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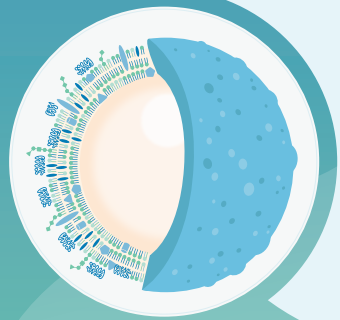
Simply lipids

A guide to understanding lipids



Abbreviations

ALA	Alpha-linoleic acid
ARA	Arachidonic acid
CFU	Colony-forming unit
DHA	Docosahexaenoic acid
EPA	Eicosapentaenoic acid
FA	Fatty acid
IF	Infant formula
LA	Linoleic acid
LCPUFA	Long-chain poly-unsaturated fatty acid
MFG	Milk Fat Globule
MFGM	Milk Fat Globule Membrane
MUFA	Mono-unsaturated fatty acid
PA	Palmitic acid
PUFA	Poly-unsaturated fatty acid
SFA	Saturated fatty acid
TG	Triglyceride

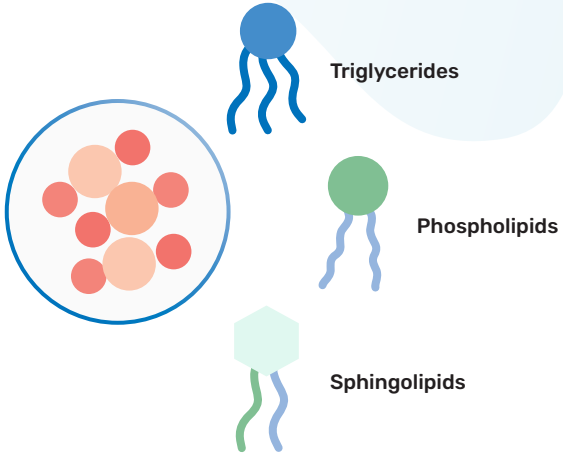
Lipids

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:

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



Did you know?

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

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:

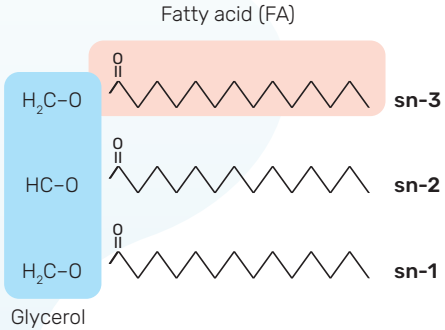
Mechanical protection.

Thermal insulation.

Electrical insulation of nerves and receptors in nerve ending membranes.

What do lipids look like?

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



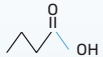
A **triglyceride** (**TG**) is an ester derived from:

- **glycerol** (backbone) and
- **three FAs** (tails).

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

FAs can be classified according to length and saturation

Length



Short chain
(<6 carbon atoms)

Medium chain
(6–12 carbon atoms*)

Long chain
(>12 carbon atoms*)

Saturation

— is saturated
═ is unsaturated

Saturated
(SFAs)

Mono-unsaturated
(MUFAs)

Poly-unsaturated
(PUFAs) for example, the omega-3 (n-3) docosahexaenoic acid (DHA) and omega-6 (n-6) arachidonic acid (ARA)

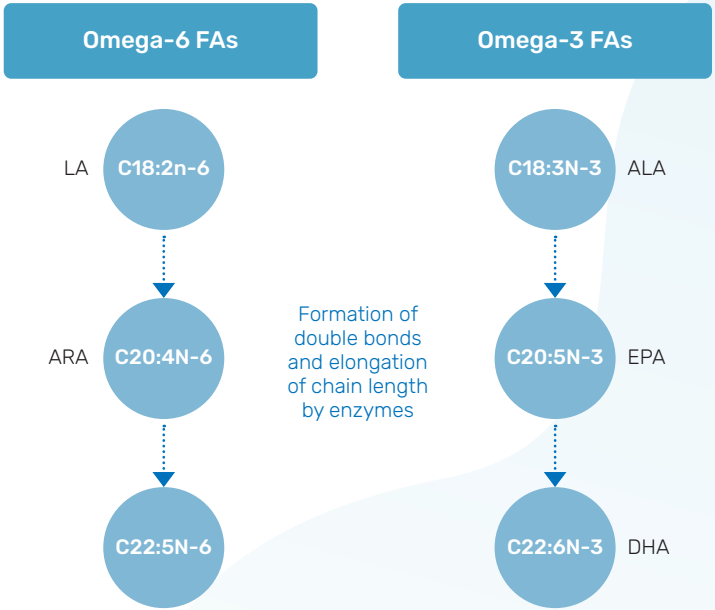
*Some publications indicate that C14 is also a medium chain fatty acid.

