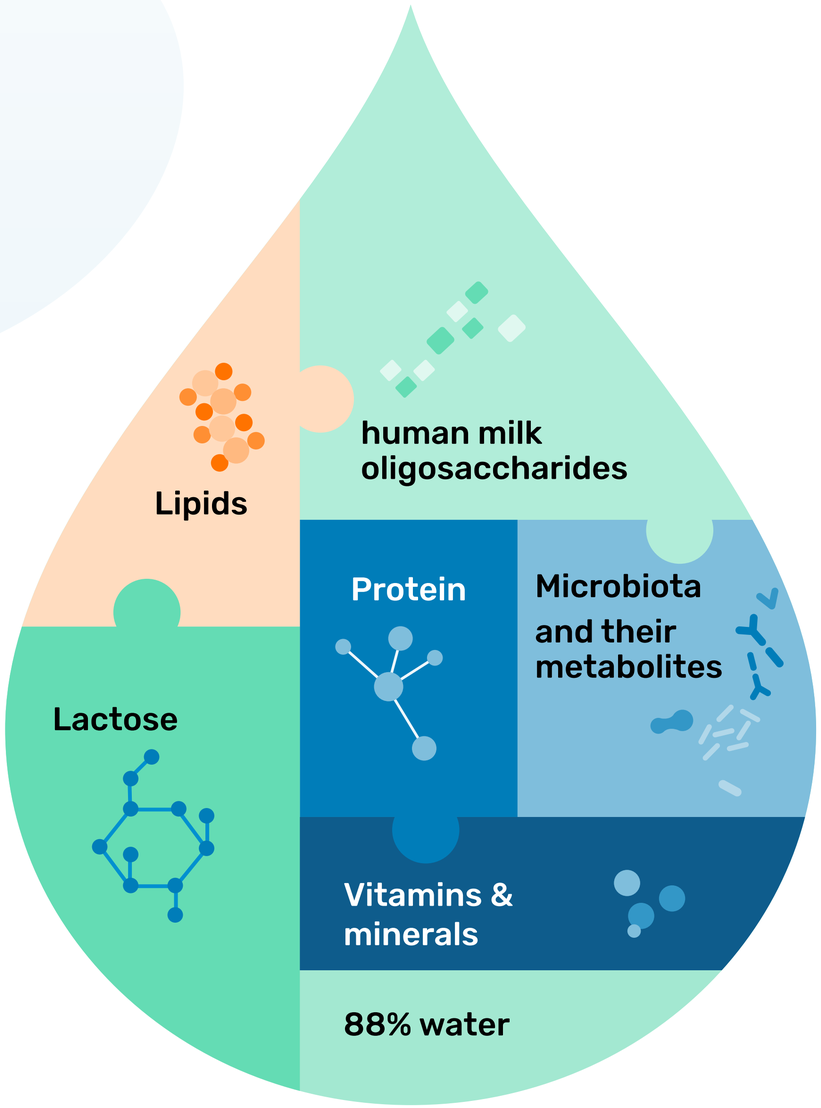
Breastmilk provides a complete supply of nutrients to optimally support infant growth and development in early life.[8]

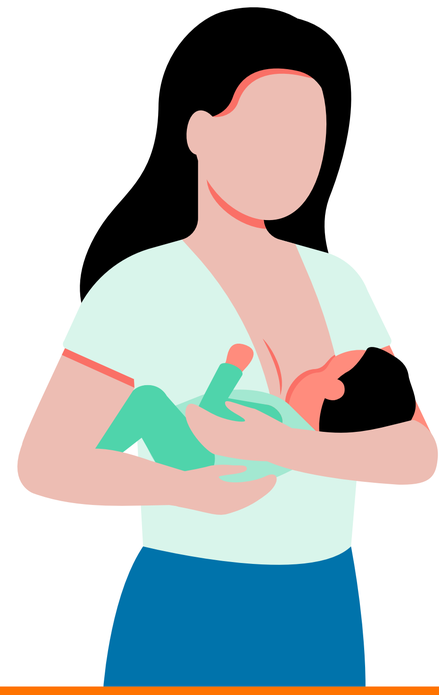
Exclusive breastfeeding for the **first 6 months** and in combination with complementary foods **up to 2 years and beyond** is the universally recommended feeding mode for infants by the World Health Organization.[9]

