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What can farmers learn from science to improve the nutritional value of our food? :

Health by Stealth

Caroline Drummond

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"Real knowledge is to know the extent of one's ignorance"
Confucius

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Caroline Drummond

The author, Caroline Drummond

The Frank Arden Memorial Award
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Health by Stealth

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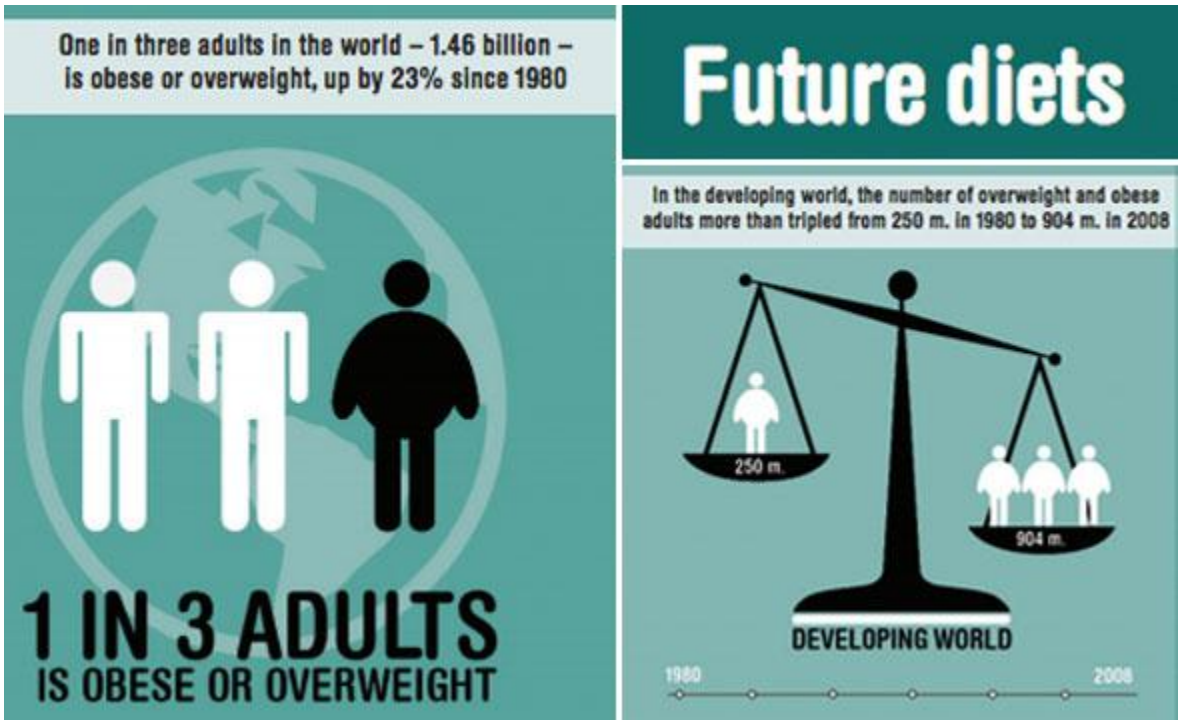
1. Executive Summary

The agricultural systems that have been built up over the past few decades have contributed greatly to alleviate hunger and raise living standards; they have served the purpose, but only up to a point. Our current food system is largely driven by economic demand and production possibilities, not nutritional goals. Thus, to be successful in the future, we require agriculture systems that focus as much attention on changing economic demand as production possibilities, alongside nutritional goals and opportunities. This will help address the issue of the growing dietary related diseases across the globe by improving the nutritional value of food and providing new opportunities for farmers to benefit, both in the field and in the market place.



This study has looked at the complex food web that is spun around farmers, retailers, marketers, nutritionists, researchers and consumers leading to the burgeoning incidence of dietary related diseases – Non-Communicable Diseases (NCD) and obesity. In particular, it aims to look at our relationship with food, the production, the technology, the social science, our culture, traditions, taste and the opportunities.

It is evident that the recommendations and ingredients for a healthy diet are well documented: we need a balanced and varied diet, fresh water and exercise, yet these steps are not taken up in a proportionate way. While there are some good examples of nutritionally enriched foods and niche market opportunities for farmers and corporate companies, this study is aimed at addressing opportunities for the majority, not the 'worried well'. Taking the pizza as a proxy to represent a typical weekly meal, the study has looked at three distinct areas within the food production agenda:

1. Traditional, cultural and soil based approaches
2. High tech, breeding and GM
3. Post farm gate processing, biofortification, nutraceuticals and functional food

through the principal ingredients of the pizza, namely wheat, tomatoes and cheese, framed within the context of behaviour change, perceptions, taste and trickery.

From my study it is evident that currently there are limited opportunities for farmers to improve the nutritional value of our food, since much of the reformulation of food is post-farm gate, and therefore within the processed food sector. Furthermore, food legislation in the Western world is becoming increasingly restrictive with regards to nutritional claims, and the opportunities for farmers to make health claims further limit the potential growth of this market. The majority of food we eat does not represent the food that the farmer grows – and that is the challenge.

Yet it is evident from social science and nutritional science that the farming sector does have a key role to play in developing a long-term plan for sustainable diets. There are niche market opportunities and if we effectively work together, farmers will be recognised for the true value they deliver to our health and wellbeing – through food and farming. The food security debate is not just about more food – it is about more and better nutrition in the right place. More needs to be done for an informed and cohesive approach to our personal relationship with food: more education and engagement, such as through Open Farm Sunday[i], Open Farm Schools Days and Healthy Food Week[ii]; better partnerships between nutritionists, breeders, researchers and farmers, plus long term policy change that effectively links Defra with the Departments for Health and Education.

The global population is growing: currently 7 billion and expected to reach over 9 billion by 2050. And that 9 billion has the appetite of 12 billion.

The health and well-being discussions are where we were with the environment some 20 years ago: an issue we know we should be doing something about, but not integrated sufficiently into 'how we do business'. There is no silver bullet to reducing obesity; it is a complex issue that requires action at individual, family, local and national levels. We can all play our part in this by eating a healthy balanced diet and being more active.

This study aims to open the door on the opportunities for farmers who, whilst more connected to our food than others, do need to be proactive in getting recognition, reward and return.

Food and Nutrition is the bed-rock of society - we need to develop the building blocks that connect health, well-being, nutrition, farming and education, creating sustainable diets and food systems that are underpinned by the need to improve health and nutrition. The investment in reducing the burden of NCDs will have high returns. Feeding a world without nourishing it at the same time is not sensible.

We all need to do more and we need to ensure that health is embedded as a value when we buy food.

2. Introduction

Unique among the annual tranche of Nuffield Farming Scholarship Awards, the Frank Arden Memorial Award is a biennial Scholarship centred on a pre-determined topic. In 2013 that topic was based around how British agriculture can seize new opportunities from the significant commercial and social benefits that can arise from using new science to optimise the nutritional value of the food – specifically to address the statement: 'How farming can learn from science to optimise the nutritional value of food produced.'

This I developed into a single question: **'what can farmers learn from science to improve the nutritional value of our food?'** with a specific focus on improvement and ensuring that the solutions were for the majority. Something an individual farmer could adopt and not a niche market, as well as making nutritionally correct foods for the majority of the general public and not the 'worried well' and affluent.

With this in mind I took the pizza to represent a proxy meal that the majority of families will eat on a weekly basis. Furthermore, it provided a focus for some key commodity products produced here in the UK, namely, wheat and cheese and also brought-in tomatoes, where a lot of nutritional work has been developed.

Over the last year every day a report on dietary related diseases NCDs (Non-Communicable Diseases), and the associated health problems, has appeared in the news. Whilst this has been extremely important, it has clearly demonstrated the confusion of messages and advice to consumers about issues relating to their health and reducing the incidences of obesity, type II diabetes and cardiovascular disease.

This report covers the synergies and conflicts between the desire to improve yields and feed the predicted 9 billion in 2050, alongside the fact that the marketplace is out of sync with what is needed to ensure we have **not just sufficient food, but the right food**. It seeks to address the need for farmers to explore the opportunities for their businesses and prepare them for being in the right place in the future. There are potential opportunities with plant breeding and moving much of the reformed and bio-fortification of processed foods pre-farm gate, and there are niche markets that are potentially available in the fresh produce sector and in the production of bio-fortification, nutraceuticals and functional foods. Furthermore, there is farming's core role and responsibility in producing an increased quantity of food that is of good quality and nutritionally dense and of course engaging the general public in the whole food and nutrition story.

At the core of this work is the drive for sustainability and more resilient food webs. More integrated approaches to connecting technology and environment are critical. This report is just a starting point, but it is evident if we do not put in the building blocks that connect health, well-being, nutrition, farming and education, then the dietary-related illnesses of today will only get worse.
We need healthy, low impact food that is affordable to all.

I have merely dipped in to this huge, complex and multi-layered topic and recognise just how much we all need to consider real and effective, integrated solutions – now! It is clear that investments in reducing the huge burden of malnutrition will pay off. It is madness that so much money is being invested to undo the problems that face society now; while unhealthy people, removed from the culture and understanding of their food face ever-growing health bills.

While much of my journey has looked at the science, and indeed the culture, behind our food one thing that struck me in many of the scientific conferences I attended was the sheer impact of breaking food down to its components. Even looking at wheat where it is nothing more than a series of chemicals and bonds (as shown in Diagram 1 below: wheat structure from Nature magazine – which in itself somewhat denatured the very importance of keeping the culture of food alongside its research and growing. The underlying message – it may taste nice, but lunch is a bundle of chemicals whose impact we should seek to understand!

