REQUIREMENTS FOR MARINE RESOURCES AND APPROACHES FOR MANAGING THE FUTURE

May 2, 2013

GOED
OMEGA-3

When we talk about production from marine resources, we only talk about the tonnage of biomass pulled from the ocean, which is primarily protein.

We need to look at what else is important from marine organisms.

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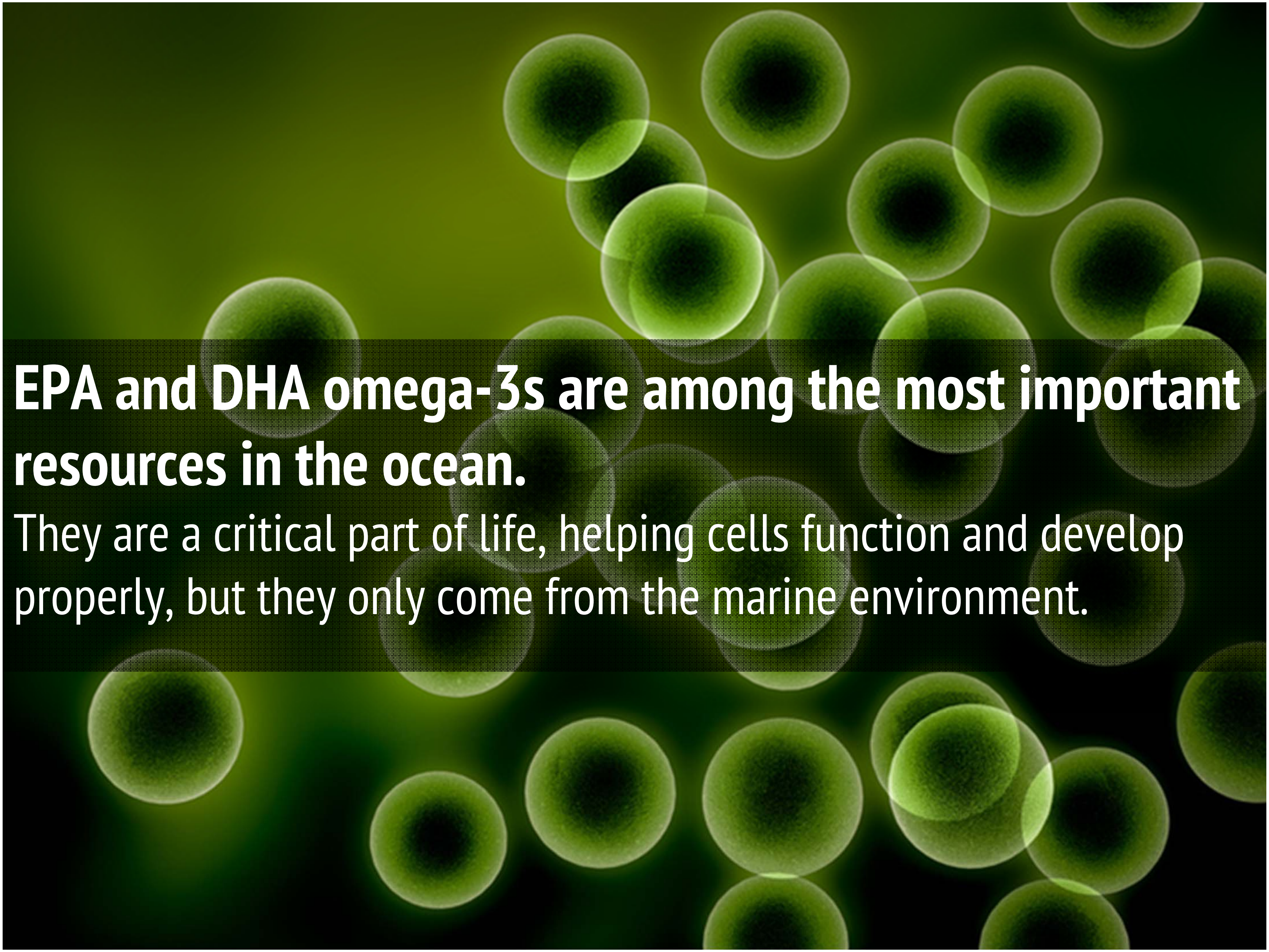
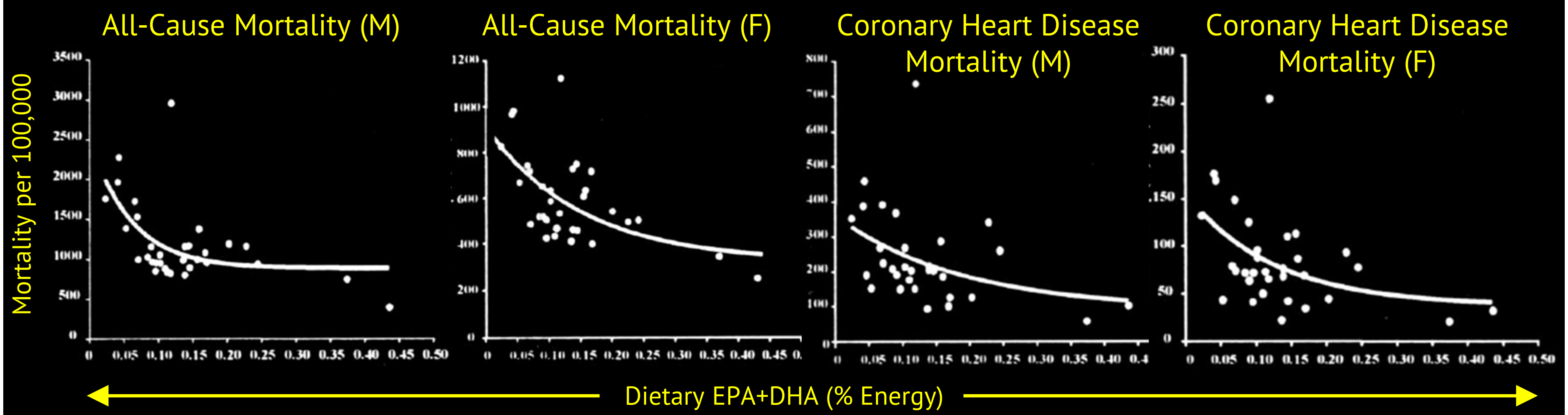

EPA and DHA omega-3s are among the most important resources in the ocean.
They are a critical part of life, helping cells function and develop properly, but they only come from the marine environment.

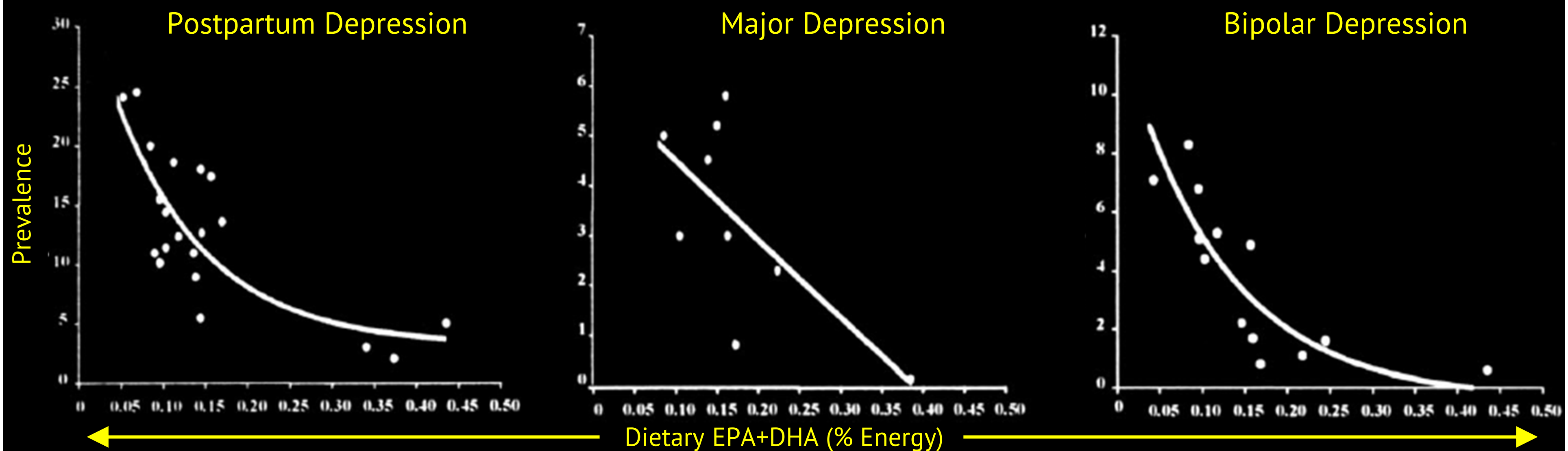
Why is this important for managing diversity of marine genetic resources?

Human beings and their nutritional needs need to be considered stakeholders as important as the fish in the ocean.



