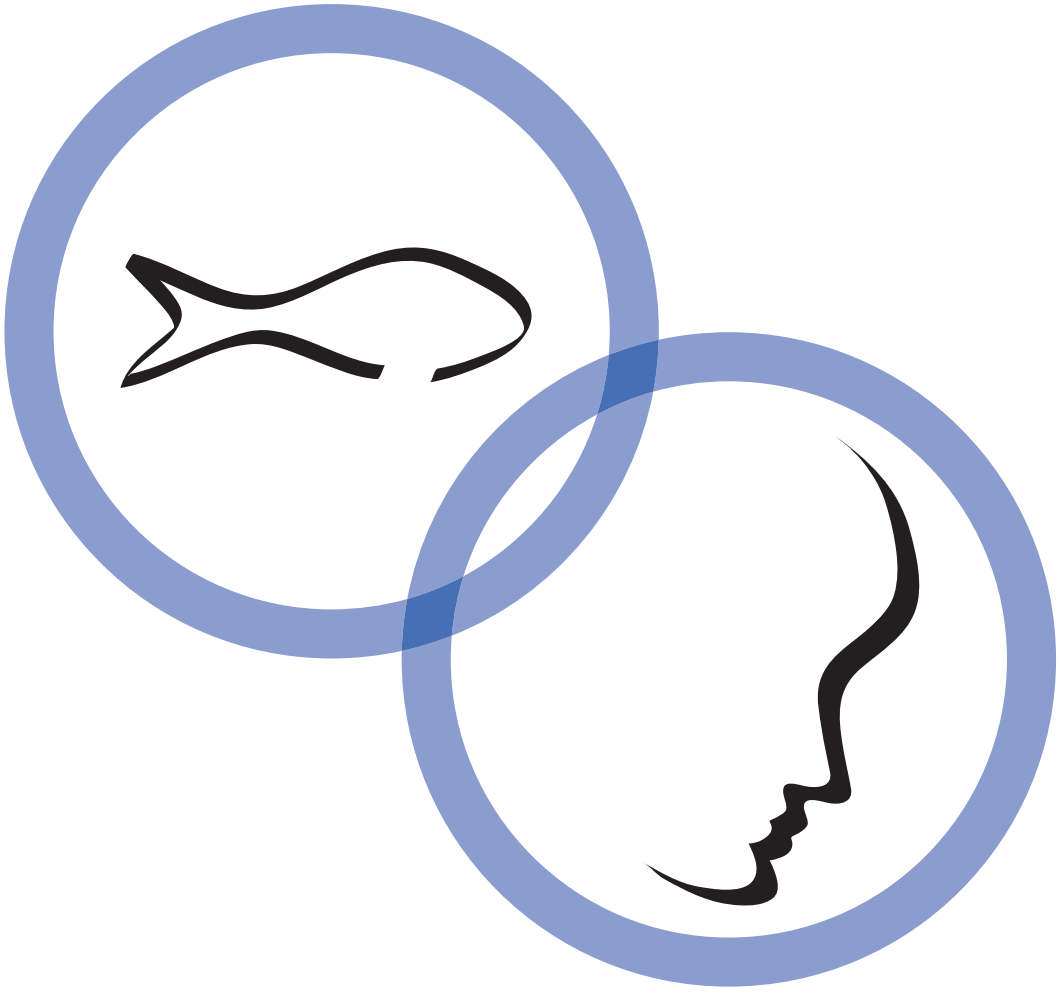
The Links Between Diet and Behaviour

The influence of nutrition on mental health



Report of an inquiry held by the Associate Parliamentary Food and Health Forum

January 2008

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Executive Summary and Recommendations

Nutrition is usually taken to be important for physical health, but mental health – brain health in its widest sense – must be considered as equally important.

A diet lacking essential nutrients or containing too many ingredients that are detrimental in excess is likely to have adverse consequences for brain function and thus mental health and behaviour. It is widely agreed that a balanced diet is required to support physical health – and there is good scientific evidence suggesting that the Mediterranean diet is a good model. It is likely that a balanced diet of this kind is also beneficial for the healthy functioning of the brain.

It is now established that certain essential fatty acids (EFAs) especially Arachidonic Acid (AA) and Docosahexaenoic Acid (DHA) form an important part of the cellular structure of the brain and in maintaining its normal functions. But there is no nutritional magic bullet. No nutrient works in isolation; a deficiency in one leads to sub optimal functioning of others. The lack of certain nutrients, however, may be associated with a range of mental and behavioural disorders as this report describes. A deficiency of omega-3 EFAs is associated with certain mental and behavioural disorders, such as ADHD, depression, dementia, dyspraxia, greater impulsivity and aggressive behaviour, but the association is still only partly understood.

We believe that on-going research into the nutritional aspects of brain structure and function should be supported and further expanded. This should be funded, and new research commissioned, by the Food Standards Agency (FSA) and the Department of Health, but also by the Department for Children, Schools and Families and the Ministry of Justice because they are responsible for the areas of policy where public benefits are most likely to accrue, if the evidence emerging from recent trials is confirmed by further research. The Medical Research Council and universities will undertake much of this research.

Public policy should be based on sound science and the evidence we have seen and heard endorses the widely held view among those working in this field that more research is needed and worth undertaking. However, what is already known about the importance of nutrition for the development of the brain and mental health has significant public policy implications. The key conclusions and recommendations that emerged from the series of inquiry meetings held by the Forum in Parliament between March and October 2007 and the written evidence submitted to the inquiry are as follows.

1. We recommend that the Government – principally the Department of Health, the Department for Children, Schools and Families and the Ministry of Justice, working with the FSA and the Medical Research Council – commission and support further research in the areas highlighted in this report.

2. We recommend that the Scientific Advisory Committee on Nutrition (SACN) should be asked to define further the optimum intake of omega-3 polyunsaturated fatty acids (PUFAs) in different stages of life, especially for pregnant women and children.

3. We also recommend that in the meantime, on a precautionary basis, the FSA should reconsider its advice to pregnant women about fish consumption, with a view to encouraging them to eat two portions of oily fish, or the equivalent in omega-3 PUFAs, a week (rather than that people should eat two portions of fish a week, of which one should be oily).[1]

[1] Scientific Advisory Committee on Nutrition (SACN) / Committee on Toxicity (COT). Advice on fish consumption; benefits and risks. 2004; The Stationary Office, London.

4. We also recommend that the FSA continues to monitor closely levels of mercury, dioxin and dioxin-like polychlorinated biphenyl (PCB) in the different species of oily fish available in the UK.

The scanty training for GPs and other medical professionals in nutrition and diet detracts from their ability to support their patients' physical and mental health; this issue should be addressed by the Royal Medical Colleges and the General Medical Council if we are to tackle the problems and costs associated with mental as well as physical ill health.

5. We recommend that the Royal Medical Colleges and the GMC consider upgrading the role of nutrition in the medical curriculum.

6. We recommend that Primary Care Trusts (PCTs) should increase the number of posts for dietitians working in the community and that GP practices should be fully reimbursed if they employ a dietitian to whom patients can be referred for nutritional advice.

The campaigns by the Department of Health and FSA to increase the consumption of fruit and vegetables and reduce consumption of sugar, salt and saturated fat are welcome, but they do not make explicit the emerging link between diet and mental well-being and the role of essential fatty acids, which appear to be crucial to children's life chances particularly *in utero* and in early childhood.

7. We believe the Government should take further action to raise public awareness of the significance of good nutrition in pregnancy and to tackle the incidence of low birth-weight in the UK.

The evidence which has emerged to date of the links between nutritional status and childhood disorders, depression, aggressive and anti-social behaviour merits further publicly funded research.

8. We recommend that more research to test the effect of selected essential fatty acids on the cognitive skills, mood and behaviour of both "healthy" children (that is, children suffering from no known disorders), as well as children suffering from a range of behavioural disorders should be undertaken.

9. We recommend that regulations should be introduced to prohibit all artificial colours and non-essential preservatives in food products and soft drinks.

10. We recommend that the Government includes financial support to School Breakfast Clubs as part of the package set up to improve school meals. We strongly recommend that all children entitled to free school lunches should be entitled also to a free school breakfast whose content, like school lunches, should be subject to quantified nutritional standards.

11. We recommend that the Department of Health encourages NHS Trusts to adopt an approach similar to that pursued by the Doncaster and South Humber Healthcare NHS Trust which undertakes a nutritional assessment of patients suffering from depression and patients with early symptoms of psychosis and provides dietary advice to them.

We recommend that consideration of the outcome of the next trial of nutritional supplements in Young Offender Institutes should be a priority for the National Offender Management Service (NOMS) given that our prisons are overcrowded and there is continuing concern about the mental health of prisoners, particularly young offenders at risk of self-harm and suicide. We recommend that any dietary intervention that can be used to improve the behaviour and mental well-being of offenders held in custody should be given serious consideration by the NOMS.

12. We recommend that the NOMS looks positively at the case for introducing nutrient-based standards for meals in prisons, similar to those introduced for schools, but based on recommended daily intakes for adults.

13. We also recommend that effective measures should be taken in all prisons to inform prisoners about the benefits of a good diet and to enable them to make healthy choices both while they are in custody and after their release.

14. We recommend that in all women's prisons national nutritional standards should be introduced to ensure that the basic dietary needs of pregnant women prisoners are achieved.

Because of the major potential benefit for the fields of education, crime, health and the well-being of vulnerable sections of society, we believe that more research is urgently needed in the area of nutrition and behaviour and we recommend that the Government devotes more resources to this, especially in corrective institutions and care homes.

We recommend that Department of Health messages on a healthy diet should emphasise the importance of a balanced diet for optimum mental as well as physical health.

While research continues to identify and produce alternative sources of omega-3 PUFAs, we recommend that all people in the UK should be encouraged to eat more fish, some of which should be oily fish, or its equivalent in omega-3 PUFAs.

Introduction

1. The Associate Parliamentary Food and Health Forum

1. As an "Associate Parliamentary Group", the Forum has Parliamentary and non-Parliamentary members, including a wide range of consumer groups, the food and drink industry and organisations with an interest in food and health issues, such as the Institute of Food Research, the Nutrition Society, the National Heart Forum, the Royal College of General Practitioners and trade associations. We exist to facilitate discussion between Parliamentarians and non-Parliamentarians on food and health issues. Further information about us is available on our website at: www.fhf.org.uk

2. The members of the Forum inquiry team were: Lord Rea, Chairman of the Food and Health Forum; his fellow Officers, Earl Baldwin of Bewdley, Dr Ian Gibson MP, Baroness Gibson of Market Rasen and Baroness Miller of Chilthorne Domer, and the Countess of Mar.

2. Acknowledgements

3. We are indebted to all the individuals and organisations who have given us oral and written evidence and advice. We take full responsibility, however, for the conclusions we have drawn and our recommendations to Government. The inquiry team would like to thank Patricia Constant of Central Lobby Consultants (CLC) for her assistance in drafting this report. CLC provides the Secretariat for the Associate Parliamentary Food and Health Forum. We are also grateful for the detailed scrutiny and criticism of an early draft by Ms Anne Dillon-Roberts, Lord Krebs, Professor Tom Sanders and Dr Lindy Williams. We would also like to thank Andrea Ross for designing the front cover.

4. We would like to acknowledge the general support of the Forum's sponsors: currently, Marks & Spencer, Princes Food and Weetabix, whose financial support for the Forum helps to make our work possible.

3. Background

5. The Officers of the Food and Health Forum decided in late 2006 that it would be potentially valuable to consider in more detail the influence of diet on mental health and behaviour and the public policy implications of current knowledge in this field. Recognising that this is a large and complex field and that our time and resources were limited, we decided that the primary focus of our inquiry would be the influence of essential fatty acids (EFAs) on mental health and behaviour (especially mood, memory, ability to concentrate, impulsivity and aggression). Our reason for this choice was that emerging evidence in this field holds out the promise of significant potential benefits (see section 4.1). We were also interested in exploring the science behind the sometimes sensational media reports which have generated much public interest in recent years.

6. The influence of diet on behaviour, while of growing academic and public interest, is not a new subject. Researchers in the UK, for example Bryce-Smith, Crawford and Peet, have been drawing attention to this subject since the 1960s.

7. In recent years there has been growing concern about increasing problems of anti-social behaviour and violence, as well as the impact of mental ill health among adults and children. A study in 2003 found that some 66,000 reports of anti-social behaviour were made to agencies

each day.[2] Depression is now the most commonly diagnosed mental health problem in the developed world and appears to be on the increase.

8. It is generally accepted that social and economic factors play a major part in these trends. However, over the same period a number of peer reviewed scientific trials in the UK and elsewhere have suggested that some people, including children with a range of behavioural/mental health disorders, benefit from a diet containing adequate omega-3 long chain polyunsaturated fatty acids (LC PUFAs). Other studies have demonstrated the significance of other micronutrients such as iron, zinc, folic acid and other vitamins.

4. Methods

9. In order to explore what is currently known about the role of nutrition and diet in influencing mental health and behaviour in certain areas - chiefly the behaviour of school children, individuals suffering from depression and offenders in custody - we issued two public calls for evidence in January and September 2007 (which are available on the FHF website at: www.fhf.org.uk/inquiry). Our call for evidence was sent to all Parliamentary and non-Parliamentary members of the Forum (including organisations such as the Nutrition Society, the British Nutrition Foundation and the Food Standards Agency), the Royal Society and the Academy of Medical Sciences. It was also posted on the FHF website and drawn to the attention of the national media.

10. Our call for evidence sought information on the effect of the consumption of essential fatty acids (EFAs) and other nutrients on mental health and behaviour. In particular it asked for evidence on which aspects of brain function were influenced by the consumption of EFAs (for example, mood, memory, ability to concentrate, impulsivity or aggression); the optimum daily intake of EFAs for the average adult or child; the ideal balance of omega-3 and omega-6; what role there might be for foods fortified with these; whether increased consumption of EFAs would be beneficial for the general population; and what policy recommendations should be made to Government concerning the consumption of EFAs in the UK.

11. We then held a series of meetings with researchers with published work in this field as well as public policy analysts and officials, to discuss what is known about the effect of diet on mental health and behaviour. We also discussed with these experts the public policy implications of this knowledge – what could, or should, be the next steps? The full minutes of these meetings are available on the Forum's website at: www.fhf.org.uk/inquiry. The contributors of oral and written evidence are listed in Appendix 1.

12. We are grateful to the Academy of Medical Sciences and others for drawing our attention to experienced scientists who take a more sceptical view of the impact of EFAs on mental health and behaviour and we have taken these views into account. We were also glad to receive evidence from scientists who drew our attention to strong evidence for the influence of other nutrients on mental health and behaviour, such as iron and glucose.

13. For those not familiar with the literature in this field, we have described briefly the relevant biochemistry of brain structure and function to indicate why omega-3 LC PUFAs are of importance for the brain (see Box 2, p.11). This has been extensively covered in many peer reviewed scientific papers and in a well referenced report produced in 2005 for non-scientists by Sustain.[3]

14. This report has been written by Parliamentarians primarily for Parliamentarians, most of whom are not scientists. We have tried to pull together the currently accepted scientific thinking as presented to us by our witnesses and published in the literature with an emphasis on the importance of EFAs in a healthy diet, but this is not a systematic review. We have tried to

[2] One day count of anti-social behaviour: September 10 2003, Home Office.
[3] Changing Diets, Changing Minds: how food affects mental well being and behaviour, 2005.

achieve a balance in our consideration of the issues under discussion, focusing in particular on research that investigated links between diet and behaviour. We fully acknowledge that more research is needed in these areas; indeed that is the primary message of this report. We recognise that dietary effects differ according to genetic disposition. Behaviour is also influenced by many other factors such as peer pressure, family attitudes, and sub-cultural and societal norms.