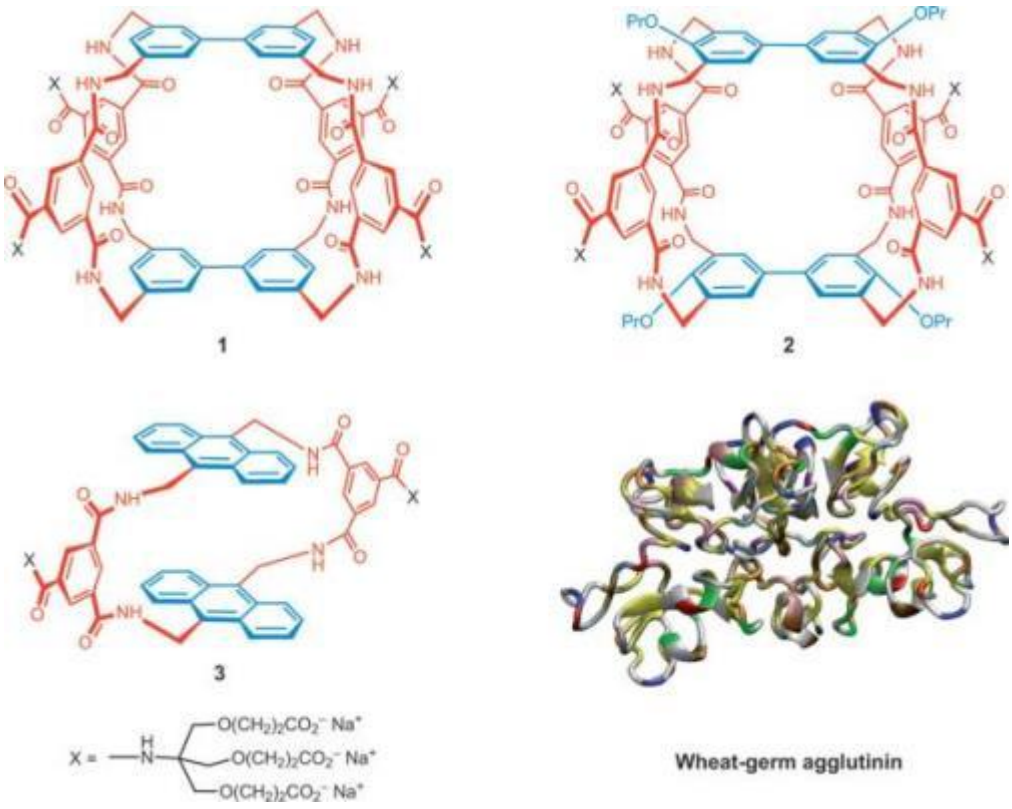


Diagram 1: Wheat structure

From all my travels there are, however, some strong conclusions I have drawn up – there is something for everyone of us and I feel strongly that steps need to be taken or we will not break the cycle we find ourselves in. **The opportunities for farmers in this whole area are relatively limited, unless the combined efforts of nutritionists, doctors, researchers, consumers, retailers and processors come together to effectively address NCDs.**

The targets are set by the World Health Assembly - to reduce the current levels of NCDs by 25% by 2025 and we have to be realistic and develop engaging approaches for everyone – and we can all do our bit. It is the community benefit of **We**llness versus the isolation of **I**llness. However, changing behaviour in less than a generation is hard and we need to use ways whereby we can put in place something that the majority of farmers can be involved in to impact positively on the majority of the general public. In the short term this is through helping to reformulate our food - *Health by Stealth* - amending the food we usually eat without even knowing it. In the longer term, by producing nutrient-enhanced food for the market, there is a real danger that farmers are nothing more than the manufacturers of raw products that are 'improved' post-farm gate. Farming's voice needs to be

heard and farmers need to play a part in this burgeoning area. I have summarised my conclusions in Table 1:

Table 1: The main conclusions – we can all play a part

	NOW	1 – 5 YEARS	5 – 10 YEARS	GOAL
ALL	**1. WORK TOGETHER TO DEVELOP A FULLY INTEGRATED FOOD PLAN BASED AROUND NUTRITION** - Community based and with people, and ideas we would usually not choose to work with **2. EMBED HEALTH AS A VALUE WHEN WE BUY FOOD** **3. WE NEED TO CREATE MORE DIVERSITY – IN OUR FOOD AND IN OUR FARMING**			**A 25% REDUCTION IN NON-COMMUNICABLE PREMATURE MORTALITY BY 2025 (World Health Assembly)**
Farmers	➢ All agricultural courses should ensure that students carry out basic human food nutrition education ➢ There is a great opportunity for farmers to link more effectively with the general public – Open Farm Sunday and Open Farm Schools days are very successful, but there is more scope for deeper and more meaningful connections for farmers and the local community around food.	➢ Reinstate farming's ownership of food – *food not commodities* ➢ Get healthy! ➢ The market place is starting to gear up to require nutrient benefits, it is more urgent in developing countries, but it will come to the Western world with the potential to improve opportunities for farmers and breakthroughs in processing – be part of it in order to benefit from added value opportunities ➢ Look at your business and identify your long term goals for food production and nutrition	➢ Consider the niche opportunities for your business in the development of fortified foods and bio-fortification ➢ Adopt more sustainable farming approaches and get closer to your market, such as LEAF Marque	
Researchers	➢ Be open to new ways of thinking, the amount of times I heard 'counter intuitive' results was amazing ➢ Look at the opportunities for Apps for individuals and doctors on improving health	➢ Develop new more integrated approaches to health and diet that links in with farm production. It appears we have only just started to get to grips with the breeding pathways, the single issue nutrients, epi-genetics, how foods interact in vitro and in vivo, our gut organisms and so much more is needed to be done to understand how we can deliver 'health by stealth'. ➢	➢ Understanding more around behaviour change is critical, social scientists and psychologists are essential in how we move things forward	
Consumers	➢ Learn to love food more, including its values and culture – the story behind our food	➢ Eat a balanced diet – one more fruit and vegetable per day per year ➢ Consider your food habits and reflect on change	➢ Get involved in government, industry and school initiatives, such as Open Farm Sunday and Open Farm Schools Days	
Doctors	➢ Be more pro-active in supporting and monitoring health – weight, wee and waist should be measured during significant milestones in people's lives ➢	➢ Consider the opportunities for your role in local community actions, at the GP or hospital	➢ Work alongside nutritionists to improve health	

Retailers and processors	➢ Health is a pre-competitive issue – we need to work together to market messages and improve performance	➢ Work with farmers to deliver the best and right raw nutrient appropriate materials – the whole package of food delivers vitamins and nutrients more effectively	➢ Your marketing and analytical skills will be increasingly important in helping deliver change among all ages	
Policy	➢ Be bold in the food debate – with strong leadership ➢ Much as it grieves me to say – it is not all about farming! Neither is it all about multinational food corporations. We need a food, health and nutrition, built around what we know and a radical rethink our approach and who is involved. (farmers have often been excluded)	➢ Build up a team and pilot a new approach to a fully integrated, community based health and wellbeing plan, built around nutrition	➢ Promote and support the pilot, built around simple and inclusive messages and community drive	

3. The journey and personal benefits

Opening up the Pandora's box of this topic truly revealed the world's food problems with the diverse and compelling arguments for opportunities, single issues, policy options, novel crops, health fads and new language, to name but a few.

The more I read around the topic, the more evident have become to me my own personal failings, the shortcomings within the farming community and the lack of joined up solutions and approaches to truly address the underlying problem of dietary-related illnesses and our society's relationship with food. Early on in the study I was fortunate to be advised to focus on a single issue and from there I developed a somewhat complex 3-D game of chess, just to simplify things! Recognising that there were many niche opportunities with exciting fruit, vegetables, seeds and pulses for farmers was not the approach I was looking for, since it failed to truly address the fact that 65%[iii] of UK adults are either overweight or obese. I was keen to learn from these areas, but also build potential solutions for identifying the farmer's role in the whole food, nutrition and well-being debate.

Throughout the year there have been initiatives launched, such as the Change4Life Smart Swaps[iv], the National Obesity Forum report[v]: State of the Nation's Waistline – Obesity in the UK: Analysis and Expectations, which have highlighted the need to treat obesity like smoking, alongside European School Fruit and Milk Schemes[vi], American $11billion School Healthy Lunch Programme[vii] and Global initiatives developed by WHO and FAO. We have been told to eat more apples, less fruit and more vegetables, low fat produce, no trans-fats, etc. Furthermore, diets such as the Dukan, 5:2[viii] and 4:3[ix] have all hit the headlines.

Despite my knowledge of the dietary requirements for cattle, sheep and pigs, I realised that I knew little on feeding people: after all that is what food technologists are for! This then prompted me to carry out a nutrition course online and demonstrated a key failing in our agricultural education system, thus leading to my first recommendation that:

A**ll agricultural courses should ensure that the students carry out basic human food nutrition education**.

I have read scientific papers, watched popular and technical programmes, videos, TED lectures and read blogs, experimented with food and our diet at home and on my travels (a "no" to sea slugs or stinking Tofu – thank you) and been perplexed by the language surrounding food: emotive, cultural, traditional and scientific. And finally realised the sheer scope and size of the industry that surrounds what we eat. Included in this is the realisation that the majority of farmers in the UK do not produce food – merely commodities and thus my second recommendation:

The sooner we can restate farming's ownership of 'food', the better.

My extensive studies have included travel to Canada, Taiwan, Southern Ireland, Italy, Brussels, the Netherlands and of course the UK. I have been looked after extremely well and am very grateful for the hospitality I have received at so many institutes and conferences. The Contemporary Scholars Conference in Canada was a unique opportunity to meet with so many inspiring and motivated individuals setting off at the start of their Nuffield Farming Scholarships. Aside from a very full and informative programme, I also took the opportunity to visit the University at Guelph and several researchers. I have visited The World Vegetable Centre in Taiwan, Rothamsted Research Institute, The Institute of Food Research, the John Innes Centre, the School of Artisan Foods, Campden BRI, the British Nutrition Foundation, Sainsbury's, Waitrose, Marks & Spencer's, BASF, the headquarters of Food and Agriculture Organisation, the University of Surrey, NIAB, Newcastle University, Glasgow

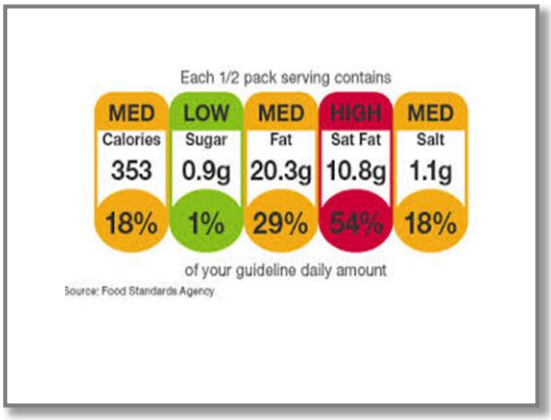
Royal Infirmary and the Restaurant of the Future at Wageningen University to name but a few. I have attended a range of conferences and farming discussion groups, raising more and more questions, all based around the simple solution – a diverse and balanced diet - eat *food,* NOT too much and *mostly* vegetables.

I am so honoured to have had the opportunity to sink my teeth into this topic and start embracing solutions for more sustainable diets and food system. I have not had a chance to go into detail on all the discussions I have had, but each and every one has been instrumental in the route that I have taken and the thoughts I have concluded. Thank you, I have loved the experience and there will be more to come!

In January 2013 the discovery of horse DNA in frozen burgers and ready meals prompted people to think more about where their food came from. A study that LEAF carried out with IGD in June 2013 showed that 18 to 24-year-olds were twice as likely (69%) to buy British than in 2007 (36%).[x] A survey by Consumer Intelligence found meat sales fell, with more than a fifth of consumers buying less meat following the horse meat scandal, with sales of frozen beef burgers falling 43% and ready meals by 13%, according to market research company Kantar Worldpanel. Although framed around the wrong reasons, eating less meat is good for health - non meat eaters are 32% less likely to die from cardiovascular issues and generally have a lower risk of type II diabetes and obesity (*Oxford University*).

