

# Omega-3 fatty acid

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**Omega-3 fatty acids**—also called **ω-3 fatty acids** or ***n*-3 fatty acids**<sup>[1]</sup>—are polyunsaturated fatty acids (PUFAs) with a double bond (C=C) at the third carbon atom from the end of the carbon chain.<sup>[2]</sup> The fatty acids have two ends, the carboxylic acid (-COOH) end, which is considered the beginning of the chain, thus "alpha", and the methyl (-CH<sub>3</sub>) end, which is considered the "tail" of the chain, thus "omega"; the double bond is at omega minus 3 (not dash 3). One way in which a fatty acid is named is determined by the location of the first double bond, counted from the methyl end, that is, the omega (ω-) or the *n*- end. However, the standard (IUPAC) chemical nomenclature system starts from the carbonyl end.

The three types of omega-3 fatty acids involved in human physiology are α-linolenic acid (ALA) (found in plant oils), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA) (both commonly found in marine oils). Marine algae and phytoplankton are primary sources of omega-3 fatty acids. Common sources of plant oils containing the omega-3 ALA fatty acid include walnut, edible seeds, clary sage seed oil, algal oil, flaxseed oil, Sacha Inchi oil, *Echium* oil, and hemp oil, while sources of animal omega-3 EPA and DHA fatty acids include fish oils, egg oil, squid oils, and krill oil. Dietary supplementation with omega-3 fatty acids does not appear to affect the risk of death, cancer or heart disease.<sup>[3][4]</sup> Furthermore, fish oil supplement studies have failed to support claims of preventing heart attacks or strokes.<sup>[5]</sup>

Omega-3 fatty acids are important for normal metabolism.<sup>[6]</sup> Mammals are unable to synthesize omega-3 fatty acids, but can obtain the shorter-chain omega-3 fatty acid ALA (18 carbons and 3 double bonds) through diet and use it to form the more important long-chain omega-3 fatty acids, EPA (20 carbons and 5 double bonds) and then from EPA, the most crucial, DHA (22 carbons and 6 double bonds).<sup>[6]</sup> The ability to make the longer-chain omega-3 fatty acids from ALA may be impaired in aging.<sup>[7][8]</sup> In foods exposed to air, unsaturated fatty acids are vulnerable to oxidation and rancidity.<sup>[9]</sup>

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## Health effects

Supplementation does not appear to be associated with a lower risk of all-cause mortality.<sup>[3]</sup>

### Cancer

The evidence linking the consumption of fish to the risk of cancer is poor.<sup>[10]</sup> Supplementation with omega-3 fatty acids does not appear to affect this either.<sup>[4]</sup>

A 2006 review concluded that there was no link between omega-3 fatty acids consumption and cancer.<sup>[4]</sup> This is similar to the findings of a review of studies up to February 2002 that failed to find clear effects of long and shorter chain omega-3 fats on total risk of death, combined cardiovascular events and cancer.<sup>[11][12]</sup> In those with advanced cancer and cachexia, omega-3 fatty acids supplements may be of benefit, improving appetite, weight, and quality of life.<sup>[13]</sup> There is tentative evidence that marine omega-3 polyunsaturated fatty acids reduce the risk of breast cancer but this is not conclusive.<sup>[14][15]</sup>

The effect of consumption on prostate cancer is not conclusive.<sup>[15]</sup> There is a decreased risk with higher blood levels of DPA, but an increased risk of more aggressive prostate cancer with higher blood levels of combined EPA and DHA (found in fatty fish oil).<sup>[16]</sup>

## Cardiovascular disease

Evidence, in the population generally, does not support a beneficial role for omega-3 fatty acid supplementation in preventing cardiovascular disease (including myocardial infarction and sudden cardiac death) or stroke.<sup>[3][17][18]</sup> However, omega-3 fatty acid supplementation greater than one gram daily for at least a year may be protective against cardiac death, sudden death, and myocardial infarction in people who have a history of cardiovascular disease.<sup>[19]</sup> No protective effect against the development of stroke or all-cause mortality was seen in this population.<sup>[19]</sup> Eating a diet high in fish that contain long chain omega-3 fatty acids does appear to decrease the risk of stroke.<sup>[20]</sup> Fish oil supplementation has not been shown to benefit revascularization or abnormal heart rhythms and has no effect on heart failure hospital admission rates.<sup>[21]</sup> Furthermore, fish oil supplement studies have failed to support claims of preventing heart attacks or strokes.<sup>[5]</sup>

Evidence suggests that omega-3 fatty acids modestly lower blood pressure (systolic and diastolic) in people with hypertension and in people with normal blood pressure.<sup>[22]</sup> Some evidence suggests that people with certain circulatory problems, such as varicose veins, may benefit from the consumption of EPA and DHA, which may stimulate blood circulation and increase the breakdown of fibrin, a protein involved in blood clotting and scar formation.<sup>[23][24]</sup> Omega-3 fatty acids reduce blood triglyceride levels but do not significantly change the level of LDL cholesterol or HDL cholesterol in the blood.<sup>[25][26]</sup> ALA does not confer the cardiovascular health benefits of EPA and DHAs.<sup>[27]</sup>

The effect of omega-3 polyunsaturated fatty acids on stroke is unclear, with a possible benefit in women.<sup>[28]</sup>

## Inflammation

Some research suggests that the anti-inflammatory activity of long-chain omega-3 fatty acids may translate into clinical effects.<sup>[29]</sup> A 2013 systematic review found tentative evidence of benefit.<sup>[30]</sup> Consumption of omega-3 fatty acids from marine sources lowers markers of inflammation in the blood such as C-reactive protein, interleukin 6, and TNF alpha.<sup>[31]</sup>

For rheumatoid arthritis (RA), one systematic review found consistent, but modest, evidence for the effect of marine n-3 PUFAs on symptoms such as "joint swelling and pain, duration of morning stiffness, global assessments of pain and disease activity" as well as the use of non-steroidal anti-inflammatory drugs.<sup>[32]</sup> The American College of Rheumatology (ACR) has stated that there may be modest benefit from the use of fish oils, but that it may take months for effects to be seen, and cautions for possible gastrointestinal side effects and the possibility of the supplements containing mercury or

vitamin A at toxic levels. The National Center for Complementary and Integrative Health has concluded that "[n]o dietary supplement has shown clear benefits for RA", but that there is preliminary evidence that fish oil may be beneficial, and called for further study.<sup>[33]</sup>

## Developmental disabilities

Although not supported by current scientific evidence as a primary treatment for ADHD, autism, and other developmental disabilities,<sup>[34][35]</sup> omega-3 fatty acid supplements are being given to children with these conditions.<sup>[34]</sup>

One meta-analysis concluded that omega-3 fatty acid supplementation demonstrated a modest effect for improving ADHD symptoms.<sup>[36]</sup> A Cochrane review of PUFA (not necessarily omega-3) supplementation found "there is little evidence that PUFA supplementation provides any benefit for the symptoms of ADHD in children and adolescents",<sup>[37]</sup> while a different review found "insufficient evidence to draw any conclusion about the use of PUFAs for children with specific learning disorders".<sup>[38]</sup> Another review concluded that the evidence is inconclusive for the use of omega-3 fatty acids in behavior and non-neurodegenerative neuropsychiatric disorders such as ADHD and depression.<sup>[39]</sup>

Fish oil has only a small benefit on the risk of early birth.<sup>[40][41]</sup> A 2015 meta-analysis of the effect of omega-3 supplementation during pregnancy did not demonstrate a decrease in the rate of preterm birth or improve outcomes in women with singleton pregnancies with no prior preterm births.<sup>[42]</sup> A systematic review and meta-analysis published the same year reached the opposite conclusion, specifically, that omega-3 fatty acids were effective in "preventing early and any preterm delivery".<sup>[43]</sup>

## Mental health

There is some evidence that omega-3 fatty acids are related to mental health,<sup>[44]</sup> including that they may tentatively be useful as an add-on for the treatment of depression associated with bipolar disorder.<sup>[45]</sup> Significant benefits due to EPA supplementation were only seen, however, when treating depressive symptoms and not manic symptoms suggesting a link between omega-3 and depressive mood.<sup>[45]</sup> There is also preliminary evidence that EPA supplementation is helpful in cases of depression.<sup>[46]</sup> The link between omega-3 and depression has been attributed to the fact that many of the products of the omega-3 synthesis pathway play key roles in regulating inflammation such as prostaglandin E3 which have been linked to depression.<sup>[47]</sup> This link to inflammation regulation has been supported in both in vitro<sup>[48]</sup> and in vivo studies as well as in meta-analysis studies.<sup>[30]</sup> The exact mechanism in which omega-3 acts upon the inflammatory system is still controversial as it was commonly believed to have anti-inflammatory effects.<sup>[49]</sup>

There is, however, significant difficulty in interpreting the literature due to participant recall and systematic differences in diets.<sup>[50]</sup> There is also controversy as to the efficacy of omega-3, with many meta-analysis papers finding heterogeneity among results which can be explained mostly by publication bias.<sup>[51][52]</sup> A significant correlation between shorter treatment trials was associated with increased omega-3 efficacy for treating depressed symptoms further implicating bias in publication.<sup>[52]</sup>

There is some evidence to support the claim that omega-3 can help treat anxiety disorder symptoms as well but studies have been limited.<sup>[53]</sup>

