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## *Long-chain Omega-3 Sources in a Resources Constrained World*

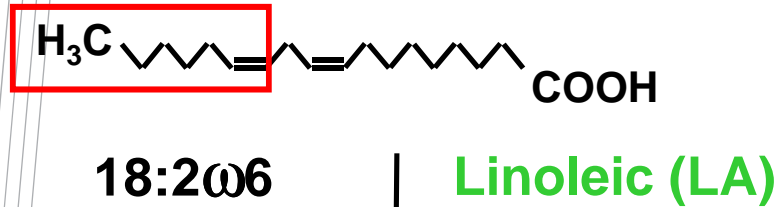
Peter Nichols, James Petrie, Surinder Singh  
Food Futures Flagship  
SA Food Industry Food Forum, August 2011

National Research  
**FLAGSHIPS**



# Essential Fatty Acid Families

## ω6 family



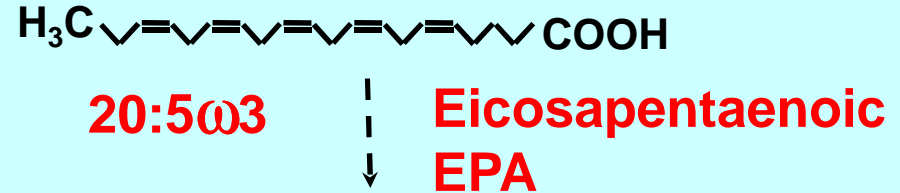
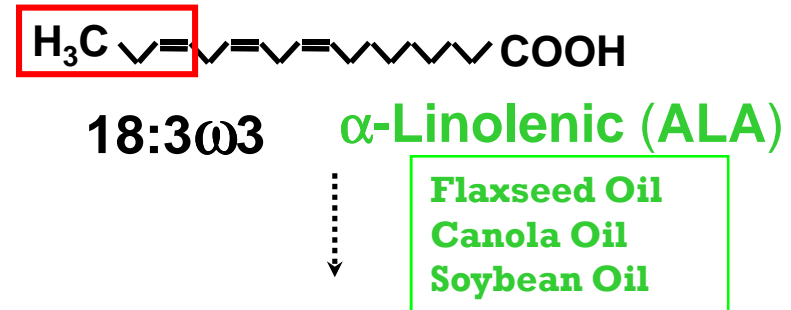
Corn Oil  
 Safflower Oil  
 Sunflower Oil



Meat, Eggs,  
 Brains

**Thrombotic  
Inflammatory**

## ω3 family



Microalgae  
 ↓  
 Seafood

**Anti-thrombotic**  
**Anti-inflammatory**

**LC Omega-3 Oils: ≥C20, two or more double bonds**



# Health benefits from LC Omega-3 Oils - I

- Prevention of CHD
- Lower blood pressure and plasma / serum lipid levels
- Anti-thrombotic
- Anti-inflammatory
- Neuropsychiatric disorders, including Alzheimers
- ADHD / related disorders
- Obesity / weight loss
- Asthma
- Kidney & liver disorders