Do we really need EPA and DHA in our diets?

Yes, low intakes of EPA and DHA are convincingly associated with increased mortality and chronic disease rates.



Source: Hibbeln et al, 2006. Am J Clin Nutr

How much omega-3 do we need?

250

mg/day

WHO and EU Recommended Intake

400

mg/day

Omega-3 Mortality Paper

1000

mg/day

Japanese Recommended Intake

Source: WHO, EFSA, Mozaffarian et al 2013 Ann Int Med, Japanese MHLW

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250 mg/day	400 mg/day	1000 mg/day
↓	↓	↓
0.65 million tons per year	1.02 million tons per year	2.55 million tons per year

Source: GOED analysis

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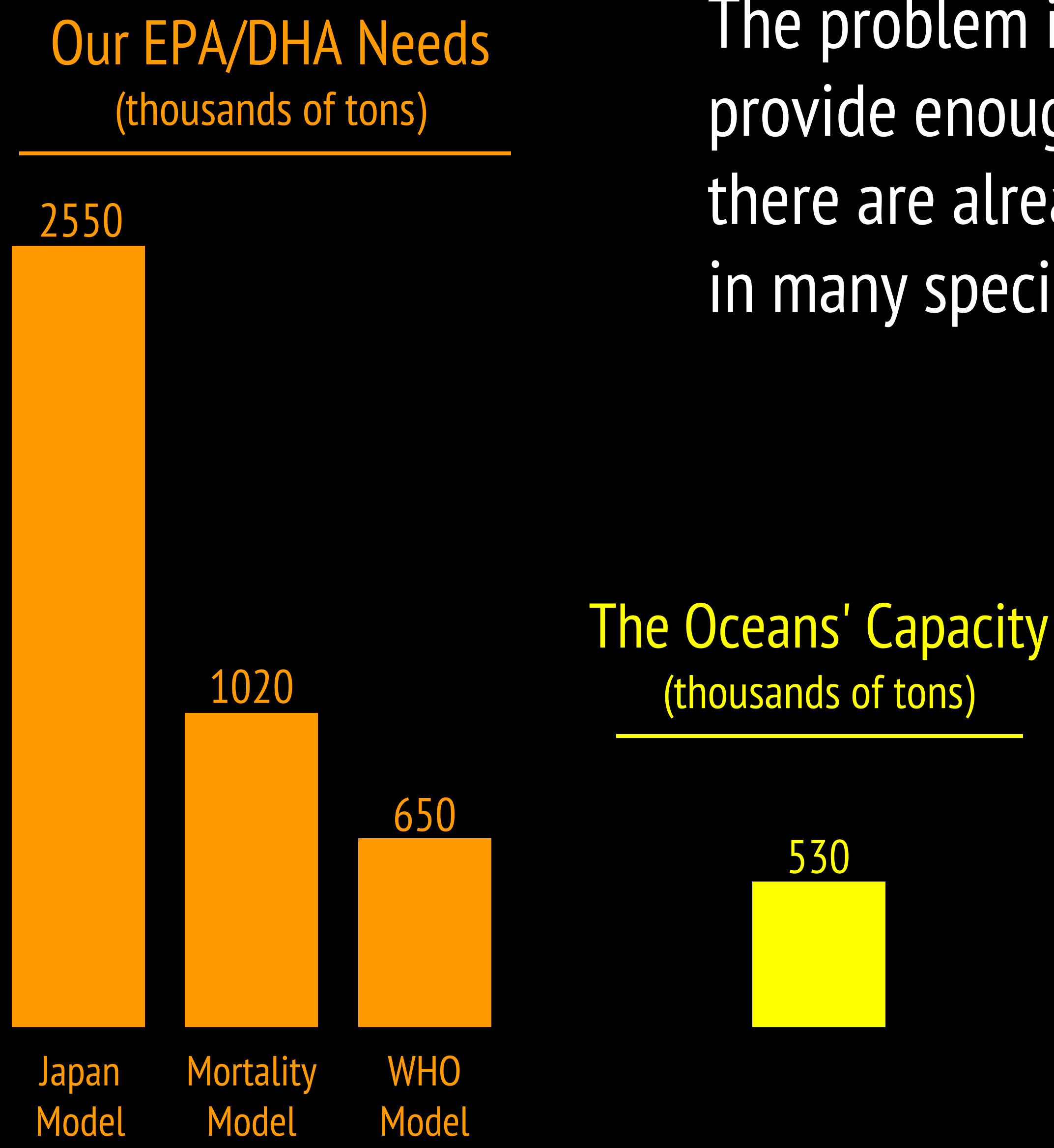
The problem is the oceans do not provide enough EPA and DHA today and there are already fears about overfishing in many species.

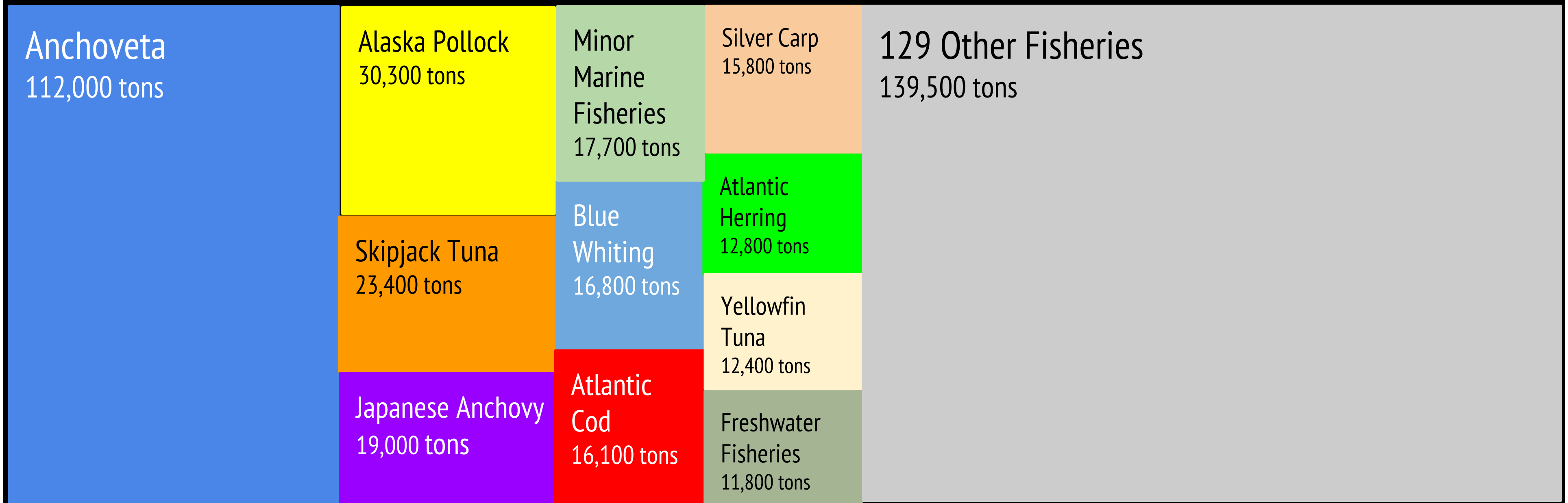


Source: GOED analysis of FAO and USDA data

There is clearly a nutrition gap, so it is important to protect the resources we have.

In addition, even more resources will be required to supply specialized pharmaceutical and clinical nutrition applications.

EPA and DHA Capacity By Fishery, 2010



Eleven fishery groups account for 55% of the earth's EPA and DHA capacity today, so any threat to these fisheries is significant to humans.

This includes overfishing, pollution, and of course, improper management of the gene pool.