Very low quality evidence finds that omega-3 fatty acids might prevent psychosis.<sup>[54]</sup>

## Cognitive aging

Epidemiological studies are inconclusive about an effect of omega-3 fatty acids on the mechanisms of Alzheimer's disease.<sup>[55]</sup> There is preliminary evidence of effect on mild cognitive problems, but none supporting an effect in healthy people or those with dementia.<sup>[56][57][58]</sup>

## Atopic diseases

Results of studies investigating the role of LCPUFA supplementation and LCPUFA status in the prevention and therapy of atopic diseases (allergic rhinoconjunctivitis, atopic dermatitis and allergic asthma) are controversial; therefore, at the present stage of our knowledge we cannot state either that the nutritional intake of n-3 fatty acids has a clear preventive or therapeutic role, or that the intake of n-6 fatty acids has a promoting role in context of atopic diseases.<sup>[59]</sup>

## Risk of deficiency

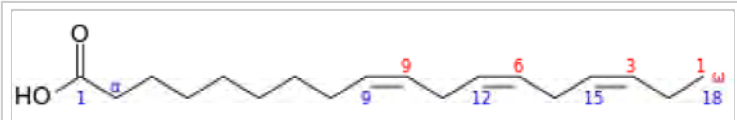
People with PKU often have low intake of omega-3 fatty acids, because nutrients rich in omega-3 fatty acids are excluded from their diet due to high protein content.<sup>[60]</sup>

## Chemistry

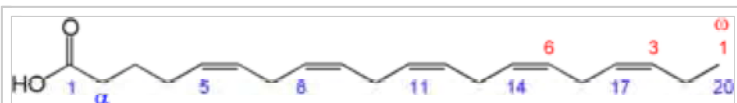
Omega-3 fatty acids that are important in human physiology<sup>[61]</sup> are  $\alpha$ -linolenic acid (18:3, *n*-3; ALA), eicosapentaenoic acid (20:5, *n*-3; EPA), and docosahexaenoic acid (22:6, *n*-3; DHA). These three polyunsaturates have either 3, 5, or 6 double bonds in a carbon chain of 18, 20, or 22 carbon atoms, respectively. As with most naturally-produced fatty acids, all double bonds are in the *cis*-configuration, in other words, the two hydrogen atoms are on the same side of the double bond; and the double bonds are interrupted by methylene bridges (-CH<sub>2</sub>-), so that there are two single bonds between each pair of adjacent double bonds.

## List of omega-3 fatty acids

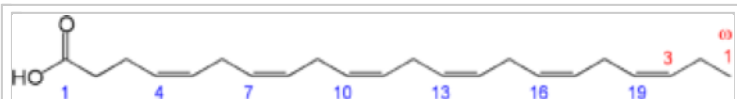
This table lists several different names for the most common omega-3 fatty acids found in nature.



Chemical structure of alpha-linolenic acid (ALA), an essential omega-3 fatty acid, (18:3 $\Delta$ 9c,12c,15c, which means a chain of 18 carbons with 3 double bonds on carbons numbered 9, 12, and 15). Although chemists count from the carbonyl carbon (blue numbering), biologists count from the  $n$  ( $\omega$ ) carbon (red numbering). Note that, from the  $n$  end (diagram right), the first double bond appears as the third carbon-carbon bond (line segment), hence the name " $n$ -3". This is explained by the fact that the  $n$  end is almost never changed during physiological transformations in the human body, as it is more energy-stable, and other compounds can be synthesized from the other carbonyl end, for example in glycerides, or from double bonds in the middle of the chain.



Chemical structure of eicosapentaenoic acid (EPA)



Chemical structure of docosahexaenoic acid (DHA)

Common name	Lipid name	Chemical name
Hexadecatrienoic acid (HTA)	16:3 ( $n$ -3)	<i>all-cis</i> -7,10,13-hexadecatrienoic acid
$\alpha$ -Linolenic acid (ALA)	18:3 ( $n$ -3)	<i>all-cis</i> -9,12,15-octadecatrienoic acid
Stearidonic acid (SDA)	18:4 ( $n$ -3)	<i>all-cis</i> -6,9,12,15-octadecatetraenoic acid
Eicosatrienoic acid (ETE)	20:3 ( $n$ -3)	<i>all-cis</i> -11,14,17-eicosatrienoic acid
Eicosatetraenoic acid (ETA)	20:4 ( $n$ -3)	<i>all-cis</i> -8,11,14,17-eicosatetraenoic acid
Eicosapentaenoic acid (EPA)	20:5 ( $n$ -3)	<i>all-cis</i> -5,8,11,14,17-eicosapentaenoic acid
Heneicosapentaenoic acid (HPA)	21:5 ( $n$ -3)	<i>all-cis</i> -6,9,12,15,18-heneicosapentaenoic acid
Docosapentaenoic acid (DPA), Clupanodonic acid	22:5 ( $n$ -3)	<i>all-cis</i> -7,10,13,16,19-docosapentaenoic acid
Docosahexaenoic acid (DHA)	22:6 ( $n$ -3)	<i>all-cis</i> -4,7,10,13,16,19-docosahexaenoic acid
Tetracosapentaenoic acid	24:5 ( $n$ -3)	<i>all-cis</i> -9,12,15,18,21-tetracosapentaenoic acid
Tetracosahexaenoic acid (Nisinic acid)	24:6 ( $n$ -3)	<i>all-cis</i> -6,9,12,15,18,21-tetracosahexaenoic acid

## Forms

### Ethyl ester

- Omega-3 acid ethyl esters (brand names Omarcor or Lovaza,<sup>[62]</sup> Omtryg,<sup>[63]</sup> and as of March 2016, four generic versions.<sup>[64]</sup>
- Ethyl eicosapentaenoic acid (Vascepa)<sup>[65]</sup>

### Free fatty acid

Called "omega-3 carboxylic acids"<sup>[66]</sup> (Epanova)<sup>[67]</sup>

### Biochemical forms

DHA is transported into the brain in the form of lysophosphatidylcholine.<sup>[68][69]</sup>

## Biochemistry

### Transporters

DHA in the form of lysophosphatidylcholine is transported into the brain by a membrane transport protein, MFSD2A, which is exclusively expressed in the endothelium of the blood–brain barrier.<sup>[68][69]</sup>

## Mechanism of action

The 'essential' fatty acids were given their name when researchers found that they are essential to normal growth in young children and animals. The omega-3 fatty acid DHA, also known as docosahexaenoic acid, is found in high abundance in the human brain.<sup>[70]</sup> It is produced by a desaturation process, but humans lack the desaturase enzyme, which acts to insert double bonds at the  $\omega_6$  and  $\omega_3$  position.<sup>[70]</sup> Therefore, the  $\omega_6$  and  $\omega_3$  polyunsaturated fatty acids cannot be synthesized and are appropriately called essential fatty acids.<sup>[70]</sup>

In 1964 it was discovered that enzymes found in sheep tissues convert omega-6 arachidonic acid into the inflammatory agent called prostaglandin  $E_2$ <sup>[71]</sup> which both causes the sensation of pain and expedites healing and immune response in traumatized and infected tissues.<sup>[72]</sup> By 1979 more of what are now known as eicosanoids were discovered: thromboxanes, prostacyclins, and the leukotrienes.<sup>[72]</sup> The eicosanoids, which have important biological functions, typically have a short active lifetime in the body, starting with synthesis from fatty acids and ending with metabolism by enzymes. If the rate of synthesis exceeds the rate of metabolism, the excess eicosanoids may, however, have deleterious effects.<sup>[72]</sup> Researchers found that certain omega-3 fatty acids are also converted into eicosanoids, but at a much slower rate. Eicosanoids made from omega-3 fatty acids are often referred to as anti-inflammatory, but

in fact they are just less inflammatory than those made from omega-6 fats. If both omega-3 and omega-6 fatty acids are present, they will "compete" to be transformed,<sup>[72]</sup> so the ratio of long-chain omega-3:omega-6 fatty acids directly affects the type of eicosanoids that are produced.<sup>[72]</sup>

## Interconversion

### Conversion efficiency of ALA to EPA and DHA

Humans can convert short-chain omega-3 fatty acids to long-chain forms (EPA, DHA) with an efficiency below 5%.<sup>[73][74]</sup> The omega-3 conversion efficiency is greater in women than in men, but less-studied.<sup>[75]</sup> Higher ALA and DHA values found in plasma phospholipids of women may be due to the higher activity of desaturases, especially that of delta-6-desaturase.<sup>[76]</sup>

These conversions occur competitively with omega-6 fatty acids, which are essential closely related chemical analogues that are derived from linoleic acid. They both utilize the same desaturase and elongase proteins in order to synthesize inflammatory regulatory proteins.<sup>[47]</sup> The products of both pathways are vital for growth making a balanced diet of omega-3 and omega-6 important to an individual's health.<sup>[77]</sup> A balanced intake ratio of 1:1 was believed to be ideal in order for proteins to be able to synthesize both pathways sufficiently, but this has been controversial as of recent research.<sup>[78]</sup>

The conversion of ALA to EPA and further to DHA in humans has been reported to be limited, but varies with individuals.<sup>[79][80]</sup> Women have higher ALA conversion efficiency than men, which is presumed<sup>[81]</sup> to be due to the lower rate of use of dietary ALA for beta-oxidation. This suggests that biological engineering of ALA conversion efficiency is possible. Goyens *et al.* argue that the absolute amounts of ALA and LA each influence conversion rates separately, rather than simply the ratio between the two.<sup>[82]</sup>