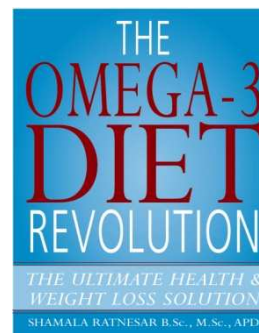
## Infant nutrition

- Brain & retina development

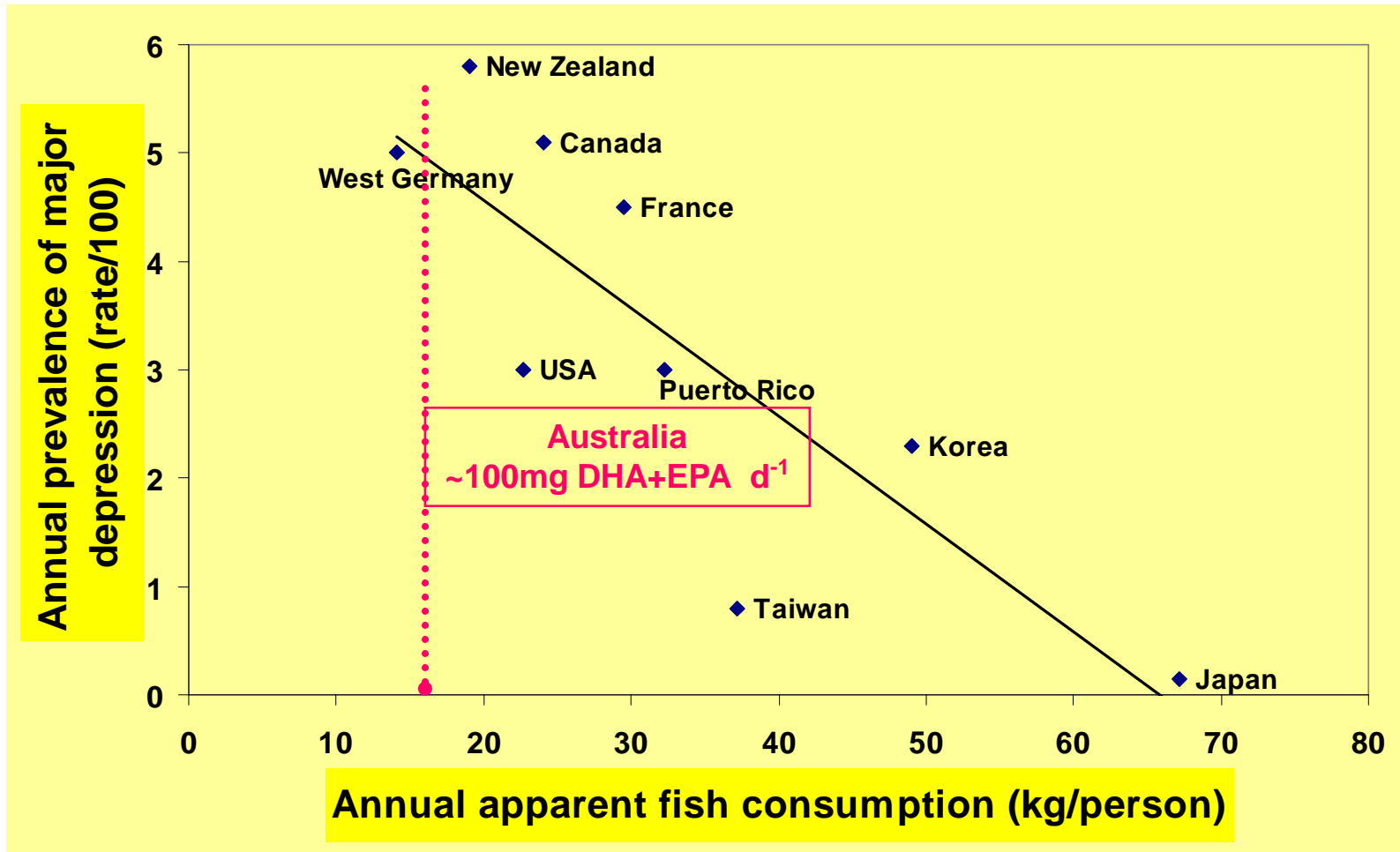


## Aquaculture & animal feed

- Larval nutrition
- Product quality



# Health benefits from LC Omega-3 Oils - II



# How Much LC Omega-3 Do We need?

Average intake - **EPA + DHA** in Australia:

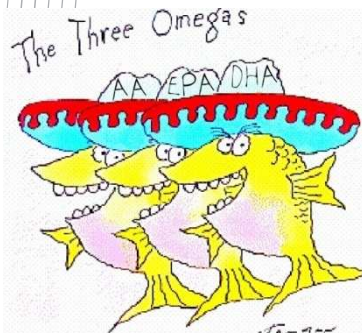
**30 mg/day** (Bureau of Statistics 1995); **175 mg/day** (Howe et al. 2006)