Source: GOED analysis of FAO and USDA data

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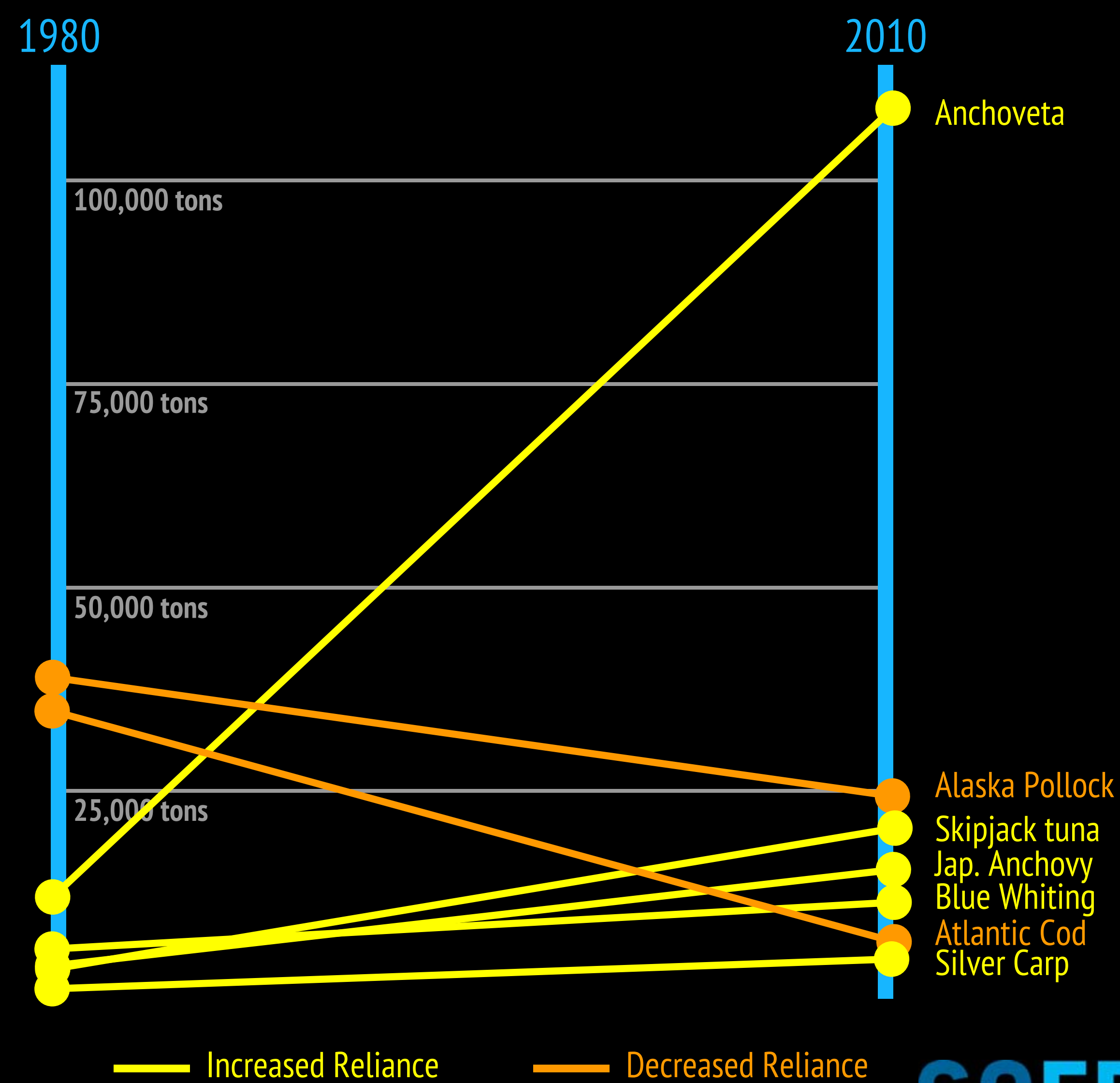
We know that fishery capacity of EPA and DHA is already changing and that we are more reliant on fewer fisheries for these nutrients, the anchoveta fishery in particular.

30-Year Change in EPA and DHA Capacities of Leading Fisheries



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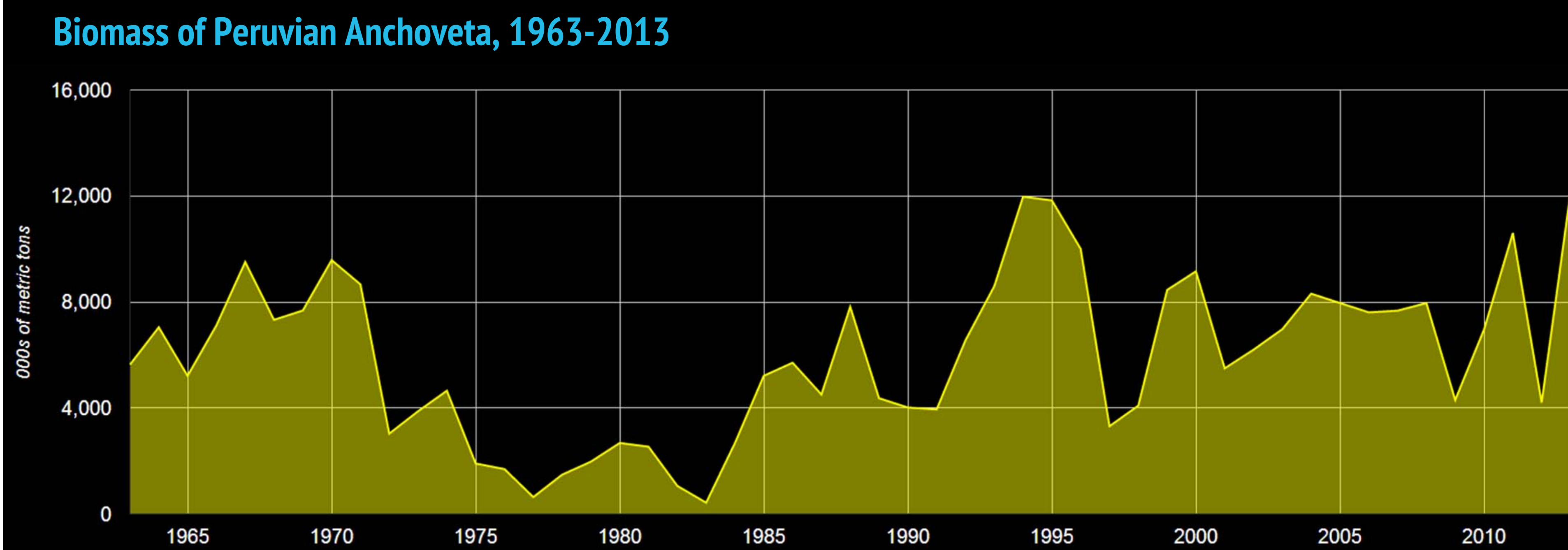
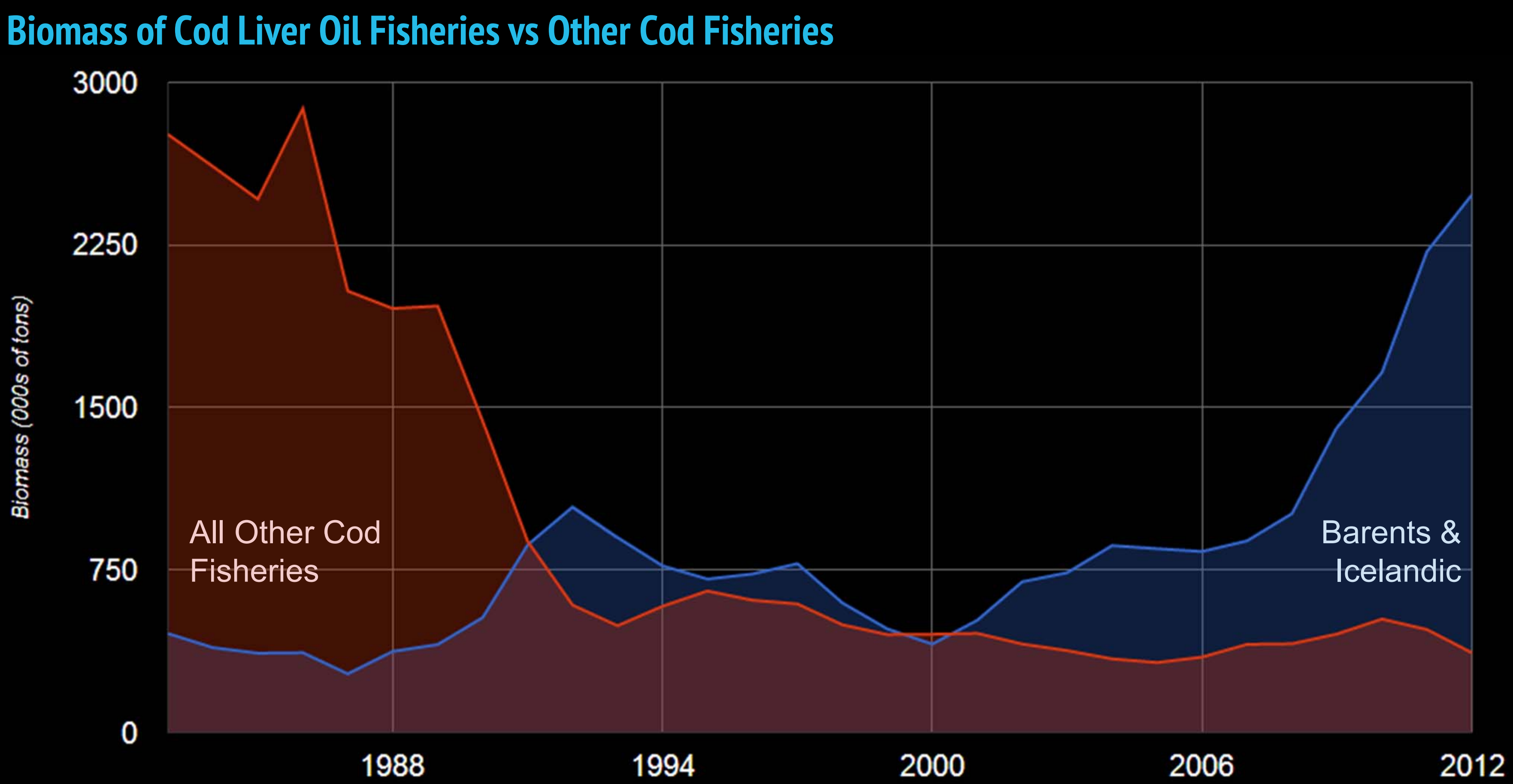
Source: GOED analysis of FAO and USDA data

The Peruvian Anchoveta fishery has suffered in the past from poor management, but has recovered due to successful, aggressive action.