### Omega-6 to omega-3 ratio

Human diet has changed rapidly in recent centuries resulting in a reported increased diet of omega-6 in comparison to omega-3.<sup>[83]</sup> The rapid evolution of human diet away from a 1:1 omega-3 and omega-6 ratio, such as during the Neolithic Agricultural Revolution, has presumably been too fast for humans to have adapted to biological profiles adept at balancing omega-3 and omega-6 ratios of 1:1.<sup>[84]</sup> This is commonly believed to be the reason why modern diets are correlated with many inflammatory disorders.<sup>[83]</sup> While omega-3 polyunsaturated fatty acids may be beneficial in preventing heart disease in humans, the level of omega-6 polyunsaturated fatty acids (and, therefore, the ratio) does not matter.<sup>[78][85]</sup>

Both omega-6 and omega-3 fatty acids are essential: humans must consume them in their diet. Omega-6 and omega-3 eighteen-carbon polyunsaturated fatty acids compete for the same metabolic enzymes, thus the omega-6:omega-3 ratio of ingested fatty acids has significant influence on the ratio and rate of production of eicosanoids, a group of hormones intimately involved in the body's inflammatory and homeostatic processes, which include the prostaglandins, leukotrienes, and thromboxanes, among others. Altering this ratio can change the body's metabolic and inflammatory state.<sup>[11]</sup> In general, grass-



fed animals accumulate more omega-3 than do grain-fed animals, which accumulate relatively more omega-6.<sup>[86]</sup> Metabolites of omega-6 are more inflammatory (esp. arachidonic acid) than those of omega-3. This necessitates that omega-6 and omega-3 be consumed in a balanced proportion; healthy ratios of omega-6:omega-3, according to some authors, range from 1:1 to 1:4.<sup>[87]</sup> Other authors believe that a ratio of 4:1 (4 times as much omega-6 as omega-3) is already healthy.<sup>[88][89]</sup> Studies suggest the evolutionary human diet, rich in game animals, seafood, and other sources of omega-3, may have provided such a ratio.<sup>[90][91]</sup>

Typical Western diets provide ratios of between 10:1 and 30:1 (i.e., dramatically higher levels of omega-6 than omega-3).<sup>[92]</sup> The ratios of omega-6 to omega-3 fatty acids in some common vegetable oils are: canola 1:2, hemp 2-3:1,<sup>[93]</sup> soybean 7:1, olive 3–13:1, sunflower (no omega-3), flax 1:3,<sup>[94]</sup> cottonseed (almost no omega-3), peanut (no omega-3), grapeseed oil (almost no omega-3) and corn oil 46:1 ratio of omega-6 to omega-3.<sup>[95]</sup>

## History

Although omega-3 fatty acids have been known as essential to normal growth and health since the 1930s, awareness of their health benefits has dramatically increased since the 1980s.<sup>[96][97]</sup>

On September 8, 2004, the U.S. Food and Drug Administration gave "qualified health claim" status to EPA and DHA omega-3 fatty acids, stating, "supportive but not conclusive research shows that consumption of EPA and DHA [omega-3] fatty acids may reduce the risk of coronary heart disease".<sup>[98]</sup> This updated and modified their health risk advice letter of 2001 (see below).

The Canadian Food Inspection Agency has recognized the importance of DHA omega-3 and permits the following claim for DHA: "DHA, an omega-3 fatty acid, supports the normal physical development of the brain, eyes and nerves primarily in children under two years of age."<sup>[99]</sup>

## Dietary sources

### Daily values

In the United States, the Institute of Medicine publishes a system of Dietary Reference Intakes, which includes Recommended Dietary Allowances (RDAs) for individual nutrients, and Acceptable Macronutrient Distribution Ranges (AMDRs) for certain groups of nutrients, such as fats. When there is insufficient evidence to determine an RDA, the institute may publish an Adequate Intake (AI) instead, which has a similar meaning, but is less certain. The AI for

**Grams of omega-3 per 3oz (85g) serving**<sup>[100]</sup>  
[101]

$\alpha$ -linolenic acid is 1.6 grams/day for men and 1.1 grams/day for women, while the AMDR is 0.6% to 1.2% of total energy.<sup>[103]</sup>

A growing body of literature suggests that higher intakes of  $\alpha$ -linolenic acid (ALA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA) may afford some degree of protection against coronary disease. Because the physiological potency of EPA and DHA is much greater than that of ALA, it is not possible to estimate one AMDR for all omega-3 fatty acids. Approximately 10 percent of the AMDR can be consumed as EPA and/or DHA.<sup>[103]</sup> There was insufficient evidence as of 2005 to set an upper tolerable limit for omega-3 fatty acids.<sup>[103]</sup>

Heavy metal poisoning by the body's accumulation of traces of heavy metals, in particular mercury, lead, nickel, arsenic, and cadmium, is a possible risk from consuming fish oil supplements. Also, other contaminants (PCBs, furans, dioxins, and PBDEs) might be found, especially in less-refined fish oil supplements. However, heavy metal toxicity from consuming fish oil supplements is highly unlikely, because heavy metals selectively bind with protein in the fish flesh rather than accumulate in the oil. An independent test in 2005 of 44 fish oils on the US market found all of the products passed safety standards for potential contaminants.<sup>[104]</sup>

The FDA has advised that adults can safely consume a total of 3 grams per day of combined DHA and EPA, with no more than 2 g from dietary supplements.<sup>[105]</sup>

Throughout their history, the Council for Responsible Nutrition and the World Health Organization have published acceptability standards regarding contaminants in fish oil. The most stringent current standard is the International Fish Oils Standard.<sup>[106]</sup> Fish oils that are molecularly distilled under vacuum typically make this highest-grade; levels of contaminants are stated in parts per billion per trillion.

A recent trend has been to fortify food with omega-3 fatty acid supplements. Global food companies have launched omega-3 fatty acid fortified bread,

Common name	grams omega-3
Flax	11.4 <sup>[102]</sup>
Hemp	11.0
Herring, sardines	1.3–2
Mackerel: Spanish/Atlantic/Pacific	1.1–1.7
Salmon	1.1–1.9
Halibut	0.60–1.12
Tuna	0.21–1.1
Swordfish	0.97
Greenshell/lipped mussels	0.95 <sup>[102]</sup>
Tilefish	0.9
Tuna (canned, light)	0.17–0.24
Pollock	0.45
Cod	0.15–0.24
Catfish	0.22–0.3
Flounder	0.48
Grouper	0.23
Mahi mahi	0.13
Orange roughy	0.028
Red snapper	0.29
Shark	0.83
King mackerel	0.36
Hoki (blue grenadier)	0.41 <sup>[102]</sup>
Gemfish	0.40 <sup>[102]</sup>
Blue eye cod	0.31 <sup>[102]</sup>
Sydney rock oysters	0.30 <sup>[102]</sup>
Tuna, canned	0.23 <sup>[102]</sup>
Snapper	0.22 <sup>[102]</sup>
Eggs, large regular	0.109 <sup>[102]</sup>
Strawberry or Kiwifruit	0.10-0.20
Broccoli	0.10-0.20
Barramundi, saltwater	0.100 <sup>[102]</sup>

mayonnaise, pizza, yogurt, orange juice, children's pasta, milk, eggs, popcorn, confections, and infant formula.

The American Heart Association has set up dietary recommendations for EPA and DHA due to their cardiovascular benefits: Individuals with no history of coronary heart disease or myocardial infarction should consume oily fish or fish oils two times per week; those having been diagnosed with coronary heart disease after infarction should consume 1 g EPA and DHA per day from oily fish or supplements; those wishing to lower blood triglycerides should consume 2–4 g of EPA and DHA per day in the form of supplements.<sup>[101]</sup>

Common name	grams omega-3
Giant tiger prawn	0.100 <sup>[102]</sup>
Lean red meat	0.031 <sup>[102]</sup>
Turkey	0.030 <sup>[102]</sup>
Cereals, rice, pasta, etc.	0.00 <sup>[102]</sup>
Fruit	0.00 <sup>[102]</sup>
Milk, regular	0.00 <sup>[102]</sup>
Bread, regular	0.00 <sup>[102]</sup>
Vegetables	0.00 <sup>[102]</sup>

## Fish

The most widely available dietary source of EPA and DHA is oily fish, such as salmon, herring, mackerel, anchovies, menhaden, and sardines. Oils from these fish have a profile of around seven times as much omega-3 as omega-6. Other oily fish, such as tuna, also contain *n*-3 in somewhat lesser amounts. Consumers of oily fish should be aware of the potential presence of heavy metals and fat-soluble pollutants like PCBs and dioxins, which are known to accumulate up the food chain. After extensive review, researchers from Harvard's School of Public Health in the *Journal of the American Medical Association* (2006) reported that the benefits of fish intake generally far outweigh the potential risks. Although fish are a dietary source of omega-3 fatty acids, fish do not synthesize them; they obtain them from the algae (microalgae in particular) or plankton in their diets.<sup>[107]</sup>

## Fish oil

Marine and freshwater fish oil vary in content of arachidonic acid, EPA and DHA.<sup>[108]</sup> They also differ in their effects on organ lipids.<sup>[108]</sup> Not all forms of fish oil may be equally digestible. Of four studies that compare bioavailability of the glyceryl ester form of fish oil vs. the ethyl ester form, two have concluded the natural glyceryl ester form is better, and the other two studies did not find a significant difference. No studies have shown the ethyl ester form to be superior, although it is cheaper to manufacture.<sup>[109][110]</sup>



Fish oil capsules

## Krill

Krill oil is a source of omega-3 fatty acids.<sup>[111]</sup> The effect of krill oil, at a lower dose of EPA + DHA (62.8%), was demonstrated to be similar to that of fish oil on blood lipid levels and markers of inflammation in healthy humans.<sup>[112]</sup> While not an endangered species, krill are a mainstay of the diets of many ocean-based species including whales, causing environmental and scientific concerns about their sustainability.<sup>[113][114][115]</sup>

## Squid oil

Squid oil (also known as calamari oil) is another source of omega-3 fatty acid.<sup>[116]</sup> The editor of health365com.au considers squid environmentally friendlier than fish or krill oil, because it is prepared from the largely unused portions of squid catches.<sup>[117]</sup>

## Plant sources

These tables are incomplete.