Research methods - a hierarchy of evidence [Box 1]

15. Several of our witnesses referred to the concept of a hierarchy of evidence, which flows from the least well established to the most. Research usually starts with a hypothesis, which may be the result of an epidemiological association or the result of direct case based observations. Although these associations may be statistically significant, in cross sectional or longitudinal cohort studies, there is always the possibility that confounding factors may explain the association, even when care is taken to rule these out as, for example, in the ALSPAC study used by Hibbeln. Having developed a hypothesis, researchers may postulate a plausible biological mechanism, which can then be tested in open (non-blinded) intervention trials. However, randomised, double-blind, placebo-controlled trials carry more weight. Still greater credence will be placed in the results of large scale trials. A meta-analysis of all or most known research studies in a particular field will be influential, but only if care is taken to include studies with negative as well as positive findings and if strict quality criteria are applied. Finally, a thorough systematic scientific review will produce the most credible results because of its transparency and the care taken to avoid bias and to assess all studies for their validity and methodology. The results of such a systematic scientific review can then provide the basis for well-justified decisions on treatment or community interventions.

16. Many earlier studies in the field of diet and behaviour were not randomised double-bind, placebo-controlled trials. Many have been small and covered a short time-span only. As a result we need to take care not to exaggerate the significance of preliminary or poorly designed studies. We also recognise that double-blinding is particularly crucial when investigating traits such as behaviour, which rely on assessments that are partly subjective. We believe therefore that the Government should provide adequate resources to enable well planned randomised controlled trials (RCTs) into nutrition and behaviour to be carried out.

17. When more research has taken place, policy makers will be faced with the task of applying information gathered from RCTs, which may have required the use of supplements in order to "blind" the study and ensure the consumption of the nutrients concerned, to recommendations about food and how to change dietary habits.

1. Nutrition and brain development

18. In the second half of the last century a rapid increase in the prevalence of coronary heart disease and stroke occurred in the developed world. This stimulated epidemiological and laboratory based research which has greatly increased understanding of the underlying factors which promote or interfere with the healthy development of the cardiovascular system.

19. Nutrition is one of these – an adequate intake of necessary nutrients (for example, micronutrients, essential fatty acids (EFAs), amino acids and anti-oxidants) is beneficial, whereas an excessive intake of some others (for example, saturated fat, sugar or salt) is detrimental.

20. The ideal "balanced diet" promoted by the Food Standards Agency (FSA) not only helps to prevent heart disease and stroke, but also reduces the risk of cancer, diabetes and other chronic diseases. Good nutrition promotes the normal healthy development and functioning of all systems. The brain and central nervous system are no exception. As human brain development is most rapid in late pregnancy and early childhood, nutritional factors have a particularly important role during these phases.

21. The eye, nervous system and the brain evolved in the marine environment of the Cambrian era some 600 million years ago in early forms of life. Although some of the original DNA of these life forms has changed over 600 million years, a significant proportion remains as it was in all forms of life today. The composition of the lipids critical for the signalling processes that eventually led to the development of the human brain, has hardly changed. Specifically Docosahexaenoic acid (DHA) has been structurally and functionally fixed in photoreceptors and synapses since that time[4] (see Box 3).

22. Arachidonic acid (AA) from omega-6 fatty acids and DHA from omega-3 fatty acids each make up some 8% of the dry weight of the brain.[5] DHA is also a vital component of the photoreceptors responsible for receiving light photons and sending image messages to the brain.[6] Some 30%-50% of the retina is made from DHA; severe DHA deficiency can reduce the efficiency of the initial stage of retinal signalling by more than a thousand-fold.[7] Omega-3 deficiency is associated with poor night vision and other problems with visual and spatial processing and focussing attention.

1. The effect of the changing human diet over time

23. Man became distinguished from the great apes about 7 million years ago, but we are only 1.2% different from the chimpanzee in our genetic make-up.[8] We are still adapted for a wild food diet that differs enormously from modern food. There are fewer calories and less fat in the wild forms of currently farmed animals and fish and what fat there is consists of a much higher proportion of polyunsaturated fatty acids (PUFAs). As we have moved from the wild to extensive animal husbandry, to selection for fast growth and intensively fed systems, the proportion of visible fat, and fat within the muscle tissue of the animals we eat, which is mostly saturated fat, has increased. Over this period the total proportion of calories derived from all fats has doubled to some 40%. Intake of saturated fats has increased, and coronary artery disease has soared since the 19th century. Similarly the annual intake of sugar (sucrose) per person in England

[4] Professor Crawford, written evidence 22 March 2007.
[5] MRC Vitamin Study Research Group. Prevention of Neural Tube Defects: Results of the Medical Research Council Vitamin Study. *Lancet* 1991; 338: no. 8760
[6] Neuringer M et al. The essentiality of n-3 fatty acids for the development and function of the retina and brain. *Annual Review of Nutrition* 1988; 8:517-41.
[7] Dr Alexandra Richardson, oral evidence 28 March 2007
[8] Fujiyama A et al. Construction and analysis of a human-chimpanzee comparative clone map. *Science* 2002 ; 295: 131-134.

increased from 6.8 kg in 1815 to nearly 54.5kg in 1970. In the USA it increased from 55.5kg in 1970 to 69.1 kg in 2000.[9]

24. The approximately equal presence of omega-3 and omega-6 fatty acids in the brain has led to the view among some researchers that dietary intake of the two should ideally also be balanced equally. However, the current intake ratio of omega-3 to omega-6 varies from 1:15 to 1:30 depending on diet and other factors. A number of scientists working in the field of nutrition believe this "imbalance" has important consequences for our mental health.

25. In the last century, average height in the UK rose by about 0.4 inches per decade. Cardio-vascular disease rose from a rarity, alongside several cancers, to be a major cause of mortality by the end of the century. Obesity is now a major health issue. Western man has thus changed in shape, size and disease pattern in one century. In the evolutionary timescale this is the "blinking of an eye". Professor Crawford and others believe that the changing lipid composition of the diet has been a major contributor to this change in body shape and disease pattern. [10]

Consumption of omega-6 and omega-3 fatty acids

26. The evidence for changes in the European food chain has been reviewed by Sanders.[11] Overall there has been a shift in the balance between omega-6 and omega-3 fatty acids over the past 30 years. He found that intake of Linoleic acid (LA) (omega-6) has risen in many northern European counties. In the UK, intakes have increased from ~ 10g/day in the late 1970s to ~ 15g/day in the 1990s. The intake of Alpha-Linolenic acid (ALA) (omega-3) is estimated to be ~1-2g/day, but varies with the culinary oil used. Soybean and rapeseed oils are currently the most plentiful liquid vegetable oils used. However both are commonly partially hydrogenated for use in commercial frying. This process leads to selective losses of ALA (omega-3). The increased use of intensive, cereal-based livestock production systems has resulted in a lower proportion of omega-3 fatty acids in meat compared with traditional extensive production systems.

27. There has been a rapid increase in soybean oil consumption from 0.12 kg/year to 12kg/year - a hundred-fold increase - in the USA food supply over the last century. Soybean oil consumption now accounts for 20% of calories in the average US diet[12] and half of these calories are derived from LA (omega-6), which creates Arachidonic acid (AA), (see Box 2, p.11) an important component of cell structures but which has inflammatory properties.

28. This dramatic change in the human diet during the last century has important implications because LA (omega-6) inhibits the conversion of ALA (omega-3) to the longer chain polyunsaturated fatty acids (PUFAs), Eicosapentaenoic acid (EPA) and Docosahexaenoic acid (DHA), because they compete for the same desaturase and elongation enzymes.[13] Thus, higher amounts of LA (omega-6) mean greater amounts of omega-3 PUFAs are required to have the same effect. The exact effect of an increased ratio of omega-6 to omega-3 is an area of on-going research and some controversy.

Links between omega-3 consumption and health

29. Hibbeln compared consumption of omega-3 from fish sources in different countries with mortality from various diseases and homicide. Japan and Iceland, with relatively high per capita consumption of omega-3 from fish sources, have the lowest premature mortality rates from

[9] Cordain L et al. Hyperinsulinemic diseases of civilisation: more than just Syndrome X. *Comparative Biochemistry & Physiology Part A* 2003; 136: 95-112.
[10] Fischer AG Fossils, Early Life, and Atmospheric History. *Proceedings of the National Acadamy of Sciences USA* 1965**;** 53 (6): 1205-1213.
[11] Sanders TAB Polyunsaturated fatty acids in the food chain in Europe. *American Journal of Clinical Nutrition 2007* (71) s: 176S-178S
[12] Gerrior S & Bente L Nutrient content of the US food supply, 1909-1999: a summary report. Washington DC, US Department of Agriculture Centre for Nutrition Policy and Promotion, 2002.
[13] Commander Joseph Hibbeln and Dr Alexandra Richardson, oral evidence March 2007

these diseases. Hibbeln also related omega-3 consumption from fish sources to post-natal depression, (omega-3 is rapidly depleted from mothers during pregnancy) and found high omega-3 intake was related to better outcomes, as in the mortality rates described above. [14]

30. Having calculated a dose response curve (see Box 3, p.17) for omega-3 intake and each of twelve diseases and all cause mortality, Hibbeln and colleagues calculated the percentage of a vulnerable population that could be protected from various illnesses by different omega-3 intakes. They found, for example, that some 48% of cardiovascular disease was potentially modifiable in this way. However, only at levels of 750mg/day of omega-3 from all food sources, as is typically the case in Japan, could 98% of the population be protected. This is far above the level currently recommended by the Scientific Advisory Committee on Nutrition (SACN) in the UK (two portions of fish per week, one of which should be oily).

31. Omega-3 intakes in the UK and US populations may need to be even higher than those of Japan to meet body tissue levels equivalent to those of Japan, because we consume higher amounts of LA (omega-6). Thus a healthy dietary allowance for omega-3 fatty acids for current US diets was estimated at 3.5g/day for a 2000-kcalorie diet.[15]

32. If high omega-6 intake is shown conclusively to inhibit EPA and DHA absorption or synthesis, an alternative to increasing fish and seafood consumption would be to reduce the intake of LA (omega-6) as each would result in more equal tissue ratios of EPA and DHA.

Biochemical factors in brain composition: why some fatty acids are essential [Box 2]

33. Appropriate nutrition is essential for the development and health of the brain, the largest organ in the human body. At least 39 essential nutrients must be provided by our food. These include vitamins and minerals, essential amino acids, and omega-3 and omega-6 fatty acids.

34. 60% of the dry weight of the brain is fat, mostly in the form of polyunsaturated fatty acids (PUFAs), whose molecules are most flexible. Moreover, essential fatty acids (EFAs) make up some 20% of dry brain mass. It would seem unsurprising, therefore, that the amount and type of fat in our diets influences brain structure and health. However it is only in recent years that this view has become more widely accepted.

35. Fatty acids are essential for the structure of all cell membranes - these omega-3 and omega-6 PUFAs increase the flexibility and fluidity of membranes. They affect brain growth and connectivity and are essential for the maintenance of optimal brain function throughout life. Cell signalling depends on membrane fluidity and omega-3 and omega-6 fatty acids and their derivatives affect many aspects of cell signalling. The substances we make from them can profoundly affect hormone balance, blood flow and immune system function.

36. Fatty acids from two “families” are called ‘essential’, because humans cannot make them – so they must come from the diet: Linoleic acid (LA) (omega-6) and Alpha-linolenic acid (ALA) (omega-3). Within the omega-3 and omega-6 series, it is the longer chain polyunsaturated fatty acids (PUFAs) that the brain really needs. They are not always called “essential” because humans can synthesise them from the “parent” essential fatty acids (EFAs).

37. Four PUFAs are particularly important for brain development and function: Dihomogamma-linolenic acid (DGLA) and Arachidonic acid (AA) from the omega-6 series and Eicosapentaenoic acid (EPA) and Docosahexaenoic acid (DHA) from the omega-3 series. AA and DHA are major structural components of neuronal membranes (making up 20% of the dry mass of the brain and more than 30% of the retina). EPA and DGLA are also crucial, but they play signalling rather than structural roles.

[14] Hibbeln J et al. Healthy intakes of n-3 and n-6 fatty acids: estimations considering worldwide diversity. *American Journal of Clinical Nutrition* 2006; 83: 1483S-93S.
[15] Hibbeln J et al. (2006) op. cit.

The essential fatty acid conversion sequence (simplified)

Omega-3 Conversion	Omega-6 Conversion
Alpha-Linolenic acid (ALA) (18 carbon atoms)	Linoleic acid (LA) (18 C atoms)
↓	↓
Eicosapentaenoic acid (EPA) (20 C atoms)	Gamma-linolenic acid (GLA) (18C atoms)
↓	↓
Docosapentaenoic acid (DPA) (22C atoms)	Dihomo-gamma-linolenic acid (DGLA) (20 C atoms)
↓	↓
Docosahexaenoic acid (DHA) (22 C atoms)	Arachidonic acid (AA) (20 C atoms)

38. However, the conversion of shorter-chain EFAs to longer-chain PUFAs in humans is poor. It is also affected by many diet and lifestyle factors including excessive consumption of saturated fats, hydrogenated fats and trans fatty acids; lack of co-factors such as zinc, magnesium, vitamins B3, B6 and C; viral infections and the presence of hormones released in response to stress; and the consumption of alcohol and smoking which help strip EFAs from the body. The conversion of EFAs to PUFAs is also affected by constitutional factors, such as ageing, atopic eczema and being male.

39. Omega-6 is available in vegetable oils, nuts, seeds and grains. The essential omega-3 fatty acid ALA is found in green leafy vegetables, seaweed (a rich source), soya, flax, some nuts and seeds (walnut and pumpkin), but the key long chain omega-3 PUFAs - Eicosapentaenoic acid (EPA) and Docosahexaenoic acid (DHA) - are mostly found pre-formed in appreciable quantities in fish and other seafood.

40. The terms 'saturated' and 'polyunsaturated'/'highly unsaturated' are derived from organic chemistry, the chemistry of carbon compounds, which includes all living substances. Carbon tends to link to four other atoms. Very many chemical compounds (including fatty acids) consist of long chains of carbon atoms. Compounds with all four links around each carbon atom, occupied by another atom, usually hydrogen or other carbon atoms, are called saturated. But sometimes there is a double link between two carbons in the chain and such compounds are called unsaturated. The double link changes the chemical properties in quite a fundamental way, making the substance more reactive. A polyunsaturated compound simply has several of these double links. The position of the double-link is important. For example, omega-3 is so-called because the first double bond between carbon atoms is three away from the methyl (omega) end (DHA has 22 carbon atoms) and this affects the way it works. Membranes are made of layers and the closer the double bond is to the methyl end of the chain, the more flexible it is. The other reason omega-3 is important is that the eicosanoids form the substrate for signalling molecules and they depend on the double bond between the third and fourth carbon atoms.