**2006 – NHMRC: Suggested Dietary Targets:**

- 610 mg/day - men, 430mg/day - women
- 1000-2000 mg/day for CHD patients

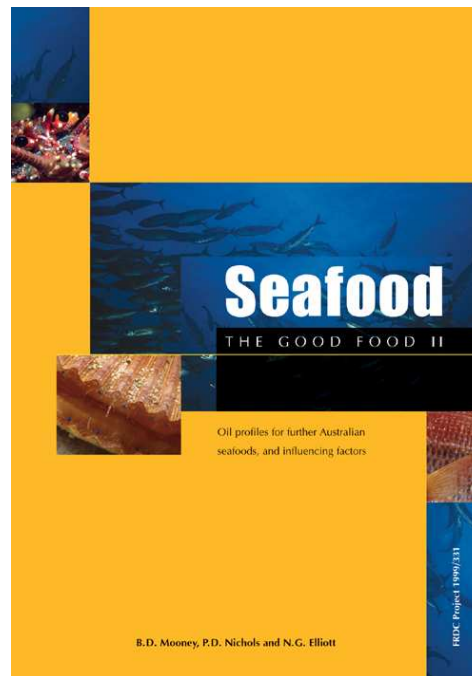
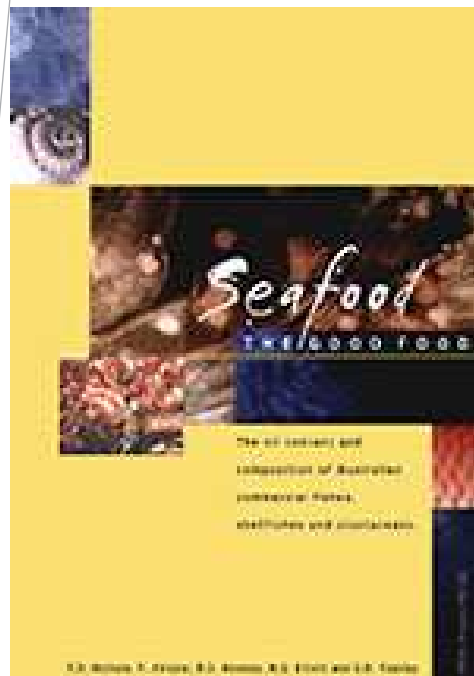
Most fish oil supplements - **18% EPA + 12% DHA**

2g fish oil supplies the SDT for **EPA + DHA**



# Australian Seafood - “The Good Oil I & II”

- Two “Guides” for consumers/industry
- By-product / by-catch included
- Results available for marketing seafood
- Results also in “Aust. Seafood Handbook”



## LC Omega-3 oils (mg per 100g)

Fish 235

Oysters 150

Prawns 130

Lobster 105

Turkey 35

Beef 22

Chicken 19

Lamb 18

Pork 0

Veal 0

# Omega-3 polyunsaturated fatty acids in Australian seafood

## fish high in omega-3

- slender tuna
- swordfish
- banded morwong
- alfonsino
- whitebait

## common fish

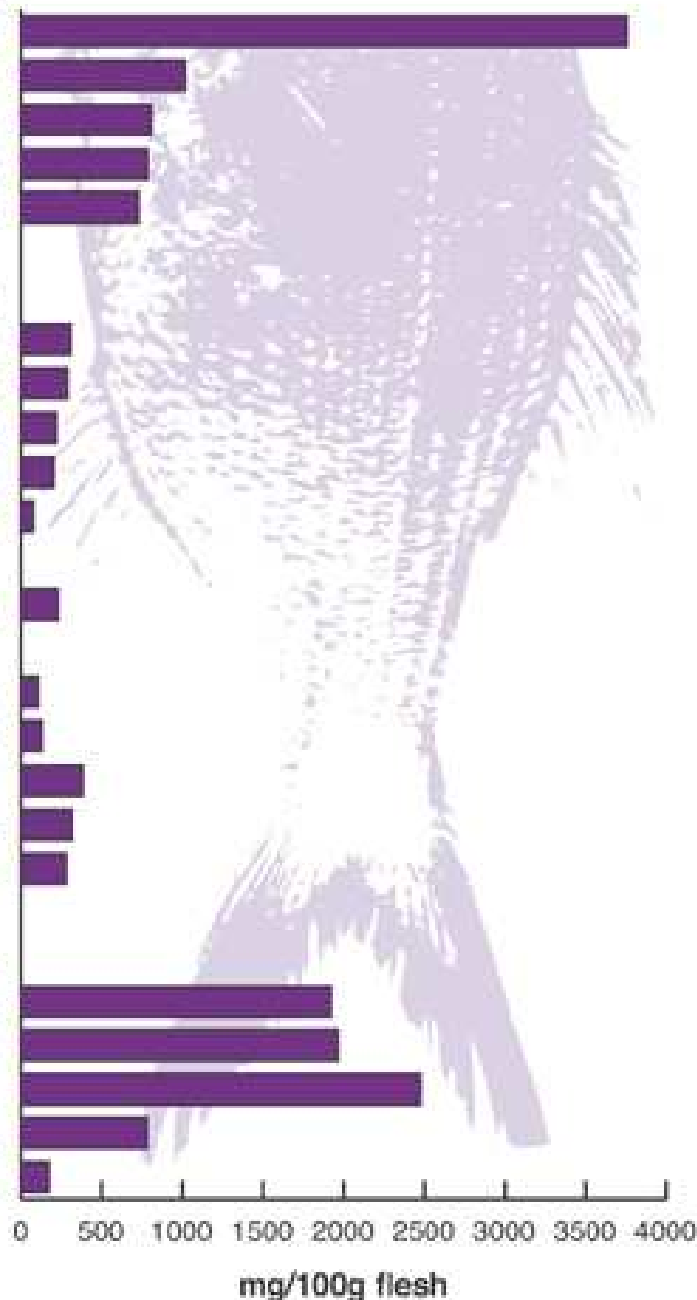
- blue eye
- gummy shark
- southern bluefin tuna
- tiger flathead
- king snapper