Essential fatty acids and early life development

There are two types of biologically **essential PUFAs** known for humans: linoleic acid (LA, omega-6 family) and alpha-linoleic acid (ALA, omega-3 family).[1] As they are not synthesized in the body, these **essential FAs** must be obtained from food.

- Humans are able to synthesize ARA from LA and DHA and eicosapentaenoic acid (EPA) from ALA.[1] However, in infants, this capacity is limited.
- Human milk which is rich in ARA and DHA, is crucial in providing these lipids to the developing infant.[2]
- Preformed **DHA is considered 'conditionally essential'** for infants. This is because the need for DHA is extremely high to support structural and functional saturation of key organs, for example the brain, but endogenous synthesis capacity is too low.
- Consequently, DHA is mandatory in infant formula.

LA and ALA can be converted to long-chain PUFAs (LCPUFAs), including ARA and 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.[3]

Brain

PUFAs have also been linked to **infant vision** and **neurodevelopment**.[1,4]

Adipose tissue[5]

Growth[4]

Breastmilk

Breastmilk provides a complete supply of nutrients to optimally support infant growth and development in early life.[6]

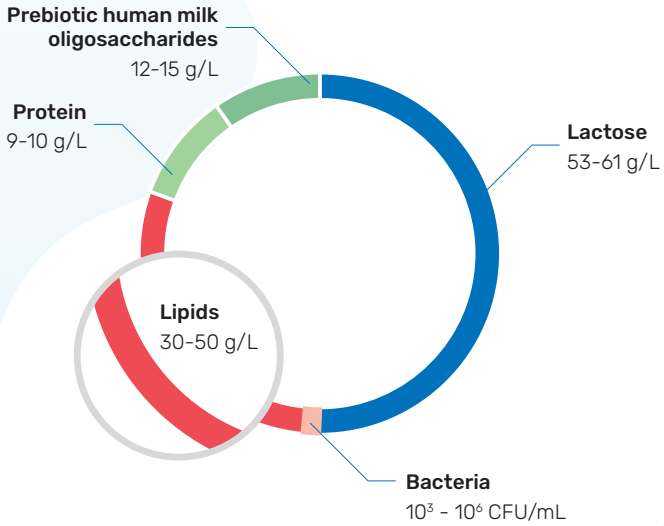
Exclusive breastfeeding for the **first 6 months** and in combination with complementary foods **up to 2 years and beyond** is the universally recommended feeding mode for infants by the World Health Organization.[7]

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.[6]

Breastmilk is rich in lipids

Lipids are the second largest group of macronutrients in breastmilk.[8]

They contribute to approximately 50% of infant energy requirement.[9]



The lipid fraction is an essential component of breastmilk due to its importance in ensuring optimal infant growth and development.[8,10]

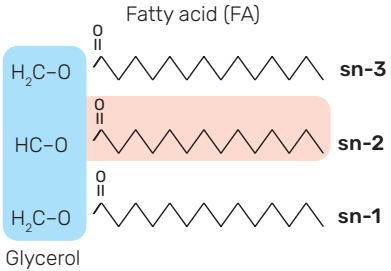
Did you know?

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]

What are the lipids in breastmilk?