41. The omega-3 long chain PUFAs can be synthesised slowly from shorter omega-3s such as Alpha-linolenic acid (18 Carbon atoms) derived from plant sources (rapeseed, flax, walnut), but the longer chain omega-3 PUFAs, EPA (20 C) and DHA (22C) that are required by the brain, are obtained much more efficiently from oily fish. However, even these fish do not synthesise them themselves; they derive them from algae including sea weed. Some companies are now using genetically engineered seaweed and simpler forms of algae to produce DHA and EPA.

42. All unsaturated chemical compounds are vulnerable to attack by peroxide free radicals. These can damage most living systems and are responsible for initiating many diseases, including cancer. Polyunsaturated fatty acids in the body need protection. Antioxidants such as the tocopherols (E306-9, also known as Vitamin E) can do this. Vitamin E is highly polyunsaturated and it mops up the dangerous free radicals before they can attack the fatty acids. Thus, many of the supplements used in trials in which omega-3 has been an active ingredient have also included small amounts of vitamin E. Oleic acid, a mono-unsaturated omega-9 fatty acid, is also easily oxidised and can act as a free radical barrier for EFAs.

2. Significance of the maternal diet for the development of the brain

43. At birth babies' heads are much closer to their final size than are their bodies, which suggests that the brain takes priority in the early development of humans. In fact brain development starts early in pregnancy and is largely finished by two years after birth. So the stage is set for life during this early developmental period. Damage or developmental restriction at this time cannot be repaired later. The cost of neuro-developmental disorders in early life is thus disproportionately high because they are life-long.[16]

44. There is evidence that the development of a child's brain is significantly affected by the mother's diet during pregnancy. Supplementing infant formula with pre-formed polyunsaturated fatty acids (PUFAs) (both omega-3 and omega-6), found naturally in breast milk, has been shown to improve visual and cognitive development.[17]

45. The consumption of pre-formed DHA in a mother's diet affects the amount present in breast milk.[18] Although this might appear to have important implications for the babies of vegetarian and vegan mothers, who have lower levels of DHA,[19] studies by Professor Sanders and others have concluded that these differences in fatty acid composition were not statistically related to differences in birth weight, head circumference or length.[20] Professor Tim Key suggested to us that "there is an absence of evidence" as to any effect on the mental development of these babies.

46. More recently, however, a consensus statement from the international Perinatal Lipid Intake (PERLIP) Working Group and the Early Nutrition Programming Project[21] concluded that intake of fish or other sources of long chain omega-3 fatty acids results in a slightly longer pregnancy duration. It found that a "higher DHA supply to the fetus (sic) during pregnancy and to the infant after birth was associated with beneficial effects on the development of visual acuity, cognitive functions and attention, maturity of sleep patterns, spontaneous motor activity and immune phenotypes, in cohort studies and in a limited number of randomised controlled trials."

47. Professor Alan Jackson advised us that, where maternal dietary supply of DHA is only marginally adequate and intake is not changed during pregnancy and lactation, meeting the increased requirement for DHA for the healthy development of the infant brain depends on conservation of PUFAs by reduced oxidation; the amount of pre-formed EPA and DHA which can be accessed from adipose tissue reserves; and the ability to increase the formation of DHA from precursors such as Alpha-linolenic acid (ALA) (omega-3).

48. A recent study[22] found evidence to support the hypothesis that breastfeeding benefits long-term stereoscopic (binocular vision) development, and an effect of DHA cannot be excluded, but the lack of difference in stereoacuity (visual function) between infants randomly assigned to DHA-containing formula and those assigned to control formula suggests that factors in breast milk other than DHA account for the observed benefits.

49. In another recent study,[23] scientists at King's College London studied the effect of breastfeeding on IQ. By looking at more than 3000 children in Britain and New Zealand they

[16] Professor Michael Crawford, written evidence 22 March 2007.
[17] Makrides M et al. Effect of maternal docosahexaenoic acid (DHA) supplementation on breast milk composition. *European Journal of Clinical Nutrition* 1996; 50(6): 352-357.
[18] Sanders TAB & Reddy S The Influence of a vegetarian diet on the fatty acid composition of human milk and the essential fatty acid status of the infant. *The Journal of Paediatrics* 1992; 120: S71-77.
[19] Sanders TAB et al. The influence of maternal vegetarian diet on essenttial fatty acid status of the newborn. *European Journal of Clinical Nutrition* 1994; 48: 358-368.
[20] Sanders TAB & Reddy S (1992) op cit. Sanders TAB et al. (1994) op cit.
[21] Koletzko B et al Dietary fat intakes for preganant and lactating women. *British Journal of Nutrition* 2007 doi: 10.1017/S0007114507764747.
[22] Singhal A et al. Infant nutrition and stereoacuity at age 4-6 y. *American Journal of Clinical Nutrition* 2007; 85(1):152-9
[23] Caspi A et al. Moderation of breastfeeding effects on the IQ by genetic variation in fatty acid metabolism. *Proceedings of the National Academy of Medical Sciences* 2007; (10.1073/pnas.o704292104).

found that it raised intelligence by an average of 7 IQ points, but only if the children had the "C" version of the FADS2 gene, which is involved in the genetic control of fatty acid pathways. Fortunately some 90% of children have this "C" version of the FADS2 gene. This study shows the intellectual development of children is influenced by both genetic inheritance and environmental experiences, in this case breastfeeding. These issues merit further investigation and some is already underway.

Low birth weight and risk of future ill health

50. The UK has the highest incidence of low birth-weight of any Western European country.[24] Although low birth-weight is only a crude marker of pregnancy outcome, it is a powerful predictor of future ill health: heart disease, stroke, diabetes, poor learning abilities, mental ill health and crime. At the extreme end, very pre-term, low birth-weight infants are at high risk of central nervous system disorders such as Cerebral Palsy. These outcomes are worst in lower socio-economic groups. The Little Foundation's European Cerebral Palsy study concluded that the majority of cases arise from adverse prenatal conditions and thus are potentially preventable.[25] [26]

51. There is evidence that lower DHA levels are associated with a shorter gestation length[27] and a greater risk of risk of preterm delivery.[28] The lower the birth-weight the greater is the risk of brain disorders. This increases from 1 or 2 per 1,000 normal live births to over 200 per 1,000 in extremely low birth-weight infants - "the tip of an iceberg of poor mental development and risk of chronic ill health."[29]

Maternal intake of EFAs - risk of exposure to toxins in fish versus children's IQ

52. In 2004 the Scientific Advisory Committee on Nutrition (SACN) and the Committee on Toxicity of Chemicals in Food, Consumers Products and the Environment (COT) published a report, *Advice on fish consumption: benefits and risks.*[30] They recommended maximum levels at which the health benefits of preventing heart disease clearly outweigh the possible risks from dioxins. The FSA has advised us[31] that their recommendations represented a "minimal and achievable average population goal, which does not correspond to the level of fish consumption required for maximum nutritional benefit." The COT report concluded that the evidence to suggest an improvement in cognitive function of the developing foetus with increasing levels of fish consumption was inconclusive. The FSA continues to hold this view, despite the publication of more recent research findings which indicate a positive benefit, such as Hibbeln et al in *The Lancet,* February 2007 (see below).

53. The FSA advised us that: "Studies investigating the effects of diet on cognitive function are hard to interpret, as factors influencing brain development are complex and multi-factorial." The FSA acknowledges that: "A range of epidemiological data suggests that low intakes or poor nutritional status is associated with poor development (including a range of cognition and other

[24] Professor Michael Crawford, written evidence 22 March 2007
[25] Bax M et al. Clinical and MRI correlates of cerebral palsy: the European Cerebral Palsy Study. *The Journal of the American Medical Association* 2006; 296(13):1602-1608.
[26] Crawford MA et al. Arachidonic and Docosahexaenoic Acids in Protection Against Central Nervous System Damage in Preterm Infants. *Lipids* 2003; 38(4): 303-315.
[27] Olsen SF et al. Gestational age in relation to marine n-3 fatty acids in maternal erythrocytes: a study of women in the Faroe Islands and Denmark. *American Journal of Obstetrics and Gynecology* 1991: 164:1203-1209. Olsen SF et al. Randomized clinical trials of fish oil supplementation in high risk pregnancies. Fish Oil Trials In Pregnancy (FOTIP) Team. *BJOG*: *An International Journal of Obstetrics and Gynaecology* 2000; 107: 382-395. Smuts CM et al. A randomized trial of docosahexaenoic acid supplementation during the third trimester of pregnancy. *Obstetrics and Gynecology* 2003; 101:469-479.
[28] Olsen SF & Secher NJ Low consumption of seafood in early pregnancy as a risk factor for preterm delivery: prospective cohort study. *British Medical Journal* 2002;324:447.
[29] Professor Michael Crawford, oral evidence 28 March 2007.
[30] SACN/COT report 2004 op cit. See: http://www.sacn.gov.uk/pdfs/fics_sacn_advice_fish.pdf
[31] FSA letter, 1 October 2007

performance outcomes relating to learning) in early childhood. Potential confounding and bias in these studies, however, makes it difficult to draw firm conclusions." [32]

54. As a result of the SACN/COT report, the FSA advises that "girls and women who might have a child in the future and women who are pregnant or breastfeeding can eat up to two portions of oily fish (280g) a week; other women, boys and men can consume up to four portions of oily fish a week." This FSA advised us that "this recommendation has been set as some oily fish contain chemicals such as dioxins and polychlorinated biphenyls (PCBs), which accumulate over time in the body and could have adverse health effects on the developing foetus if consumed at high levels over a long period of time. However, the majority of the UK population does not consume enough fish, particularly oily fish, and should therefore be encouraged to increase their fish consumption."[33]

55. The US Food and Drug Administration issued recommendations in 2004 advising pregnant women that while they should eat fish and seafood because it contains high quality protein and omega-3 fatty acids, nearly all fish and shellfish contain traces of mercury and that higher levels of mercury " may harm an unborn baby or young child's developing nervous system."

56. Commander Joseph Hibbeln stated that the adverse effects of methyl-mercury resulting from the consumption of pilot whales substantially influenced the USA advice. However, they have relatively high levels of mercury and low levels of omega-3 fats in comparison with oily fish. Salmon, for example, has high levels of omega-3 and no significant level of mercury.[34]

57. Hibbeln believed this official advice was in error because it did not take into account the balance of risks associated with deprivation of the beneficial nutrients in fish. He therefore used data from the Avon Longtitudinal Study of Parents and Children (ASLPAC) initiated by Professor Jean Golding, the largest epidemiological study of pregnancy and its outcomes in the world,[35] to evaluate the efficacy of the Federal Government's advice.

58. The results, published in *The Lancet* in February 2007, showed that increased intake of omega-3 from fish and seafood during pregnancy was associated with an increase in the IQ of the child at age eight.[36] The IQ of the children was highest in the group whose mothers had consumed more than the recommended amount of fish. The benefit was greater than any theoretical risk from mercury contamination. This positive effect also applied to fine motor skills and social development.

59. The findings from the ALSPAC study were that: maternal fish and seafood consumption of less than 340g/week during pregnancy did not protect children from adverse outcomes; there were beneficial effects on child development when maternal seafood intakes exceeded 340 g/week; and these improved further among those who had eaten well above this level (up to 700g/week). These findings persisted after adjustment for multiple potential confounders. The study concluded that advice for women to limit seafood intake to the FSA recommended level of up to 280g (two portions)/week (which the FSA advises equates to 0.45g/day of long chain omega-3) during pregnancy – is set too low.[37]

60. We believe these findings from a large, carefully conducted longtitudinal study are of importance in public policy terms and therefore recommend that the Scientific Advisory

[32] FSA written evidence, October 2007.
[33] FSA written evidence, October 2007.
[34] Commander Hibbeln, oral evidence 28 March 2007.
[35] For more detailed information about the ALSPAC study see the 25 April 2007 inquiry meeting minutes.
[36] Hibbeln et al. Maternal seafood consumption in pregnancy and neurodevelopmental outcomes in childhood (ALSPAC study): an observational cohort study. *Lancet* 2007; 369: 578–585.
[37] Current FSA advice for pregnant women is to avoid eating shark, swordfish and marlin and to limit the amount of tuna eaten to no more than two fresh tuna steaks (280gm) or four medium-size cans of tuna a week because of the risk of mercury contamination. The FSA also advises pregnant women to avoid having more than two portions of oily fish a week, such as salmon, trout, mackerel and herring, because it can contain pollutants such as dioxins and PCBs (polychlorinated biphenyls).

Committee on Nutrition (SACN) should be asked to further define the optimum intake of omega-3 polyunsaturated fatty acids (PUFAs) in different stages of life, especially for pregnant women and children.

61. We also recommend that in the meantime, on a precautionary basis, the FSA should reconsider its advice to pregnant women about fish consumption, with a view to encouraging them to eat at least two portions of oily fish, or the equivalent in omega-3 PUFAs, a week. We believe that pregnant women who do not wish to eat oily fish should be encouraged to consider taking fish oil supplements during pregnancy and while they are breast-feeding. In this context we note the advice we have received from other contributors to our inquiry that it is virtually impossible to overdose on omega-3 PUFAs. We noted the conclusions adopted by the PERLIP Working Group, in partnership with the Early Nutrition Programming Project, that pregnant and lactating women should aim to achieve an average daily intake of at least 200mg/day of DHA.[38] We have also taken into account the views (recently published in English)[39] of the Norwegian Scientific Committee for Food Safety (VKM). Like the 2004 SACN/COT report, this assessment sought to bring together evidence of the nutritional benefits and toxicological risks associated with seafood consumption. It recommended that fertile women should not eat more than two portions of fatty fish per week (with the current levels of dioxins and dioxin-like PCBs), but added: "However, the equivalent of over two meals of fatty fish per week must be consumed from childhood and continue throughout the entire fertile period in order for a woman to accumulate and exceed the body burden of dioxins and dioxin-like PCBs against which the tolerable intake is intended to protect." It also noted that the "tolerable intake level represents a safety level, not a limit for when adverse health effects will necessarily occur"…"Even if the safety limit is moderately exceeded, the risk is likely to be modest."

62. We also recommend that the FSA continues to monitor levels of mercury, dioxin and dioxin-like polychlorinated biphenyl (PCB) contamination in the different species of oily fish available in the UK. We believe this is important if mothers, and others, are to be encouraged to eat more oily fish, in order to assess and put into context any concern there may be about the risk of mercury contamination.

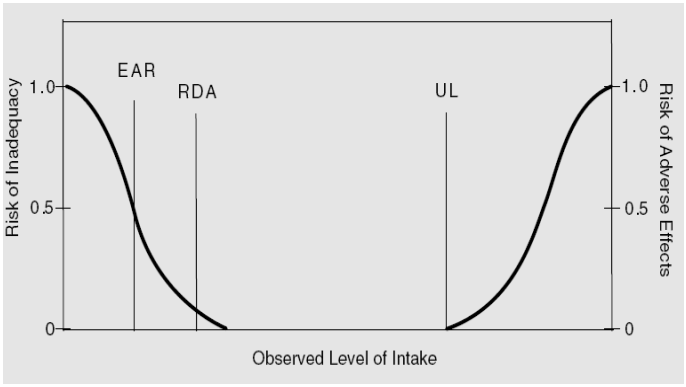
63. We believe the Government should take further action: to raise public awareness of the significance of good nutrition in pregnancy and to tackle the incidence of low birth-weight in the UK. These efforts would most usefully be focused initially on deprived mothers. We hope the Government will consider driving such an initiative forward, for example through an expansion of the SureStart[40] scheme with a greater involvement of registered nutritionists, registered dietitians and health visitors.