Thus the issue of food products and their authenticity is being blighted by increasing adulteration problems, not just in Europe but across the globe, and this is consequently leading to behaviour change in buying habits. While I was in Taiwan, there was a scandal where cotton oil and cheaper versions were being substituted into olive oil, and so there was a growing realisation of adulteration, meaning that transparency, traceability and quality will continue to be drivers, particularly for the EU food chain.

This has been against a background of sugar being quoted as the new tobacco and the introduction of the traffic light system on food labels in-store in June 2013. This combination of colour coding and nutritional information shows how much fat, salt and sugar and how many calories are in each product and adds more to the confusion around food choice. Fresh produce, fruit and vegetables are always excluded from such schemes and as yet only just over 60% of foods will be covered by the system because it will remain voluntary. However, getting a consistent system has proved problematic, partly because of the difficulty of getting industry leaders to agree on the labels and because mandatory regulations require agreement on a European level.



The challenge is understanding what makes up a balanced diet when mixing and matching labels – could you get a balanced diet from just red labels? Is excluding everything with a red label detrimental to your diet?

My real journey started in March 2013 with Canada and a thorough insight into farming and related industry. Then to London and the International Food and Drink Event (IFE) where a large area was dedicated to functional foods. This biennial event is the biggest food and drink trade show and I was

surprised by just how many supplements, drinks and fortified foods were on sale, and little of it representing the food we know that comes off farm. This was further reinforced as I travelled; I was shocked by the discussions and language around food and its role; ranging from well-respected and valued, as at the Schumacher College in Devon where every meal is blessed, revered then shared, to a commodity, a raw material and a series of chemicals and bonds! I fundamentally believe that we need to work out how we can bring together the passion of those 'foodies' in the slow food movement, with the passion of farmers to do an excellent job in producing food.

Next I attended Ireland's Bord Bia's inaugural Global Sustainability Conference 'Our Food, Our Future. Sustainability: The Bottom Line'. This was eye opening and demonstrated a really bold commitment from their government to working with the food industry. The Prime Minister, plus the Agricultural Minister for Ireland together with the Heads of Sustainability for the major food companies, led the discussions for the 800 attendees from all over the world in an effective 'sell' of Irish products under the 'Origin Green' banner. Sourcing and concern about food safety are at the top of the agenda for promoting Irish products, in a bid to drive the economy to a better place – but interestingly with no nutrition priorities discussed. Their mission - *to drive through market insight and, in partnership with industry, the commercial success of a world class Irish food, drink and horticulture industry.*

Travelling on to Rome to meet with some of the biggest global processors was an eye opener. Unilever, Nestle, Danone, Friesland Campina as well as the chemical companies such as BASF, Dow and Syngenta are spending millions on developing new foods and nutrition; furthermore they have open information and good debates. Nestle, for example, has a very strong nutrition advice team. With such economic power across the globe these players are important agents for change. I also spent two days at the headquarters of the Food and Agriculture Organisation (FAO). It was interesting to see the stark contrast of the different approaches between developing and developed nations in the bid to address malnutrition – the 1 billion starving and the 1 billion obese.

The lovely and talented people I met in Taiwan opened my eyes to the importance of mixing high science with culture and tradition. By 7:30am I would have eaten four different vegetables types with my breakfast. One thing that my visit to Taiwan demonstrated was the great opportunity to learn from those cultures where science and technology have built around strong cultural traditions; for example China has the long held traditions around Chinese medicine and philosophies, such as Confucius. The sayings and statements of Confucius are as relevant today as they were over 2,500 years ago, and form the basis for the global interest in functional foods and bio-fortification which is well accepted across the world with the growing markets for supplements, health drinks and re-discovered and new vegetables.

> *"He that takes medicine and neglects diet, wastes the skills of the physician."*
> *Chinese proverb*

Here in the UK the Government White Paper (2010) 'Healthy Lives, Healthy People: Our strategy for public health in England' is far from inspiring. In addition the Green Food Project has been a starting point but, with some three ministerial changes, it has lost the drive needed to really engage everyone. It is critical that we work out how to effectively **embed health as a value when we buy food.**

4. Some Reflections

As with anything it is always important to understand the future. We need to be aware of the past and look backwards to move forwards, and there are some interesting lessons from people such as the American dentist Weston Price who, together with his wife Florence, in the 1930s gave up his practice to study diets across many different continents. At a time when Americans were abandoning their traditional diets in favour of the new, manufactured foods - white bread, margarine, pasteurised milk and refined white sugar - he was seeing tooth decay alongside degenerative diseases such as arthritis, osteoporosis and diabetes and chronic fatigue. The photos below demonstrate these startling results.

Figure 1 shows how the development of the facial bones determines the size and shape of the plate and the size of the nasal air passages. Note the strength of the neck of the men and the well-proportioned faces of the girls. Such faces are usually associated with properly portioned bodies. Tooth decay is rare in these mouths so long as they use an adequate selection of the native foods.

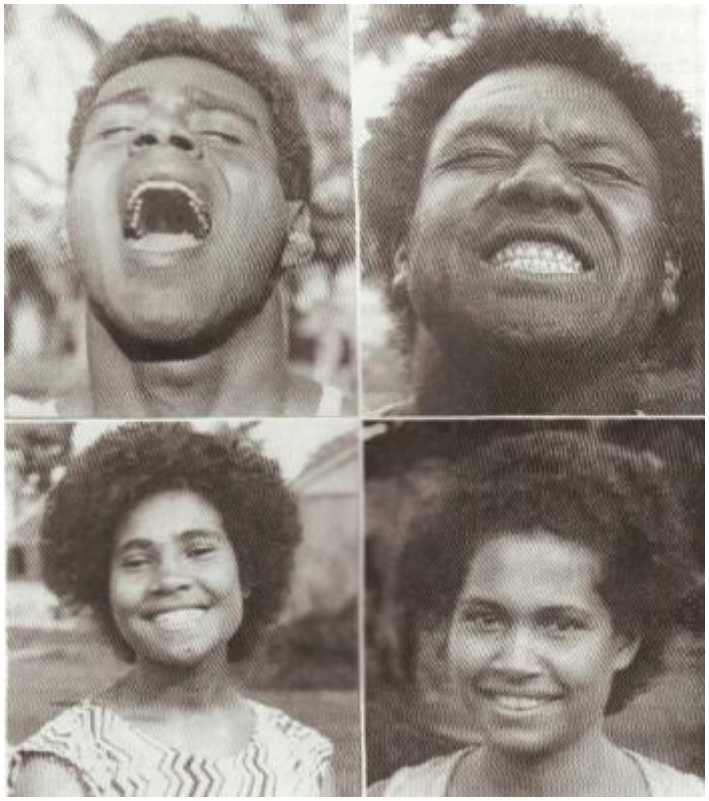


Figure 1 The excellent teeth structure associated with native foods and a good diet

Note from Figure 2 on next page where in the '*modernised districts of Switzerland tooth decay is rampant. The girl upper left is 16 and the one on the right is younger. They use white bread and sweets liberally. The children below have very badly formed dental arches with crowding of the teeth. This deformity is not heredity. It is a typical expression of inadequate nutrition of the parents.'*

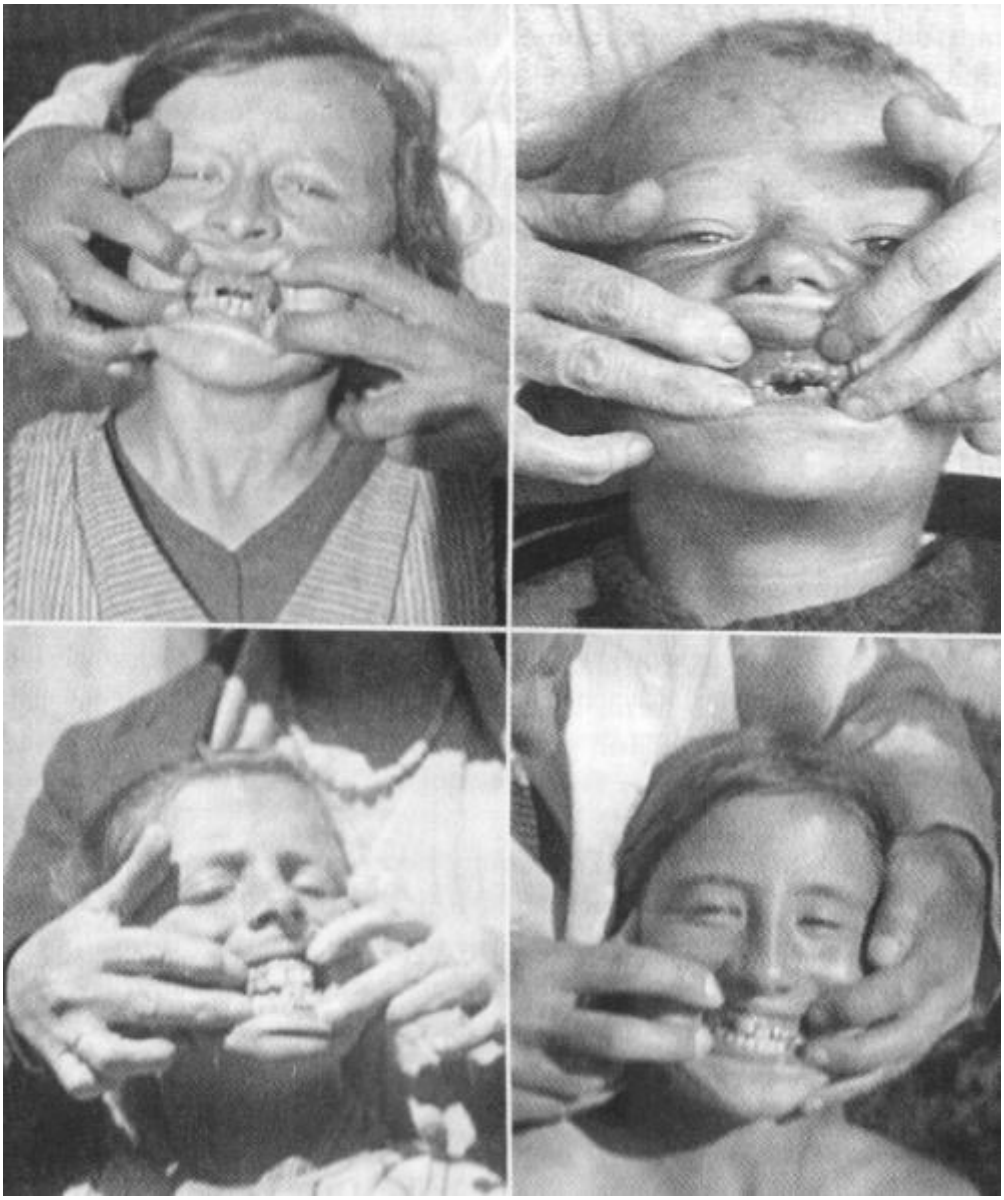


Figure 2 : The poor development associated with diets rich in refined foods

For 10 years Weston Price travelled around the world in search of the secret to health. Instead of looking at people with disease symptoms he focused on healthy individuals and challenged himself to understand how they achieved such amazing health. Dr Price travelled to hundreds of cities in 14 different countries in his search to find healthy people. He investigated some of the most remote areas in the world. He observed perfect dental arches, minimal tooth decay, high immunity to tuberculosis and overall excellent health in those groups of people who ate indigenous foods. He found that when people were introduced to modernised foods, such as white flour, white sugar, refined vegetable oils and canned goods, signs of degeneration quickly became apparent. Dental caries, deformed jaw structures, crooked teeth, arthritis and low immunity to tuberculosis became rampant amongst them. His findings are as relevant today as they were some 80 years ago – we ignore the laws of nature at our peril. Dr. Price's findings spell it out: poor nutrition causes physical degeneration. '*With the coming of the modern man with his foods of convenience, comes disease and even death. Great harm is done, in my judgment, by the sale and use of substitutes for natural foods.*' What harm is he referring to? *'That human beings can degenerate physically so rapidly by*

the use of a certain type of nutrition, particularly the dietary products used so generally by modern civilisation.'