In case breastfeeding is not possible, the provided infant formula (IF) must be safe and suitable to meet the **nutritional requirements of infants** promoting their growth and development.[10]

Breastmilk is rich in lipids

Breastmilk is an amazing complex and diverse matrix of nutritional and bioactive components*





Did you know?

Breastmilk adapts over the course of one feeding:

hindmilk (the last milk of a feed) may contain up to 2 to 3 times the lipid concentration as found in foremilk (the initial milk of a feed).[11]

*amongst other components.

What are lipids in breastmilk?

Lipids are the second largest group of macronutrients in breastmilk

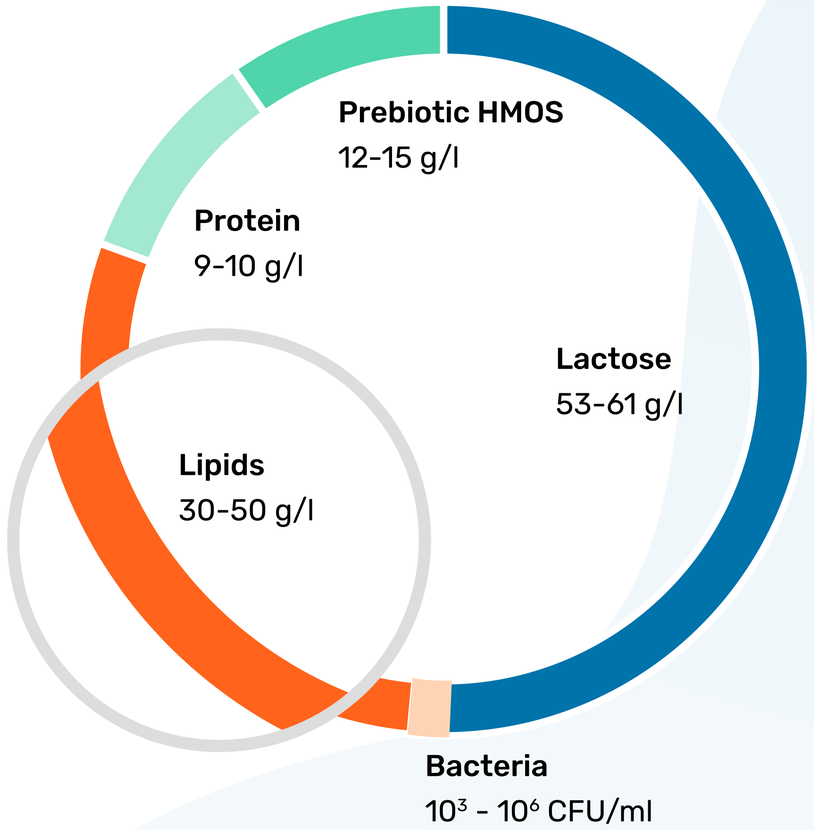
Breastmilk contains different forms of lipids, such as:

- **Triglycerides**
- **Phospholipids**
- **Cholesterol**
- **Sphingolipids**

Did you know?