## fish average

- banana prawn
- southern rock lobster
- blue mussel
- Pacific oyster
- southern calamari

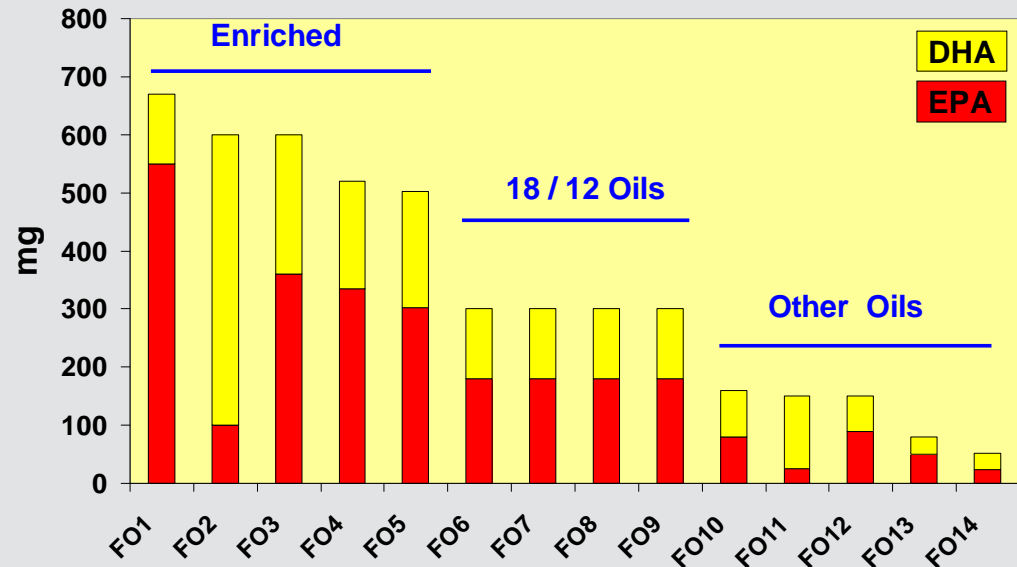
## farmed fish

- Atlantic salmon
- barramundi
- jade perch
- silver perch
- Murray cod

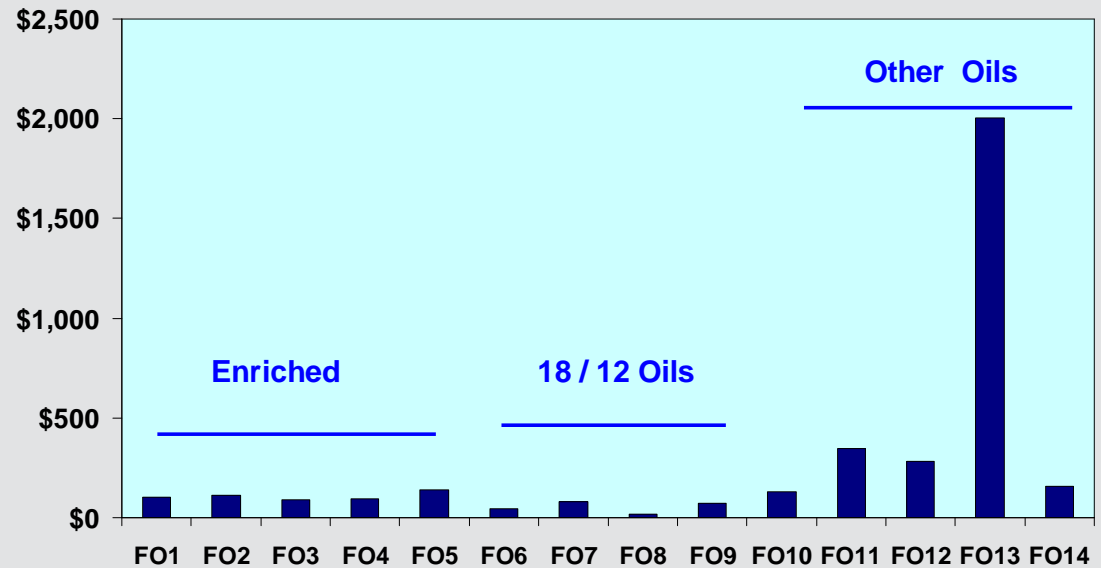


# Fish Oil Capsules

mg of EPA & DHA per Capsule



Cost per Annum to Supply 500 mg/day EPA+DHA



## Three Product groups

	Cost (pa)
Enriched oils	\$90-140
18/12 oils	\$20-80
Other oils	\$130-2000

# Aquaculture - Has the Good Oil gone missing?

July 2002, INFORM, AOCS:  
“warned that some species of farm-raised fish may have little or no omega-3 fatty acids.....”

(Stoll, Harvard Med. School)



20 — THE WEEKEND AUSTRALIAN SEPTEMBER 4-5, 2004 — 20

 Health

## Farm fish fail omega-3 trial

Emma Ross

**T**HE health benefit of eating oily fish such as salmon and mackerel seems to depend on what the fish are fed, new research has revealed. Also, adding vegetable oil to feed pellets appears to dilute the powerful heart disease fighting effect.

Fatty fish such as salmon, tuna, mackerel, sardines and herring are rich in omega-3 fatty acids, the healthy fat that scientists believe raises the good HDL cholesterol, lowers unhealthy triglycerides and slows the growth of plaque, protecting the heart from disease.

However, in modern fish farming, the fish are usually fed pellets

that contain a mixture of natural fish oil and vegetable oil.

In a study presented at the annual meeting of the European Society of Cardiology, Norwegian scientists showed that people who ate salmon fed on pure vegetable oil, or on 50 per cent fish oil and 50 per cent vegetable oil, did not get show meaningful improvement in the relevant blood tests.