And do we learn from these findings – the story has not really moved on – '*thousands of sickly parents are begetting sickly children with sickly teeth, and instead of feeding them with such food as is calculated to counterbalance the inherited predisposition, are doing just the opposite.' (The Teeth and how to solve them L.P. Meredith, 1872).*

UK Guideline Daily Amounts and Food Standards Agency advice on meals:

- have 20% of your daily nutrition at breakfast,
- 30% at lunch,
- 30% at dinner,
- with 20% left for snacks.

Couple this with the work of Sir Jack Drummond (very distant relative!) adviser to the Ministry of Food from 1940 to 1946 who, through tracking the history of food over 500 years identified the basic principles of food and nutrition and its underlying importance as THE bedrock of society. He noted, '*if people are properly nourished, cold and unhygienic conditions are much less likely to harm them.*' In the days when most people had to turn to bread and potatoes to take the place of rationed meat, it was Professor Drummond who reassured the public: '*surely foods do not make you fat unless you eat too much. Starch is not more fat-making than butter; it is only over-eating which puts weight on the average person*'.

We take for granted how recent the scientific understanding behind food really is. Prof. Drummond was working at a time when nutritional science, and the constituents of food necessary to maintain, and improve the quality of life, were defined. Proteins, fats carbohydrates, water and mineral salts, the five 'proximate principles' essential to any diet, were satisfactorily classified in the closing years of the nineteenth century and nutritionists laboured initially to relate the meaning of calories and protein to ideas of dietary sufficiency. Experiments showed, however, that subjects fed on materials that had these principles in generous quantity did not flourish. The search for the missing magic ingredient led to the discovery of vitamins – properly defined by the biochemist Sir Frederick Hopkins in 1912. Once dealt a full hand of components, nutritionists got to work to assess how far the lack of any one of them would affect the life and health of the population.

This emphasis on what was missing is different to our own nutritional preoccupations. Today, we are far more interested in the consequences of excess, in how the interaction of various components may itself give rise to illness: cancer, heart and circulatory disease, intestinal troubles and obesity. Whereas, Prof. Drummond and his colleagues were anxious to supplement diet, for example by extending the consumption of green vegetables, fruit, high protein and milk and dairy products, as well as introduce added vitamins to necessary staples such as flour or margarine, we are far more worried by how too much of any of these may cause us to operate below par. The intellectual transition has been very rapid and is a measure of the successes of those first scholars in explaining, then eradicating, deficiency diseases.

Where we need to move forward demonstrates that **it is critical that we shape our food systems in such a way that they can help promote better nutrition.** However, the opportunities for the farming sector are potentially limited if we do not grab them.

5. Methodology

Trying to develop a strategic and process-driven approach to this study was difficult. The issues surrounding food systems are complex and multi-layered. Thus, for me, it was taking a broad brush approach to understand the issues behind human diets, dietary-related diseases, behaviour change and the science – social, environmental and production - before focusing on the growing issue of 'malnutrition' in the developed world and using 'the pizza' as a proxy of something that is eaten by the majority in the Western world and that could provide opportunity for the majority of farmers.

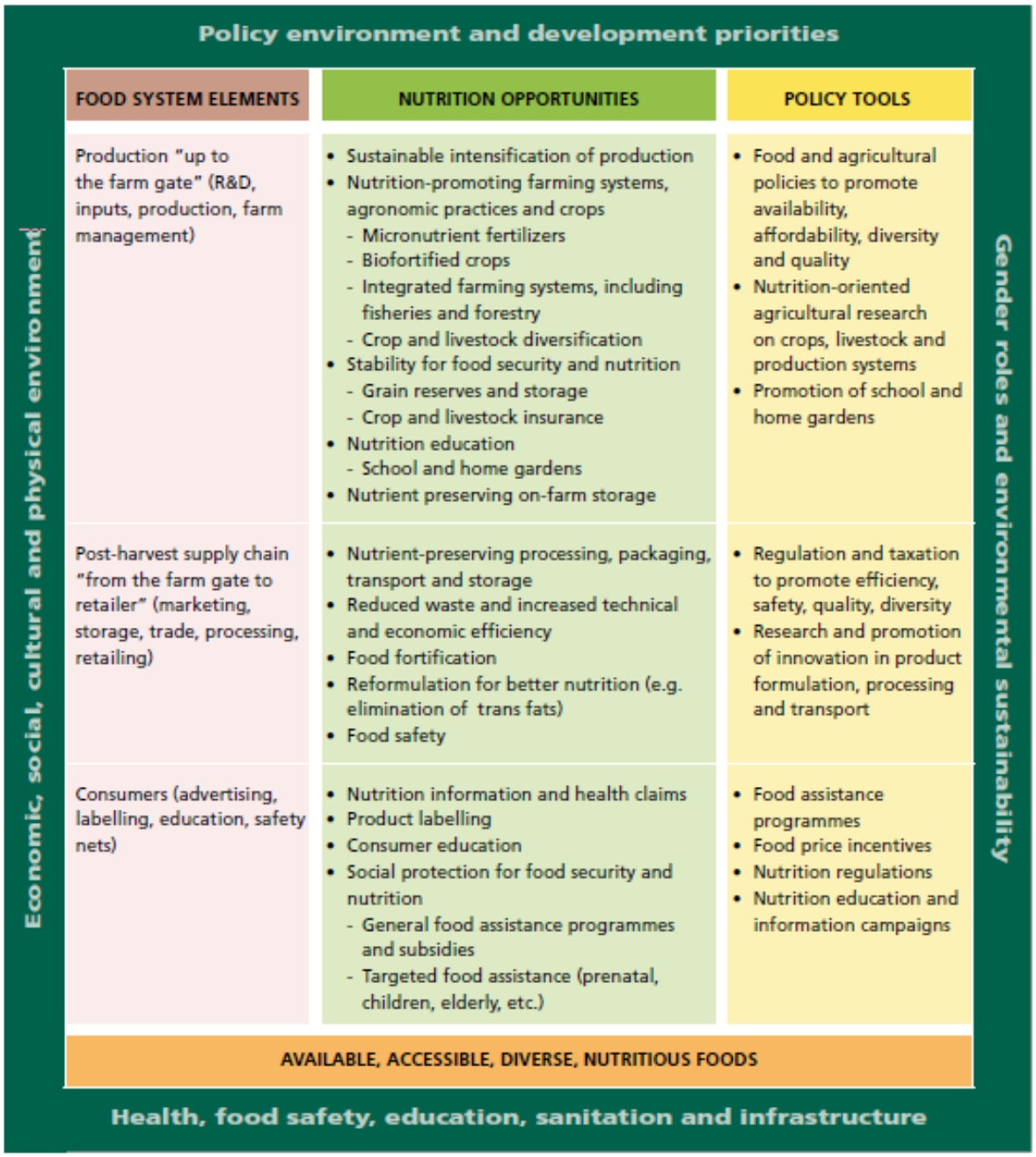
I have spent the last 22 years involved in the development and promotion of more ***sustainable farming systems***, through Integrated Farm Management with my work at LEAF. What this Farming Scholarship has done is opened my eyes up to the importance of developing more ***sustainable food systems*** to address malnutrition in all its forms: under nutrition; micronutrient deficiencies; and overweight and obesity, whilst including the features of a fully integrated approach for farming.

It is evident that the solutions are complex and multidimensional – hence my 3-D game of chess. They include inadequate availability of, and access to, safe, diverse, nutritious food; lack of access to clean water, sanitation and health care; and inappropriate child feeding and adult dietary choices, with the root causes of malnutrition being even more complex and including broader economic, social, political, cultural and physical environment. In this study I have not addressed the issues surrounding under-nutrition relating to poverty in developing countries – but the solutions are the same for malnutrition in all its forms, requiring integrated action and complementary interventions in agriculture and the food system in general, in public health and education, as well as broader policy solutions. Indeed there are some excellent examples in the work of Harvest Plus and the government's involvement in the Global Food Plan.

A key part of sustainable food systems is how sustainable consumption is captured, and it is critical that we frame this within the concept of sustainable diets: "*those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations.* ***Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimising natural and human resources***" (*Burlingame and Dernini, 2012*, p. 7[xi]). Sustainable diets imply a change in dietary preferences to reduce overconsumption and a shift to nutritious diets with lower environmental footprints. They also mean a reduction of losses and waste throughout the food system. Thus it has been critical to be mindful of this multi-levelled need for better resource management. For purposes of simplicity and focus I have not looked in detail at the full environmental and resource management implications of the conclusions I have drawn up, but I have aimed to ensure that in the drive to improve nutrition the food system is more efficient, diverse, relevant and integrated, thus reducing waste and enhancing efficiency and biodiversity.

In 2013 FAO took a leading role in addressing the nutrient issues in the objective of zero hunger. Personally not knowing enough about what FAO did, meant it was fascinating to understand more the breadth, commitment and ambition. To me, Table 2 below encompasses much of the opportunities for farmers, retailers and processors, consumers and the policy that can be put in place to change things, and I have expanded on this to draw my conclusions.