A mother's diet influences the composition of fatty acids in her breastmilk. Eating fish leads to higher levels of breastmilk DHA concentrations.[11,12]

Lipids are a key component in breastmilk



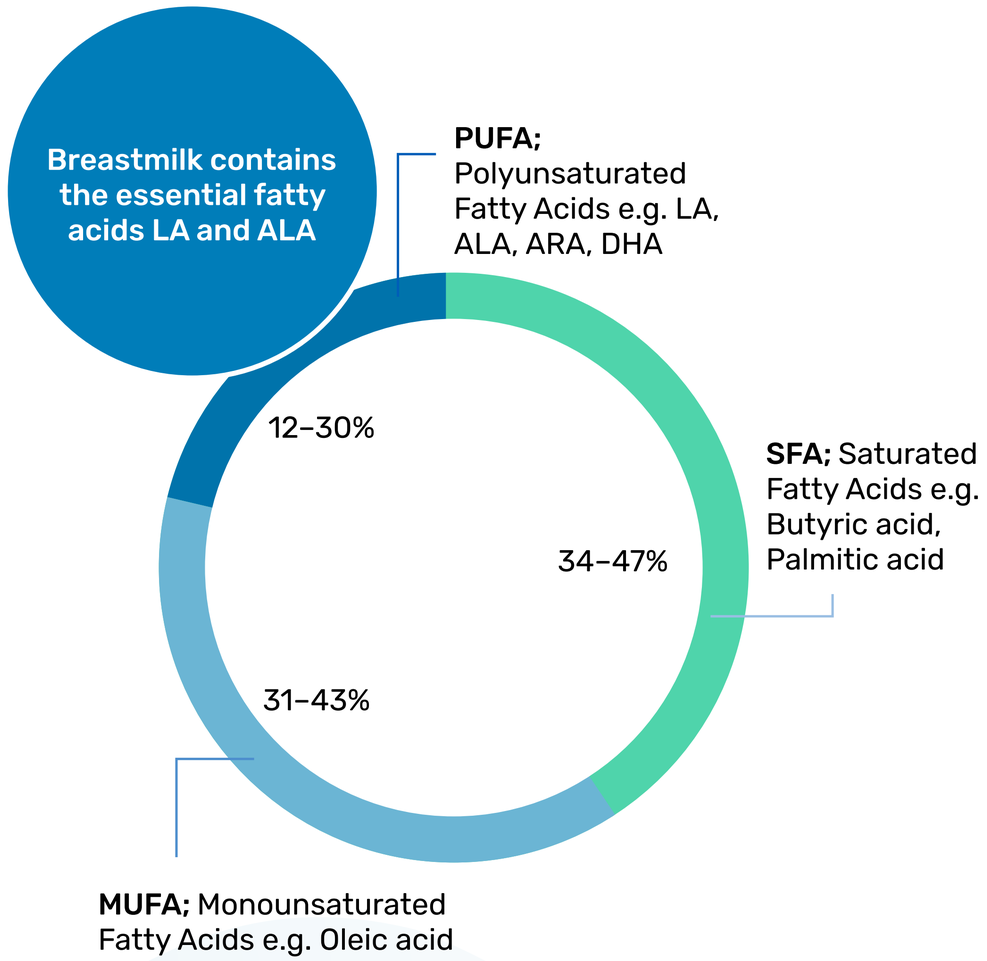
What are lipids in breastmilk?

Saturated fatty acids (**SFAs**, including the medium chain fatty acids, **MCFAs**) are the most abundant, followed by monounsaturated fatty acids **(MUFAs)** and polyunsaturated fatty acids **(PUFAs)**.

Did you know?

Breastmilk lipids depend on maternal BMI: total milk fat concentration has been found to increase with maternal BMI.[13]

Lipids provide approximately 50% of the energy in breastmilk



What are lipids in breastmilk?