The research involved 58 people with heart disease in Oslo, Norway. The fish was farmed in north-west Norway, colour-coded according to the pellets they were fed and shipped to a central kitchen in Oslo where they were transformed into meals and served.

One-third of the volunteers were

fed salmon that had been given pellets of fish oil, another third got fish fed on a 50/50 mix of fish oil and rapeseed oil, and the last group got salmon reared on pure rapeseed oil pellets. Each volunteer ate 700g of the fish per week, or one fish meal per day, for six weeks.

The scientists, led by Dr Harold Arnesen of Ullevål University Hospital in Norway, examined the blood of the volunteers at the beginning and the end of the six-week period to see the concentrations of omega-3 fatty acids and track changes in blood chemicals linked to heart disease.

“The composition of the food pellets was mirrored in the flesh of

the salmon fillets and again mirrored in the serum fatty acids of the patients,” Arnesen said.

Omega-3 levels increased substantially in the patients who ate salmon fed on fish oil, but not in the patients who ate salmon fed on mixed pellets or vegetable oil pellets. The results were the same for improvements in chemical markers of inflammation, which is involved in building plaque in the arteries.

The most impressive difference was in triglycerides, which fell by 30 per cent in the fish-oil group and not at all in the patients who ate fish reared on the vegetable oil or the fish oil mix. Triglycerides are the chemical form in which most

fat exists in food and in the body.