Source: IMARPE

Most of the Atlantic Cod fisheries have been unable to recover despite fishing bans. Could this be related to low genetic diversity?



Source: FishSource

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Maximum Sustainable Yield

Managing the reproduction of the exploited species

Precautionary Principle

Managing variance in reproduction of the exploited species

Ecosystem Approach

Managing uncertainty in predators (usually) of the exploited species

Conservation Genetics

Managing genetic diversity to natural levels in the exploited species

What is being done to protect fisheries today?

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Preserving genetic diversity is not a significant part of fisheries management today, except in aquaculture and hatchery fisheries. Sustainability management is a constantly evolving process though, and genetic measurement can play a role.

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We also need to find new sources of EPA and DHA outside of the marine environment to close the broader gap and relieve pressure on fisheries.

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Commercially Available

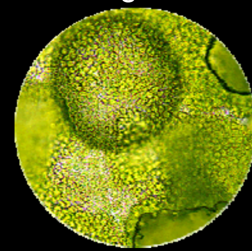
In Development

Fish

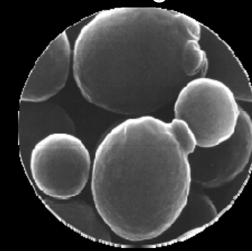
Squid

Zooplankton

Algae



Fungi



GM Plants

Fish:
Anchovy
Sardine
Mackerel
Tuna
Cod
Salmon
Menhaden
Trout
Pollock
Hoki
Halibut
Sandeel
Angelfish
Saithe

Squid:
Market Squid
Shortfin Squid

Zooplankton:
Antarctic Krill
Pacific Krill
Northern Krill
Calanus
Shrimp

Algae:
Schizochytrium
Crypthecodinium
Euglena
Nannochloropsis
Phaeodactylum
Nitzschia alba

Fungi:
Y. Lipolytica
M. alpina
Sap. diclina
Sac. kluyveri
C. elegans

GM Plants:
Soybeans
Rapeseed
Brassica
Linseed
Rockcress

The list of omega-3 sources, both commercial and in research, is getting longer with new algaes, new fish and new zooplankton projects having been announced in the last six months

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Algal sources of omega-3s are being researched in three predominant types of production systems

Fermentation

- Commercially producing DHA today
- High cost of capital
- Uses sugars as energy sources

Open-Air

- Limited production of EPA today
- High cost of capital
- Uses sunlight as energy source

Photobioreactor

- No commercial production today
- High cost of capital
- Uses sunlight as energy source

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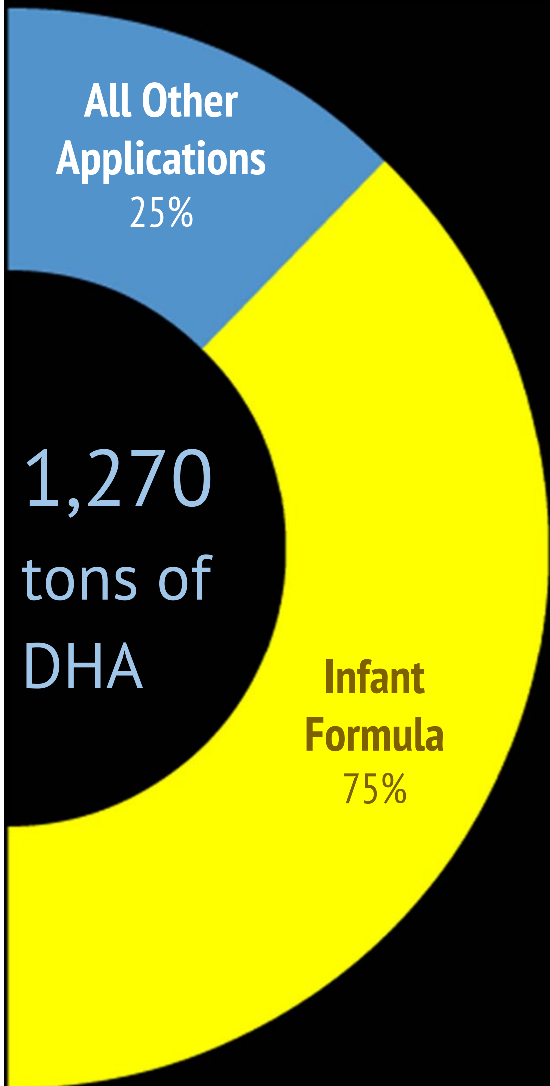


Most algal DHA is going into infant formulas and provides less than 0.2% of the world's omega-3 nutrition needs today.

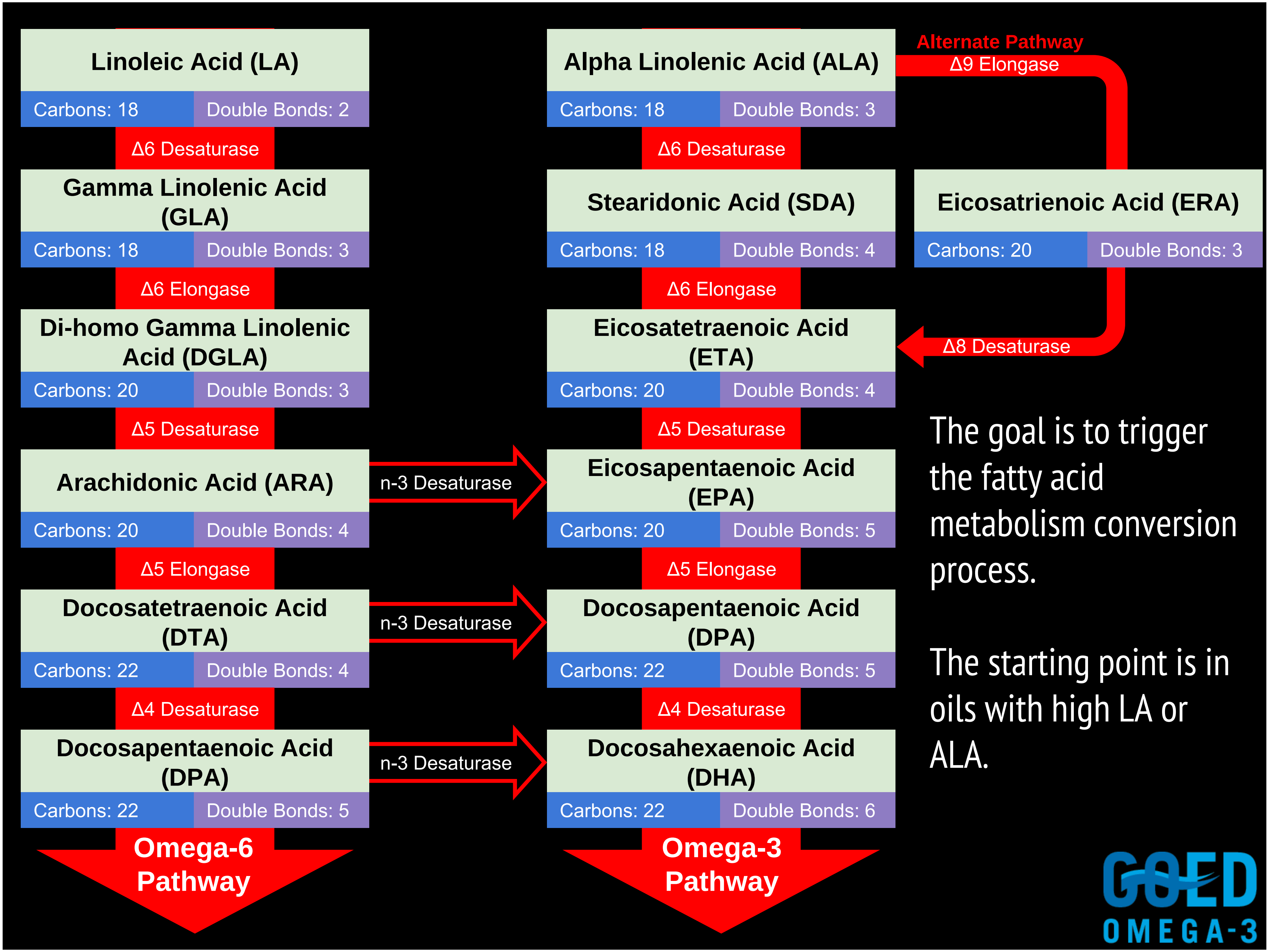
Source: Frost & Sullivan report commissioned by GOED

What is the potential of algae to fill demand that the oceans cannot provide?