**Table 1.** ALA content as the percentage of the seed oil.<sup>[118]</sup>

Common name	Alternative name	Linnaean name	% ALA
Kiwifruit seed oil	Chinese gooseberry	<i>Actinidia deliciosa</i>	63 <sup>[119]</sup>
Perilla	shiso	<i>Perilla frutescens</i>	61
Chia seed	chia sage	<i>Salvia hispanica</i>	58
Flax	linseed	<i>Linum usitatissimum</i>	53 <sup>[83]</sup> – 59 <sup>[120]</sup>
Lingonberry	Cowberry	<i>Vaccinium vitis-idaea</i>	49
Fig seed oil	Common Fig	<i>Ficus carica</i>	47.7 <sup>[121]</sup>
Camelina	Gold-of-pleasure	<i>Camelina sativa</i>	36
Purslane	Portulaca	<i>Portulaca oleracea</i>	35
Black raspberry		<i>Rubus occidentalis</i>	33
Hemp		<i>Cannabis sativa</i>	19
Canola			9 <sup>[83]</sup> – 11



**Table 2.** ALA content as the percentage of the whole food.<sup>[83][122]</sup>

Common name	Linnaean name	% ALA
Flaxseed	<i>Linum usitatissimum</i>	18.1
Hempseed	<i>Cannabis sativa</i>	8.7
Butternuts	<i>Juglans cinerea</i>	8.7
Persian walnuts	<i>Juglans regia</i>	6.3
Pecan nuts	<i>Carya illinoensis</i>	0.6
Hazel nuts	<i>Corylus avellana</i>	0.1



Flax seeds produce linseed oil which has high ALA content

Flaxseed (or linseed) (*Linum usitatissimum*) and its oil are perhaps the most widely available botanical source of the omega-3 fatty acid ALA. Flaxseed oil consists of approximately 55% ALA, which makes it six times richer than most fish oils in omega-3 fatty acids.<sup>[123]</sup> A portion of this is converted by the body to EPA and DHA, though the actual converted percentage may differ between men and women.<sup>[124]</sup>

In 2013 Rothamsted Research in the UK reported they had developed a genetically modified form of the plant *Camelina* that produced EPA and DHA. Oil from the seeds of this plant contained on average 11% EPA and 8% DHA in one development and 24% EPA in another.<sup>[125][126]</sup>

## Eggs

Eggs produced by hens fed a diet of greens and insects contain higher levels of omega-3 fatty acids than those produced by chickens fed corn or soybeans.<sup>[127]</sup> In addition to feeding chickens insects and greens, fish oils may be added to their diets to increase the omega-3 fatty acid concentrations in eggs.<sup>[128]</sup>

The addition of flax and canola seeds to the diets of chickens, both good sources of alpha-linolenic acid, increases the omega-3 content of the eggs, predominantly DHA.<sup>[129]</sup>

The addition of green algae or seaweed to the diets boosts the content of DHA and EPA, which are the forms of omega-3 approved by the FDA for medical claims. A common consumer complaint is "Omega-3 eggs can sometimes have a fishy taste if the hens are fed marine oils".<sup>[130]</sup>

## Meat

Omega-3 fatty acids are formed in the chloroplasts of green leaves and algae. While seaweeds and algae are the source of omega-3 fatty acids present in fish, grass is the source of omega-3 fatty acids present in grass fed animals.<sup>[131]</sup> When cattle are taken off omega-3 fatty acid rich grass and shipped to a feedlot to be fattened on omega-3 fatty acid deficient grain, they begin losing their store of this beneficial fat. Each day that an animal spends in the feedlot, the amount of omega-3 fatty acids in its meat is diminished.<sup>[132]</sup>

The omega-6:omega-3 ratio of grass-fed beef is about 2:1, making it a more useful source of omega-3 than grain-fed beef, which usually has a ratio of 4:1.<sup>[86]</sup>

In a 2009 joint study by the USDA and researchers at Clemson University in South Carolina, grass-fed beef was compared with grain-finished beef. The researchers found that grass-finished beef is higher in moisture content, 42.5% lower total lipid content, 54% lower in total fatty acids, 54% higher in beta-carotene, 288% higher in vitamin E (alpha-tocopherol), higher in the B-vitamins thiamin and riboflavin, higher in the minerals calcium, magnesium, and potassium, 193% higher in total omega-3s, 117% higher in CLA (cis-9 trans-11, which is a potential cancer fighter), 90% higher in vaccenic acid (which can be transformed into CLA), lower in the saturated fats linked with heart disease, and has a healthier ratio of omega-6 to omega-3 fatty acids (1.65 vs 4.84). Protein and cholesterol content were equal.<sup>[86]</sup>

In most countries, commercially available lamb is typically grass-fed, and thus higher in omega-3 than other grain-fed or grain-finished meat sources. In the United States, lamb is often finished (i.e., fattened before slaughter) with grain, resulting in lower omega-3.<sup>[133]</sup>

The omega-3 content of chicken meat may be enhanced by increasing the animals' dietary intake of grains high in omega-3, such as flax, chia, and canola.<sup>[134]</sup>

Kangaroo meat is also a source of omega-3, with fillet and steak containing 74 mg per 100 g of raw meat.<sup>[135]</sup>

## Mammalian brains and eyes

The brains and eyes of mammals are extremely rich in DHA as well as other omega-3 fatty acids.<sup>[136]</sup> DHA is a major structural component of the mammalian brain, and is in fact the most abundant omega-3 fatty acid in the brain.<sup>[137]</sup>

## Seal oil

Seal oil is a source of EPA, DPA, and DHA. According to Health Canada, it helps to support the development of the brain, eyes, and nerves in children up to 12 years of age.<sup>[138]</sup> Like all seal products, it is not allowed to be imported into the European Union.<sup>[139]</sup>

## Other sources



The microalgae *Cryptocodinium cohnii* and *Schizochytrium* are rich sources of DHA but not EPA, and can be produced commercially in bioreactors.

Oil from brown algae (kelp) is a source of EPA.<sup>[140]</sup> The alga *Nannochloropsis* also has high levels of EPA.<sup>[141]</sup>



In 2006 the Journal of Dairy Science published a study which found that butter made from the milk of grass-fed cows contains substantially more CLA, vitamin E, beta-carotene, and omega-3 fatty acids than butter made from the milk of cows that have limited access to pasture.<sup>[142]</sup>