Everybody’s cholesterol dropped, but that was probably because they were eating fish instead of meat, which is high in saturated fat, the scientists concluded. Nobody lost weight during the study, which means the results could not have been due to differences in weight loss, Arnesen said.

“Only two per cent of the market today is wild salmon. The farmed salmon market today is very close to 50/50 feed. It’s what we have in Norway and it’s more or less the same all over the world,” Arnesen said. “The findings underline the importance of tailoring the salmon with heart protective properties.”

AP

# *Australian Farmed Fish – Good Oil (2011)*

- **Global fish catches static or declining**
  - *Fish oil used in aquaculture – replaced by other oils*
- **Farmed fish in Australia - LC Omega-3 oils **have decreased** cf 2002 findings**
- **Possible solutions include:**
  - *Change feeding strategies*
  - *Other sources (e.g. Single Cell Oils, Krill)*
  - ***Develop new sustainable sources of LC Omega-3 oils***



# **Global Fisheries:** **are there enough fish anyway – landmark papers**

**Myers & Worm (2003)** *Rapid worldwide depletion of Predatory fish communities.* **Nature** “large predatory fish biomass today is only about 10% of pre-industrial level”



**Worm (2006)** *Impacts of Biodiversity Loss on Ocean Ecosystem Services.* **Science** “..there would be no fish left by 2048”...

**Worm, Hilborn et al. (2009)** *Rebuilding Global Fisheries* **Science**. “ In 5 of 10 well-studied ecosystems, average exploitation rate has declined and is now at or below the rate predicted to achieve maximum sustainable yield for 7 systems”....

**Ray Hilborn (2010 pers. comm.)** “An interesting aspect in the equation is that the environmental impact of marine fisheries is seen as much less than for production of animal protein from agriculture that requires removal of forest and in many dimensions is also less than for vegetarian diets”

**Smith et al. (2011)** “New approach to sustain ‘forage’ fishing. **Science** Reduced catches of oceanic ‘forage’ fish like sardines & anchovies may be required to protect larger predators that rely on these species for food.”

## *Food Futures Flagship: LC Omega-3 Oils*

- LC Omega-3 oils essential for human & marine fish health
- Global fish catches static or declining
- Microalgae biosynthesize the **LC omega-3 oils** that fish consume & store. **Fish do not make EPA+DHA.**

### *CSIRO-wide project*

**Goal: Isolate omega-3 genes from microalgae & transfer them to crop plants to sustainably produce **LC omega-3 oils****