It will depend on the economies of scale that these companies can achieve in order to displace their higher capital costs.

Research is also ongoing into plant sources of EPA and DHA, but plants do not natively contain these fatty acids.

This means genetic modification is required in plants.


Linoleic Acid (LA)
Carbons: 18
Double Bonds: 2
Δ6 Desaturase
Gamma Linolenic Acid (GLA)
Carbons: 18
Double Bonds: 3
Δ6 Elongase
Di-homo Gamma Linolenic Acid (DGLA)
Carbons: 20
Double Bonds: 3
Δ5 Desaturase
Arachidonic Acid (ARA)
Carbons: 20
Double Bonds: 4
Δ5 Elongase
Docosatetraenoic Acid (DTA)
Carbons: 22
Double Bonds: 4
Δ4 Desaturase
Docosapentaenoic Acid (DPA)
Carbons: 22
Double Bonds: 5
Omega-6 Pathway
n-3 Desaturase
n-3 Desaturase
n-3 Desaturase
Alpha Linolenic Acid (ALA)
Carbons: 18
Double Bonds: 3
Δ6 Desaturase
Stearidonic Acid (SDA)
Carbons: 18
Double Bonds: 4
Δ6 Elongase
Eicosatetraenoic Acid (ETA)
Carbons: 20
Double Bonds: 4
Δ5 Desaturase
Eicosapentaenoic Acid (EPA)
Carbons: 20
Double Bonds: 5
Δ5 Elongase
Docosapentaenoic Acid (DPA)
Carbons: 22
Double Bonds: 5
Δ4 Desaturase
Docosahexaenoic Acid (DHA)
Carbons: 22
Double Bonds: 6
Omega-3 Pathway
Alternate Pathway
Δ9 Elongase
Eicosatrienoic Acid (ERA)
Carbons: 20
Double Bonds: 3
Δ8 Desaturase
The goal is to trigger the fatty acid metabolism conversion process.
The starting point is in oils with high LA or ALA.
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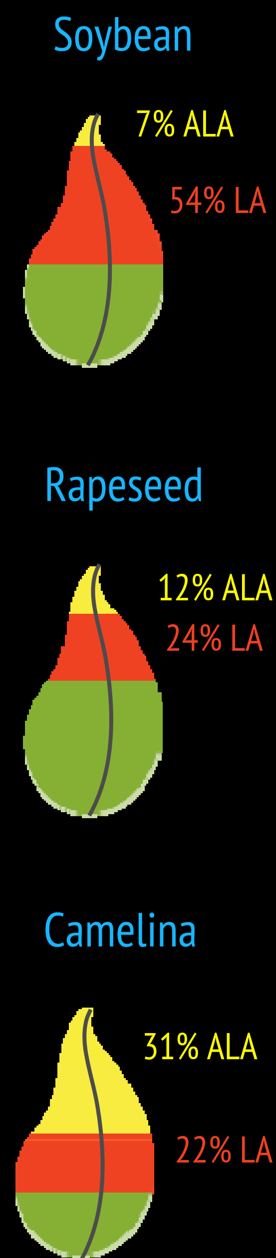
There are three primary sources of plant EPA and DHA under development, but the challenges are the same for all.



Open Questions

How much EPA and DHA will they yield?

Can the EPA and DHA be extracted?

What is the cost of extraction?

When will they be commercialized?

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What is the potential of plants to fill demand that the oceans cannot provide?

We do not know yet. However, if you can achieve 10% EPA+DHA content in the oil and normal oil yields, it could take 2.5 million hectares to yield 10,000 tons of EPA +DHA from soybeans. There are about 100 million hectares of non-EPA/DHA modified soybeans planted today. So EPA+DHA content is important!

Source: GOED Analysis of data from the International Food and Agricultural Management Review

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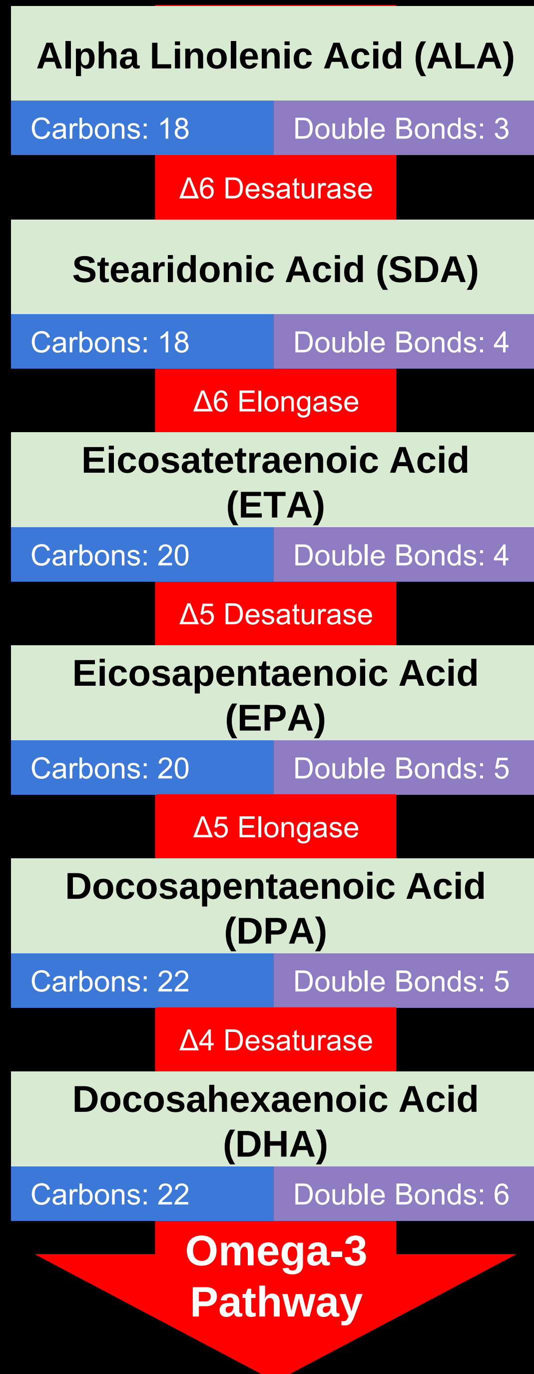
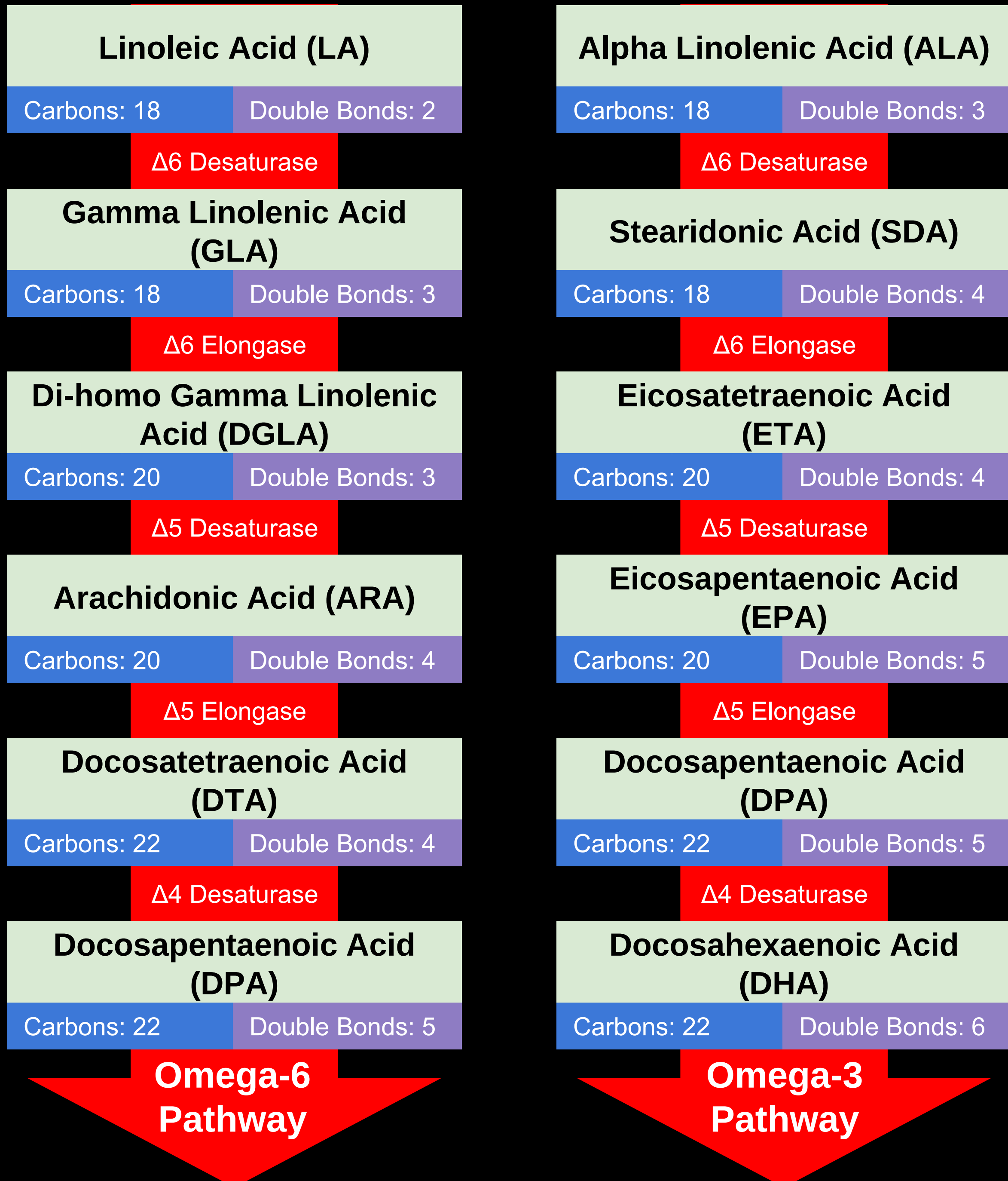
Background Appendix Slides