## References

1. "Related terms". *Omega-3 fatty acids, fish oil, alpha-linolenic acid*. Mayo Clinic. Retrieved June 20, 2012.
2. Scorletti E, Byrne CD (2013). "Omega-3 fatty acids, hepatic lipid metabolism, and nonalcoholic fatty liver disease". *Annual Review of Nutrition*. **33** (1): 231–48. doi:10.1146/annurev-nutr-071812-161230. PMID 23862644.
3. Rizos EC, Ntzani EE, Bika E, Kostapanos MS, Elisaf MS (September 2012). "Association Between Omega-3 Fatty Acid Supplementation and Risk of Major Cardiovascular Disease Events A Systematic Review and Meta-analysis". *JAMA*. **308** (10): 1024–33. doi:10.1001/2012.jama.11374. PMID 22968891.
4. MacLean CH, Newberry SJ, Mojica WA, Khanna P, Issa AM, Suttorp MJ, Lim YW, Traina SB, Hilton L, Garland R, Morton SC (2006-01-25). "Effects of omega-3 fatty acids on cancer risk: a systematic review.". *JAMA: The Journal of the American Medical Association*. **295** (4): 403–15. doi:10.1001/jama.295.4.403. PMID 16434631. Retrieved 2006-07-07.
5. Grey, Andrew; Bolland, Mark (March 2014). "Clinical Trial Evidence and Use of Fish Oil Supplements". *JAMA Internal Medicine*. **174** (3): 460–62. doi:10.1001/jamainternmed.2013.12765. PMID 24352849.
6. "Omega-3 Fatty Acids and Health: Fact Sheet for Health Professionals". US National Institutes of Health, Office of Dietary Supplements. 2005. Retrieved 12 April 2014.
7. Freemantle E, Vandal M, Tremblay-Mercier J, Tremblay S, Blachère JC, Bégin ME, Brenna JT, Windust A, Cunnane SC (2006). "Omega-3 fatty acids, energy substrates, and brain function during aging". *Prostaglandins, Leukotrienes and Essential Fatty Acids*. **75** (3): 213–20. doi:10.1016/j.plefa.2006.05.011. PMID 16829066.
8. Gao F, Taha AY, Ma K, Chang L, Kiesewetter D, Rapoport SI (2012). "Aging decreases rate of docosahexaenoic acid synthesis-secretion from circulating unesterified  $\alpha$ -linolenic acid by rat liver". *AGE*. **35** (3): 597–608. doi:10.1007/s11357-012-9390-1. PMID 22388930.
9. Chaiyasit W, Elias RJ, McClements DJ, Decker EA (2007). "Role of Physical Structures in Bulk Oils on Lipid Oxidation". *Critical Reviews in Food Science and Nutrition*. **47** (3): 299–317. doi:10.1080/10408390600754248. PMID 17453926.
10. Sala-Vila A, Calder PC (October–November 2011). "Update on the relationship of fish intake with prostate, breast, and colorectal cancers". *Critical reviews in food science and nutrition*. **51** (9): 855–71. doi:10.1080/10408398.2010.483527. PMID 21888535.
11. Hooper L, Thompson RL, Harrison RA, Summerbell CD, Ness AR, Moore HJ, Worthington HV, Durrington PN, Higgins JP, Capps NE, Riemersma RA, Ebrahim SB, Davey Smith G (2006). "Risks and benefits of omega-3 fats for mortality, cardiovascular disease, and cancer: systematic review". *BMJ*. **332** (7544): 752–60. doi:10.1136/bmj.38755.366331.2F. PMC 1420708. PMID 16565093. Retrieved 2006-07-07.
12. "Omega-3 Fatty Acids and Health".
13. Colomer R, Moreno-Nogueira JM, García-Luna PP, García-Peris P, García-de-Lorenzo A, Zarazaga A, Quecedo L, del Llano J, Usán L, Casimiro C (May 2007). "N-3 fatty acids, cancer and cachexia: a systematic review of the literature". *Br. J. Nutr.* **97** (5): 823–31. doi:10.1017/S000711450765795X. PMID 17408522.
14. Zheng JS, Hu XJ, Zhao YM, Yang J, Li D (27 June 2013). "Intake of fish and marine n-3 polyunsaturated fatty acids and risk of breast cancer: meta-analysis of data from 21 independent prospective cohort studies". *BMJ*. **346** (jun27 5): f3706. doi:10.1136/bmj.f3706. PMID 23814120.
15. Heinze VM, Actis AB (February 2012). "Dietary conjugated linoleic acid and long-chain n-3 fatty acids in mammary and prostate cancer protection: a review". *International journal of food sciences and nutrition*. **63** (1): 66–78. doi:10.3109/09637486.2011.598849. PMID 21762028.
16. Chua ME, Sio MC, Sorongon MC, Morales ML (May–June 2013). "The relevance of serum levels of long chain omega-3 polyunsaturated fatty acids and prostate cancer risk: a meta-analysis". *Canadian Urological Association Journal*. **7** (5–6): E333–43. doi:10.5489/cuaj.1056. PMC 3668400. PMID 23766835.
17. Kwak SM, Myung SK, Lee YJ, Seo HG (2012-04-09). "Efficacy of Omega-3 Fatty Acid Supplements (Eicosapentaenoic Acid and Docosahexaenoic Acid) in the Secondary Prevention of Cardiovascular Disease: A Meta-analysis of Randomized, Double-blind, Placebo-Controlled Trials". *Archives of Internal Medicine*. **172** (9): 686–94. doi:10.1001/archinternmed.2012.262. PMID 22493407.
18. Billman, George E. (2013-10-01). "The effects of omega-3 polyunsaturated fatty acids on cardiac rhythm: a critical reassessment". *Pharmacology & Therapeutics*. **140** (1): 53–80. doi:10.1016/j.pharmthera.2013.05.011. ISSN 1879-016X. PMID 23735203.



19. Casula M, Soranna D, Catapano AL, Corrao G (August 2013). "Long-term effect of high dose omega-3 fatty acid supplementation for secondary prevention of cardiovascular outcomes: A meta-analysis of randomized, placebo controlled trials [corrected]". *Atherosclerosis Supplements*. **14** (2): 243–51. doi:10.1016/S1567-5688(13)70005-9. PMID 23958480.
20. Delgado-Lista J, Perez-Martinez P, Lopez-Miranda J, Perez-Jimenez F (June 2012). "Long chain omega-3 fatty acids and cardiovascular disease: a systematic review". *The British journal of nutrition*. 107 Suppl 2: S201–13. doi:10.1017/S0007114512001596. PMID 22591894.
21. Kotwal S, Jun M, Sullivan D, Perkovic V, Neal B (18 September 2012). "omega-3 Fatty Acids and Cardiovascular Outcomes: Systematic Review and Meta-Analysis". *Circ Cardiovasc Qual Outcomes*. **5** (6): 808–18. doi:10.1161/CIRCOUTCOMES.112.966168. PMID 23110790.
22. Miller PE, Van Elswyk M, Alexander DD (July 2014). "Long-chain omega-3 fatty acids eicosapentaenoic acid and docosahexaenoic acid and blood pressure: a meta-analysis of randomized controlled trials". *American Journal of Hypertension*. **27** (7): 885–96. doi:10.1093/ajh/hpu024. PMID 24610882.
23. Morris MC, Sacks F, Rosner B (1993). "Does fish oil lower blood pressure? A meta-analysis of controlled trials". *Circulation*. **88** (2): 523–33. doi:10.1161/01.CIR.88.2.523. PMID 8339414.
24. Mori TA, Bao DQ, Burke V, Puddey IB, Beilin LJ (1993). "Docosahexaenoic acid but not eicosapentaenoic acid lowers ambulatory blood pressure and heart rate in humans". *Hypertension*. **34** (2): 253–60. doi:10.1161/01.HYP.34.2.253. PMID 10454450.
25. Weintraub HS (November 2014). "Overview of prescription omega-3 fatty acid products for hypertriglyceridemia". *Postgraduate Medicine*. **126** (7): 7–18. doi:10.3810/pgm.2014.11.2828. PMID 25387209.
26. Wu L, Parhofer KG (December 2014). "Diabetic dyslipidemia". *Metabolism: clinical and experimental*. **63** (12): 1469–79. doi:10.1016/j.metabol.2014.08.010. PMID 25242435.
27. Wang C, Harris WS, Chung M, Lichtenstein AH, Balk EM, Kupelnick B, Jordan HS, Lau J (July 2006). "n-3 Fatty acids from fish or fish-oil supplements, but not alpha-linolenic acid, benefit cardiovascular disease outcomes in primary- and secondary-prevention studies: a systematic review". *The American Journal of Clinical Nutrition*. **84** (1): 5–17. PMID 16825676.
28. Larsson, SC (February 2013). "Dietary fats and other nutrients on stroke.". *Current opinion in lipidology*. **24** (1): 41–48. doi:10.1097/mol.0b013e3283592eea. PMID 23123763.
29. Wall R, Ross RP, Fitzgerald GF, Stanton C (2010). "Fatty acids from fish: the anti-inflammatory potential of long-chain omega-3 fatty acids". *Nutr Rev*. **68** (5): 280–89. doi:10.1111/j.1753-4887.2010.00287.x. PMID 20500789.
30. Robinson LE, Mazurak VC (2013). "n-3 Polyunsaturated fatty acids: Relationship to inflammation in health adults and adults exhibiting features of metabolic syndrome". *Lipids*. **48** (4): 319–32. doi:10.1007/s11745-013-3774-6. PMID 23456976.
31. Li K1, Huang T, Zheng J, Wu K, Li D (February 2014). "Effect of marine-derived n-3 polyunsaturated fatty acids on C-reactive protein, interleukin 6 and tumor necrosis factor  $\alpha$ : a meta-analysis". *PLOS ONE*. **9** (2): e88103. doi:10.1371/journal.pone.0088103. PMC 3914936 . PMID 24505395.
32. Miles EA, Calder PC (June 2012). "Influence of marine n-3 polyunsaturated fatty acids on immune function and a systematic review of their effects on clinical outcomes in rheumatoid arthritis.". *The British journal of nutrition*. 107 Suppl 2 (S2): S171–84. doi:10.1017/S0007114512001560. PMID 22591891.
33. "Rheumatoid Arthritis and Complementary Health Approaches". National Center for Complementary and Alternative Medicine. Retrieved 14 January 2014.
34. Levy SE, Hyman SL (2005). "Novel treatments for autistic spectrum disorders". *Ment Retard Dev Disabil Res Rev*. **11** (2): 131–42. doi:10.1002/mrdd.20062. PMID 15977319.
35. Richardson AJ (2006). "Omega-3 fatty acids in ADHD and related neurodevelopmental disorders". *Int Rev Psychiatry*. **18** (2): 155–72. doi:10.1080/09540260600583031. PMID 16777670.
36. Bloch, Michael H.; Qawasmi, Ahmad. "Omega-3 Fatty Acid Supplementation for the Treatment of Children With Attention-Deficit/Hyperactivity Disorder Symptomatology: Systematic Review and Meta-Analysis". *Journal of the American Academy of Child & Adolescent Psychiatry*. **50** (10): 991–1000. doi:10.1016/j.jaac.2011.06.008. PMC 3625948 . PMID 21961774.
37. Gillies D; Sinn JKh; Lad SS; Leach MJ; Ross MJ (July 11, 2012). "Polyunsaturated fatty acids (PUFA) for attention deficit hyperactivity disorder (ADHD) in children and adolescents". *The Cochrane database of systematic reviews*. **7**: CD007986. doi:10.1002/14651858.CD007986.pub2. PMID 22786509.