# LC Omega-3 Oils - engineering in land plants

16:0 → 18:0 → 18:1 → 18:2 → α-18:3

Land Plants



Δ6-des

18:4 SDA

Δ6-elo

20:4

Δ5-des

20:5 EPA

Δ5-elo

22:5

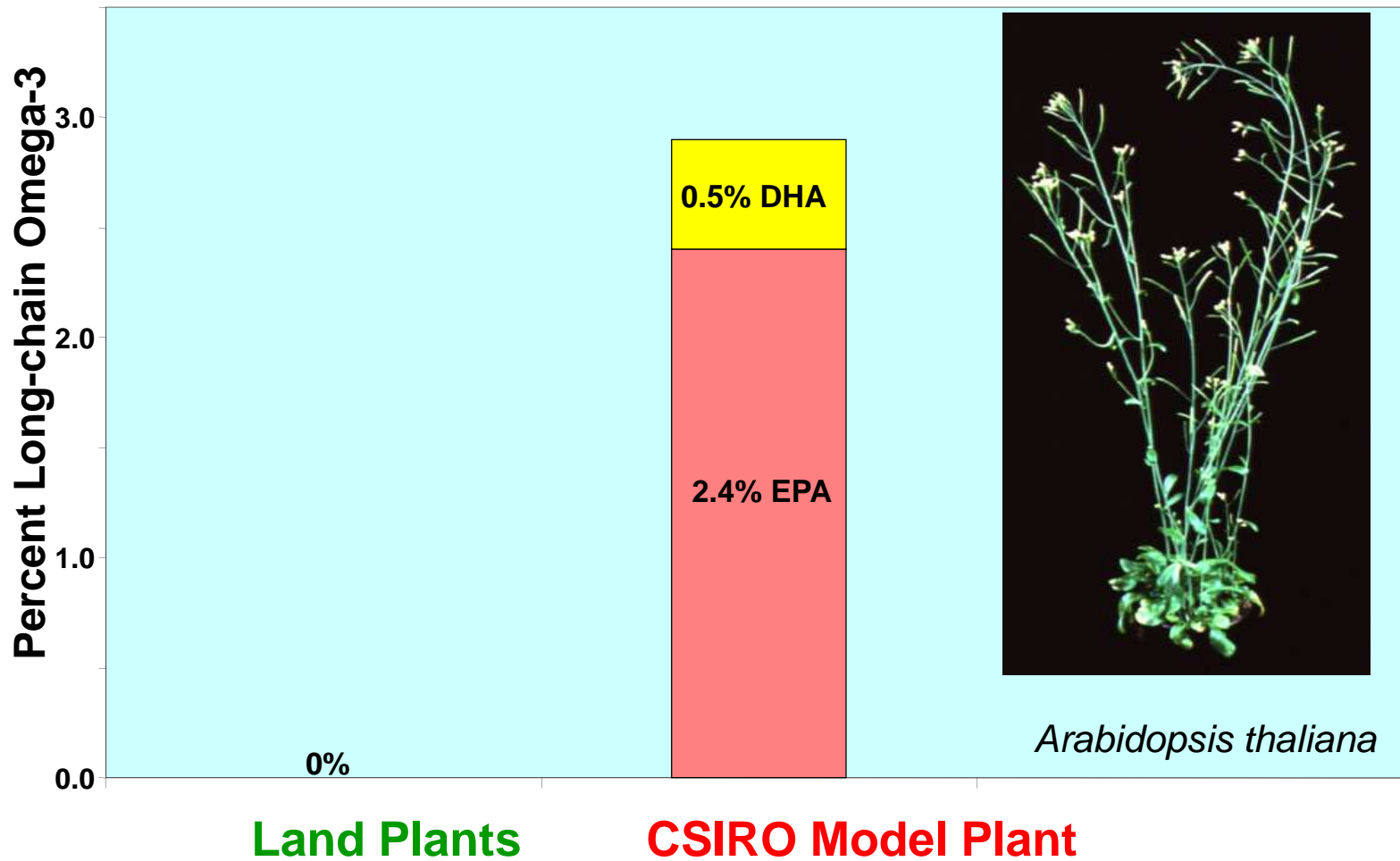
Δ4-des

22:6 DHA

Marine Algae

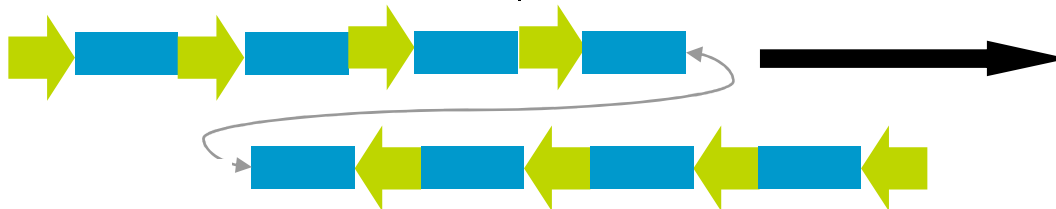
# Land Plant Achievements

First land plant with **EPA + DHA** in its seed oil



# SDA, EPA and DHA – New Land Plant Oils (2010-11)

	SDA	EPA %	ARA %	DHA %
<b>CSIRO: oilseeds</b> (includes model plants)	10	5		1
	1	26	2	
		0.2	22	5
<b>BASF: mustard</b>		15	7	1.5
		3	26	-
<b>Monsanto: soy</b>	20			
<b>Dupont: soy</b>		20		3
<b>Farmed salmon</b> <i>fed fish oil diet</i> <i>fed plant oil diet</i>		10		17
		1.2		5