Omega-3 fatty acids follow a biological conversion pathway. ALA, a short- chain omega-3 is plentiful in land-based plants. Long-chain EPA and DHA are found in marine organisms.

Any organism can theoretically convert shorter-chain omega-3s like ALA into EPA and DHA, if they have the right enzymes.



The problem for humans is that omega-6 fatty acids compete for the same enzymes needed to convert short-chain omega-3s into EPA and DHA.

Omega-6s are even more plentiful in the diet than ALA, coming from soybeans, red meats, etc., and thus dominate enzyme usage and limiting omega-3 conversion.

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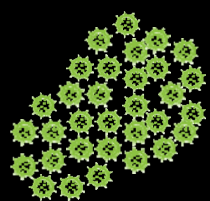
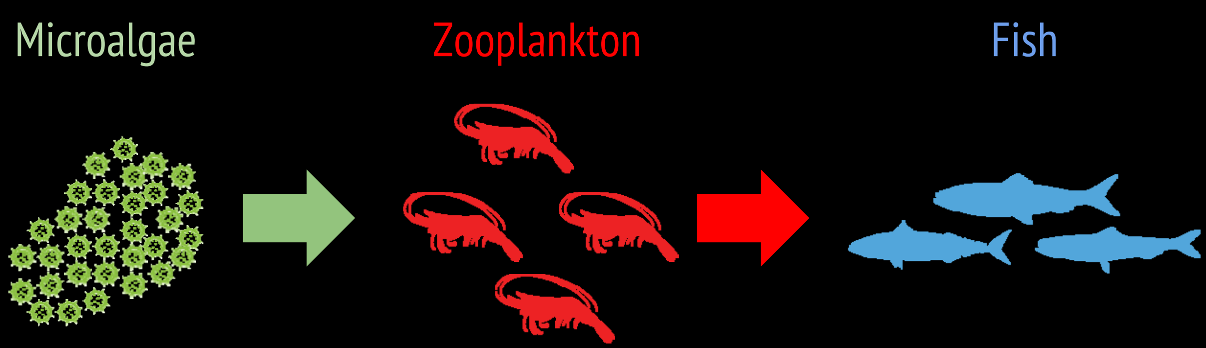
Microalgae



Human consumption of EPA and DHA starts with marine algae.

Marine microalgae synthesize sunlight with photoreceptors to produce carbohydrates, proteins and ultimately oxygen. The photoreceptors are formed from fatty acids, primarily omega-3s.



Successively larger marine organisms concentrate the EPA and DHA in their flesh and other organs.

Coldwater fish tend to accumulate EPA and DHA in their flesh because it allows for a more flexible cellular structure that is important for movement in cold environments.

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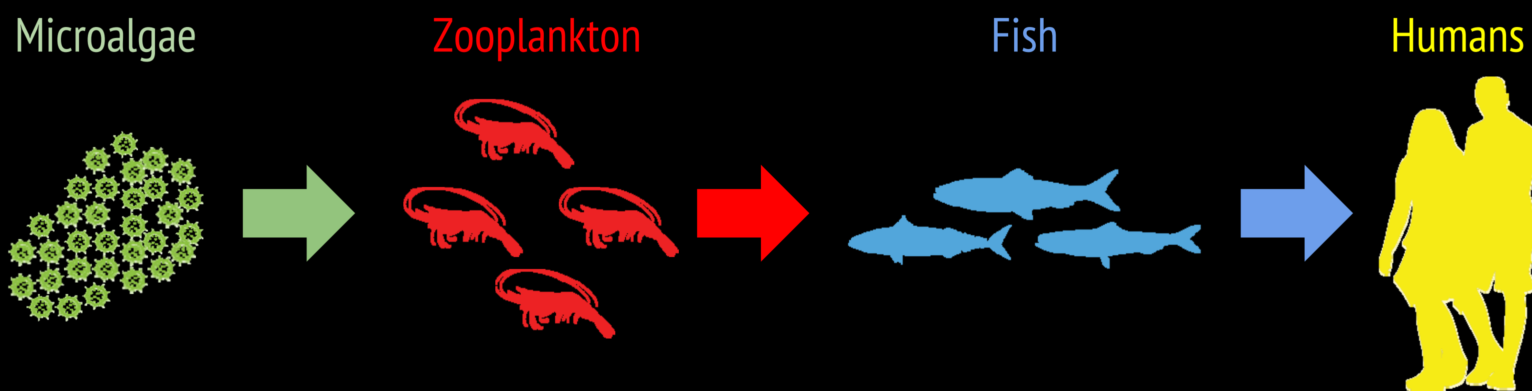

Humans consume EPA and DHA naturally through seafood consumption.

However, oil is extracted from some reduction fisheries and consumed through supplements and fortified foods as well.

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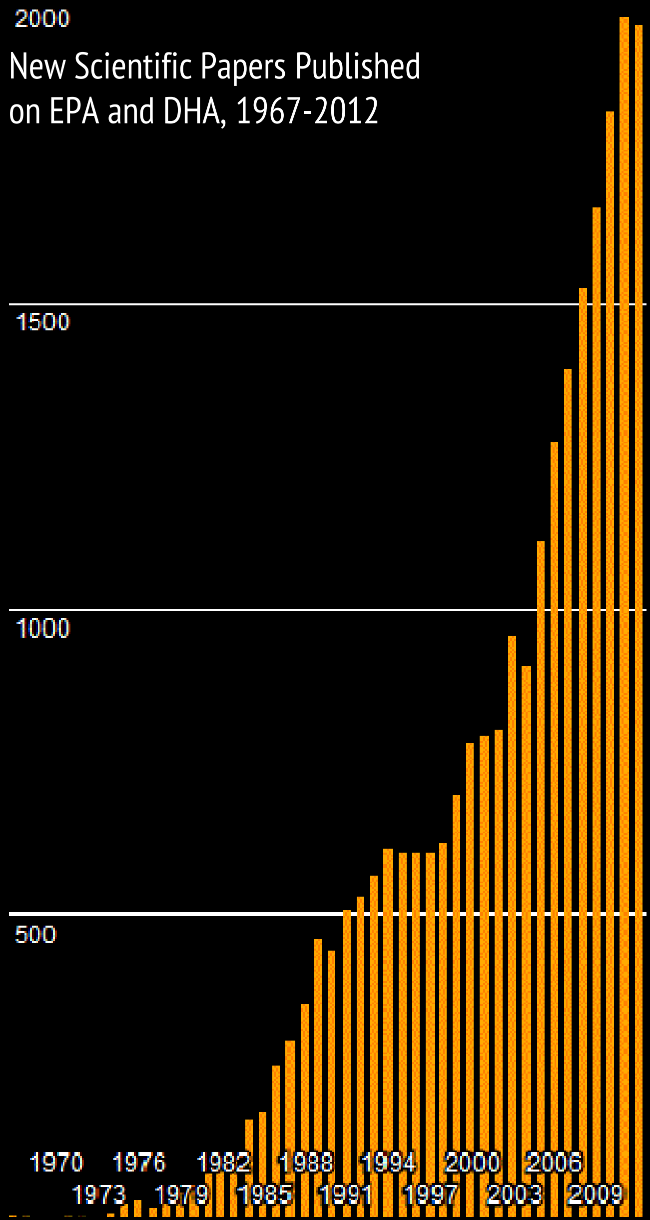