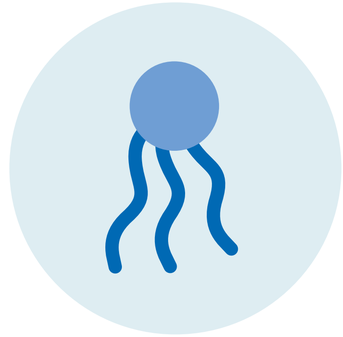
Palmitic acid

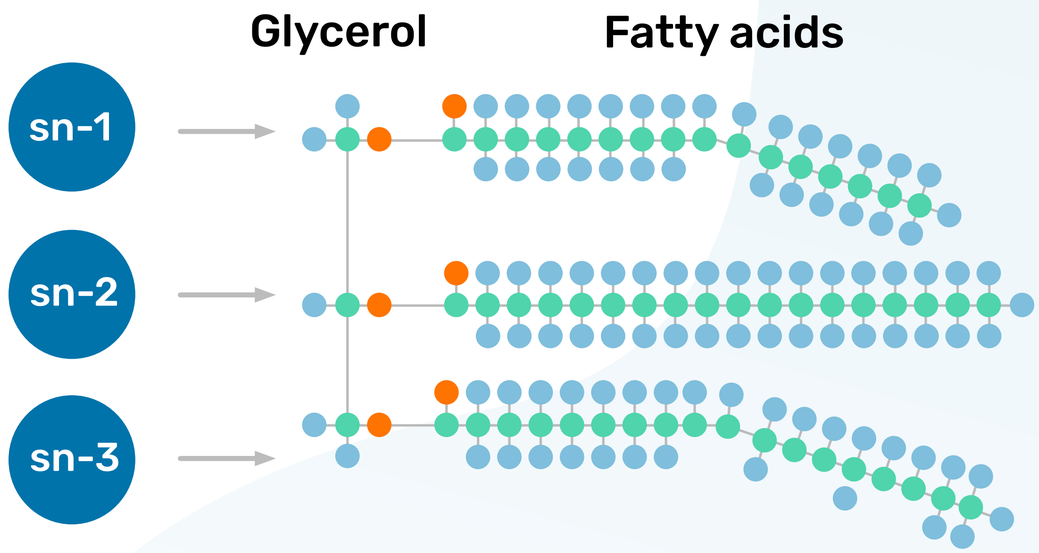
- **Palmitic acid** (PA, C16:0), is the most abundant saturated fatty acid and represents 20–25% of all breastmilk fatty acids.[14]
- 70–75% of breastmilk palmitic acids are linked to the glycerol backbone in the sn-2 position (also referred to as **beta-palmitate** or **sn-2 palmitic acid**).[14]

Did you know?

Cow's milk fat closely resembles human milk fat as it contains higher β-palmitate levels than vegetable oils.