Table 2 : Food system interventions for better nutrition. FAO (2013)[xii]



Many of the nutrition opportunities highlighted in Table 2 are nutrient specific and nutrition specific. They are followed with the primary purpose of making the system more attuned to producing good nutritional outcomes. For example, the importance of developing bio-fortified crops to improve nutrition; at the same time these crops may be more disease resistant and better adapted to grow in nutrient-deficient soils. They may improve nutrition but also produce higher crop yields and increase producer incomes, providing opportunities for consumers and producers[xiii]. There are also 'nutrition-sensitive actions' that can have both a positive impact (improved yields, income and nutrition) or potentially negative (for example the introduction of new crops that might lead of higher productivity but also higher demands on women's labour) and they may use different breeding techniques including GM.

I have adapted the concepts of Table 2 into my study to capture the range of options open to farmers to improve the nutrition of our food, looking at the three core areas:

1. Traditional, cultural and soil based approaches
2. High tech, breeding and GM
3. Post farm gate processing, biofortification, nutraceuticals and functional food

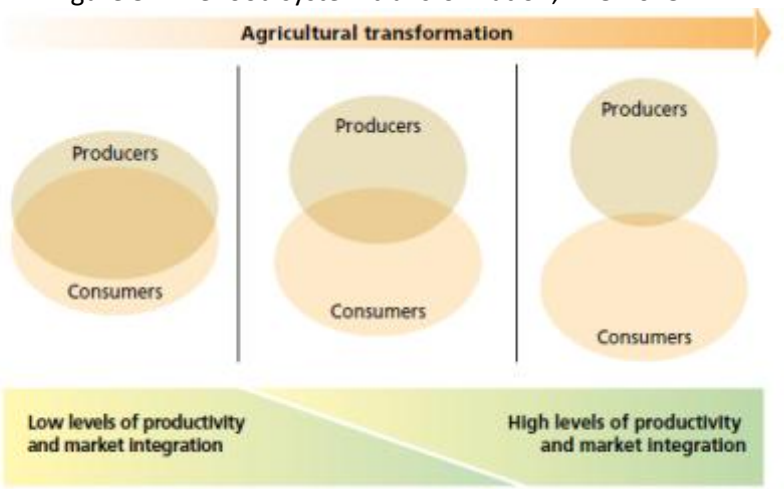
surrounding the production of wheat, tomatoes and cheese.

My solutions are geared towards the involvement of:

- Farmers, researchers, consumers, doctors, retailers and processors and politicians

In particular these solutions need to be set in the context of the food system transformation that we find ourselves in. Figure 3 demonstrates the transformation of the food system revolution, typically characterised by rising labour productivity, less people in agriculture and increasing urbanisation. As the food system transforms, centralised food-processing facilities develop along with large scale wholesale and logistics companies, supermarkets emerge in the retail sector and fast-food restaurants become widespread. The transformation affects the whole system, changing the ways food is produced, harvested and stored, traded, processed, distributed, sold and consumed[xiv]. In subsistence farming the food system is basically closed - producers generally consume what they produce. With economic development subsistence farming gives way to commercial agriculture in which producers and consumers are increasingly separated in space and time and their interactions are mediated via markets. In the later stages of the food system transformation, very little overlap exists between producers and consumers and the system opens up reaching beyond the local economy to tie together producers and consumers who may even be in different countries. It is this transformation in the Western world that has had a significant impact on the communication, understanding and behavioural change, and it is crucial we use this as the context for how we address the urgent need to bring nutrition and improved diets to our population and develop their relationship with food.

Figure 3 : The food system transformation, FAO 2013



6. Why food matters

Good nutrition is the foundation for human health and well-being, physical and cognitive development, and economic productivity. Nutritional status is a critical indicator of overall human and economic development, and good nutritional status is an essential social benefit in its own right. As an input to social and economic development, good nutrition is the key to breaking intergenerational cycles of poverty, because good maternal nutrition produces healthier children, who grow into healthier adults. Good nutrition reduces disease and raises labour productivity and incomes, and this includes people working in agriculture.

Malnutrition, on the other hand, imposes high economic and social costs on countries at all income levels. Global losses in economic productivity due to under-nutrition and micronutrient deficiencies have been estimated at more than 10% of lifetime earnings and 2– 3 % of global Gross Domestic Product (GDP)[xv] – a global cost of US$1.4 – 2.1 trillion. At the same time obesity is associated with lower labour productivity and higher medical costs arising from associated non-communicable chronic diseases, such as diabetes and heart disease[xvi]. It is estimated that the cumulative output loss due to non-communicable diseases, for which overweight and obesity are key risk factors, will be US$47 trillion over the next twenty years[xvii]; this suggests that 'malnutrition' may impose a cost of US$2.8-3.5 trillion, equivalent to 4-5% of global GDP, or US$400-500 per person per year. **Investments in reducing this burden will have high pay-offs.** Figure 4 [xviii]shows the multiple burdens of malnutrition, many of which overlap. The three types of malnutrition considered here (designated as: A = child stunting, B = child micronutrient deficiencies and C = adult obesity) occur in different combinations around the world. The figure also shows the very few countries in the world that have no significant malnutrition problems in these categories. It is therefore interesting to note and understand more about: Why this is the case? Is the issue changing? And what can we learn from the successes in these countries? Do we have the right steps in place to change?

Across Europe there are many countries where obesity is a growing problem and, in the UK, 64% of adults are overweight or obese (PHE 2014[xix]). This is a staggering increase from 29% in 1993, costing an estimated £5 billion each year through addressing type 2 diabetes, heart disease and certain cancers, and the issues relating to self-esteem and mental health.

Most cases of obesity are caused by eating too much and moving too little. If you consume high amounts of energy from your diet, but do not burn off the energy through exercise and physical activity, the surplus energy is turned into fat. Over the past three months I have worn a FitBit, a techno pedometer. On average I walk 4000 steps a day and burn off around 1400 calories, including maintenance. I should walk and exercise more but I have all the adequate excuses as to why I do not. However, while I may not quite reach the 9000 steps I should do a day, it is easy for me to set personal targets of say 1000 more steps a day.

Like the fact obesity does not just happen overnight – it develops gradually from poor diet and lifestyle choices - neither do the solutions. It is important to develop approaches that are achievable and are delivered in bite-sized pieces; in the short-term delivering reformulated foods that offer 'health by stealth' benefits against the backdrop of a long term, thorough and thought-out structure.

In the longer term it is finding the answers to questions such as: what works in a plant to deliver better nutrition? How do we account for the interactions in the plant? And then those interactions when a plant is cooked, eaten raw, etc. even before the gut micro-organisms have had their go!

We know that unhealthy food choices include:

- eating processed or fast food high in fat, especially saturated and trans-fats
- not eating fruit, vegetables and unrefined carbohydrates, such as wholemeal bread and brown rice
- drinking too much alcohol – alcohol contains a lot of calories, and heavy drinkers are often overweight
- eating out a lot – you may have a starter or dessert in a restaurant, and the food can be higher in fat and sugar
- eating larger portions than you need – you may be encouraged to eat too much if your friends or relatives are also eating large portions. Indeed work at Wageningen University has shown that people tend to eat more when eating together.
- comfort eating – if you feel depressed or have low self-esteem, you may comfort eat to make yourself feel better.

We need to work out ways to improve our nutrition and gain more understanding about those countries where malnutrition is not such as problem as defined by Weston Price back in the 1930s and as set out in the figure shown on the next page.

See Figure 4 on next page

Figure 4 : The multiple burdens of malnutrition (*Croppenstedt et al 2013*)

Aside from managing diets effectively a key part is also being mindful of micronutrient intakes. Tiny as the amounts required are, the consequences of their absence are severe. This has been a major point for the discussions I was involved in. Billions of pounds are put into developing supplements and vitamins and it is clear that taking too many of specific vitamins and nutrients can be devastating. Table 2 overleaf illustrates those micronutrients that are an issue among some of the UK public.

Low intake	Low status
Vitamin A	Iron
Riboflavin	Riboflavin
Iron	Vitamin D
Calcium	
Magnesium	
Potassium	
Zinc	
Selenium	
Iron	

Table 2 : National Diet and Nutrition Survey, Rolling Programme Years 1, 2 and 3, 2008 – 2011. (*BNF 2013)*

Unhealthy eating habits tend to run in families, as you learn bad eating habits from your parents. In the UK the diversity of our diets has reduced dramatically – there are some 10 meals that form the majority of people's regular diets, which includes the pizza. The research by Hello Fresh (July 2013) suggests children as young as six are eating convenience foods on a regular basis; half of the 6 - 8 - year-olds polled said their parents fed them takeaway or microwave meals at least once a week. And when asked which food they ate most regularly, the children answered crisps, chicken nuggets, ice cream and frozen pizza. Not only are these often high in sugar and saturated fat but it does not teach kids about the benefits of preparing meals from scratch using the raw ingredients. Leading child nutritionist and author Jenny Tschiesche said: "*The research appears to suggest a decline in the family tradition of eating a home-cooked meal in the evening. Many children are now completely removed from the food preparation process."* No surprises, but it really offers a genuine opportunity for farmers to link up more with chefs.

In my travels across Taiwan the range of foods, vegetables and fruits was immense. Such diversity leads to healthier lifestyles and economies. As I have said, by 7:30 am I would have eaten at least 4 vegetables. To put this into context, specifically there are around 270,000 species of higher plants. About 20,000 are edible, and about 7,000 are used in agriculture; but only 14 animal species currently account for 90% of all livestock production and only 20 crops dominate global cultivation providing approximately 90% of the dietary energy. Eighty per cent of the world's population lives principally on four main crop species: maize; wheat; potatoes and rice.

The diversity in Taiwan was astounding; not only was there the sheer diversity of the diet but also the work carried out at the research centres there demonstrated the breadth of knowledge and opportunities for improved nutrition at all levels. The unique geographical features of Taiwan also add to the richness of the indigenous and endemic plant species there. These plants serve as a resourceful bank for biologically active phytochemicals. Because of Taiwan's unique geographical location, climate, and terrain structure, plants have evolved to create a very high ratio of endemic species on the island - there are a total of 4,077 species of native vascular plants in Taiwan and, among these species, up to 1,067 are unique to Taiwan, making up 26.2%. The distribution density of unique species tends to increase with altitude. The ratio of unique species is proportional to altitude, a fact that makes sense in the light of plant dispersion and evolution. By comparison, a recent assessment of Europe's Vascular Plants has assessed 1,826 species.

Yet this diversity is increasingly not being reflected in the opportunity for health. Taiwan has a higher rate of obesity than many other Asian countries, possibly because the Taiwanese are less physically active, according to Bureau of Health Promotion director-general Chiou Shu-ti (邱淑媞). Taiwan's rate of obesity is higher than that of Singapore, Japan, Malaysia, South Korea, Thailand and

China, which is “alarming” because obesity is a precursor to serious disease, said Chiou at the 2012 Taiwan-Europe Health Dialogue in Taipei. The obesity rate in Taiwan is 19.2% in men and 16.6% in women, she said, far higher than in Singapore, Thailand and Malaysia, where the rates for males are 6.4%, 4.7% and 4% respectively.