38. Tan ML, Ho JJ, Teh KH (December 12, 2012). "Polyunsaturated fatty acids (PUFAs) for children with specific learning disorders". *The Cochrane database of systematic reviews*. **12**: CD009398. doi:10.1002/14651858.CD009398.pub2. PMID 23235675.
39. Ortega RM, Rodríguez-Rodríguez E, López-Sobaler AM (June 2012). "Effects of omega-3 fatty acids supplementation in behavior and non-neurodegenerative neuropsychiatric disorders". *The British journal of nutrition*. 107 Suppl 2: S261–70. doi:10.1017/S000711451200164X. PMID 22591900.
40. Secher NJ (2007). "Does fish oil prevent preterm birth?". *Journal of perinatal medicine*. 35 Suppl 1: S25–27. doi:10.1515/JPM.2007.033. PMID 17302537.
41. Jensen, Craig L (2006). "Effects of n-3 fatty acids during pregnancy and lactation" (PDF). *Am J Clin Nutr*. **83** (6): 1452–57. ISSN 0002-9165.
42. "Omega-3 long chain polyunsaturated fatty acids to prevent preterm birth: a meta-analysis of randomized controlled trials". *www.crd.york.ac.uk*. Retrieved 2016-03-01.
43. Kar, S; Wong, M; Rogozinska, E; Thangaratinam, S (30 November 2015). "Effects of omega-3 fatty acids in prevention of early preterm delivery: a systematic review and meta-analysis of randomized studies.". *European journal of obstetrics, gynecology, and reproductive biology*. **198**: 40–46. doi:10.1016/j.ejogrb.2015.11.033. PMID 26773247.
44. Perica MM, Delas I (August 2011). "Essential fatty acids and psychiatric disorders". *Nutrition in clinical practice : official publication of the American Society for Parenteral and Enteral Nutrition*. **26** (4): 409–25. doi:10.1177/0884533611411306. PMID 21775637.
45. Montgomery P, Richardson AJ (2008-04-16). Montgomery, Paul, ed. "Omega-3 fatty acids for bipolar disorder". *Cochrane database of systematic reviews (Online)* (2): CD005169. doi:10.1002/14651858.CD005169.pub2. PMID 18425912.
46. Hegarty B, Parker G (January 2013). "Fish oil as a management component for mood disorders - an evolving signal". *Current Opinion in Psychiatry*. **26** (1): 33–40. doi:10.1097/YCO.0b013e32835ab4a7. PMID 23108232.
47. Ruxton CHS, Calder PC, Reed SC, Simpson MJA (2005). "The impact of long-chain n-3 polyunsaturated fatty acids on human health". *Nutrition Research Reviews*. **18** (1): 113–29. doi:10.1079/nrr200497.
48. Miles EA, Aston L, Calder PC (2003). "In vitro effects of eicosanoids derived from different 20-carbon fatty acids on T helper type 1 and T helper type 2 cytokine production in human whole-blood cultures". *Clinical and Experimental Allergy*. **33** (5): 624–32. doi:10.1046/j.1365-2222.2003.01637.x.
49. Bucolo C, Caraci F, Drago F, Galvano F, Grosso G, Malaguarnera M, Maryentano S (2014). "Omega-3 fatty acids and depression: Scientific evidence and biological mechanisms". *Oxidative Medicine and Cellular Longevity*. **2014**: 1–16. doi:10.1155/2014/313570.
50. Sanhueza C, Ryan L, Foxcroft DR (October 18, 2012). "Diet and the risk of unipolar depression in adults: systematic review of cohort studies". *Journal of Human Nutrition and Dietetics*. **26** (1): 56–70. doi:10.1111/j.1365-277X.2012.01283.x. PMID 23078460.
51. Appleton KM, Rogers PJ, Ness AR (2010). "Updated systematic review and meta-analysis of the effects of n-3 long-chain polyunsaturated fatty acids on depressed mood". *American Journal of Clinical Nutrition*. **91** (3): 757–70. doi:10.3945/ajcn.2009.28313. PMID 20130098.
52. Bloch MH, Hannestad J (2012). "Omega-3 fatty acids for the treatment of depression: Systematic review and meta-analysis". *Molecular Psychiatry*. **17** (12): 1272–82. doi:10.1038/mp.2011.100. PMC 3625950 . PMID 21931319.
53. Ross BM (2009). "Omega-3 polyunsaturated fatty acids and anxiety disorders". *Prostaglandins, Leukotrienes and Essential Fatty Acids (PLEFA)*. **81** (5-6): 309–12. doi:10.1016/j.plefa.2009.10.004.
54. Stafford, MR; Jackson, H; Mayo-Wilson, E; Morrison, AP; Kendall, T (18 January 2013). "Early interventions to prevent psychosis: systematic review and meta-analysis.". *BMJ (Clinical research ed.)*. **346**: f185. doi:10.1136/bmj.f185. PMC 3548617 . PMID 23335473.
55. Cederholm T, Palmblad J (March 2010). "Are omega-3 fatty acids options for prevention and treatment of cognitive decline and dementia?". *Current Opinion in Clinical Nutrition and Metabolic Care*. **13** (2): 150–55. doi:10.1097/MCO.0b013e328335c40b. PMID 20019606.
56. Mazereeuw G, Lanctôt KL, Chau SA, Swardfager W, Herrmann N (2012). "Effects of omega-3 fatty acids on cognitive performance: a meta-analysis". *Neurobiol Aging*. **33** (7): e17–29. doi:10.1016/j.neurobiolaging.2011.12.014. PMID 22305186.

57. Chew, EY; Clemons, TE; Agrón, E; Launer, LJ; Grodstein, F; Bernstein, PS; Age-Related Eye Disease Study 2 (AREDS2) Research, Group (25 August 2015). "Effect of Omega-3 Fatty Acids, Lutein/Zeaxanthin, or Other Nutrient Supplementation on Cognitive Function: The AREDS2 Randomized Clinical Trial." *JAMA*. **314** (8): 791–801. doi:10.1001/jama.2015.9677. PMID 26305649.
58. Forbes, SC; Holroyd-Leduc, JM; Poulin, MJ; Hogan, DB (December 2015). "Effect of Nutrients, Dietary Supplements and Vitamins on Cognition: a Systematic Review and Meta-Analysis of Randomized Controlled Trials." *Canadian Geriatrics Journal*. **18** (4): 231–45. doi:10.5770/cgj.18.189. PMC 4696451 . PMID 26740832.
59. Lohner S, Decsi T. Role of Long-Chain Polyunsaturated Fatty Acids in the Prevention and Treatment of Atopic Diseases. In: Polyunsaturated Fatty Acids: Sources, Antioxidant Properties and Health Benefits (edited by: Angel Catalá). NOVA Publishers. 2013. Chapter 11, pp. 1–24. (ISBN 978-1-62948-151-7)
60. Lohner, S.; Fekete, K.; Decsi, T. (Jul 2013). "Lower n-3 long-chain polyunsaturated fatty acid values in patients with phenylketonuria: a systematic review and meta-analysis." *Nutr Res*. **33** (7): 513–20. doi:10.1016/j.nutres.2013.05.003. PMID 23827125.
61. <http://www.hsph.harvard.edu/nutritionsource/omega-3-fats/>
62. University of Utah Pharmacy Services (August 15, 2007) "Omega-3-acid Ethyl Esters Brand Name Changed from Omacor to Lovaza" (<http://pharmacyservices.utah.edu/alerts/251.html>)
63. Omtryg Label ([https://www.accessdata.fda.gov/drugsatfda\\_docs/label/2014/204977s0001bl.pdf](https://www.accessdata.fda.gov/drugsatfda_docs/label/2014/204977s0001bl.pdf)) Revised April 2014
64. FDA Omega-3 acid ethyl esters products (<http://www.accessdata.fda.gov/scripts/cder/drugsatfda/index.cfm?fuseaction=Search.Overview&DrugName=OMEGA-3-ACID%20ETHYL%20ESTERS>) Page accessed March 31, 2016
65. CenterWatch Vascepa (icosapent ethyl) (<http://www.centerwatch.com/drug-information/fda-approved-drugs/drug/1215/vascepa-icosapent-ethyl>) Page accessed March 31, 2016
66. "Omega-3 carboxylic acids" is the USAN, see here (<http://www.ama-assn.org/ama/pub/physician-resources/medical-science/united-states-adopted-names-council/adopted-names.page?>) under 2014 and the proposed INN – see 3.8 here (<https://www.clinicaltrialsregister.eu/ctr-search/trial/2014-003638-26/SE#D>)
67. "Epanova (omega-3-carboxylic acids)". *CenterWatch*. Retrieved 15 December 2014.
68. "Sodium-dependent lysophosphatidylcholine symporter 1". *UniProt*. Retrieved 2 April 2016.
69. Nguyen LN, Ma D, Shui G, Wong P, Cazenave-Gassiot A, Zhang X, Wenk MR, Goh EL, Silver DL (2014). "Mfsd2a is a transporter for the essential omega-3 fatty acid docosahexaenoic acid". *Nature*. **509** (7501): 503–06. doi:10.1038/nature13241. PMID 24828044. Retrieved 2 April 2016.
70. van West, Dirk; Maes, Michael (2003). "Polyunsaturated fatty acids in depression". *Acta Neuropsychiatrica*. **15** (1): 15–21. doi:10.1034/j.1601-5215.2003.00004.x. ISSN 0924-2708.
71. Bergstrom, Danielson, Klenberg, and Samuelsson (November 1964). "The Enzymatic Conversion of Essential fatty Acids into Prostaglandins" (PDF). *The Journal of Biological Chemistry*. **239** (11): PC4006–PC4008.
72. Lands WE (1992). "Biochemistry and physiology of n–3 fatty acids" (PDF). *FASEB Journal*. Federation of American Societies for Experimental Biology. **6** (8): 2530–36. PMID 1592205. Retrieved 2008-03-21.
73. Gerster H (1998). "Can adults adequately convert alpha-linolenic acid (18:3n-3) to eicosapentaenoic acid (20:5n-3) and docosahexaenoic acid (22:6n-3)?" *Int. J. Vitam. Nutr. Res*. **68** (3): 159–73. PMID 9637947.
74. Brenna JT (March 2002). "Efficiency of conversion of alpha-linolenic acid to long chain n-3 fatty acids in man". *Current Opinion in Clinical Nutrition and Metabolic Care*. **5** (2): 127–32. doi:10.1097/00075197-200203000-00002. PMID 11844977.
75. Burdge GC, Calder PC (September 2005). "Conversion of alpha-linolenic acid to longer-chain polyunsaturated fatty acids in human adults". *Reprod. Nutr. Dev*. **45** (5): 581–97. doi:10.1051/rnd:2005047. PMID 16188209.
76. Lohner, S.; Fekete, K.; Marosvölgyi, T.; Decsi, T. (2013). "Gender differences in the long-chain polyunsaturated fatty acid status: systematic review of 51 publications." *Ann Nutr Metab*. **62** (2): 98–112. doi:10.1159/000345599. PMID 23327902.
77. Simopoulos AP (2001). "The importance of the omega-3/omega-6 fatty acid ratio in cardiovascular disease and other chronic diseases". *Experimental Biology and Medicine*. **233** (6): 674–88. doi:10.3181/0711-MR-311. PMID 18408140.