TG in Breastmilk





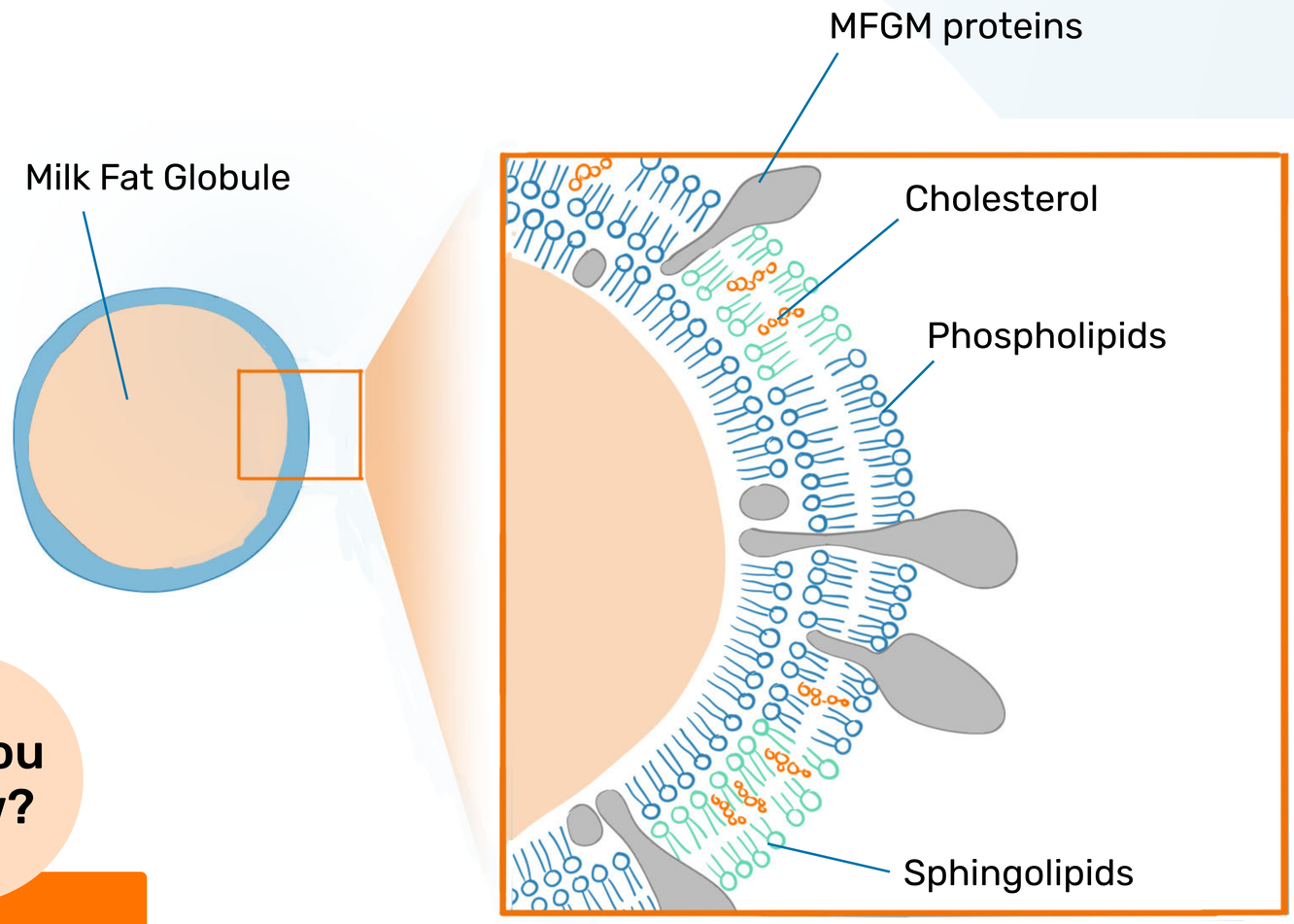
What are lipids in breastmilk?

Triglycerides represent the major form of breastmilk lipids

In breastmilk, these lipids are incorporated into Large **Milk Fat Globules** (MFG) surrounded by a complex triple-layer milk fat globule membrane (MFGM).[15]

Biological triple layer membrane consisting of phospholipids, sphingolipids, MFGM proteins, glycosphingolipids and cholesterol

(Average diameter: 4 µm)



Did you know?

Breastmilk fatty acid concentrations have been found to vary across geographical regions, likely caused by differences in dietary factors. In particular, DHA variances have been found between populations with different dietary habits.[12,16]