64. Against this background, we welcome the Government's decision to pilot in ten areas of the UK a version of the American "Nurse-Family Partnership" programme.[41] We hope that the Government will ensure that nutritional advice – based on the most up to date research – forms an important part of this programme. This advice should emphasise to pregnant women and new mothers that their diet will have a crucial effect on the physical and mental wellbeing of their children as they develop in the womb and thereafter.

[38] Koletzko B et al. 2007 op cit. NB. The authors report that 200 mg DHA/d can be reached by consuming one to two portions of sea fish per week, including oily fish.
[39] A comprehensive assessment of fish and other seafood in the Norwegian diet. English translation published 2007. Vitenskapskomiteen for mattrygghet (VKM) (The Norwegian Scientific Committee for Food Safety) ISBN: 978-82-8082-207-9.
[40] Sure Start is a Government programme which aims to deliver the "best start in life for every child". It brings together early education, childcare, health and family support (for more information see: http://www.surestart.gov.uk/).
[41] *Hansard* 18 April 2007, col. 643-645W.

Calculation of Recommended Dietary Intakes [Box 3]

65. Recommended daily intakes (RDI) are calculated so as to protect the majority (>98%) of a population from increased risk of chronic illnesses (for example vitamin C and scurvy) whilst also protecting against a risk of adverse effects. Response curves of this kind need to take account of the sensitivities of a diverse population. [42]



EAR- estimated average requirement, RDA, recommended daily allowance, UL – upper limit (not to be exceeded)

[42] Dietary Reference Intakes: Guiding Principles for Nutrition Labelling and Fortification Committee on Use of Dietary Reference Intakes in Nutrition Labelling. National Academies Press USA, 2003.

2. Nutrition and brain function

66. Our witnesses were unanimous in pointing out the importance of the long chain polyunsaturated fats (PUFAs) omega-3 and omega-6, especially Docosahexaenoic acid (DHA) and Eicosapentaenoic acid (EPA) for the structure and function of brain cells.

67. Because brain growth is most rapid i*n utero* and in early childhood an adequate supply of these essential fatty acids (EFAs) for pregnant mothers and infants is desirable to ensure optimal brain health and function. Some witnesses put more emphasis on the role of micronutrients (minerals and vitamins) enabling brain cells (including their EFA components) to function effectively.

68. There is still uncertainty regarding the actual amounts of specific EFAs needed in the diet at different life stages and there is a need for more research into this. New data[43] suggests DHA has an effect on the release of neurotransmitters, which may have a potential impact on the mood/behaviour of children. The consensus view at the present time is that these fatty acids are important to support early brain and visual development. Professor Alan Jackson, for example, informed us that mental processing is significantly improved in babies with higher levels of DHA.[44]

69. Beyond this, apart from the benefits of breast milk, which contains high levels of omega-3 PUFAs, on cognitive skill, much of the evidence of a beneficial effect of EFAs on brain function is inconsistent or inconclusive. As Professor Eric Taylor advised us, differentiation and comparison of the effects of various kinds of EFAs may yield more consistent findings. It is inaccurate to "lump all EFAs in the same basket".[45]

70. All the witnesses who submitted evidence to our inquiry emphasised that no nutrient works alone and that there is persuasive evidence of the importance for mental health and behaviour of several nutritional factors other than EFAs, such as vitamin and mineral status (especially iron and zinc) and glucose. We fully recognise that many nutrients other than EFAs are vital for optimum mental health and behaviour and, although EFAs were the primary focus of our inquiry, we would like to draw attention to these other, important, factors.

71. Many developmental disorders, first evident in childhood, including dyslexia, hyperactivity, autism and related conditions are more frequently reported as well as milder forms of the traits and features that define these disorders. Definitions and diagnoses of specific behavioural and learning disorders, such as dyslexia, ADHD and autism are being clarified.[46] This may in part explain the apparent increase in these conditions (see para 115, p.26).

72. These childhood disorders involve complex gene-environment interactions but nutritional factors and diet influence this interaction. Some of our witnesses believe that EFAS have a vital part to play. We fully recognise, however the importance of family, social and environmental factors.

1. The role of essential fatty acids

73. Arachidonic Acid (AA) is very important for the brain and heart, and there is an abundance of this omega-6 fatty acid in modern diets. This is particularly true of the omega-6 EFA precursor, Linoleic acid (LA) – but AA is also provided 'ready-made' by meat, dairy products and eggs. On

[43] Innis SM et al. Dietary Polyunsaturated Fat that Is Low in (n-3) and High in (n-6) Fatty Acids Alters the SNARE Protein Complex and Nitrosylation in Rat Hippocampus. *Journal of Nutrition* 2007;137: 1852-1856.
[44] Professor Alan Jackson, oral evidence 25 October 2007.
[45] Professor Eric Taylor, written evidence November 2007.
[46] Dr Alexandra Richardson, oral evidence 28 March 2007.

the other hand, the amount of the omega-3 EFA, Alpha-linolenic acid (ALA), in most children's diets is low, being found mainly in green vegetables and some of the less commonly consumed nut and seed oils and oily fish. There appears to be some variability between individuals in the efficiency of the biochemical process of converting shorter chain EFAs to long chain polyunsaturated fatty acids (LC PUFAs). Those who are not good at converting shorter chain EFAs to the LC PUFAs are likely to be deficient in the key long chain omega-3 PUFAs, Eicosapentaenoic (EPA) and Docosahexaenoic (DHA), unless they frequently eat fish and seafood. In particular, vegetarians and vegans may not obtain optimum EPA and DHA levels because it is difficult to convert effectively the simplest omega-3 (ALA), found in foods such as green vegetables and flax oil, into these PUFAs. However this does not appear to affect their children (see paragraph 45). It is possible that they have developed enhanced ability to convert ALA to long chain omega-3 PUFAs.

74. It is known that constitutional factors, including gender (male sex), affect the efficiency of synthesis of PUFAs from shorter-chain EFAs. Many behavioural disorders, such as ADHD, dyslexia, dyspraxia and autism are more common in males than females.

75. Omega-3 fatty acids are important for the flexibility and fluidity of brain cell membranes, favouring rapid neurotransmission; they also protect neuronal function - 30% of some nerve cell membranes consist of DHA mostly in the form of phospholipids. Professor John Stein pointed out that if DHA is deficient, signalling can be slowed down by up to 90%.

Omega-3 and neurotransmission [Box 4]

76. Some brain nerve cells ("magnocellular") are much larger than others. The smaller nerve cells ("parvocellular") are important for static responses, for example for detection of colour and fine detail, whereas the larger ones are specialised for temporal processing, for example tracking changes in light, sound and position. Thus they provide rapid signalling and fast conduction, and are important for rapid responses and for timing events. They have a high sensitivity to motion and flicker, hence the visual magnocellular system helps to control attention and eye movements. They are found throughout the brain: in the visual, auditory, skin, and muscle proprioceptors, the cerebral cortex, hippocampus, cerebellum and brainstem. The high dynamic sensitivity of these magnocellular neurones requires high membrane flexibility, which is provided by a local environment of essential fatty acids, particularly the omega-3s. This is why they are particularly vulnerable to omega-3 deficiency.

77. The omega-3 polyunsaturated fatty acid (PUFA), Docosahexaenoic acid (DHA), speeds up neuronal responses by increasing membrane flexibility, thus improving magnocellular neuronal timing functions. The other main omega-3 PUFA, Eicosapentaenoic acid (EPA), is converted into eicosanoid signalling molecules: thromboxanes, prostaglandins (3 series), leucotrienes (5 series) and resolvins These are important because they are all anti-inflammatory and lead to a reduction in stress reactions coupled with increased neural connectivity, in contrast to the effects of omega-6 PUFAs which tend to be pro-inflammatory and inhibit connectivity. The eicosanoids increase neurogenesis and neurite outgrowth and synapse formation by increasing the production of a protein, syntaxin, which helps communication between nerve cells and thus contributes to the consolidation of memories. EPA also inhibits programmed cell death (apoptosis). As a result omega-3 PUFAs can improve memory (in patients with Alzheimer's), strengthen hemispheric lateralisation, protect against inflammation, reduce pain transmission (via inhibiting TRPV1 receptors) and prevent the accumulation of insoluble amyloid precursor protein (which develops in patients with Alzheimer's). Thus for example, it has been shown that the more fish a person eats the less likely he is to get Alzheimer's disease,[47] (but see section 3.4 on dementia).

78. Omega-3 deficiency is important for children's behaviour because the ability to focus attention is vital for sequencing letters and numbers, skilled movements, and detecting facial and

[47] Morris MC et al. Consumption of fish and n-3 fatty acids and risk of incident Alzheimer disease. *Archives of Neurology* 2003; 60(7): 940-946.

emotional expressions such as tone of voice and gestures. Impaired development of magnocellular neurones is found in many neuro-developmental disorders, such as prematurity, foetal alcohol syndrome, developmental dyslexia, dyspraxia, dysphasia, ADHD, autistic spectrum disorders, as well as in schizophrenia, depression and anti-social behaviour. In all these conditions ability to focus attention precisely is reduced.[48]

79. These conditions all differ to a greater or lesser degree though they overlap, and omega-3 is not the only factor that is relevant. Genetic and environmental factors are also important. Impaired magnocellular function in these children may make them vulnerable to omega-3 fatty acid deficiency. This may be why some randomised controlled trials using omega-3 supplements, such as the Oxford-Durham study,[49] have shown improvement in these developmental disorders (for example, dyslexia, dyspraxia and ADHD), depression, schizophrenia and anti-social behaviour.

80. As the importance of EFAs for the structure and function of the brain – and thus mood and behaviour – has become more widely recognised, more trials have been carried out to test their significance. There have been mixed results from five trials conducted internationally to date, the largest being the randomised, double-blind, placebo-controlled trial (RCT), the Oxford-Durham study, led by Dr Alexandra Richardson (see below).[50]

81. Of the five trials, three found benefits for behaviour and learning in children with a primary diagnosis of either dyslexia, ADHD or dyspraxia. These trials used supplements containing both EPA and DHA, evening primrose oil and vitamin E. The biggest trial, though still comparatively small (117 under-achieving children from mainstream schools aged 5-12), was the Oxford-Durham trial. This trial demonstrated significant improvements for those taking the supplement in terms of learning, behaviour and working memory. Their reading improved at three times the normal rate and their spelling improved at twice the normal rate. Similarly, significant reductions in ADHD-type symptoms (including inattention, hyperactivity, impulsivity and other disruptive behaviours) were found.[51]

82. Two of the five trials showed no benefits from treatment primarily or exclusively with DHA for children with ADHD. In one of these trials (Voight et al) sixty-three 6 year old to 12 year old children with ADHD, all receiving effective maintenance therapy with stimulant medication, were assigned randomly, in a double-blind fashion, to receive DHA supplementation (345 mg/d) or placebo for 4 months. The trial concluded that a 4-month period of DHA supplementation (345 mg/d) does not decrease symptoms of ADHD.[52]

83. Although there is no recommended daily intake (RDI) of EPA and DHA for optimum mental health, daily intake of 500mg/day of EPA and DHA has been recommended for cardiovascular health (ISSFAL[53] statement 2004, Joint Health Claims Initiative (JHCI) 2005). In the UK the average intake is some 100-150mg/day and most children consume less.

84. In the Oxford-Durham trial and other trials described above which showed benefit, the supplements used were similar to the minimum recommended intake – some 550-750mg/day EPA and DHA. The fatty acid composition of the five trials differed, with four out of five studies using a mixture rich in DHA. The other study (Richardson 2005) used a mixture rich in EPA and

[48] Professor John Stein, oral evidence 9 May 2007.
[49] Richardson AJ & Montgomery P The Oxford-Durham Study: A Randomized Controlled Trial of Dietary Coordination Disorder Supplementation With Fatty Acids in Children With Developmental Coordination Disorder. *Pediatrics* 2005; 115:1360-1366.
[50] These five trials are summarised in greater detail in Richardson AJ Omega-3 fatty acids in ADHD and related neurodevelopmental disorders. *International Review of Psychiatry* 2006; 18(2): 155-172.
[51] Richardson AJ & Montgomery P (2005) op. cit.
[52] Voight RG et al. A randomized, double-blind, placebo-controlled trial of docosahexaenoic acid supplementation in children with attention-deficit/hyperactivity/ *Journal of Pediatrics* 2001; 139(2):189-96.
[53] International Society for the Study of Fatty Acids and Lipids (ISSFAL) is an International Scientific Society established in 1991, of more than 500 members from more than 40 countries. ISSFAL members are scientists, health professionals and others with an interest in the health effects of dietary fats, oils and lipids.

contained Gamma-linolenic acid (GLA). Richardson believes that EPA may be more important than DHA for brain function (though not for the structure of the brain) and this view would appear to be supported by the other results described above and the findings from a recent study conducted by Professor Andrew Scholey which showed no benefit from DHA on the cognitive performance of healthy school children (unpublished at the time of writing this report). However, the relative importance of EPA and DHA is still to be accurately defined.

85. The view of the Hyperactive Children's Support Group (HACSG)[54] is that while increasing the intake of PUFAs may benefit many children with ADHD, it is unlikely to benefit them all because the causes of behavioural disorders are so varied. The HACSG's early work in this field has been supported by some more recent randomised controlled trials.

86. The FSA's view of the evidence from these five studies[55] is that although "there is some evidence of some benefits for some children with learning difficulties, the evidence is not clear enough to justify recommending supplements be taken by this group. However it does underline the importance of a healthy balanced diet including fish for these children and the need for their carers and meal providers to be advised and trained to deliver this." We agree with the FSA that "the results of these studies have to be interpreted with care in relation to their applicability to children without any learning difficulties" and that more research is needed.

87. **We recommend that more research to test the effect of selected essential fatty acids (EFAs) on the mood and behaviour of both "healthy" children (that is, children suffering from no known disorders), and children suffering from a range of behavioural disorders should now be a priority for public policy.** It would be most useful if the children's nutrient status were tested before and after the trials take place, so it is clear whether the findings relate to bringing children with nutritional deficiencies up to satisfactory nutrient levels. We believe further research will be needed thereafter to look in more detail at the relative importance and effects of EPA, DHA and other long chain PUFAs.

2. The effect of artificial food additives on behaviour

88. At present there is a lack of agreement on the methods being used to help children apparently susceptible to food additives. Conventional medical opinion is sceptical of the value of many exclusion diets and little rigorous research has been done in this field until recently.

Tartrazine

89. Professor Neil Ward conducted a RCT [56] to measure the effect of tartrazine on children, in which the children's blood serum and urine were analysed. This revealed that the ADHD children had relatively low levels of zinc. When the children were given the tartrazine containing solution their low levels of zinc became further depleted – they were excreting it at a higher rate through their urine than the control children, whose zinc levels were depleted less significantly and more slowly.

90. Tartrazine and sunset yellow are azo dyes and it is believed that they could be acting as chelating agents, binding the available blood zinc in the body to form complex metals, which are then excreted. Azo dyes inhibit gut enzyme activity and this can induce inadequate digestion. This could explain why many ADHD children are unable to absorb all the nutrients in the food they eat. However, although azo dyes are associated with behavioural changes in hyperactive children, the precise reasons for this association are not known.