78. Griffin BA (2008). "How relevant is the ratio of dietary omega-6 to omega-3 polyunsaturated fatty acids to cardiovascular disease risk? Evidence from the OPTILIP study". *Current Opinion in Lipidology*. **19** (1): 57–62. doi:10.1097/MOL.0b013e3282f2e2a8. PMID 18196988.
79. Oregon State University Micronutrient Information Center: Essential Fatty Acids-Metabolism and Bioavailability <http://lpi.oregonstate.edu/infocenter/othernuts/omega3fa/#metabolism>
80. "Conversion Efficiency of ALA to DHA in Humans". Retrieved 21 October 2007.
81. "Women have better ALA conversion efficiency". *DHA EPA omega-3 Institute*. Retrieved 21 July 2015.
82. Goyens PL, Spilker ME, Zock PL, Katan MB, Mensink RP (1 July 2006). "Conversion of alpha-linolenic acid in humans is influenced by the absolute amounts of alpha-linolenic acid and linoleic acid in the diet and not by their ratio". *American Journal of Clinical Nutrition*. **84** (1): 44–53. PMID 16825680.
83. DeFilippis, Andrew P.; Sperling, Laurence S. (March 2006). "Understanding omega-3's" (PDF). *American Heart Journal*. **151** (3): 564–70. doi:10.1016/j.ahj.2005.03.051. PMID 16504616. Archived from the original (PDF) on 22 October 2007.
84. Hofmeijer-Sevink MK, Batelaan NM, van Megen HJ, Penninx BW, Cath DC, van den Hout MA, van Balkom AJ (2012). "Clinical relevance of comorbidity in anxiety disorders: A report from the Netherlands Study of Depression and Anxiety (NESDA)". *Journal of Affective Disorders*. **137** (1-3): 106–12. doi:10.1016/j.jad.2011.12.008. PMID 22240085.
85. Willett WC (2007). "The role of dietary n-6 fatty acids in the prevention of cardiovascular disease". *J Cardiovasc Med*. **8**: Suppl 1:S42–5. doi:10.2459/01.JCM.0000289275.72556.13. PMID 17876199.
86. Duckett SK, Neel JP, Fontenot JP, Clapham WM (2009). "Effects of winter stocker growth rate and finishing system on: III. Tissue proximate, fatty acid, vitamin and cholesterol content" (PDF). *Journal of Animal Science*. **87** (9): 2961–70. doi:10.2527/jas.2009-1850. PMID 19502506.
87. Lands, WEM (2005). *Fish, omega-3 and human health*. American Oil Chemists' Society. ISBN 978-1-893997-81-3.
88. Simopoulos AP (October 2002). "The importance of the ratio of omega-6/omega-3 essential fatty acids". *Biomedicine & Pharmacotherapy*. **56** (8): 365–79. doi:10.1016/S0753-3322(02)00253-6. PMID 12442909.
89. Daley, C. A.; Abbott, A.; Doyle, P.; Nader, G.; and Larson, S. (2004). "A literature review of the value-added nutrients found in grass-fed beef products". California State University, Chico (College of Agriculture). Retrieved 2008-03-23.
90. Simopoulos AP (September 2003). "Importance of the ratio of omega-6/omega-3 essential fatty acids: evolutionary aspects". *World Review of Nutrition and Dietetics*. World Review of Nutrition and Dietetics. **92**: 1–174. doi:10.1159/000073788. ISBN 3-8055-7640-4. PMID 14579680.
91. Simopoulos AP, Leaf A, Salem N (2000). "Workshop Statement on the essentiality of and recommended dietary intakes for n-6 and n-3 fatty acids". *Prostaglandins Leukot Essent Fatty Acids*. **63** (3): 119–21. doi:10.1054/plf.2000.0176. PMID 10991764.
92. Hibbeln JR, Nieminen LR, Blasbalg TL, Riggs JA, Lands WE (2006). "Healthy intakes of n-3 and n-6 fatty acids: Estimations considering worldwide diversity". *The American Journal of Clinical Nutrition*. **83** (6 Suppl): 1483S–93S. PMID 16841858.
93. Martina Bavec; Franc Bavec (2006). *Organic Production and Use of Alternative Crops*. London: Taylor & Francis Ltd. p. 178. ISBN 1-4200-1742-X. Retrieved 2013-02-18.
94. Erasmus, Udo, *Fats and Oils*. 1986. Alive books, Vancouver, ISBN 0-920470-16-5 p. 263 (round-number ratio within ranges given.)
95. "Oil, vegetable, corn, industrial and retail, all purpose salad or cooking; USDA Nutrient Data, SR-21". Conde Nast. Retrieved 12 April 2014.
96. Dusheck J (October 1985). "Fish, Fatty Acids, and Physiology". *Science News*. **128** (16): 241–256. doi:10.2307/3970056.
97. Holman RT (February 1998). "The slow discovery of the importance of omega-3 essential fatty acids in human health". *J. Nutr.* **128** (2 Suppl): 427S–33S. PMID 9478042.
98. "FDA announces qualified health claims for omega-3 fatty acids" (Press release). United States Food and Drug Administration. September 8, 2004. Retrieved 2006-07-10.
99. Canadian Food Inspection Agency. Acceptable nutrient function claims (<http://www.inspection.gc.ca/food/labelling/food-labelling-for-industry/health-claims/eng/1392834838383/1392834887794?chap=8#s16c8>). Accessed 30 April 2015
100. "Fish, Levels of Mercury and Omega-3 Fatty Acids". American Heart Association. Retrieved October 6, 2010.