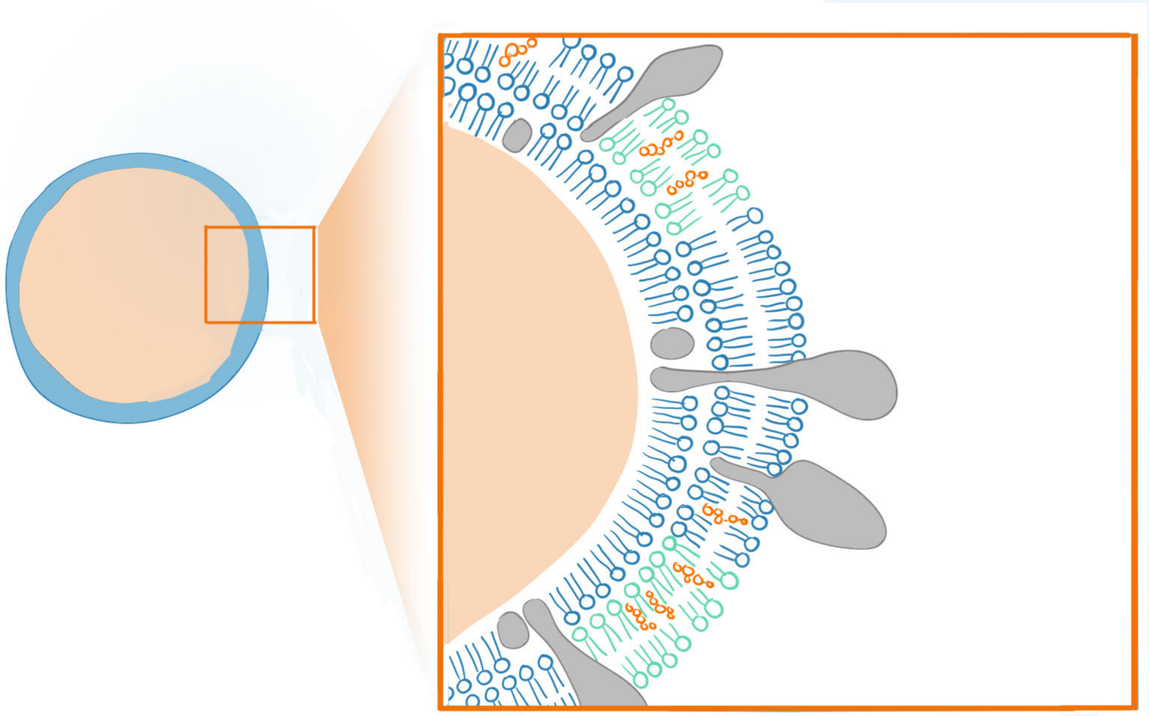
What are lipids in breastmilk?

Milk Fat Globules

- **Milk Fat Globules (MFGs)** are surrounded by a **milk fat globule membrane (MFGM)**.[17]
- The MFGM acts as an **emulsifier**, protecting against coalescence and aggregation, and thus ensures a **stable distribution** of the MFGs in the milk.[17,18]
- The stability of the MFGs allows for the delivery of **lipids** and **bioactive proteins** to the infant gut.[18]
- Due to this highly complex structure, the lipids in breastmilk are digested and absorbed very efficiently.
- MFGM components have been suggested to play an important role in infants' **brain and neurocognitive development**.[19]

In cow's milk and most infant formulas, the MFG structures are disrupted and not maintained due to the processing of the milk source.

- The MFGM is composed of a **triple-layer**, consisting of a phospholipid monolayer plus a phospholipid bilayer in which (glyco) proteins, cholesterol and (glyco) sphingolipids are incorporated.[20]
- 70% protein, 25% phospholipid, and 5% (glycol) sphingolipids and cholesterol.[21]
- The MFGM contains more than 400 different proteins with various functions.[22]



Where do the lipids in breastmilk come from?

Both the **composition** and the **structure** of the MFGM in breastmilk result from the mechanisms of **secretion of MFG** from the epithelial cells of the mammary gland during the **lactation period**.[23]