“Although Taiwan did better than the West, the country should still be worried because obesity is one of the risk factors for non-communicable diseases,” she said. Dubbing Taiwan a “fat Asian country,” Chiou said exercise is needed to improve the population’s overall health. About 68% of Taiwanese men and 79% of women are not physically active enough, meaning they take less than 30 minutes of moderate exercise three times a week, she said.

Obesity is a growing problem in Asia and Oceania, and the combination of people being overweight and having poor diets, is becoming more of a concern among the poor than the rich, and resulting in spiralling health costs to the governments. In mainland China the estimated prevalence of diabetes among a representative sample of Chinese adults was 11.6% and the prevalence of pre-diabetes was 50.1%. Projections based on sample weighting suggest this may represent up to 113.9 million Chinese adults with diabetes and 493.4 million with pre-diabetes. These findings indicate the importance of diabetes as a public health problem in China[xx].

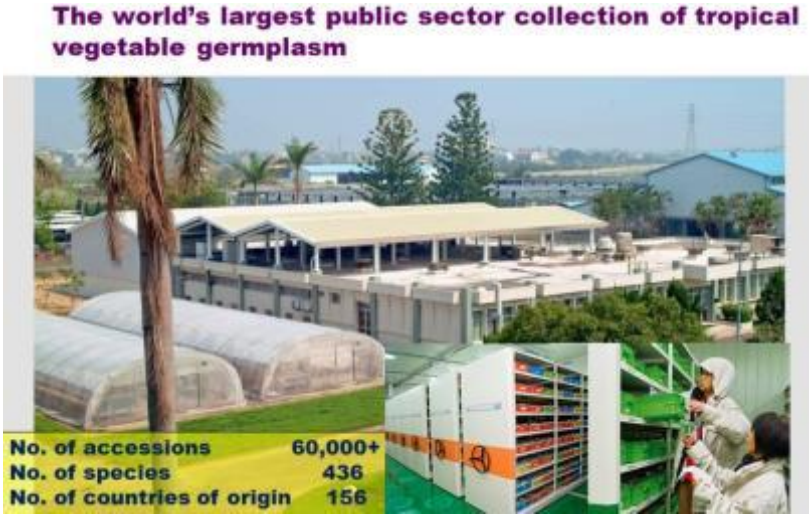
The growing issue of obesity in Asia

In Asia, like Northern Europe, the aggressive marketing of food has in recent years increased consumption of “Western diets”, i.e. energy-dense and nutrient-poor foods, high in saturated fats and sugars, especially popular among youth worldwide. With reduced physical activity, often due to increased urbanisation, this trend poses a major risk of suffering from NCDs. Effective advocacy campaigns are needed now for better balanced diets, recognising the short falls and successes of existing campaigns, and building stronger bridges right across the developed nations. While physical exercise is important it is the wealth of a nation and increasing food consumption that predetermines an overweight country. Lack of physical exercise does not lead to obesity in its own but obesity does reduce the ability to exercise.

And some of the key players needed are such as those people I met with while in Taiwan. I visited the World Vegetable Center (AVDRC), and I am very grateful to Dr Dyno Keating and all his staff who were so welcoming and helpful.

AVRDC
The World Vegetable Center

At the AVRDC they seek to overcome malnutrition and poverty and facilitate good health for both the rural and urban poor by increasing the production, quality, consumption and profitability of wholesome and nutritious vegetables. In particular this is by promoting crop diversity and better balanced diets - which should help to reduce obesity and associated health problems - alongside good agricultural practices, opportunities for greater employment and effective post-harvest value-addition and marketing mechanisms.



The staggering diversity of accessions and plants species demonstrates the sheer challenge and opportunity for us all to learn from the breeding programmes developed at AVDRC and across the Asian countries where these diets are working.

An accession is a collection of plant material from a particular location. An accession is assigned an identification number, which is usually preceded by the abbreviation PI (plant identification). **A species** is a group of organisms that is capable of interbreeding to produce fertile offspring. However, this biological test of a species is not always available, so there is also a morphological species concept, based on anatomical similarities. **A trait** is an attribute or character of an individual within a species for which heritable differences can be defined.

Here I looked at the questions around the issue of 'is Feeding the World without nourishing it at the same time sensible'? There was extensive work demonstrating the much higher rate of return accruing to research in developing opportunity crops, investing more in vegetables and fruits to help abolish malnutrition. **Many highly nutritious crops are under-utilised and since research consistently shows that minerals and vitamins are better absorbed from fresh produce we need to learn more from this work.**

Aside from the work on nutrition, AVRDC also looks at economic benefits around the growing of vegetables in developing countries and outreach programmes for farming systems, including Integrated Pest & Farm Management and the development of hospital gardens in Rwanda, gardens in schools and gardens among local communities. This included seed kits for disaster relief based around small vegetable garden research and development, but with large-scale uptake.

- Seeds multiplied at AVRDC's regional offices
- An alternative production method for these disaster relief seeds focuses on public-private partnerships – an example is the current relationship with East-West Seed Indonesia
- Storage of the seeds and seed kits can become an issue to respond quickly to disasters with quality seed

It was in Taiwan the recommendation to '***eat the rainbow everyday***' came before me at nearly every meal (and that does not mean eat a tube of smarties!) While I was lucky enough to attend several banquets, and these really were a food orgy, I also indulged in quite a bit of street food. While there are things that, in the Western diet, we do not favour - cat, dog, snake, duck heads, etc. - the vast majority of the food was so fresh, ranging from raw fish, pork, noodles and rice to the widest selection ever of vegetables. I am now a dab hand at chopsticks, and carry a pair with me all the time – and the Asian countries do use spoons too! But what is clear is the message: that **plant diversity is key**, in order to deliver a range of nutrients, vitamins, micronutrients and fibre.

Eat a rainbow – every day!

Prof. Susan Jebb[xxi], the Professor of Diet and Population Health at Oxford University, is a nutrition scientist focusing on how what we eat affects the risk of gaining weight or becoming obese and the interventions that might be effective to help people lose weight or reduce the risk of obesity-related diseases. Her findings demonstrate that, in general, body weight is a more important risk factor for ill-health than differences in the nutritional composition of the diet.

She chairs the Food Network of the Department of Health's responsibility deal where the Public Health Responsibility Deal has been developed. This aims to tap into the potential for businesses and other influential organisations in order to make a significant contribution to improving public health by helping us to create the right environment. The Responsibility Deal embodies the Government's ambition for a more collaborative approach to tackling the challenges caused by our lifestyle choices. This includes food pledges that have been developed to support and enable consumers to control their calorie intake and choose a healthier diet. They include improving the nutritional content of food, increasing the availability and promotion of healthier food choices and providing consistent information to consumers.

Within the Responsibility Deal businesses can commit to taking action to:

- **provide calorie information on menus for food and drinks when eating out**
- **reduce salt in foods sold across the retail and catering sector**
- **remove artificial trans fats from all foods**
- **support and enable customers to eat and drink fewer calories through a range of actions**
- **increase the consumption of fruit and vegetables**

While the message is simple - a balanced diet - it is evident that short term hits, such as the reformulation of processed foods, are needed. Particular success has been around a 15% reduction in salt in foods in the UK. For Prof. Jebb the next challenge is working with the processing industry to address the issue of fats and sugars which will not be so easy, as 30% less fat in digestive biscuits does not necessarily mean less calories. The clarity of Prof. Jebb's messages is that **we need to embed health as a value when we buy food.** Reformulation of processed food is only a sticking plaster over the issue and she states that it is a multi-staged approach, working with the large processors such as PepsiCo where the Chairman and CEO Indra Nooyi has driven their agenda to being more responsible, that focuses the importance of food companies on being more responsible. It is evident that some of the broader aspects, such as respecting food, more could have massive consequences, re-engaging people with food and changing habits.

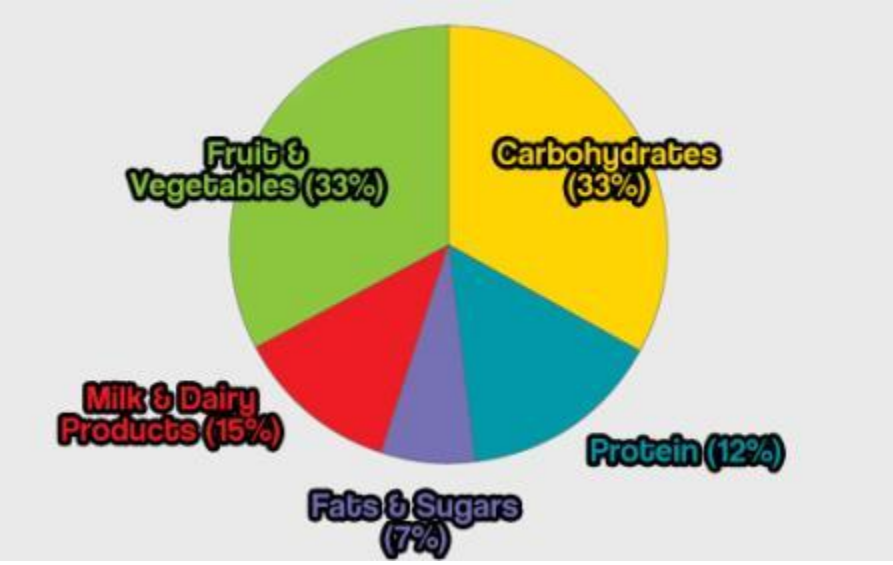
Michelle Obama has been driving a huge campaign in America with garden growing and encouraging children to eat more fruit and vegetables, but with little on eating less sugar and biscuits. In America the solution is often seen as losing weight – but in reality it is about preventing weight *gain*, which is more difficult. However, there is a lot of passion and enthusiasm behind what Michelle Obama is doing, and the Lets Move! approach to encourage exercise is even being taken to the 'soaps' with the First Lady making a guest appearance – I can see a storyline for EastEnders!

Prof. Jebb stresses that our bodies are very well designed to maintain weight, the gut hormone:brain mechanism is strong and we require cognitive control to avoid overeating; we have little control

biology to stop us overeating. Losing weight has to be done individually and kept going for ever. Unless we change the food environment the weight goes back on. For her the big **opportunities for farmers are around biodiversity and understanding the different nutritional profiles of seminally similar crops. We increasingly need to look deeper at the nutritional profile for crops and the interactions of different crops between each other.**

Even the Eat Well Plate is being increasingly questioned; the challenge is the simple messages targeted at a mass audience are increasingly not reaching out to everyone; in fact in some instances missing all intended audiences. We need more targeted messages that respond to the unique differences surrounding each and every one of us.