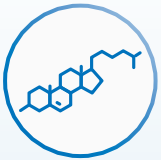
Triglycerides constitute 98%–99% of breastmilk lipids and act as the major energy source for infants.[8]



Palmitic acid (PA, C16:0), is the most abundant SFA and represents 20–25% of all breastmilk FAs.[12]

Almost 75% of breastmilk PAs are linked to the glycerol backbone in the sn-2 position.[12]

Other breastmilk components:

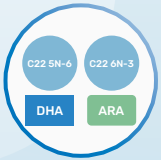


Cholesterol
Necessary for neurological development and is the basis for certain enzymes [13]

Phospholipids
Essential for brain and cognitive development [14]

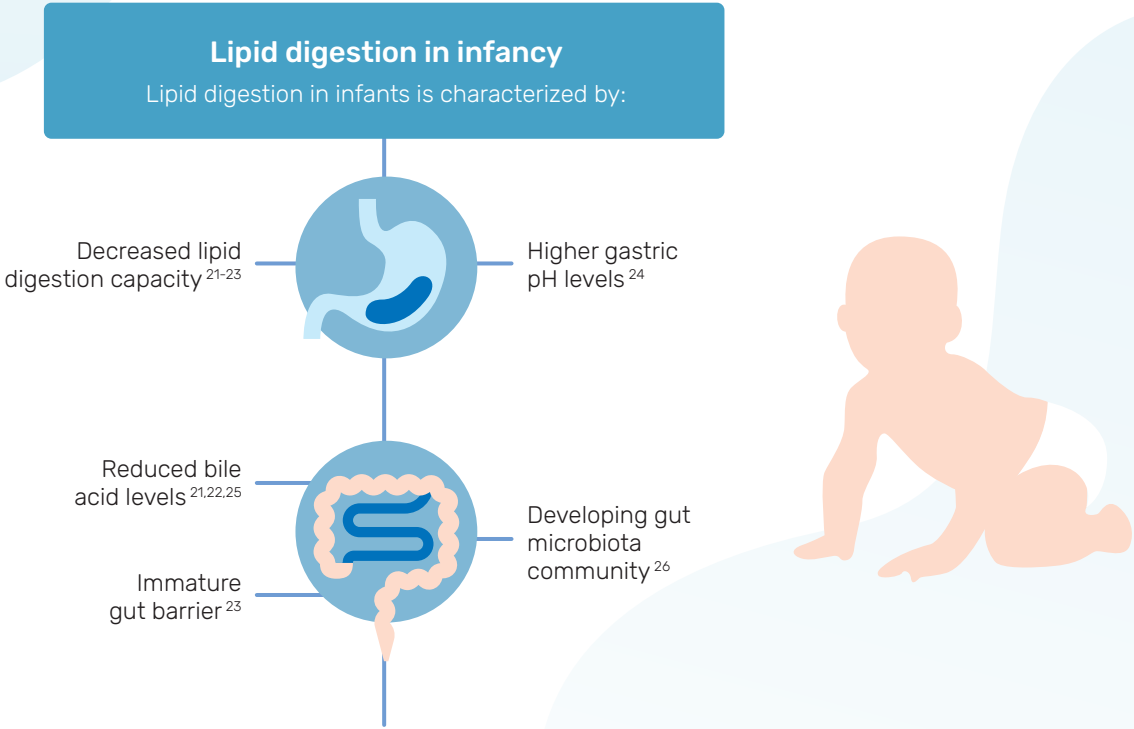
Sphingolipids
(mainly sphingomyelins)
Important for optimal functioning of the central nervous system and cognitive development [15,16]

Glycolipids
(including gangliosides)
Crucial for signal transduction, brain growth and maturation, immune function and infection prevention [17-19]