Recent research

91. Public attention was focused on the impact of artificial additives on children's health and behaviour by media coverage of research from the University of Southampton for the FSA,

[54] Hyperactive Children's Support Group, written evidence February 2007.
[55] FSA written evidence, October 2007.
[56] Ward NI et al. The influence of the chemical additive tartrazine on the zinc status of hyperactive children – a double-blind placebo-controlled study. *The Journal of Nutrition* 1990; 1: 51-7.

published in *The Lancet*[57] in September 2007. This research supports the findings of a 2002 study on the Isle of Wight[58] which concluded that artificial food colouring and benzoate preservatives have a general adverse effect on the behaviour of 3 year old children, detectable by parents but not by a simple clinic assessment.

92. The University of Southampton study recruited over 140 children in each of two age groups (3 year olds and 8 to 9 year olds) to represent a range of behaviour from normal through to high level hyperactivity. For the purposes of this research, hyperactivity was defined as over-activity, inattention and impulsivity. Two different mixes of commonly used artificial additives were tested against placebo. For both 3 year old and 8 year old children it was found that certain genes involved in the release of histamine from cells, were associated with greater responses to the test mixtures.

93. *The Lancet* reported that this study "demonstrates that using an aggregated measure of hyperactivity based on parent ratings, teacher ratings, direct observation of behaviour and, in the case of older children, direct testing of attention, certain mixtures of additives based on artificial colours and benzoate preservative, had adverse effects on the hyperactive behaviour of some children. The significant effects observed were an increase in the mean level of hyperactivity for the group. Not all children showed more hyperactive behaviour on the active mix than on the placebo. This work is based on a representative sample of children selected from the general population; the results are not limited to an extreme group of children showing ADHD." [59]

94. Professor Jim Stevenson, who led this research, said "we now have clear evidence that mixtures of certain food colours and benzoate preservatives can adversely influence the behaviour of children." [60]

95. Commenting on this research, Dr Alexandra Richardson said: "significant changes in children's behaviour could be produced by the removal of colourings and additives from their diet (and) benefit would accrue for all children from such a change and not just for those already showing hyperactive behaviour or who are at risk of allergic reactions." [61]

96. The media attention that followed the public release of these findings was soon followed by statements from many of the UK's leading supermarkets, which emphasised that they either had withdrawn, or are withdrawing, artificial food additives from their own-brand labels. We welcome this voluntary action on the part of these retailers, which at least provides parents with a choice as to whether or not their children are exposed to artificial additives.

97. We welcome the decision of the European Food Standards Agency (EFSA) to review the safety of all food additives, starting with colours. The FSA has shared the findings of the Southampton University research with the EFSA so it can be taken into account as part of the EFSA review.

98. We note the FSA has amended its advice to consumers in the light of this research to say: "Parents of children showing signs of hyperactivity are being advised that cutting out certain artificial food colours from their diets might have some beneficial effects on their behaviour." We would encourage the FSA to consider providing general advice to <u>all</u> parents about the desirability of limiting their children's consumption of artificial food additives on the precautionary principle. This advice could point out that whilst these food colours remain legally approved in the European Union, some additives used in the UK are already banned in the USA and some

[57] McCann D et al. Food additives and hyperactive behaviour in 3 year old and 8/9 year old children in the community. *The Lancet* 6 September 2007; DOI:10.1016/S0140-6736(07)61306-3.
[58] Bateman B et al. The effects of a double blind, placebo controlled, artificial food colourings and benzoate preservative challenge on hyperactivity in a general population sample of preschool children. *Archives of Disease in Childhood* 2004; 89: 506-511.
[59] Food Standards Agency website, 6 September 2007.
[60] Professor Jim Stevenson, *The Guardian* 6 September 2007.
[61] Dr Alexandra Richardson, *The Guardian* 8 May 2007.

Scandinavian countries, and none of the artificial additives used for colouring food have any nutritional value. We would like to see stronger action by the FSA.

99. We note that subsection (4) of Section 16 of the Food Safety Act 1990 provides that in making regulations in relation to food safety and consumer protection, the Secretary of State must have "regard to the desirability of restricting, so far as practicable, the use of substances of no nutritional value as foods or as ingredients of foods." **We recommend that regulations should be introduced to prohibit all artificial colours and non-essential preservatives in food products and soft drinks.**

3. Breakfast and school performance

100. A majority of the studies investigated during the 2006 FSA systematic review[62] noted good evidence that eating breakfast is beneficial to the performance and behaviour of school children. This view was reinforced by our witnesses, Professor David Benton and Professor Andrew Scholey. Both had conducted research which found that eating breakfast improved the cognitive performance of some children. A low glycaemic breakfast appeared to produce the most beneficial results.

101. Professor Scholey explained that physiological activity in the brain is intense and requires considerable amounts of energy. The brain forms only 2% of body weight, but in the resting, fasted state the brain accounts for 55% of the body's total glucose consumption.[63] Furthermore the brain stores negligible amounts of glucose, so it requires a continuous supply. The brain activity of a child up to the age of 3 is less than that of an adult, but it then accelerates rapidly. If omega-3 is important for brain structure and function, glucose is vital as its fuel.

The Glycaemic Index [Box 5]

102. The Glycaemic Index is a system for the classification of carbohydrate containing foods that is based on their blood glucose raising potential. It was originally devised in 1980 to help diabetics control the glycaemic impact of their diet.

103. The Glycaemic Index reflects the degree to which blood glucose rises after a meal and the speed at which carbohydrate is converted into glucose. The presence of protein, fat and fibre are also influential. After a meal, blood glucose levels rise, but then fall as insulin is released. Food stimulated hypoglycaemia occurs if blood glucose levels fall below 40mg/dl between 2 and 4 hours after eating. Foods with a high glycaemic index induce a rapid rise in blood insulin level. This tends to persist after the glucose level has been metabolised, resulting in a hypoglycaemic "overshoot". Low levels of blood glucose starve the brain and can result in hunger, blurred vision, slurred speech and even violence.

104. In normal individuals clinical hypoglycaemia is uncommon; a normal diet produces remarkably stable levels of blood glucose. However, some people exhibit a tendency to periodic low glucose levels (higher than those that can be described as hypoglycaemic) which may be associated with irritability and violence. Professor David Benton reported studies from Finland[64] that criminals with a history of violence have such a tendency. Those with low levels of blood glucose are more likely than normal to commit violent crime when under the influence of alcohol; alcohol increases the action of insulin reducing the levels of blood glucose.

[62] Summerbell C et al. A systematic review of the effect of nutrition, diet and dietary change on learning, education and performance of children of relevance to UK schools. 2006 (FSA Project Code: N05070).
[63] Amiel SA Organ fuel selection: brain. *Proceedings of the Nutrition Society* 1995; 54: 151-5
[64] Virkkunen M Reactive hypoglycaemic tendency among habitually violent offenders. *Neuropsychobiology* 1982; 8:35-40. Vikkunen M Insulin secretion during the glucose tolerance test in antisocial personality. *British Journal of Psychiatry* 1983; 142: 598-604. Virkkunen M Reactive hypoglycaemic tendency among arsonists. *Acta Psychiatrica Scandanavica* 1984; 69: 445-452. Virkkunen M Insulin secretion during the glucose tolerance test among habitually violent and impulsive offenders. *Aggressive Behaviour* 1986; 12: 303-310.

105. There is evidence that eating breakfast protects against the decline of children's attention during the morning.[65] Professor David Benton and colleagues monitored children's ability to attend to work in the classroom and found that those children who had had breakfast, or who were given a mid morning snack, were better able concentrate on their work.[66]

106. In another study this year, [67] Professor Benton and colleagues took over the running of a breakfast club and provided breakfasts with the same calories but different glycaemic loads to the children on different days. The results indicated that a low glycaemic load was associated with better memory and attention and more time was spent on a task in class.

107. Professor Andrew Scholey designed a study comparing the cognitive effects in children of two breakfasts: one with a high glycaemic load (*Coco-pops*) and one with a low glycaemic load (*All Bran*). This showed that a low GI breakfast is more effective in protecting against a decline in performance, measured in terms of memory and attention, during the morning.[68] However, Professor Sanders advised us that the study results were of borderline significance and that the data showing that a low GI breakfast is superior is not secure. The products also differed in several other respects, so it may be premature to conclude that a low GI breakfast is better without confirmation in further studies which we understand are now taking place at King's College London.

108. This evidence supports the introduction of School Breakfast Clubs and we suggest that a low glycaemic load breakfast may be of value. **We would also like to encourage the Government to include financial support to School Breakfast Clubs as part of the package set up to improve school meals. We strongly recommend that all children entitled to free school lunches should be entitled also to a free school breakfast, whose content should, like school lunches, be subject to quantified nutritional standards.** This is particularly important because poor school performance may contribute to a life-cycle of under achievement.

4. Vitamins and minerals

109. The effective physiological functioning of all cells, including brain cells, depends on the presence of a range of nutrients. A deficiency of one or more of these can affect a cell's ability to absorb or make use of other nutrients so it is not always possible to identify the precise effect of individual micro nutrients. However, our witnesses did give examples of the effect on mental performance of the lack of certain micro nutrients in the diet.

Iron

110. Professor Benton demonstrated that there is consistent evidence of a link between children's behaviour and iron deficiency. Children under 2 years of age with iron deficiency anaemia often show problems of language, motor coordination, attention and mood. He also suggested that the benefits of iron treatment are more apparent in pre-school children (aged 2-5 years) than in infants. The evidence is however limited, although improvements in attention and cognition from iron supplementation have been reported.[69] Anaemia in toddlers is often associated with developmental delay. For example an inner-city English sample of 18 month old children responded to iron supplementation with an increased weight gain and rate of development.[70] For school age children (5-18 years) there is evidence that iron deficiency

[65] Wesnes et al. Breakfast reduces declines in attention and memory over the morning in school children. *Appetite* 2003; 41: 329-331.
[66] Benton D & Jarvis M The role of breakfast and a mid-morning snack on the ability of children to concentrate at school. *Physiology and Behavior* 2007; 90: 382-385.
[67] Benton D et al. The influence of the glycaemic load of breakfast on the behaviour of children in school. *Physiology and Behavior* 2007; (in press).
[68] Ingwersson J et al. A low glycaemic index breakfast cereal preferentially prevents children's cognitive performance from declining throughout the morning. *Appetite* 2007; (in press).
[69] Nokes C et al. The effects of iron deficiency and anaemia on mental and motor performance, educational achievement and behaviour in children: an annoted bibliography. 1998 ISLI Human Nutrition Institute, Washington DC
[70] Aukett MA et al. Treatment with iron increases weight gain and psychomotor development. *Archives of Disease in Childhood* 1986; 61(9): 849-57.

anaemia is associated with poorer cognition and school performance. However, these adverse effects of iron deficiency appear to be more transitory than with younger children.

111. The National Diet and Nutrition Survey[71] indicates that there is a deficient iron intake in some children, especially teenage girls. Professor Sanders reported that iron deficiency may result from a failure to properly regulate iron absorption rather than a deficient intake. The bioavailability of iron from cereals and vegetables can be enhanced by consuming fruit juice.

112. In developing countries iron supplementation improves mental development in those who are iron-deficient,[72] particularly above 7 years of age. Although the evidence is limited it would be surprising if there was not a similar response to increased iron intake in iron deficient children in industrialised countries.

Zinc

113. Zinc is needed for more than 200 different enzymes in the brain and body, including those involved in cell division and replication, immune system function and the building of PUFAs from the EFA precursors available from vegetable sources. Zinc has a biophasic relationship with serotonin receptors[73] and low concentrations of both zinc[74] and serotonin[75] metabolites have been shown to be associated with violence.

114. A majority of children (more than 80% in some age groups) consume less than the population daily Reference Nutrient Intake (RNI) of zinc and at least 10% consume less than the Lower RNI (an acknowledged index of dietary deficiency).[76] We believe the significance of these deficiencies merits further research.

[71] National Diet and Nutrition Survey: young people aged 4 to 18 years. 2001;1.
[72] Sachdev H et al. Effect of iron supplementation on mental and motor development in children: systematic review of randomised controlled trials. *Public Health Nutrition* 2005; 8 (2): 117-32.
[73] Hubbard PC & Lummis SC Zn(2) enhancement of the recombinant 5-HT(3) receptor is modulated by divalent cations. *European Journal of Pharmacology* 2000; 394 (2–3): 189–97.
[74] Walsh WJ et al. Elevated blood copper/zinc ratios in assaultive young males. *Physiology & Behavior* 1997: 62(2):327-9. Tokdemir M et al. Blood zinc and copper concentrations in criminal and non-criminal schizophrenic men. *Archives of Andrology* 2003; 49(5):365-8.
[75] Stanley B et al. Association of aggressive behavior with altered serotonergic function in patients who are not suicidal. *American Journal of Psychiatry* 2000; 157 (4): 609–14.
[76] Gregory et al 2000. National Diet and Nutrition Surveys, HMSO.

3. Nutrition and mental health

115. For several years there has been growing concern about an apparent increase in mental illness. However, it is possible that this increase is more apparent than real. The reported increase may be due to changes in the recognition and nomenclature of some forms of mental illness and behaviour which were previously unrecognised or classified as physical illness. For example, there is now much greater awareness that many unexplained somatic (bodily) (physical) symptoms presented to health professionals are actually manifestations of depression. Autism is now better defined and recognised, leading to an increase in reported cases. The same may apply to attention deficit hyperactivity disorder (ADHD).

1. Depression

116. There is increasing recognition of the high prevalence of depression, including childhood depression. More than 31 million prescriptions were written for anti-depressants in 2006 in England and Wales, 6% more than in 2005 (*The Times*, 14 May 2007). Although they are often effective, side effects are a serious issue and NICE recommends they should not be used as a first line remedy for mild depression. Yet alternatives such as the "talking therapies" often have long waiting-lists, are labour intensive and thus expensive, although they may have longer lasting benefit.

Links between omega-3 consumption and the incidence of depression

117. The significance of diet in depression is becoming increasingly recognised. Although there is as yet no unequivocal evidence of cause and effect, there is a strong negative correlation between the prevalence of depression in different populations and the amount of fish they consume in their normal daily diet. People who suffer from depression have reduced levels of omega-3 fatty acids in their blood and other body tissues.[77] Moreover there is now some evidence that omega-3 fatty acid supplements may be helpful in the treatment of depression.[78]

118. Countries with greater per capita rates of seafood consumption have lower reported rates of major depression, bipolar depression, post-partum depression and mortality from homicide.[79] Greater intake of fish was associated with a lower risk of suicide among 260,000 Japanese men followed for 17 years[80] and with a lower risk of suicidal ideation among 1767 Finns.[81] It seems likely that self-harm might be more frequent among people with low plasma omega-3 EFAs. The rapid reported increase in the prevalence of depression in North America directly correlates with the increase in consumption of saturated fats and omega-6 EFAs, as part of the "modern" diet, at the expense of omega-3 EFAs.[82] More recently Norwegian scientists used data from a population-based cross-sectional survey of more than 21,000 people to evaluate the association between intake of cod liver oil, rich in vitamins A and D as well as omega-3 fatty acids, and levels of depression and anxiety in the general population. They found that that the users of cod liver oil were significantly less likely to have depressive symptoms than non-users after adjusting for multiple possible confounding factors including age, gender, smoking habits, coffee consumption, alcohol consumption, physical activity and education. In addition they found that the prevalence of depression decreased with increasing duration of cod liver oil use.[83]

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[77] Professor Malcolm Peet, oral evidence 9 May 2007. Garland M.R. el al. Lipids and essential fatty acids in patients presenting with self-harm. *British Journal of Psychiatry* 2007; 190: 112-117.
[78] Freeman MP et al. Omega-3 fatty acids: Evidence basis for treatment and future research in psychiatry. *Journal of Clinical Psychiatry* 2006; 67: 1954-1967.
[79] Hallahan B & Garland MR Essential fatty acids and mental health, *British Journal of Psychiatry* 2005; 186: 275-277.
[80] Hirayama T Lifestyle and Mortality: a Large Census-Based Cohort Study in Japan 1990; Karger.
[81] Tanskanen A et al. Fish consumption, depression and suicidality in a general population. *Archives of General Psychiatry* 2001; 58: 512-513.
[82] Hibbeln JR Membrane lipids in relation to depression. *Phospholipid Spectrum Disorder in Psychiatry* 1999; 195-210, Marius Press.
[83] Raeder MB et al. Associations between cod liver oil use and symptoms of depression: the Hordaland Health Study. *Journal of Affective Disorders* 2007; 101: 245-249.