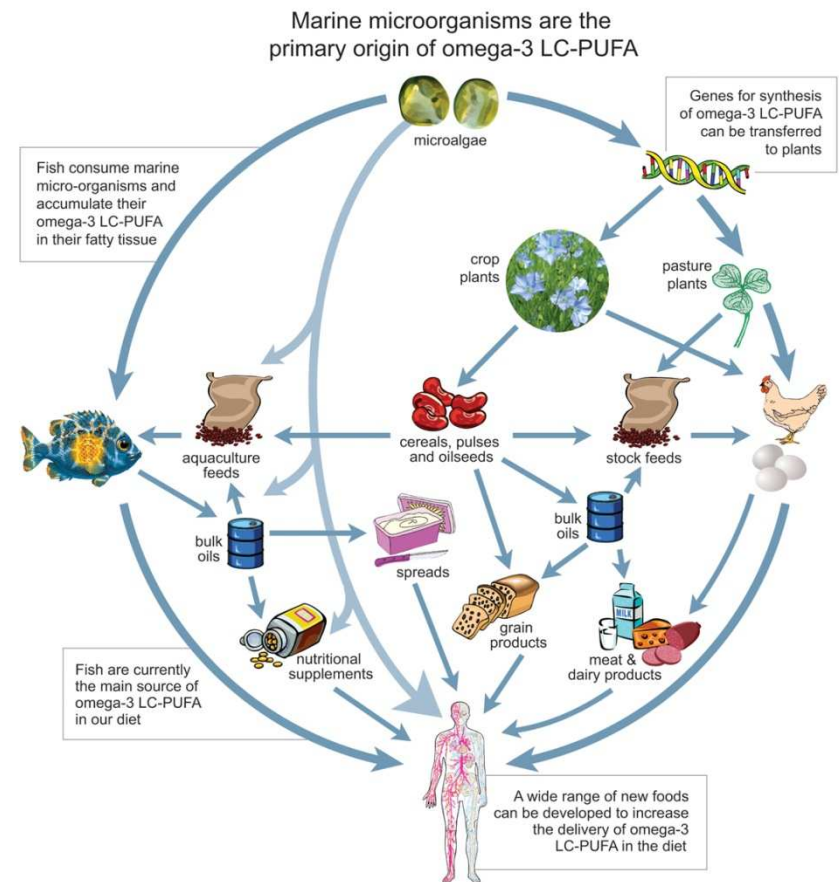
# DHA synthesis in seed oil – next hurdles

- CSIRO results show feasibility of developing oil seed crops with significant amounts of **DHA**

- Research ongoing to develop commercial oilseed crops with **LC Omega-3 Oils** – increase levels

of key components & oil content

- Research underway to open up new avenues for delivery of **DHA** to consumers via grains:
  - whole grains in foods
  - extracted oil in spreads
  - extracted oil as food ingredients
  - aquaculture and livestock feeds



# Consumer preferences

## ***Take home message:***

A large proportion of the population are accepting of GM land plant LC omega-3 oil that:

- provides a health benefit,
- was supported by health claims from a trusted source,
- was indirectly consumed (e.g. food for farming fish)

(Cox et al, 2008, 2010, in press)

## Summary – Novel Land Plant LC-Omega-3 Oils

- Need for alternate sources of **LC Omega-3** established: *drivers – health & supply issues, & environment*
- First demonstration that land-based plants can make **DHA** in their seeds when they have the necessary genes
- Research is progressing to develop commercial oilseed crops with **LC Omega-3 Oils**, and to open up new avenues for delivery of **DHA** to consumers
- *Industry, regulatory & consumer engagement underway or planned by CSIRO and partners*



# Summary – Novel Land Plant LC-Omega-3 Oils

## Next stage of R&D

- Nuseed-CSIRO-GRDC partnership announced April 2011

## ➤ Canola DHA



# The LC Omega-3 Oils Team

- **Plant Industry**

- Surinder Singh, James Petrie, Clive Hurlstone, Adam White, Ann Mackenzie, Qing Liu, Allan Green

- **Marine & Atmospheric Research**

- Peter Nichols, Sue Blackburn, Stan Robert, Dion Frampton, Peter Mansour, *Matt Miller, Julie Kimber, Basseer Codabaccus, Ramez Al Hazzaa, Will Bignell*

- **Food Science Australia**

- Chakra Wijesundera, Claudio Ceccato, Peter Fagan, Peter Watkins, Shiping Shen, Amy Richards

- **Human Nutrition**

- Mahinda Abeywardena, Julie Dallimore, Michael Adams, David Cox, Greg Evans, Haidee Lease

- **Livestock Industries**

- Soressa Kitessa, Paul Young

- **Food Futures – HQ and BD**

- Bruce Lee, Matthew Morell, Lindsay Adler, Rob Defeyter