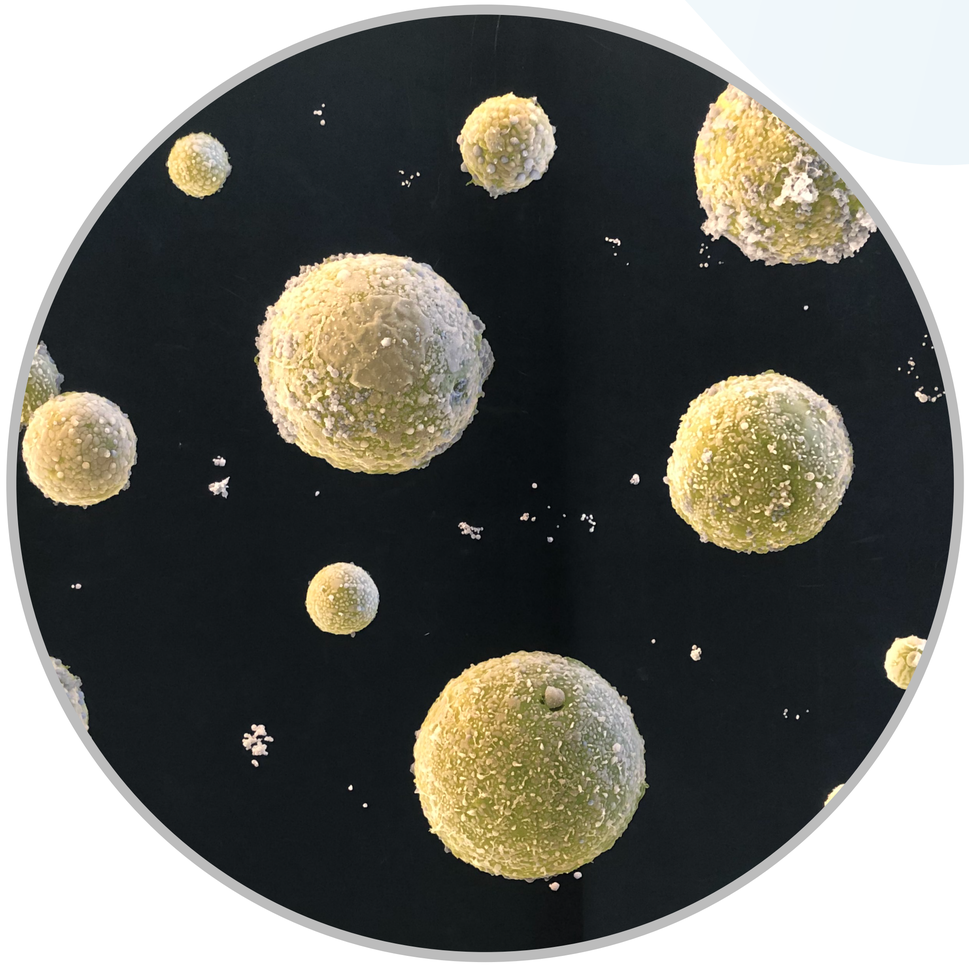


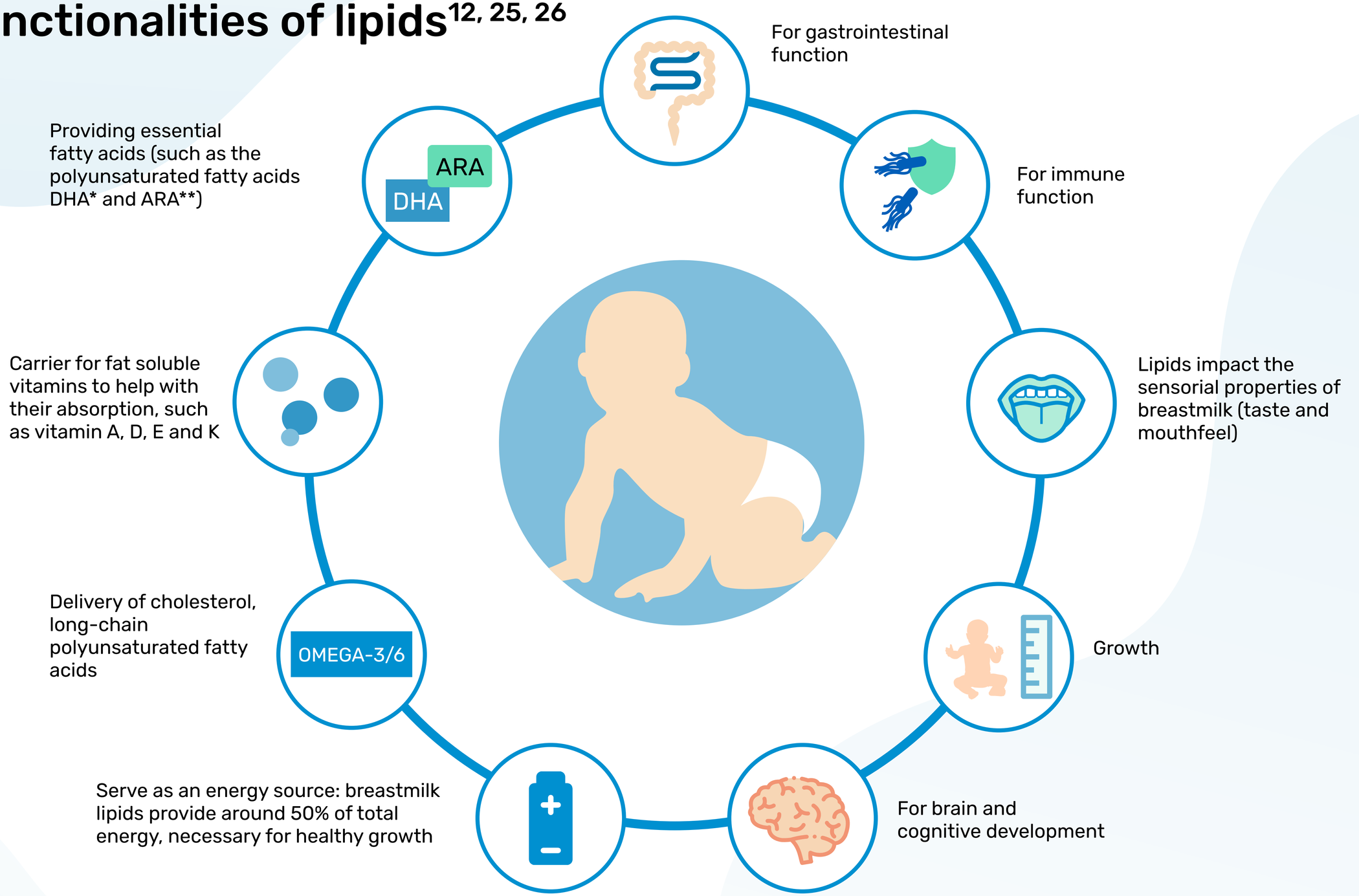
Image taken by Field Emission Scanning Electron Microscopy, with a magnification of 5000:1

Did you know?

Over lactational stages: lipid concentration generally increases from colostrum till mature milk, yet long-chain polyunsaturated fatty acids decrease from colostrum to mature milk.[24]

Why are lipids in breastmilk important?

Functionalities of lipids[12, 25, 26]



Summary

Breastmilk is the best and the gold standard in infant feeding. Breastmilk composition **is very complex**, and naturally provides many different nutritive and protective compounds that interact with each other in a unique way and are specifically tailored to the infant's needs.

Lipids are the 2nd largest group of macronutrients in breastmilk. Lipids in breastmilk are present as lipid droplets with a mode diameter of 4 µm and are enveloped by a triple layered membrane mainly consisting of phospholipids, membrane-specific proteins and cholesterol.

Breastmilk lipids provide 50% of the energy to the infant to optimally support growth and development in early life. In addition, breastmilk lipids provide essential fatty acids such as DHA and ARA and carry important fat-soluble vitamins (vit A,D, E, K).

Although breastfeeding is highly recommended, it may not always be possible to exclusively breastfeed. **Infant formula is an alternative** and it is important that it mimics the composition and functionality of breastmilk as closely as possible.

One way of **mimicking breastmilk's complexity** and functionality is by staying as close as possible to the lipid composition and structure as in breastmilk.

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