Recent work has led to a review of the 50% carbohydrates : 30–35% fat : 15% protein that was historically used to demonstrate the importance of the right fats (not saturated or trans fats) and more protein which helps appetite control due to more satiety properties - and changed the recommendation to 40% carbohydrates: 20% protein, with the right fats. In fact after looking at so many different versions of the Eat Well Plate I too was confused!



The Eat Well Plate

More recently the US government has scrapped the much-maligned food pyramid icon and replaced it with a fruit and vegetable-rich plate, seeking a simpler way to show Americans how to eat right. While it is seen as a major improvement, the new icon still falls short of giving people the nutrition advice they need to choose the healthiest diets.

The new logo, MyPlate, shows a circle divided into four brightly-coloured wedges. Vegetables and fruits take up half the plate. Proteins and grains each get one quarter of the plate. Just off to the side is a smaller blue circle for dairy products, looking a bit like a glass of milk or a cup of yogurt. A fork and placemat complete the place setting.

See the logo, MyPlate on next page.

"It's simple enough for children to understand," said First Lady Michelle Obama at the announcement in Washington, D.C. on June 2, 2011, promising that her Let's Move! child obesity prevention initiative will be part of a coordinated campaign to promote MyPlate. "*Kids can learn how to use this tool now and they can use it for the rest of their lives*."

Without a doubt Michelle Obama has a lot of drive and has won over Warner Brothers to freely allow the use of the Sesame Street characters on fresh fruit and vegetables to appeal to young children. At last there is a campaign that actively promotes produce that comes directly from the farm, has not been processed, is fresh and good for you!

The challenge, though, is that this is set against a reality of houses and flats with no kitchens, due to microwave dinners and the increasing number of children eating with their fingers as opposed to a knife and fork. Processed foods are increasingly blamed. The modern diet is deficient in hundreds of important plant-derived immunity-building compounds, which makes us highly vulnerable to viruses, infections and disease. It is the micronutrients in certain foods that have the most profound effects on immunity, and which most people are sorely lacking. A combination of these compounds is far more effective than any single agent. In other words, although a fresh red pepper may be rich in vitamin C, it is the other smaller compounds it contains that work with vitamin C that increase its health-giving properties. This explains why fresh fruit and vegetables are more effective than a simple high-dose vitamin C tablet.

American Doctor and nutritionist Dr Joel Fuhrman has designed a variation on the Eat Well Plate (as shown in Fig 4).[xxii] It boils back down to the straightforward wisdom of Michael Pollan – Eat Food, Not much and Mainly Vegetables.

Figure 4 : How to construct your daily diet

Since childhood obesity can be a strong indicator of weight-related health problems in later life, demonstrated by the fact that learned unhealthy lifestyle choices continue into adulthood, getting everyone involved in finding solutions is critical in order to deliver change. Work led by France, the Epode project, has demonstrated success. It is very much a bottom-up project that engages the whole community and has some key successes (See **Case Study One: Preventing Childhood Obesity: the EPODE Methodology. Page 26**).

In the UK another effective study has been the Early Bird project in Plymouth where a cohort of 300 children has been studied over 11 years. Prof. Terry Wilkins, father of someone I met out in Taiwan, (what a small world!), working on a similar process as was Wageningen University, and their observation work at the Restaurant of the Future – i.e. 'don't ask, don't tell' - the work has been ground breaking and observes without intervention.

Key findings from the Early Bird are key observations that we need to take heed of in building a successful framework for reducing the number of deaths associated with NCDs. They include:

- **Obese children – parents unaware and unconcerned.** *Today's parents are oblivious of their children's weight* - Parents are key partners in the drive to halt obesity, but will have little impact unless educated to recognise the problem.
- **Children's activity not determined by environmental opportunity.** *Green spaces and sports centres do not influence the physical activity of children* - Like most things biological, a child's activity level seems to be 'set' by the brain, and therefore strongly defended against change.
- **Social inequalities no longer a major factor in obesity.** *All children today are at risk, regardless of family income or postcode* - Targeting by SES unlikely to be effective.
- **Obesity leads to inactivity, rather than the other way round.** *Time-lag analysis from one year to the next suggests obesity comes first* - Crucially important - calorie reduction, rather than physical activity, appears to be the key to weight reduction.
- **Healthy weight for life? Start at birth.** *Most excess weight is gained before the child ever starts school* - School initiatives are probably too late. Mums should be encouraged not to over-feed low birth weight babies, who are most at risk of later weight gain.
- **Average pre-pubertal child no heavier than 25 years ago.** The rise in obesity is confined to a small group of children who are behaving differently from the majority who have not changed in a generation - Only at puberty does the whole childhood population get involved. There may be no general childhood obesity epidemic before puberty
- **Taller children are fatter.** Children who gain excess weight are taller and more insulin resistant than their shorter peers - Taller does not always mean healthier.

People who are obese are at increased risk of related conditions, such as cardiovascular disease (two to three fold higher), diabetes and hypertension (greater than threefold higher) and some cancers.

- **Obese parents, in particular those of the same gender, key to childhood obesity.** *Daughters of obese mothers are 10 times more likely to be obese than the daughters of normal weight mothers, and the sons of obese fathers six times.* - It may be more effective to target the obese parent than the obese child.
- **Girls at greater risk of type 2 diabetes than boys.** *Girls are intrinsically more insulin resistant than boys, which could explain why more girls get type 2 diabetes in childhood* - Scarce resources might be better targeted at girls.
- **Health risks of childhood obesity unrelated to parents.** Although a child's height and weight are related to their parents', the health risks for obese children are much the same, whether or not the parent is obese - The diabetic risk for obese children derives exclusively from their own weight gain, and is thus potentially avoidable.
- **Type 1 and Type 2 diabetes essentially the same disorder of insulin resistance, differing only in tempo.** Keeping weight down should help prevent, or at least delay, the onset of both type 1 and type 2 diabetes.

If obesity underpins insulin resistance, three questions emerge: Who, When and Why? Which children develop obesity, when does it start, and why do some, but not others?

A further study is the successful North Karelia Project in Finland (**Case Study Two: The North Karelia Project. Page 27)**

From these studies the real driver for change is the involvement of multi-stakeholder groups adopting an integrated approach to tackling disease prevention. What is currently missing in many of these studies and projects is the involvement of the farmers. This is, however, recognised in many of the global projects such as Harvest Plus, where addressing malnutrition is a key issue. Ultimately it is about behavioural change and the **strong community-based approaches of the Epode and Karelia Projects that make the issue personal and not isolating and create a culture for hope and change.**

It demonstrates the importance of **Wellness** as opposed to **Illness** – wellness works best through community approaches. – 'WE' not 'I'! - and farming needs to be part of building the right environment for everyone to eat the right foods and grow opportunities for the market, diversity and communication.

Case Study One: Preventing Childhood Obesity: the EPODE Methodology

The EPODE (Ensemble Prévenons l'Obésité Des Enfants (Together Let's Prevent Childhood Obesity), developed in several European countries since 2004, is a large scale community-based intervention aimed at preventing childhood obesity by involving local stakeholders in a sustainable way. The 4 pillars of EPODE are: political commitment, public and private partnerships, community based actions and evaluation. The work has shown promising results in preventing childhood obesity

in France and Belgium and reduced the socioeconomic gap in obesity prevalence in France. It provides a valuable model that may be applicable to other lifestyle related diseases.

EPODE Methodology

The EPODE model is based on the **involvement of the community for the community**, at the very **heart of the "ecological niche"**: the town. It is a long-term programme and involves methodology that integrates the family daily life and its constraints. It is a **positive**, **concrete** and **step-by-step** learning process on food and physical activity. EPODE is a **behaviour-centred** approach, with an educational philosophy prompting fun and non-stigmatisation of any food and behaviours. A **national coordination team** using social marketing and organisational techniques trains and coaches a **local project manager** nominated by the **mayor** (or other local leader able to champion the programme) to mobilise local stakeholders. Dedicated tools and roadmaps are prepared by the National Coordination team and delivered to the project manager who will disseminate the communication tools for each stakeholder. The national coordination team gathers several skills, from strong social marketing skills to network organisation techniques, "train the trainers" techniques, general public communication and press relations serving public health issues. The national coordination team operates under the supervision of a **committee of independent expert specialists** and in collaboration with professionals in the fields of education, psychology, sociology, sports and nutrition, school catering, community life, etc. This methodology enables the entire community (teachers, school catering, health professionals, parents, media …) to empower and contribute to create a healthy environment that facilitates social norms changes. The involvement of local authorities is therefore a core component of the EPODE methodology, which aims to **curb the progression of childhood obesity**.

EPODE results to date

Today 167 towns in France (**EPODE** programme), 13 in Belgium (**VIASANO** Programme), 32 in Spain (**THAO** Salud Infantil Programa) and 5 in Greece (**PAIDEIATROFI** programme) are implementing the EPODE methodology across Europe. Success to date is measured by a large scale involvement of individuals within the community and by the encouraging evolution of the BMI of children in the French pilot cities. Sociological evaluations focusing on the perception of EPODE in families and local stakeholders indicate particularly that the programme is seen as a common positive action for the community, a "healthy lifestyle" programme and a concrete aid that helps parents to guide and support their educational role towards their children.

Case Study Two: The North Karelia Project:

After World War II, chronic diseases, cardiovascular diseases in particular, became a major public health problem in industrialised countries. These diseases were perceived as diseases of affluence. Finland's North Karelia Project has been successful in preventing chronic diseases. In the 1960s, Finland had the world's highest rate of deaths from coronary heart disease. Middle-aged men were dying in great numbers. The rates were even higher in the east of the country – the highest figures being in the Province of North Karelia. In 1971, representatives of the Province of North Karelia signed a petition to national authorities appealing for urgent help to reduce the burden of cardiovascular diseases in the area. In response to the petition, and in an attempt to prevent the rising tide of chronic disease, Finnish authorities, with expert support and the help of the World Health Organisation, launched the North Karelia project. Pekka Ruska, the director general of the National Public Health Institute, Helsinki, Finland, and president-elect of the World Heart Federation, has been a driving force in making this change happen and many countries have learnt from the

success of this project, which started off locally and was then rolled out across regions and other countries.

Table 3: Mortality changes in North Karelia (per 100,000) among men aged 35 to 64 years

	1969-1971	2006	Change
All causes	1509	572	-62%
All cardiovascular	855	182	-79%
Coronary heart disease	672	103	-85%
All cancers	271	96	-65%
Lung cancers	147	30	-80%

Since the start of the project there has been a dramatic change in people's dietary habits. At the outset of the project, almost all people used butter on their bread and in cooking. Nowadays, less than 5% use butter on bread, and around 60% of households use mainly vegetable oil in cooking. Overall salt intake has been greatly reduced. In the early 1970s, more than half of the men smoked; now only around 20% of men smoke every day. The overall average level of blood cholesterol in North Karelia has dropped by over 20%. The impact of these changes on public health has been dramatic (Table 3). According to the latest statistics, the annual age-standardised mortality rate for coronary heart disease among working-age men in North Karelia in 2006 was 85% lower than during the period between 1969 and 1971; nationally, the reduction was around 80%.