Even with more than

23,000

published papers and

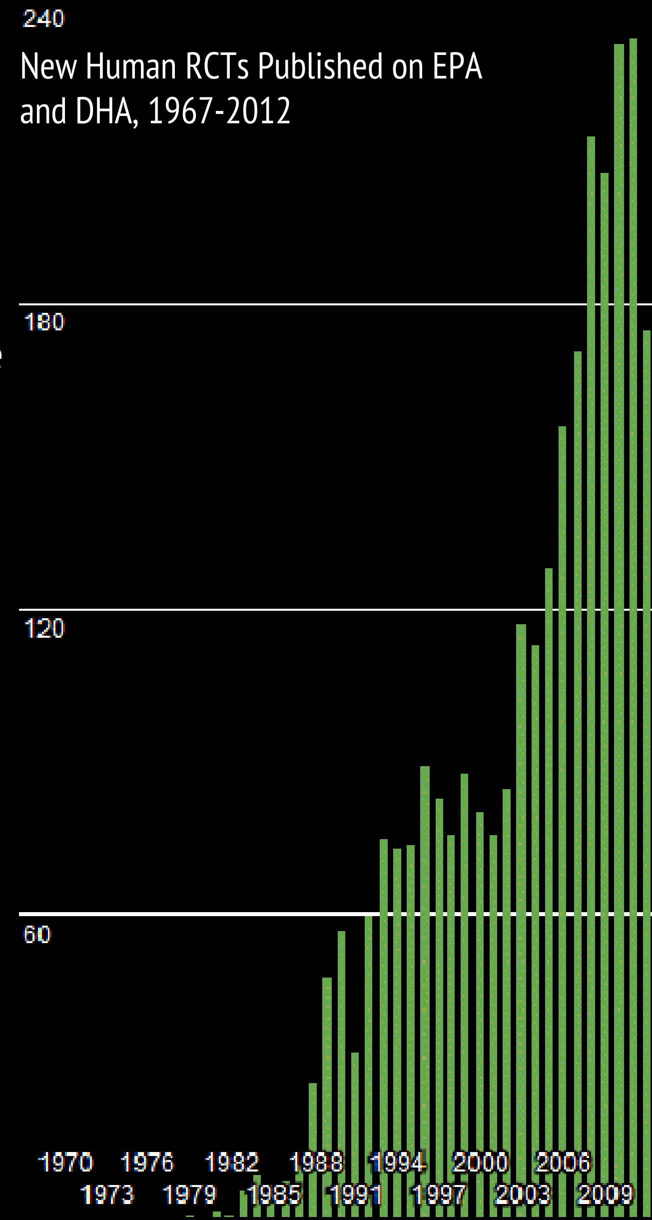
2,500

human clinical trials, we are still only

beginning

to discover the complete role EPA and DHA play in

human health



Source: Pubmed, as of August 25, 2012

EPA and DHA have four known biological functions.

Source: Norwegian Scientific Committee for Food Safety

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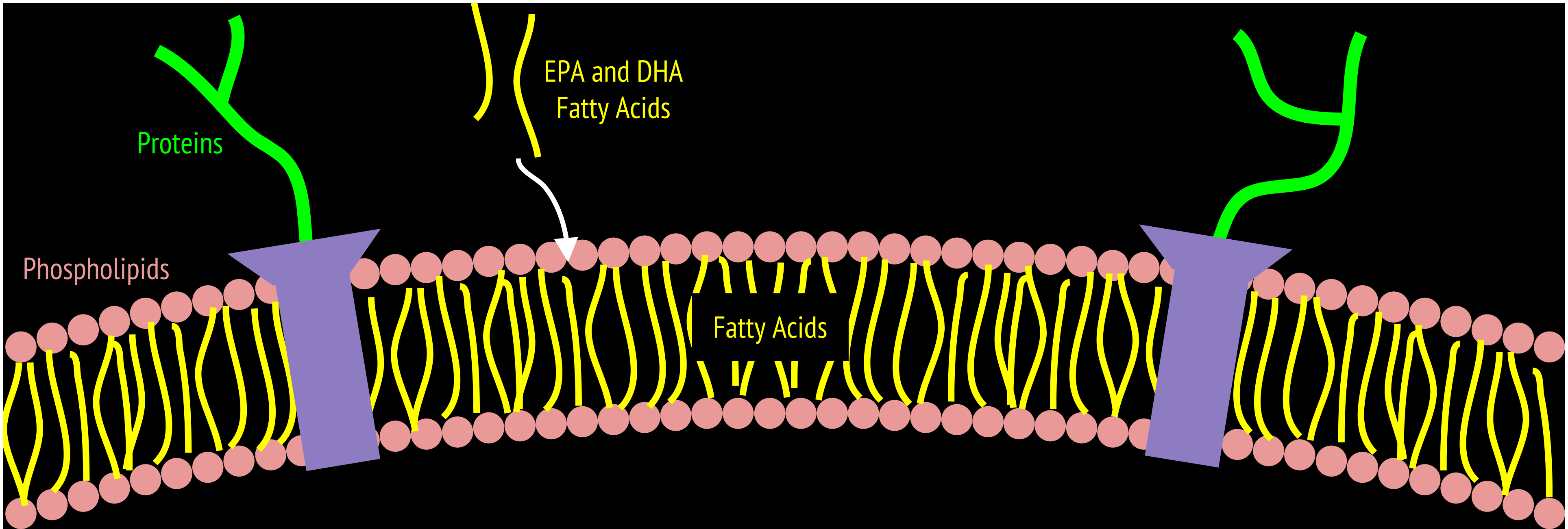

EPA and DHA have four known biological functions.

They are incorporated as structural components of cell membranes, increasing fluidity and allowing for proper functioning of proteins