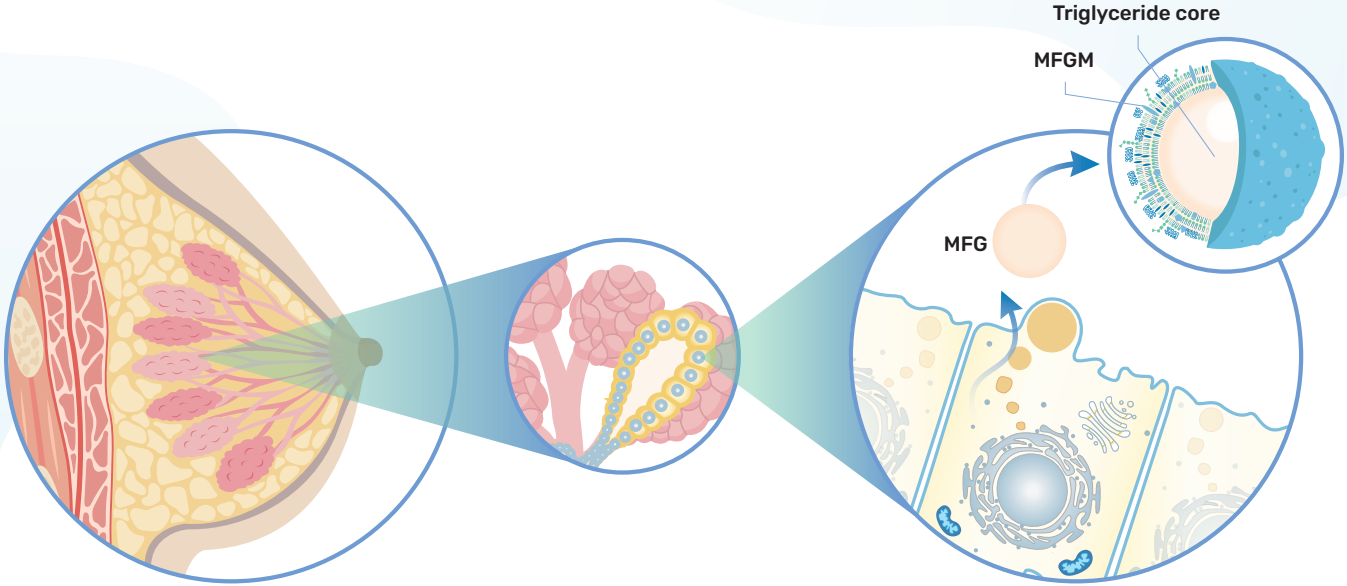


Important FAs:
(LA, ALA, ARA and DHA)
Important for infant's neuronal development and sensory qualities [1,20]

Lipid digestion in infants differs from adults due to ongoing developmental mechanisms



Where do the lipids in breastmilk come from?



Secretion mechanisms in the mammary gland epithelial cells during lactation determine the size, composition and structure of the milk fat globules (MFG) in breast milk.[27]

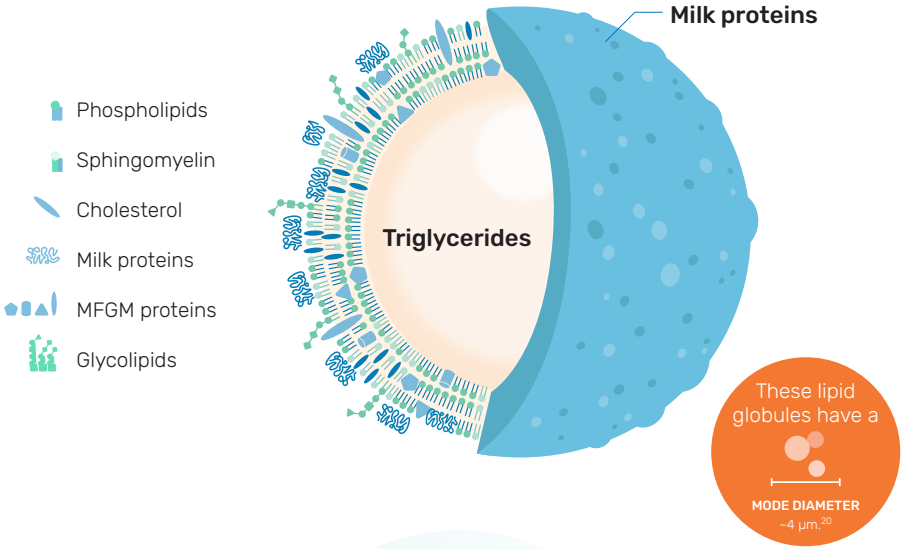
Breastmilk lipid characteristics enhance lipid digestion

Breastmilk triglycerides are stored in the core of large Milk Fat Globules (MFGs), surrounded by a unique triple-layer membrane known as the Milk Fat Globule Membrane (MFGM).[9,28]