101. Kris-Etherton, PM; Harris, WS; Appel, LJ (2002). "Fish Consumption, Fish Oil, Omega-3 Fatty Acids, and Cardiovascular Disease". *Circulation*. **106** (21): 2747–57. doi:10.1161/01.CIR.0000038493.65177.94. PMID 12438303.
102. "Omega-3 Centre". *Omega-3 sources*. Omega-3 Centre. Archived from the original on 2008-07-18. Retrieved 2008-07-27.
103. Food and Nutrition Board (2005). *Dietary Reference Intakes For Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids* (PDF). Washington, D.C.: Institute of Medicine of the National Academies. pp. 423, 770. ISBN 0-309-08537-3.
104. "Product Review: Omega-3 Fatty Acids (EPA and DHA) from Fish/Marine Oils". ConsumerLab.com. 2005-03-15. Retrieved 2007-08-14.
105. Bent S, Bertoglio K, Hendren RL (August 2009). "Omega-3 fatty acids for autistic spectrum disorder: a systematic review". *J Autism Dev Disord*. **39** (8): 1145–54. doi:10.1007/s10803-009-0724-5. PMC 2710498 . PMID 19333748.
106. "IFOS Home - The International Fish Oil Standards Program".
107. Falk-Petersen, S.; et al. (1998). "Lipids and fatty acids in ice algae and phytoplankton from the Marginal Ice Zone in the Barents Sea". *Polar Biology*. **20** (1): 41–47. doi:10.1007/s003000050274. ISSN 0722-4060. INIST:2356641.
108. Innis SM, Rioux FM, Auestad N, Ackman RG (September 1995). "Marine and freshwater fish oil varying in arachidonic, eicosapentaenoic and docosahexaenoic acids differ in their effects on organ lipids and fatty acids in growing rats.". *The Journal of Nutrition*. **125** (9): 2286–93. PMID 7666244.
109. Lawson LD, Hughes BG (1988). "Absorption of eicosapentaenoic acid and docosahexaenoic acid from fish oil triacylglycerols or fish oil ethyl esters co-ingested with a high-fat meal". *Biochem. Biophys. Res. Commun*. **156** (2): 960–63. doi:10.1016/S0006-291X(88)80937-9. PMID 2847723.
110. Beckermann B, Beneke M, Seitz I (1990). "Comparative bioavailability of eicosapentaenoic acid and docosahexaenoic acid from triglycerides, free fatty acids and ethyl esters in volunteers". *Arzneimittel-Forschung* (in German). **40** (6): 700–04. PMID 2144420.
111. Tur JA, Bibiloni MM, Sureda A, Pons A (2012). "Dietary sources of omega-3 fatty acids: public health risks and benefits". *Br J Nutr*. **107** (Suppl 2): S23–52. doi:10.1017/S0007114512001456. PMID 22591897.
112. Ulven SM, Kirkhus B, Lamglait A, Basu S, Elind E, Haider T, Berge K, Vik H, Pedersen JI (January 2011). "Metabolic Effects of Krill Oil are Essentially Similar to Those of Fish Oil but at Lower Dose of EPA and DHA, in Healthy Volunteers". *Lipids*. **46** (1): 37–46. doi:10.1007/s11745-010-3490-4. PMC 3024511 . PMID 21042875.
113. Atkinson A, Siegel V, Pakhomov E, Rothery P (2004). "Long-term decline in krill stock and increase in salps within the Southern Ocean". *Nature*. **432** (4 November 2004): 100–03. doi:10.1038/nature02996. PMID 15525989.
114. Orr A (2014). "Malnutrition behind whale strandings". Stuff, Fairfax New Zealand Limited. Retrieved 8 August 2015.
115. "Krill fisheries and sustainability". Commission for the Conservation of Antarctic Marine Living Resources, Tasmania, Australia. 2015. Retrieved 8 August 2015.
116. Horner, Hayden. "Calamari: A source of omega-3". Health 365. Retrieved 13 January 2014.
117. Editor, Health. "Sustainability of calamari oil". Health 365. Retrieved 13 January 2014.
118. "Seed Oil Fatty Acids - SOFA Database Retrieval". In German. Google translation (<https://translate.google.com/translate?tl=en&u=www.bfel.de/sofa>)
119. [http://www.osel.co.nz/content/Product\\_Flyers/Kiwifruit.pdf](http://www.osel.co.nz/content/Product_Flyers/Kiwifruit.pdf)
120. [http://www.osel.co.nz/content/Product\\_Flyers/FlaxSeedOil.pdf](http://www.osel.co.nz/content/Product_Flyers/FlaxSeedOil.pdf)
121. Soltana, H; Tekaya, M; Amri, Z; El-Gharbi, S; Nakbi, A; Harzallah, A; Mechri, B; Hammami, M (2016). "Characterization of fig achenes' oil of *Ficus carica* grown in Tunisia". *Food Chemistry*. **196**: 1125–30. doi:10.1016/j.foodchem.2015.10.053. PMID 26593597.
122. Wilkinson, Jennifer. "Nut Grower's Guide: The Complete Handbook for Producers and Hobbyists" (PDF). Retrieved 21 October 2007.
123. Thomas Bartram (September 2002). *Bartram's Encyclopedia of Herbal Medicine: The Definitive Guide to the Herbal Treatments of Diseases*. Da Capo Press. p. 271. ISBN 978-1-56924-550-7.
124. Decsi T, Kennedy K (2011). "Sex-specific differences in essential fatty acid metabolism". *American Journal of Clinical Nutrition*. **94** (6\_Suppl): 1914S–19S. doi:10.3945/ajcn.110.000893. PMID 22089435.

125. Ruiz-Lopez N, Haslam RP, Napier JA, Sayanova O (January 2014). "Successful high-level accumulation of fish oil omega-3 long-chain polyunsaturated fatty acids in a transgenic oilseed crop". *The Plant Journal*. **77** (2): 198–208. doi:10.1111/tpj.12378. PMC 4253037. PMID 24308505.
126. Coghlan, Andy (4 January 2014) "Designed plant oozes vital fish oils (http://www.newscientist.com/article/mg22129503.000-designer-plants-have-vital-fish-oils-in-their-seeds.html#.Us3gItIUQUo)" *New Scientist*, volume 221, issue 2950, page 12
127. "How Omega-6s Usurped Omega-3s In US Diet".
128. Trebunová A, Vasko L, Svedová M, Kastel' R, Tucková M, Mach P (July 2007). "The influence of omega-3 polyunsaturated fatty acids feeding on composition of fatty acids in fatty tissues and eggs of laying hens". *Deutsche Tierärztliche Wochenschrift*. **114** (7): 275–79. PMID 17724936.
129. Cherian, G. Effect of feeding full fat flax and canola seeds to laying hens on the fatty acids composition of eggs, embryos, and newly hatched chicks. http://agris.fao.org/agris-search/search/display.do?f=1991%2FUS%2FUS91146.xml%3BUS9138554
130. Sterling, Colin (2010-06-03). "Washington Post's Egg Taste Test Says Homegrown And Factory Eggs Taste The Same [UPDATED, POLL]". Huffingtonpost.com. Retrieved 2011-01-03.
131. Garton, G. A. (1960). "Fatty Acid Composition of the Lipids of Pasture Grasses". *Nature*. **187** (4736): 511–12. doi:10.1038/187511b0.
132. Duckett SK, Wagner DG, Yates LD, Dolezal HG, May SG (1993). "Effects of time on feed on beef nutrient composition". *J Anim Sci*. **71** (8): 2079–88. PMID 8376232.
133. "Specially Labeled Lamb".
134. Azcona, J.O., Schang, M.J., Garcia, P.T., Gallinger, C., R. Ayerza (h), and Coates, W. (2008). "Omega-3 enriched broiler meat: The influence of dietary alpha-linolenic omega-3 fatty acid sources on growth, performance and meat fatty acid composition". *Canadian Journal of Animal Science*. **88** (2): 257–69. doi:10.4141/CJAS07081.
135. "Gourmet Game - Amazing Nutrition Facts".
136. "DHA in Brain and Retina Structure" (PDF).
137. "Nutrition for the Brain" (PDF).
138. "Natural Health Product Monograph – Seal Oil". Health Canada. June 22, 2009. Retrieved June 20, 2012.
139. European Parliament (9 November 2009). "MEPs adopt strict conditions for the placing on the market of seal products in the European Union". *Hearings*. European Parliament. Retrieved 12 March 2010.
140. van Ginneken VJ, Helsper JP, de Visser W, van Keulen H, Brandenburg WA (2011). "Polyunsaturated fatty acids in various macroalgal species from north Atlantic and tropical seas". *Lipids in Health and Disease*. **10** (104): 104. doi:10.1186/1476-511X-10-104. PMC 3131239. PMID 21696609.
141. Collins ML, Lynch B, Barfield W, Bull A, Ryan AS, Astwood JD (2014). "Genetic and acute toxicological evaluation of an algal oil containing eicosapentaenoic acid (EPA) and palmitoleic acid". *Food and Chemical Toxicology*. **72**: 162–68. doi:10.1016/j.fct.2014.07.021. PMID 25057807.
142. Couvreur S, Hurtaud C, Lopez C, Delaby L, Peyraud JL (June 2006). "The linear relationship between the proportion of fresh grass in the cow diet, milk fatty acid composition, and butter properties". *Journal of Dairy Science*. **89** (6): 1956–69. doi:10.3168/jds.S0022-0302(06)72263-9. PMID 16702259. Retrieved 16 March 2013.

## Further reading

- Allport, Susan. *The Queen of Fats: Why Omega-3s Were Removed from the Western Diet and What We Can Do to Replace Them* (http://worldcat.org/search?q=The+Queen+of+Fats%3A+Why+Omega-3s+Were+Removed+from+the+Western+Diet+and+What+We+Can+Do+to+Replace+Them&qt=mozilla-search). University of California Press, September 2006. ISBN 978-0-520-24282-1.
- Chow, Ching Kuang. *Fatty Acids in Foods and Their Health Implications* (http://worldcat.org/oclc/25508943&referer=brief\_results). Routledge Publishing. New York. 2001.
- Clover, Charles. *The End of the Line: How overfishing is changing the world and what we eat* (http://worldcat.org/oclc/67383509&referer=brief\_results). Ebury Press, London 2004. ISBN 0-09-189780-7

- Stoll, Andrew L. *The Omega-3 Connection* ([http://worldcat.org/search?q=The+Omega-3+Connection&fq=ap%3AAndrew+L+Stoll&qt=facet\\_ap%3A](http://worldcat.org/search?q=The+Omega-3+Connection&fq=ap%3AAndrew+L+Stoll&qt=facet_ap%3A)). Simon & Schuster 2001. ISBN 0-684-87138-6.

## External links

- University of Maryland Medical Center, omega-3 Fatty Acids (<http://umm.edu/health/medical-reference-guide/complementary-and-alternative-medicine-guide/supplement/omega3-fatty-acids>)

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