Source: Norwegian Scientific Committee for Food Safety

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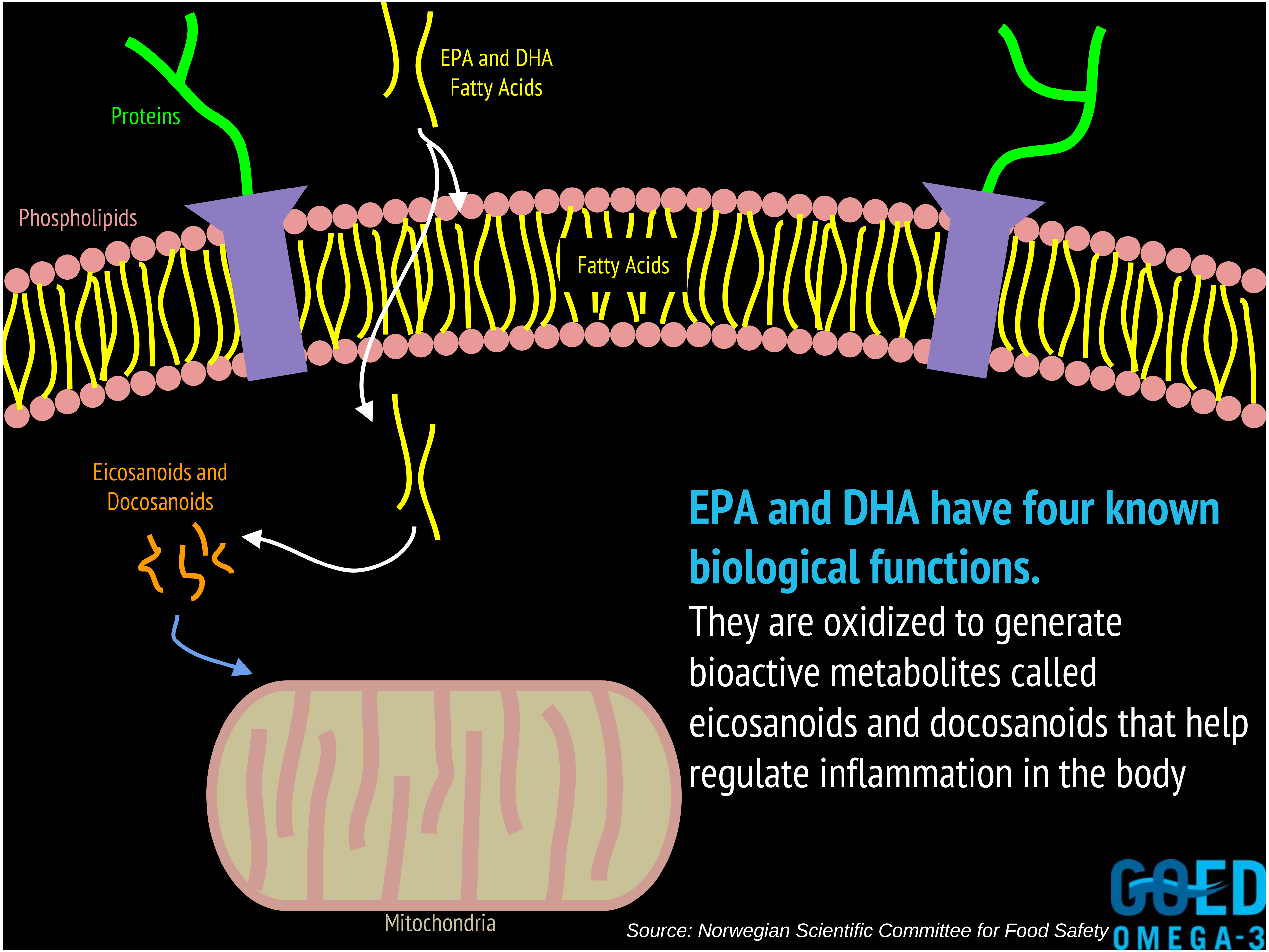
EPA and DHA
Fatty Acids
Proteins
Phospholipids
Fatty Acids
Eicosanoids and
Docosanoids
Mitochondria
EPA and DHA have four known biological functions.
They are oxidized to generate bioactive metabolites called eicosanoids and docosanoids that help regulate inflammation in the body
Source: Norwegian Scientific Committee for Food Safety
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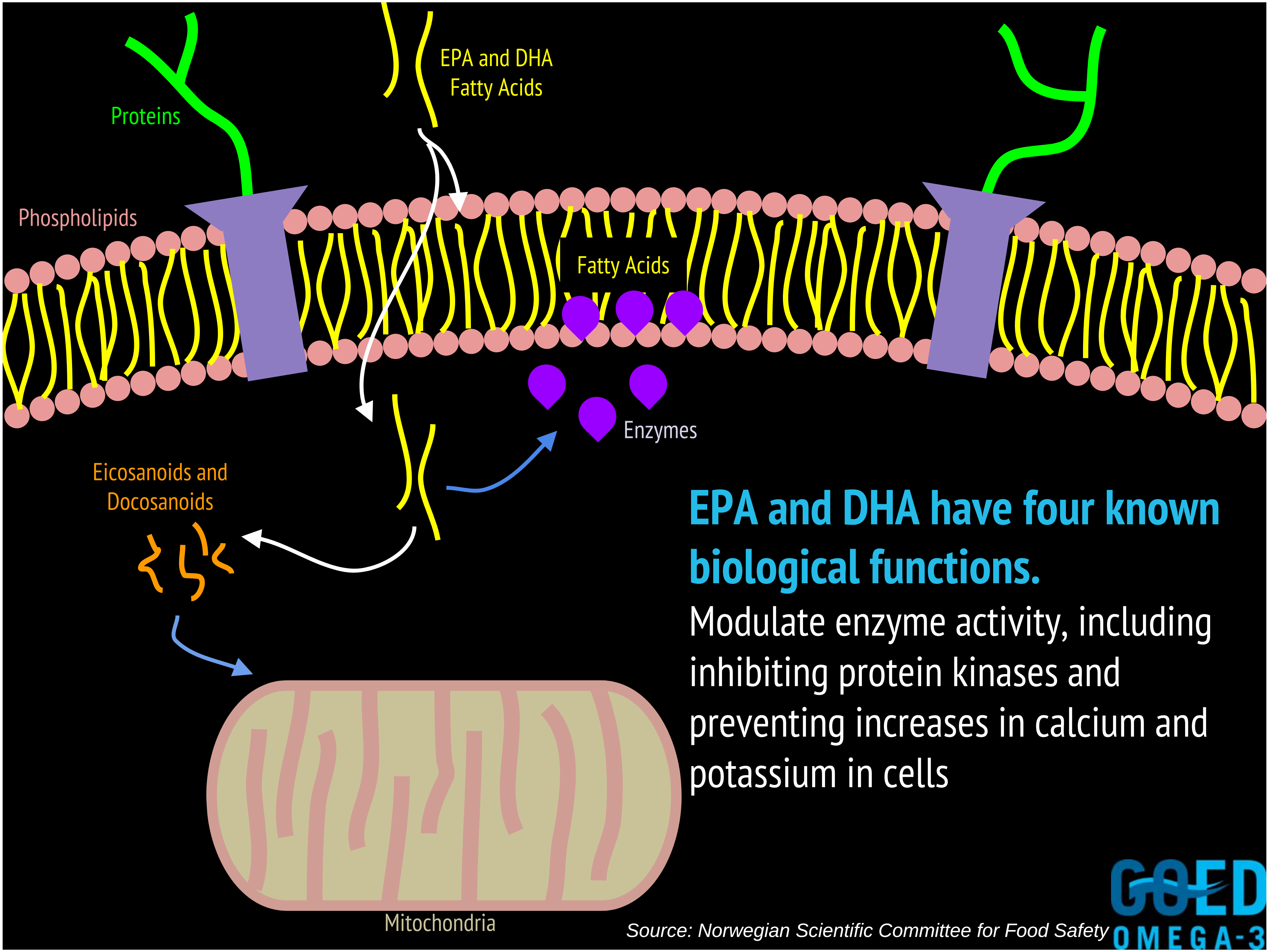
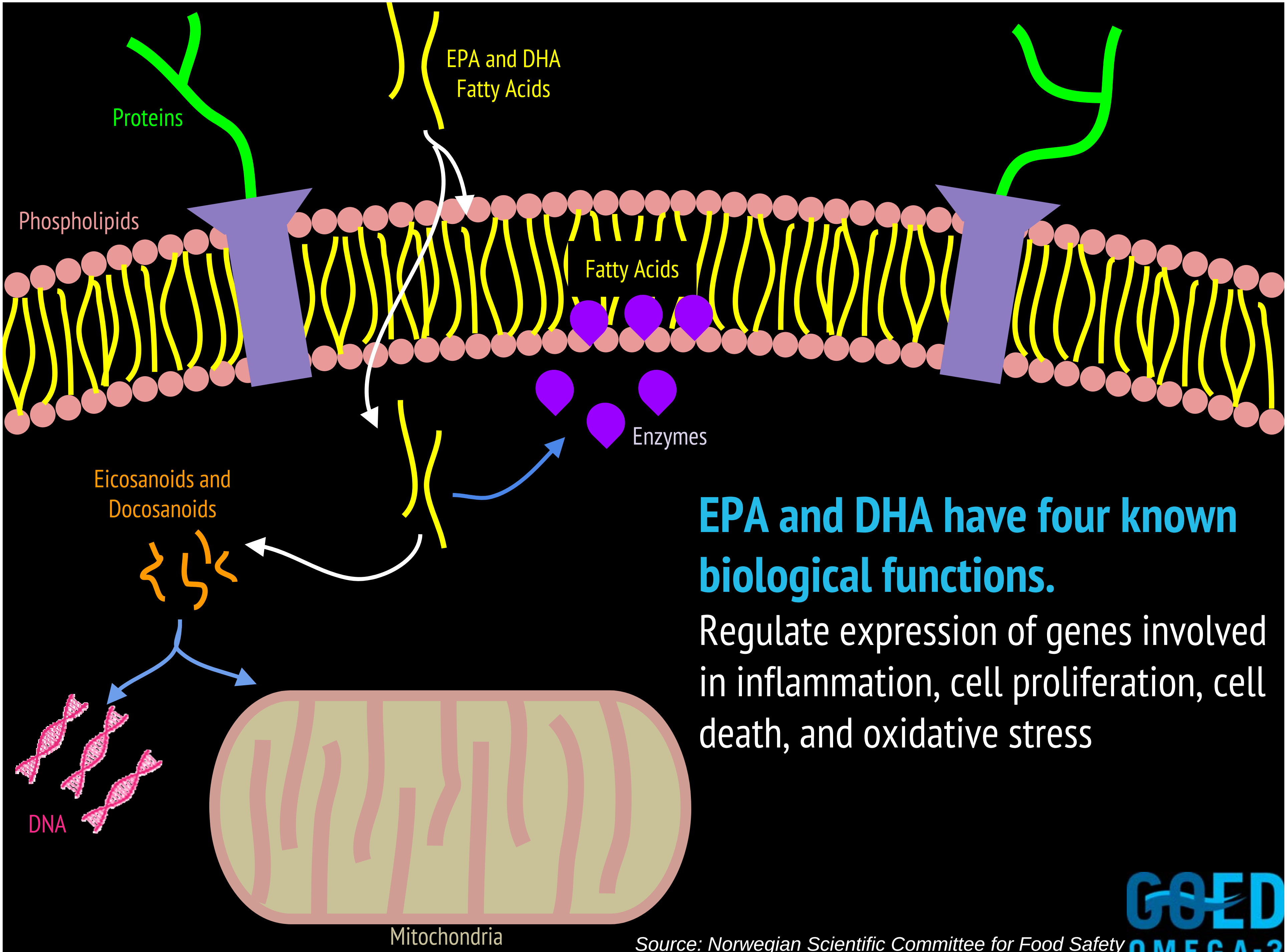

EPA and DHA Fatty Acids
Proteins
Phospholipids
Fatty Acids
Enzymes
Eicosanoids and Docosanoids
Mitochondria
EPA and DHA have four known biological functions.
Modulate enzyme activity, including inhibiting protein kinases and preventing increases in calcium and potassium in cells
Source: Norwegian Scientific Committee for Food Safety



EPA and DHA have four known biological functions.

Regulate expression of genes involved in inflammation, cell proliferation, cell death, and oxidative stress

Source: Norwegian Scientific Committee for Food Safety