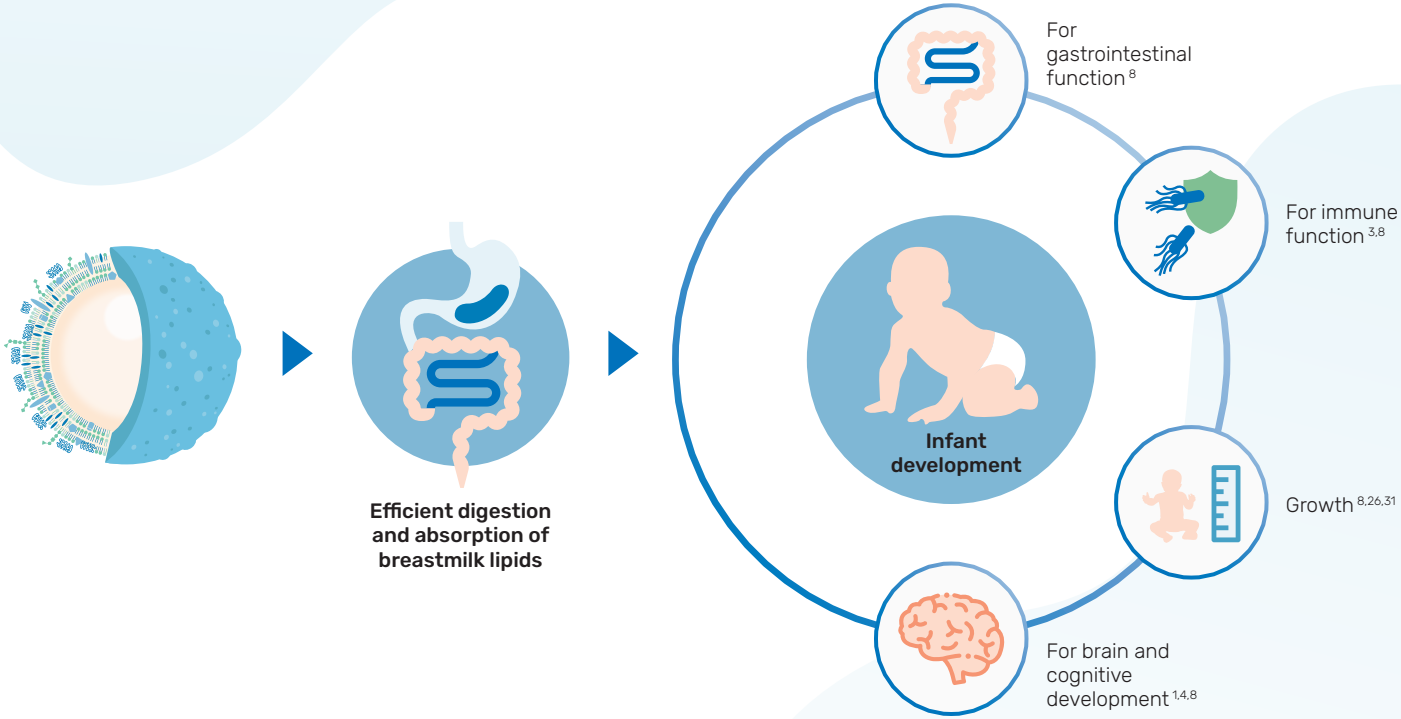
The inner MFGM monolayer is rich in phospholipids, while the outer bilayer contains phospholipids, sphingolipids, glycolipids and cholesterol, with incorporated membrane glycoproteins.[28]

The MFGM acts as an emulsifier, protecting against coalescence and aggregation, ensuring a stable distribution of the MFGs in the milk.[29,30]

The composition and structure of the MFGs **play a role in the digestion and metabolism of milk lipids** and impact health of infants.[30]



Efficient lipid absorption is crucial for infant growth [21]

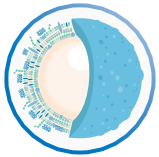


Summary

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.

Breastmilk lipids provide 50% of the energy to support the **growth and development of infants.** They also provide **important FAs** (LA, ALA, DHA, and ARA) and **fat soluble vitamins** (vitamins A, D, E, K).

Lipids are the 2nd largest group of macronutrients in breastmilk and is a **major source of energy** for infants.



Lipids in breastmilk are present as MFGs with a mode globule diameter of 4 µm enveloped by a triple-layered membrane.

The structure, composition, and size of the coated MFG are critical for **efficient delivery, absorption and digestion of lipids** by infants.

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