Therapeutic value of omega-3 consumption

119. Evidence for the effectiveness of omega-3 fatty acids in the treatment of depression comes from several double-blind placebo-controlled trials conducted by independent groups in different countries. The majority of these trials in adults with unipolar depression have used Eicosapentaenoic acid (EPA) and have consistently reported significant improvements in depressive symptoms.[84] [85] [86] Stoll et al[87] showed in 1999 that omega-3 helps achieve remission in bipolar disorder.

120. Dr Malcolm Garland presented some evidence that "healthy" people function better, feel less fatigued and have reduced levels of anger, anxiety, confusion and depression when taking omega-3 supplements.[88] More recent research[89] has looked at the effect of omega-3 supplementation on "noisy" patients – those patients presenting with a number of problems including self-harm, impulsivity and family problems.

121. It was found that total levels of omega-3 and omega-6 were significantly lower in the self-harm group than the control group after adjusting for confounding factors. Moreover lower levels of omega-3, but not omega-6, correlated closely with increased levels of impulsivity and depression.

122. In a randomised controlled trial (RCT) of forty-nine depressed patients[90] Beck Depression Inventory (BDI)[91] scores improved in those taking the supplements and the scores were still diverging from the control group when the study ended (at 12 weeks), suggesting that they might have continued to improve with a longer period of supplementation. Garland emphasised that a change in a BDI score of 16-17 points, as found in this study, is a significant change and would be very noticeable clinically. The "Daily Hassles and Uplift" score again showed benefit for those taking the active treatment. This score is independent of the scores for depression and possibly indicates several different mechanisms of omega-3 action.

123. Professor Sanders reported that some other studies have been unable to demonstrate that depression is improved by fish oil intake. Garland's conclusion, however, is that overall the evidence suggests that reversal of an omega-3 deficit improves psychological status in such patients, but more research is needed to confirm this and establish the source of such deficits and identify the mechanism underlying the improvement.

124. The efficacy of omega-3 treatment for depression is supported by a recent meta-analysis conducted by a working group of the American Psychiatric Association, which included all available placebo controlled trials to date. The studies generally used omega-3 fatty acids, given together with existing anti-depressant treatment, and found that omega-3 improved the response to anti-depressants.[92] In his evidence to us, Hibbeln noted that in the trials under investigation, the omega-3 supplements had been used on patients with treatment-resistant depression. On the basis of this evidence, treatment recommendations were issued by The American Psychiatric

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[84] Nemets et al. Omega-3 treatment of childhood depression: a controlled, double-blind pilot study. *American Journal of Psychiatry* 2006; 163: 1098-1100.

[85] Peet M & Horrobin DF A dose-ranging study of the effects of ethyl-eicosapentaenoate in patients with ongoing depression despite apparently adequate treatment with standard drugs. *Archives of General Psychiatry* 2002; 43: 315-319.

[86] Su KP et al. Omega-3 fatty acids in major depressive disorder. A preliminary double-blind, placebo-controlled trial. *European Neuropsychopharmacology* 2003; 13: 267-271.

[87] Stoll AL et al. Omega-3 fatty acids in bipolar disorder: a preliminary, double-blind, placebo-controlled trial. *Archives of General Psychiatry* 1999; 56(5): 407-412.

[88] Fontani G et al. Cognitive and physiological effects of omega-3 polyunsaturated fatty acid supplementation in healthy subjects. *European Journal of Clinical Investigation* 2005; 35: 691-699.

[89] Garland MR el al. 2007 op cit.

[90] Hallahan B et al. Omega-3 fatty acid supplementation in patients with recurrent self-harm. *British Journal of Psychiatry* 2007; 190:118-122.

[91] The Beck Depression Inventory (BDI) is a series of questions developed to measure the intensity, severity, and depth of depression in patients with psychiatric diagnoses.

[92] Freeman MP et al (2006) op. cit. This meta-analysis of ten trials found an overall effect size of 0.54, which is considered to be of high significance, as anti-depressant medications typically have effect sizes smaller that 0.3.

Association endorsing the American Heart Association's recommendation that all adults eat fish (particularly fatty fish) at least two times a week. Professor Malcolm Peet said that the best evidence for improvement, as indicated by this meta-analysis, was with a dose of 1 gm daily of EPA and DHA but that more research is necessary to establish the optimum ratio of EPA and DHA for treating depression.

125. Given the evidence pointing to the possible therapeutic value of EFAs, and in particular long-chain omega-3, for patients suffering from depression and vulnerable to self-harm, there is a good case for providing EFA supplements to these patients in addition to any other treatment they receive. At the very least, patients suffering from depression should be given dietary advice. We believe this is particularly important because people who suffer from depression or schizophrenia also have an increased risk of developing chronic physical diseases, such as heart disease and diabetes.[93] Our view is reinforced by Bamber el al.[94] who studied depression in adolescence and concluded: "improving understanding of the role of diet in mental health and promotion of appropriate dietary practices could significantly reduce the personal and social impact of depression in young people."

2. Schizophrenia

126. The incidence of schizophrenia is similar across the world, but the outcome of treatment for schizophrenia is better in developing countries than in more developed countries. This correlates with national diets; a high saturated fat, high sugar diet appears to be associated with worse long-term outcomes.[95]

127. While blood levels of omega-3 and omega-6 fatty acids are reduced in people with schizophrenia, treatment studies using omega-3 fatty acids in schizophrenia have given mixed results.[96]

128. Professor Peet described a study carried out in Europe (unpublished at the time of writing this report) which indicated that young people at high risk of schizophrenia may be less likely to develop the illness if they are given omega-3 fatty acids. Other trials have shown that people who have developed their first episode of schizophrenia may need less anti-psychotic medication if they are also treated with omega-3 fatty acids.[97] However, in established schizophrenia, treatment with omega-3 fatty acids has shown no consistent benefit.

3. General mental health

129. Professor Peet's view is that the preliminary evidence supporting the benefits of omega-3 fatty acids in childhood depression and in young people at high risk of psychosis, together with evidence from other sources on the effects of dietary change and supplementation on the behaviour of children and young people, suggests that the risk of developing certain mental health problems may be preventable at least in part by improving the diet of children and young people.

130. A Department of Health publication[98] recognises that there are insufficient specialist dietetic posts within the mental health services and action needs to be taken to address this. However,

[93] Peet M & Edwards RW Lipids, depression and physical diseases. *Current Opinion in Psychiatry* 1997: 10: 477-480.
[94] Bamber DJ et al. (2007) op. cit.
[95] Hopper K & Wanderling J Revisiting the developed versus developing country distinction in course and outcome in schizophrenia: results from ISOS, the WHO collaborative follow-up project. *Schizophrenia Bulletin* 2000; 26:835-846.
[96] Professor Peet, oral evidence 9 May 2007.
97 Berger GE et al. Ethyl-eicosapentaenoic acid (E-EPA) supplementation in early psychosis: a double-blind randomised placebo-controlled add on study in 80 drug-naïve first episode psychosis patients. The International Journal of Neuropsychopharmacology 2004; 8 (1): S422. Peet M. et al. Two double-blind placebo-controlled pilot studies of eicosapentaenoic acid in the treatment of schizophrenia. Schizophrenia Research 2001; 49: 243-251.
[98] "New Ways of Working for Psychiatrists: enhancing effective person-centred services through new ways of working in multi-disciplinary, multi-agency contexts" October 2005; Department of Health.

despite this report and the fact that many patients need and want nutritional advice, Professor Peet considers insufficient progress has been made. He thinks that the importance of good nutrition is better accepted by patients than by medical professionals. We agree with his view that everyone suffering from their first episode of psychosis or major depression should at least have access to proper dietary advice.

131. The Doncaster and South Humber Healthcare Trust provides a nutritional assessment for young people presenting to services with early symptoms of psychosis and they have established a "Mood and Lifestyle Clinic" for people with depression. The clinic looks at diet and other factors, such as exercise, which has been shown to be important in tackling depression. They are developing a simplified and structured procedure for dietary analysis and advice for use by non-specialists within mental health services, in order to disseminate this knowledge and skill to other NHS Trusts. **We recommend that the Department of Health encourages NHS Trusts to adopt an approach similar to that pursued by the Doncaster and South Humber Healthcare NHS Trust by undertaking a nutritional assessment of patients suffering from depression and/or with early symptoms of psychosis and providing them with dietary advice.**

4. Dementia

132. More people are living longer and reaching the age when dementia typically appears. In the UK today there are 700,000 people with dementia – 1 in 88. On current trends this is expected to rise to 940,000 by 2021 and to 1,735,000 by 2050.[99]

133. There is now good evidence of an association between nutritional status and cognitive function in older people. However, Dr Alan Dangour quoted a 2006 Cochrane systematic review which could not identify a single RCT in this area. It concluded, though, that: "There is a growing body of evidence from biological, observational and epidemiological studies that suggests a protective effect of omega-3 long chain polyunsaturated fatty acids (PUFAs) against dementia. However, until data from randomised trials become available for analysis, there is no good evidence to support the use of dietary or supplemental omega-3 PUFAs for the prevention of cognitive impairment or dementia."[100]

134. Dr Dangour outlined the problems in carrying out randomised controlled trials (RCTs) in the community and why they may not demonstrate an effect of a particular nutrient when cohort or cross sectional studies show a clear association. He described the Older People and omega-3 Long-chain polyunsaturated fatty acids (OPAL) Study of 868 subjects aged 70-79 recruited from 20 general practices which he is currently conducting to a protocol designed to eliminate some common faults in RCTs (for example, number of subjects too low, dosage of nutrient insufficient, inadequate duration, insensitive outcome measures and inadequate allowance for confounding factors).

135. The OPAL study is a randomised controlled trial designed to determine the effect of daily supplementation with omega-3 long-chain polyunsaturated fatty acids on cognitive and retinal function in older people in the UK.

136. The FSA commissioned this research and will assess the findings and be guided by them in any recommendations it makes. We were impressed by the thoroughness of the research protocol and suggest it could act as a model for other large scale RCTs to assess whether dietary intervention is effective in improving any measure of mental health status.

[99] Alzheimers Society 2007.
[100] Lim WS et al. Omega-3 fatty acid for the prevention of dementia. C*ochrane Database of Systematic Reviews* (1) 2006.

5. Diet and violent behaviour

137. Professor Benton recently completed a review of the impact of diet on anti-social, violent and criminal behaviour[101]. He found that in eight studies supplementation with the omega-3 fatty acid DHA decreased hostility and aggression.[102]

138. Hibbeln reported that his research on violent offenders in the USA since 1995 has demonstrated a 50% reduction in violence among substance abusers given omega-3 supplements.[103]

139. Hibbeln also found that increased Linoleic Acid (LA) (omega-6) consumption is correlated with increases in homicide in various countries, including the UK, Australia, Canada, Argentina and the USA.[104] In the UK, as omega-6 has increased in the diet, the number of homicides has increased four-fold. These correlations do not prove that greater omega-6 intake causes a rise in homicide, but Hibbeln pointed out that increasing EPA and DHA (that is, omega-3) intake has been shown to reduce anger or violence in 3 placebo controlled studies.[105] In general omega-6 intake appears to counter this effect.

140. Bernard Gesch argued that nutrients are not only important during pregnancy, when the brain is first developing, but also during adolescence, the peak age for anti-social behaviour, when there is "secondary brain development".

141. Gesch also referred to the work of Schoenthaler, who published the results of 14 trials in which the diet of offenders had been improved by adding different nutrients. However, Schoenthaler's work has been criticised because it did not always include a control group. Further trials are necessary to determine whether these findings can be replicated in controlled studies.

HM YOI Aylesbury research

142. The trial Gesch conducted in 1996-7 at HM YOI Aylesbury[106] set out to test the hypothesis that changes in diet could reduce the incidence of recorded offences by young offenders inside prison. The trial had a double blind, placebo controlled, stratified, randomised experimental design with up to nine months baseline and up to nine months treatment. Many were consuming less than the recommended intake for zinc. The supplements were randomly distributed to 159 18-21 year old male offenders. The only systematic difference between the active and the control groups was the content of the capsules. Anti-social behaviour was measured by Governor's reports and Minor reports.[107]

143. The supplements given to the offenders broadly represented 100% of the recommended daily intake of vitamins, minerals and essential fatty acids. 80% of the essential fatty acids provided in the trial were omega-6 and 20% were omega-3. In their next study Gesch and his colleagues propose to reverse this ratio and provide 80% omega-3 and 20% omega-6.

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[101] Benton D The impact of diet on anti-social, violent and criminal behaviour. *Neuroscience and Biobehavioral Reviews* 2007; 02:002.

[102] A meta-analysis produced a moderate effect size of 0.61 of a standard deviation.

[103] Budens-Branchey L, Branchey M, Hibbeln JR. Associations between increases in plasma n-3 polyunsaturated fatty acids following supplementation and decreases in anger and anxiety in substance abusers. *Progress in Neuropharmacology and Biological Psychiatry* (In press, 2008).

[104] Hibbeln JR et al. Increasing homicide rates and linoleic acid consumption among five western countries, 1961-2000. *Lipids* 2004; 39 (12): 1207-1213.

[105] Gesch B et al. Influence of supplementary vitamins, minerals and essential fatty acids on the anti-social behaviour of young prisoners, *British Journal of Psychiatry* 2002; 181: 22-28. Hallahan B & Garland MR Essential fatty acids and their role in the treatment of impulsivity disorders. *Prostaglandins Leukotrienes and Essential Fatty Acids* 2004; 71: 211-216. Zanarini MC et al. Omega-3 Fatty Acid Treatment of Women with Borderline Personality Disorder: A Double-Blind, Placebo-Controlled Pilot Study. *American Journal of Psychiatry* 2003; 160:167–169.

[106] Gesch B et al. (2002) op. cit.

[107] Governor and Minor reports are adjudicated against the "offences against discipline" set out in Young Offender Institution Rule 55. Governor reports tend to deal with the more serious incidents such as fighting, violence, drugs and theft, while the Minor reports are dealt with on the Wing and tend typically to involve insolence.

144. The results of the Aylesbury trial show that when the nutrients were provided there was a 26% reduction in the rate of recorded disciplinary incidents and a 37% reduction in the rate of more serious offences including violence reported to the Governor among the group receiving the supplements. However, more research is needed to establish whether the positive effect of supplementation in this trial was the result of ensuring all prisoners reached the UK Government's dietary standards or because some of the prisoners exceeded them.

145. Gesch suggested that a nutritional approach offers a relatively inexpensive and cost-effective way to tackle anti-social and criminal behaviour. The evidence for the effectiveness of the cognitive skills approaches used in prisons in England and Wales appears to be mixed,[108] whereas the nutritional approach implemented by Natural Justice[109] at HM YOI Aylesbury, just described, appeared to be effective. The value of the double-blind, placebo-controlled trial method used at Aylesbury is that it firmly establishes that the change in behaviour noted during the trial was related to consumption of the supplements. The degree of effect was measured by objective criteria, and the prison staff reporting offences were unaware of which offenders were receiving supplements.

146. Following the publication of the Aylesbury trial results, the Dutch Government commissioned similar research to see whether Gesch's findings could be replicated. The Dutch trial ended this year and, though the findings are as yet unpublished in a peer reviewed journal, the key findings were announced in July.

147. The preliminary results of this randomised placebo controlled trial in eight Dutch correctional institutions were published by the Dutch Agency of Correctional Institutions in May 2007. The objective of the study was to investigate whether the level of aggression and the psychological condition of young adult offenders could be influenced by their dietary intake. 221 young adult offenders were given supplement or placebo capsules for an average of 2.5 months. The active capsules contained essential fatty acids (omega-3 and omega-6) and 25 vitamins and minerals. The total number of incident reports for those in the active group of 116 offenders receiving supplements fell by 34% in comparison with their baseline, whereas it increased by 13% for the 105 offenders given placebo. However, other subjective measures of aggression and psychological functioning showed no significant change. The researchers regard the evidence on the reduction of incident reports as promising and recommended further research should be conducted with subjects whose aggressive or rule breaking behaviour is marked.[110]

Next steps within the National Offender Management Service (NOMS)

148. More research is necessary to see if the Aylesbury findings can be replicated and to identify optimal nutrient levels to minimise anti-social behaviour, bearing in mind that most nutrients interact. It is therefore welcome that the Home Office has decided to allow further studies to re-test the Aylesbury findings in larger trials. These will be conducted in three institutions holding juvenile offenders, with a projected population of at least 1000. This new study is investigating possible mediating mechanisms, including assessments of interpersonal relating, frontal lobe mediated tasks and heart rate variability. An additional aim will be to investigate the range and dosages of nutrients involved in reducing anti-social behaviour so that the researchers can advise on dietary standards. At the invitation of the Home Office, Natural Justice is also designing a double blind trial using nutrition as an adjunct to the "Intensive Supervision and Surveillance Programmes" for convicted offenders serving sentences in the community.

149. We suggested to the National Offender Management Service (NOMS) when they gave evidence to us that the second Natural Justice trial should involve, as part of the overall project, a cost-benefit analysis. This should take into account the reduced prison officer hours involved

[108] Cann et al. Home Office Findings 2003; 226.
[109] Natural Justice is a UK charity based in Oxford and Cumbria, established by former probationary officers, which has carried out research to investigate links between diet, violence and anti-social behaviour.
[110] The effects of food supplements on aggression and other violations of prison rules, and psychological wellbeing of Dutch young adult offenders. Radboud University Nijmegen, 2007.

in disciplinary proceedings if benefit is shown and the increased time available to staff and offenders for other rehabilitation programmes, work, exercise and leisure. This could provide evidence to support the implementation of a programme ensuring improved nutritional content of food actually consumed by prisoners.

150. **We recommend that consideration of the outcome of the next trial of nutritional supplements in Young Offender Institutes should be a priority for the NOMS given that our prisons are overcrowded and there is continuing concern about the mental health of prisoners, particularly young offenders at risk of self-harm and suicide. We recommend that any dietary intervention that can be used to improve the behaviour and mental well-being of offenders held in custody should be given serious consideration by the NOMS.**

151. We welcome the concern shown by Baroness Corston's inquiry into the diets of pregnant women and nursing mothers in women's prisons.[111] The inquiry looking into the UK's prison and penal system led by Ms Cherie Booth and Professor David Wilson is another welcome development. We hope that the effect of nutrition on offenders' behaviour and mental well-being and the diet of pregnant and nursing women prisoners will form part of this inquiry's work.

152. In the meantime, though we recognise that food currently provided in prisons includes healthy options, **we recommend that the NOMS look positively at the case for introducing nutrient-based standards for meals in prisons, similar to those introduced for schools, but based on recommended daily intakes for adults**. We believe the introduction of nutrient based standards for prison food is necessary. This would restrict the availability of less healthy food options, resulting in prisoners eating a better diet. **We also recommend that effective measures should be taken in all prisons to inform prisoners about the benefits of a good diet and to persuade and encourage them to make healthy choices, both while they are in custody and after their release.** From the evidence we have heard, making healthy food available as an option will not on its own result in an improved diet for the average offender given the nutritional poverty of the preferred diet of many offenders.

153. We have been concerned to learn about one area in which the food provided by the Prison Service appears to us to be inadequate in at least some establishments. A recent evaluation of Sure Start provision in HMP Holloway[112] noted that pregnant women in the prison "have little access to fruit and no access to fresh milk". "Not even the breastfeeding women on the MBU (Mothers and Baby Unit) have access to fresh milk". It notes that Department of Health leaflets on *Healthy Eating in Pregnancy* are readily available and says "considering the Government's 5-a-day initiative and the emphasis on the importance of a healthy diet in pregnancy, this is puzzling and requires action". We agree. In evidence to us the Prison Service stated that "the needs of those in Mother and Baby Units together with the needs of pregnant women in custody are managed locally. Any dietary provision outside the general approach is provided in consultation with the establishment's primary care trust."[113] We recognise the value of a local approach, but **we recommend that in all women's prisons national nutritional standards should be introduced to ensure that the basic dietary needs of pregnant women prisoners are achieved**. These standards should require the daily provision of fresh milk and fruit to all pregnant and breastfeeding women held in custody. We believe this is particularly important because any failure to provide adequate nutrients to a pregnant woman is likely to prejudice the future mental and physical health of her unborn child.

154. We would also encourage the Prison Service to extend the provision of cookery classes, provided in some Mother and Baby Units, to pregnant women. We note that the provision of such life skill classes is one of Baroness Corston's central recommendations in the "pathways to resettlement" section of her report looking at women held in custody.[114]

[111] The Corston Report: a review of women with particular vulnerabilities in the criminal justice system. Home Office 2007.
[112] Evaluation of Sure Start Provision in Holloway, Noemi Fabry, May 2007.
[113] HM Prison Service, written evidence June 2007.
[114] The Corston Report 2007 op.cit.

4. Public policy options

1. Public benefit of research into nutrition and behaviour

155. We believe public funding of the additional research we have recommended is fully justified because of the potential public benefit and economic gain that would flow if the results established the importance of sound nutrition for childhood mental health and improved behaviour in schools and prisons. Improved ability to learn and better academic attainment might also be demonstrated. There is now increasing evidence to support the importance of an adequate intake of essential fatty acids. Professor John Stein reported studies which showed that the IQ of children fed on breast milk, which is rich in omega-3, is 5-10% higher than formula-fed babies. Moreover, Hibbeln and his colleagues in Bristol found the IQ of children aged 8 correlated directly with their mothers' previous fish consumption in pregnancy, allowing for a large number of confounding variables. It is possible that the mean IQ of children would rise if consumption of omega-3 polyunsaturated fatty acids (PUFAs) was increased – particularly in the less privileged section of the population.

156. Similarly if the findings of the Gesch research at Aylesbury on diet and behaviour are replicated and then applied throughout the prison service, the costs of ensuring discipline in prisons could fall significantly, providing an opportunity for more resources to be deployed on the education, training and rehabilitation of offenders.

157. If, as some evidence suggests, omega-3 fatty acids have a protective effect against depression – and a positive therapeutic effect in treating it – some depressive illness could be avoided or ameliorated.

158. We believe therefore that Government funded research is strongly indicated. We cannot rely on commercial companies who manufacture fish oil supplements to fund this research because their resources are limited in comparison with the vastly better resourced pharmaceutical companies. Furthermore, no individual company would undertake research on the scale needed because that company would derive no benefit relative to its competitors from positive results given the difficulty of patenting a fish oil supplement, which is a natural food not a drug. Research funded by fish oil supplement suppliers is also likely to be viewed sceptically. Government funded research should be seen as an investment in the future health of the population and in keeping with the Government's increasing stress on health promotion and the prevention of disease. **Because of the major potential benefit for the fields of education, crime, health and the well-being of vulnerable sections of society, we believe that more research is urgently needed in the area of nutrition and behaviour, and we recommend that the Government devotes more substantial resources to this, especially in corrective institutions and care homes.** The need for more research was repeatedly stressed by all our witnesses.

2. Government advice on diet.

159. A better balanced omega-3:omega-6 intake can be achieved either by: increasing fish consumption or by reducing omega-6 consumption; or by reducing consumption of foods that inhibit the conversion of essential fatty acids (EFAs) to polyunsaturated fatty acids (PUFAs), such as saturated fats and trans fatty acids; or by reducing the use of products that deplete EFAs in the body, such as alcohol and smoking.

160. The current approach of the Department of Health and the FSA, emphasising the importance of healthy food choices goes some way towards achieving this. However, official advice needs to be updated in the light of research highlighting the importance of EFAs in the diet. There has been a strong emphasis to date in the Government's advice on healthy eating

on the importance of nutrition for physical health. **We recommend that Department of Health messages on a healthy diet should emphasise the importance of a balanced diet for optimum mental as well as physical health.**

161. In this context we would like to express our support for the Ofcom proposals to restrict the marketing on television to children of foods high in saturated fat, salt and sugar, though many consumer and public health bodies consider they do not go far enough and are only a first step. These restrictions have been introduced chiefly because of increasing concern about rising levels of obesity in the UK. However, they may also prove beneficial in terms of improved mental health and behaviour given the evidence that the consumption of saturated fats, hydrogenated fats and trans fatty acids have an adverse affect on the body's ability to convert short chain precursor EFAs into the long-chain omega-3 PUFAs which the brain requires.

162. We would also like to express our strong support for the Government's efforts to reduce excessive alcohol consumption and to reduce smoking, given that the consumption of alcohol and smoking help "strip" EFAs from the body.[115]

163. We welcome the increasing availability of "healthy" ranges of relatively low fat food and call on the food industry to make faster progress in further reducing the amount of trans fatty acids in processed food. We would encourage the Government to monitor this progress and to consider introducing legislation to require trans fatty acids to be eliminated as far as possible from processed food sold in the UK if sufficient progress is not achieved. If that is not possible in the UK because of EU legislation, we would encourage the Government to work at a European level to encourage other Member States to agree to harmonise the reduction of trans fatty acids throughout the EU.

Fish stocks

164. There is widespread concern about the effect on fish stocks if the public is encouraged to eat more fish – ideally, in our view, at least two portions of fish a week. Better, national and international sustainable fish management policies are undoubtedly needed. However, at the present time the vast majority of fish oils produced by the industry do not enter the food chain directly. Only some 50,000 of the 1 million tonnes of fish oil currently produced each year is being used directly in the human food chain, while the rest is diverted to the animal feed chain, aquaculture or used as industrial oils. In 2006 aquaculture used an estimated 87% of global fish oil production.[116] If the food industry were to divert a greater proportion of the fish oils currently produced into the human food chain, our diets could be significantly improved without further depleting world fish stocks.

Changes in the nutritional profile of animal feeds and food

165. There is significant potential for achieving higher human intakes of omega-3 polyunsaturated fatty acids (PUFAs) by modifying the fatty acid profile of animal feeds. The omega-3 PUFAs present in animal-derived foods may be an important source for increasing intake, and this is an area that is being investigated in depth as part of the EU Sixth Framework Integrated Programme, Lipgene. The primary focus of Lipgene is the interaction of nutrients and genotype in the metabolic syndrome (a clustering of several risk factors for cardiovascular disease and diabetes). Among its aims, Lipgene seeks to enable greater availability of food products that enhance human health. In particular the programme intends to generate a linseed oil product enriched with the dietary fatty acids naturally present in fish oil (long chain omega-3 fatty acids) which are known to play a role in reducing the risk of the metabolic syndrome. It also intends to produce a protocol for feeding dairy cows which changes the composition of milk fat to one with less saturated fats and more monounsaturated fatty acids. In addition the protection and supply of poultry meat enriched with long-chain omega-3 PUFAs will be examined.[117]

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[115] Dr Alexandra Richardson, oral evidence 28 March 2007.
[116] Jackson A Fishmeal and fish oil – will they limit the development of aquaculture? *Feed Technology Update* 2007; 2 (1): 3-11.
[117] Extract from the Lipgene project overview on the Lipgene website at: www.lipgene.tcd.ie/about/

Meanwhile, US firms are developing methods of growing naturally occurring algae to produce omega-3 on an industrial scale.

166. Even without recourse to modifying animal feeds, selective animal breeding and choice of existing feed can result in improved nutritional profiles in meat and milk.

167. **While research continues, we recommend that all people in the UK should be encouraged to eat more fish, some of which should be oily fish, or its equivalent**. Whilst oily fish provide more Eicosapentaenoic acid (EPA) and Docosahexaenoic acid (DHA) than white fish, the fat content of the latter, although small by comparison, is rich in DHA.[118] In the UK at the present time, intake of omega-3 PUFAs is substantially below the current recommended intake of 450mg per day. The average intake for the majority of the population has been estimated to be only some 113mg per day and for those who consume little or no fish the intake may be as low as 46mg per day. The evidence we have heard indicates that increasing the average amount per person consumed to two portions of oily fish per week would be beneficial for the physical and mental health of people in the UK because it remains the best source of omega-3 PUFAs. Further advice on fish consumption could be introduced once the optimum recommended daily intake for omega-3 fatty acids for adults and children is established.

168. We recognise, however, that currently only 27% of the population consumes oily fish regularly and it is unlikely that oily fish consumption will increase unless there is a substantial change in food preferences.

3. Supplements

169. Many health professionals and scientists have described how the British diet was healthier during and just after World War II (1939-45) than today. Nevertheless, Professor Hugh Sinclair advised the Government during World War II that pregnant women and children should be given orange juice and cod liver oil because there was a prima facie case that they would benefit from this dietary intervention. Several of our witnesses believe there is a case now for increasing omega-3 consumption for all children and adults in the UK. Such intervention would be beneficial if, as many believe, there is still much concealed nutritional deficiency due to the average relatively unhealthy diet we consume.

170. Research to date has not indicated whether healthy, cognitively intact children would benefit from increased essential fatty acid (EFA) intake. Recommended daily intakes (RDIs) have been established to date with reference to physical, not mental, health and from a basis of preventing overt deficiency diseases. However, many people in the UK still do not eat a healthy diet, but continue to consume a diet high in fat, salt and sugar and deficient in fruit, vegetables and fish, including oily fish, rich in micro nutrients and EFAs.

171. There is no basis at present for recommending universal EFA supplementation until RDIs for adults and children have been established, but those people who are unwilling or unable to eat fish may need to consider taking omega-3 supplements. Supplementing diets low in fish may be important for some groups for whom omega-3 intake is particularly necessary, including pregnant and breast-feeding women, children with behavioural disorders, children and adults suffering from mental ill health particularly depression, and the prison population. But it is preferable to persuade and educate people to obtain these nutrients for themselves and their children from a good diet.

172. Vegans or vegetarians who do not wish to eat EFA supplements derived from fish oils increasingly have the choice of algae-derived omega-3 supplements – but there is little evidence at the present time that they are prone to omega-3 deficiency symptoms despite having low blood levels of EFAs.[119]

[118] Professor Michael Crawford, written evidence September 2007.
[119] Professor Tom Sanders, written evidence September 2007.

4. Fortification of food

173. Fortification of food with omega-3 would be viewed in some quarters as enforced, and possibly unnecessary medication, although there are precedents and there is virtually no risk of overdosing on omega-3. However, the fortification of food does nothing to encourage people to make healthier food choices.

174. Foods fortified with omega-3 are usually more expensive than their conventional alternatives and we have seen no evidence that consumers are deriving benefit from this additional expense where the dosage of omega-3 available from a normal portion of the food is much less than that used in trials where a positive effect was seen. The new EU regulation on nutrition and health claims on food[120] may play an important role by scrutinising the validity of both new and long established claims. Responsible food companies, providing food fortified with nutrients at a dosage at which their consumers will benefit, have everything to gain from a regulation which will remove less responsible claims from the marketplace.

175. Adding omega-3 to food products is at present a commercial decision taken by food companies. However the FSA wants controls on the voluntary addition of folic acid to products such as breakfast cereals and spreads. If evidence of the importance of omega-3 for physical and mental health becomes more fully established, there may be a case for fortifying some foods with it, but with controls in place.

176. The option of encouraging and/or requiring the "restorative fortification" of food with omega-3 has been suggested to us. This would entail returning to a processed food, for example canned tuna, the EFAs which had been removed during processing. We believe, however, that it would be premature to require the restorative fortification of food with EFAs until recommended daily intakes of EFAs for children and adults have been established.

5. Genetic modification of food

177. Several witnesses described commercial research under way to develop crops with reduced omega-6 content and increased omega-3 content. DuPont is expecting commercial plantings of its high omega-3 soybeans in 2008. Monsanto is not far behind with genetically modified soybean crops and BASF is developing high omega-3 brassicas.[121] Solae is also genetically modifying soybeans in an attempt to reduce the amount of omega-6 in them and to see if they can produce EPA and DHA.[122] Genetic modification is likely to remain highly controversial in the UK for the foreseeable future, but omega-3 derived from naturally occurring algae holds considerable promise.

178. Such research also heralds the possibility of achieving a more beneficial omega-6: omega-3 intake for people in the UK, perhaps removing the need for people to change their dietary habits to make healthier food choices. As such, it may prove helpful in improving the diet of those who are the least responsive to public health messages. However, it is clearly preferable to encourage people to adopt healthier diets. In the meantime, we trust the FSA is monitoring this international research carefully and will advise the Government on it, as well as commission appropriate research itself.

[120] The Nutrition and Health Claims (England) Regulations 2007 (SI no. 2080) came into force on 1 October 2007. These regulations make provision for the execution and enforcement of Regulation (EC) No 1924/2006 of the European Parliament and of the Council on nutrition and health claims made on foods, as corrected by a Corrigendum (OJ No. L12, 18.1.2007, p3).
[121] Professor Jack Winkler, oral evidence 23 May 2007.
[122] Joseph Hibbeln oral evidence, 28 March 2007 (the Solae Company is an alliance between DuPont and Bunge Ltd)

5. Appendix

1. Oral evidence

Oral evidence was received from:

Professor David Benton, Psychology Department, The University of Wales, Swansea

Mr Graham Bryant, Area Catering Manager, HM Prison Service

Professor Michael Crawford, Institute of Brain Chemistry and Human Nutrition, London Metropolitan University

Dr Alan Dangour, Nutrition and Public Health Intervention Research Unit, London School of Hygiene and Tropical Medicine

Dr Malcolm Garland, The Clinical Sciences Institute, National University of Ireland, Galway

Mr Bernard Gesch, Department of Physiology, Anatomy and Genetics, Oxford University

Dr Gemma Harper, Research Development and Statistics Unit, National Offender Management Service

Commander Joseph Hibbeln, The National Institutes of Health, Washington

Professor Alan Jackson, Institute for Human Nutrition, Southampton University and Chairman of the Scientific Advisory Committee on Nutrition

Ms Sara Kahner, Women & Young People's Group, HM Prison Service

Mrs Valerie Moore, Eaton Hall School, Norfolk

Professor Malcolm Peet , Doncaster and South Humber Healthcare NHS Trust

Ms Liane Quantrill, Eaton Hall School, Norfolk

Lord Ramsbotham, former Chief Inspector of Prisons

Dr Alexandra Richardson, Department of Physiology, Anatomy and Genetics, Oxford University

Professor Andrew Scholey, Human Cognitive Neuroscience Unit, Northumbria University

Professor John Stein, Department of Physiology, Anatomy and Genetics, Oxford University

Dr Jackie Stordy, independent nutrition consultant

Professor Carolyn Summerbell, School of Health and Social Care, Teeside University

Mr Andrew Thomas, Cotswold Community School

Professor Neil Ward, School of Biomedical and Molecular Sciences, Surrey University

Ms Courtney van de Weyer, Sustain

Professor Jack T. Winkler, Nutrition Policy Unit, London Metropolitan University

2. Written evidence

Written evidence was received from:

Professor David Benton, Psychology Department, The University of Wales, Swansea

Professor Philip C. Calder, School of Medicine, The University of Southampton

Dr Robert Child and Dr Mark Tallon CR-Technologies Ltd

Mr Peter Clough, Technical Director, Efamol Ltd

Professor Michael Crawford, Institute of Brain Chemistry and Human Nutrition, London Metropolitan University

Dr Alan Dangour, Nutrition and Public Health Intervention Research Unit, London School of Hygiene and Tropical Medicine

Equazen Ltd

Dr Malcolm Garland, The Clinical Sciences Institute, National University of Ireland, Galway

Mr Bernard Gesch, Department of Physiology, Anatomy and Genetics, Oxford University

Commander Joseph Hibbeln, The National Institutes of Health, Washington

Mr Patrick Holford, Food for the Brain Foundation

Professor Alan Jackson, Institute for Human Nutrition, Southampton University and Chairman of the Scientific Advisory Committee on Nutrition

Professor Alan Lucas, MRC Childhood Nutrition Research Centre, UCL Institute of Child Health

Martek Biosciences

Mrs Valerie Moore, Eaton Hall School, Norfolk

Professor Malcolm Peet , Doncaster and South Humber Healthcare NHS Trust

Dr Alexandra Richardson, Department of Physiology, Anatomy and Genetics, Oxford University

Dr Simon Rudland, StowHealth

Professor Tom Sanders, Nutritional Sciences Research Division, King's College London

Professor Andrew Scholey, Human Cognitive Neuroscience Unit, Northumbria University

Professor John Stein, Department of Physiology, Anatomy and Genetics, Oxford University

Dr Jackie Stordy, independent nutrition consultant

Professor Carolyn Summerbell, School of Health and Social Care, Teeside University

Professor Eric Taylor, Institute of Psychiatry, King's College London

The Academy of Medical Sciences

The British Nutrition Foundation

The Food Standards Agency

The Hyperactive Children's Support Group

The National Offender Management Service

The Nutrition Society

Mr Andrew Thomas, Cotswold Community School

Professor Neil Ward, School of Biomedical and Molecular Sciences, Surrey University

Courtney van de Weyer, Sustain

Professor Jack T. Winkler, Nutrition Policy Unit, London Metropolitan University

Minutes of the oral evidence are available on the Forum's website at: www.fhf.org.uk. Copies of the written evidence are available on request.

3. Glossary

Antioxidant	A substance, for example Vitamin E, which slows oxidation and can mop up free radicals (see below).
AA - Arachidonic acid	A long chain omega-6 fatty acid (see fatty acids) with 20 carbon atoms. It is a major structural component of neuronal membranes.
ADD	Attention Deficit Disorder (see ADHD)
ADHD	Attention deficit hyperactivity disorder (ADHD) and attention deficit disorder (ADD) refer to a range of problem behaviours associated with poor attention span. These may include impulsiveness, restlessness and hyperactivity, as well as inattentiveness, and often prevent children from learning and socialising well. ADHD is sometimes referred to as hyperkinetic disorder.
ALA - Alpha-linolenic acid	A long chain omega-3 fatty acid (see fatty acids) with 18 carbon atoms.
Aquaculture	The farming of marine and freshwater animals and plants for human consumption.
Azo dyes	Azo dyes are artificial dyes such as Tartrazine or Sunset Yellow which contain an azo group (that is, a molecule with two adjacent nitrogen atoms).
BDI - Beck Depression Inventory	The Beck Depression Inventory is a series of questions developed to measure the intensity, severity, and depth of depression in patients with psychiatric diagnoses.
Chelators (chelating agents)	Substances capable of combining with free metal ions; they are important in preventing the oxidation of food.
DGLA - Dihomo-gamma-linolenic acid	A long chain omega-6 fatty acid (see fatty acids) with 20 carbon atoms, important for neuron transmission.
DHA – Docosahexaenoic acid	A long chain omega-3 fatty acid (see fatty acids) with 22 carbon atoms. It is a major structural component of neuronal membranes.
Double-blind trial	A double-blind trial is a placebo-controlled (see placebo-controlled) group test where neither the evaluator nor the subject knows which items are placebo and which are the active treatment.
DPA – Docosapentaenoic acid	A long chain omega-3 fatty acid (see fatty acids) with 22 carbon atoms.
Eicosanoids	They form the substrate for signalling molecules (and depend on the double bond between the third and fourth carbon atoms in omega-3 fatty acids). The eicosanoid signalling molecules: thromboxanes, prostaglandins, leucotrienes and resolvins are all anti-inflammatory and lead to a reduction in stress reactions coupled with increased neural connectivity.

EFAs - Essential fatty acids	These fatty acids from two “families” (omega-3 and omega-6) are called essential because humans cannot make them, so they must be derived from food that is eaten. They are the precursor or “parent” fatty acids to the highly unsaturated fatty acids needed by the brain (see PUFAs).
EPA – Eicosapentaenoic acid	A long chain omega-3 fatty acid (see fatty acids) with 20 carbon atoms, which is important for neuron transmission (see Box 2).
Epidemiological study	A study of human populations, which attempt to link human health problems, for example cancer, to a cause.
Fats	Fats are a major food component consisting of glycerol and fatty acids. They can be classified as “fuel” fats, used for energy and padding (triglycerides) or structural fats including the EFAs (see above), which form a vital part of cell membranes.
FAs - Fatty acids	Fatty acids are molecules which consist of long chains of carbon and hydrogen atoms with a carboxyl (COOH = acid) radical at the “alpha” end of the chain. The other “omega” end consists of a simple methyl (CH3) radical (see saturated/unsaturated fatty acids).
Food additive	Food additives are those substances deliberately added to food by the manufacturer to facilitate processing or to improve the flavour appearance, texture, keeping quality or nutritional value of foods.
Free radicals	All unsaturated chemical compounds (see saturated/unsaturated fatty acids) are vulnerable to attack by peroxide free radicals, which usually have an unpaired/free electron. Anti-oxidants (see above) can protect fatty acids against oxidation caused by free radicals.
GLA - Gamma-linolenic acid	A long chain omega-6 fatty acid (see fatty acids) with 18 carbon atoms, which is important for neuron signalling (see Box 2)
Glucose	A simple sugar.
Glycaemic Index	The Glycaemic Index is a system for the classification of carbohydrate containing foods that is based on their blood glucose raising potential. It was originally devised in 1980 to help diabetics control the glycaemic impact of their diet.
LA - Linoleic acid	A long chain omega-6 fatty acid (see fatty acids) with 18 carbon atoms.
LRNI – Lower Reference Nutrient intakes	This is an intake below which it is unlikely that normal health could be maintained (see RNIs). It represents a minimum threshold.
Neurotransmitters	Chemical messengers in the brain. Neurotransmitters attach to receptors on nerve cells causing a specific action in the cell.
NMOS	National Offender Management Service.
Oleic acid	Oleic acid is a monounsaturated omega-9 fatty acid found in large quantities in olive oil.

Omega-3	An unsaturated fatty acid (see unsaturated fatty acids) where the first double link between carbons in the chain is three away from the methyl (omega) end. Membranes are made of layers and the closer the double bond is to the methyl end of the chain, the more flexible it is.
Omega-6	An unsaturated fatty acid (see unsaturated fatty acids) where the first double link between carbons in the chain is six away from the methyl (omega) end. Omega-6 PUFAs (see PUFAs) tend to be pro-inflammatory and inhibit neural connectivity.
Organic compounds	Compounds that contain chains of atoms of the element carbon for example, proteins, fats and carbohydrates.
Oxidation	A chemical reaction which involves at least one of the following: loss of electrons, the gain of oxygen or the loss of hydrogen. Rust is the result of the oxidation of iron; the oxidation of fats in foods results in rancidity.
Phospholipids	Phospholipids are fat derivatives in which one fatty acid has been replaced by a phosphate group and one of several nitrogen-containing molecules. The hydrocarbon chains are hydrophobic (as in all fats). However, the charges on the phosphate and amino groups (in red) make that portion of the molecule hydrophilic. The result is an amphiphilic molecule.
Placebo-controlled	A term used to describe a method of research in which an inactive substance (a placebo) is given to one group of participants, while the treatment (usually a drug or vaccine) being tested is given to another group. The results obtained in the two groups are then compared to see if the investigational treatment is more effective than the placebo.
PUFAs - Polyunsaturated fatty acids	A fatty acid with several double bonds between carbon atoms in the chain (see also saturated/unsaturated fatty acids). Four PUFAs are particularly important for brain development and function (see DGLA, AA, EPA and DHA).
RCTs – Randomised controlled trials	A randomised-controlled trial is one that randomly assigns items to the control group (receiving a placebo) and the experimental group (receiving the active treatment).
RDA	Reference Dietary Allowance. The RDA is the average daily nutrient intake level sufficient to meet the nutrient requirements of nearly all (97-98%) healthy individuals in a particular life stage.
RNI - Reference Nutrient Intakes	RNIs are an estimate of the amount of a micronutrient, protein or fat that should meet the needs of most of the group to which they apply. They are not minimum targets.
SACN	Scientific Advisory Committee on Nutrition. The Scientific Advisory Committee on Nutrition (SACN) is an advisory Committee of independent experts that provides advice to the Food Standards Agency and the Department of Health as well as other Government Agencies and Departments. Its remit includes matters concerning nutrient content of individual foods, advice on diet and the nutritional status of people.

Saturated/unsaturated fatty acids	(see also “fatty acids”) The terms ‘saturated' and ‘polyunsaturated’ or ‘highly unsaturated’ are derived from organic chemistry, the chemistry of carbon compounds. Carbon tends to link to four other atoms. Compounds with all four links around each carbon atom, occupied by another atom, usually hydrogen or other carbon atoms, are called saturated. Sometimes there is a double link between two carbons in the chain and such compounds are called unsaturated. The double link changes the chemical properties in quite a fundamental way, making the substance more reactive. A polyunsaturated compound has several of these double links.