Furthermore, rates of stroke and of tobacco-related cancers among men have greatly reduced. **The main aim was to transform the social and physical environment.** Community involvement entails the participation of various sectors of society. Experiences from North Karelia emphasise the important role played by primary healthcare, voluntary organisations, the food industry and supermarkets, schools, and local media. Good understanding of the community plus close collaboration with a range of organisations have been essential elements of success. Rather than a number of vertical disease specific programmes, an integrated approach targets the main common behavioural risk factors for a range of chronic diseases.

7. Learning more

Throughout the last 12 months I have met with some of the most inspiring, enthusiastic and intellectually challenging people. Everyone that I have met has given their thoughts freely and these have developed the route and journey I have taken. Whilst I have not documented all those stories in this report and I have had to cut out vast pieces of information, they have created the backbone for this work and have influenced me sufficiently to explore this topic more – in fact it sits neatly alongside everything I do and believe in. Whether it is the enthusiasm of Prof. Tim Lang and his challenge of our systems and compulsion to chop fruit and vegetables, or Prof. Gordon Jameson (JIC) and the sugar bomb apples (12% sugar in apples when I was a child – 20% now in many popular varieties), Prof. Tim Brocklehurst (IFR) and all the gut stories, the people I met at the FAO or Matthew Thomson at Jamie's Fifteen, there will be time enough to build on all that I have seen, heard and questioned.

7a. Pizza – as a proxy

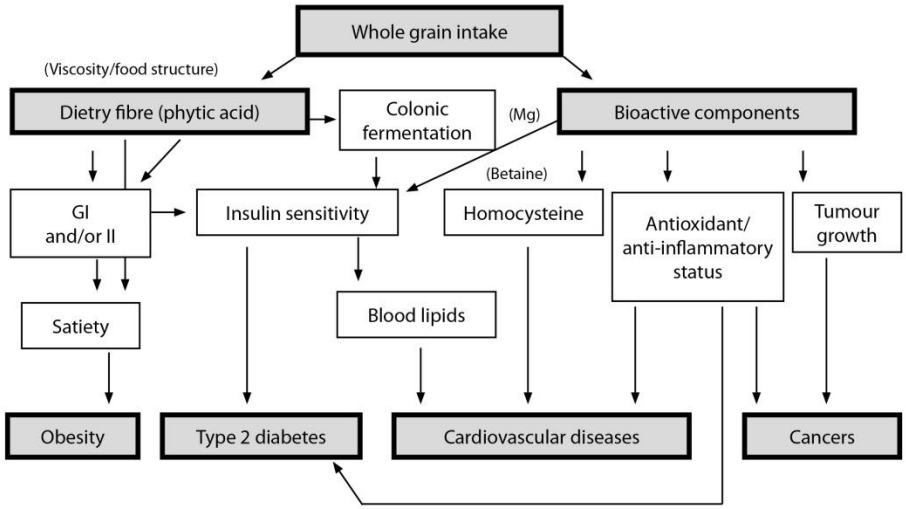
So to focus within the timescale I return to the pizza and its base ingredients: wheat, tomatoes and cheese (and there is a bit of poetic license as I have not gone for mozzarella, different wheat varieties, etc.; this is just a representative example) and the opportunity for farmers to change the basic nutrition content of these core ingredients.

7b. Wheat and cereals

Wheat accounts for about 20% of the calories consumed by the world's population. The total global production is about 600-700 million tonnes, of which about 500 million tonnes are utilised within the country of origin and the remainder is traded internationally. This trade has been facilitated by the classification of grain samples into classes suitable for the major end uses (breadmaking, noodles, animal feed etc.), based mainly on the texture (hard vs soft) and on the content and quality of the grain proteins. Historically this classification has been focused on technological quality attributes but, with the significance of wheat consumption and the growth of NCDs, the nutritional quality of cereal, especially wheat, is increasingly recognised.

It is well know that whole grain cereal products relate to the enhanced intake of micronutrients and phytochemicals, and dietary fibre[xxiii], reducing the risk of a range of conditions including CVD and forms of cancer (summarised in Figure 5). In addition there is considerable interest in manipulating the glycaemic responses to cereal foods by altering the proportion of resistant starch in ingredients, such as wheat flour, including approaches where the starch composition of the wheat grain itself is manipulated. However, the market does not routinely analyse grain samples for bioactive components that may enhance the health benefits of cereals and we know little about the extent to which the amounts and compositions of such components vary between grain samples, plus the extent this is determined by the genotype, the environment and the production system. However my discussions with breeders, millers and merchants suggest that these market requirements could change.

Added to this, there are some significant findings from the HEALTHGRAIN Project in the understanding of wheat breeding and nutrition, and work led by scientists from the John Innes Centre and Bristol University has led to the breakdown of the wheat genome. Both these breakthroughs will provide opportunities to speed up breeding programmes to enhance production and nutrition.



Current accepted mechanisms for how whole grain protects against major chronic diseases (used with permission from Anthony Fardet, INRA and Clermont Universite', UFR Me'decine, France). GI, glycaemic index; II, insulinaemic index.

Figure 5 : How the whole grain helps

Professor Peter Shewry at Rothamsted Research feels strongly about the benefits of eating whole grain crops and has been involved in the HEALTHGRAIN study. **This study has provided the largest database yet available on the content and composition of bioactive components in wheat**, showing the presence of wide variation between samples with high heritability of some important components, such as Arabinoxylan (AX) fibre (known to improve metabolic control in people with Type II diabetes) in white flour, and tocols, sterols and alkylresorcinols in wholemeal. Furthermore, the work has demonstrated that these components are not related to the age and origin of the lines, or to the agronomic and functional properties. This means that it should be possible to develop new wheat lines with high contents of bioactive components, combined with high yields and good agronomic performance and processing quality. This would provide the win-win we need to ensure the features that farmers currently need - since the latter are principally paid on yield - come together with the nutrient benefits needed to influence diet and develop the market. Importantly, a number of tools and technologies have also been developed within HEALTHGRAIN, including biochemical and molecular markers, specific antibodies and (Near Infrared) NIR calibrations, which will further help speed up the whole process (see Figure 6)

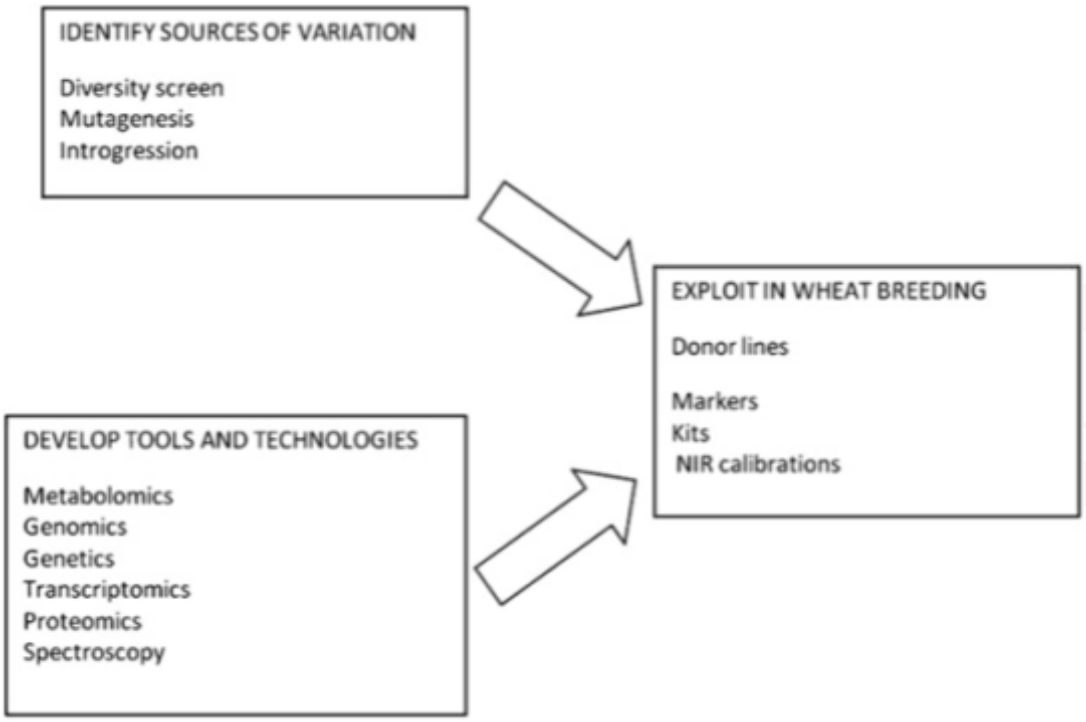


Figure 6. The HEALTHGRAIN concept for wheat improvement

Epidemiological studies have linked whole grain intake to the prevention of the 'metabolic syndrome', obesity and associated NCDs. Aside from the agronomy aspects there is also the Nutrition module within the HEALTHGRAIN project, which includes 10 partners who undertook *in vitro*, animal and human *in vivo* studies with the overall aims of clarifying the components and mechanisms underlying the health benefits of cereal grains[xxiv].

Professor Shewry emphasises that fibre is a critical component of our diets. Currently the average daily intake is 13 grams – it should be 18g. With bread currently making up 20% of the diet, enhancing the fibre content in bread is critical, in particular maximising the merits of wholegrain. Bread is regularly consumed in the UK diet. However, its contribution to energy and nutrient intake and the frequency of consumption have not been thoroughly investigated. [xxv] The National Diet and Nutrition Survey 2000–2001 showed bread consumption among adults in that year was dominated by white bread, which consequently made a greater contribution to energy, fibre and nutrient intakes than other types of bread, particularly among men and manual workers. Replacing white bread with wholemeal bread would increase the nutrient density of the diet. Our diets typically contain highly refined processed foods which are rich in starch, sugars, and fats, including products made from white wheat flour, and there is clear evidence that the consumption of either wholegrain cereals or components present in these (notably dietary fibre) has beneficial effects in reducing the risk of the metabolic syndrome and associated diseases. There is still so much we simply do not know, especially how our gut micro-organisms function. Indeed in discussions with Tim Brocklehurst at IFR, and in several of the papers in Taiwan, there is so much more we need to work out about how the millions of genes in our own guts respond to different foodstuffs and are influenced by different combinations of foods, our health, the weather, age, etc. and that is before we have even considered our own genes. Just to note, our bodies carry about 100 trillion microorganisms in our intestines, a number ten times greater than the total number of human cells in the body. The metabolic activities alone performed by these bacteria resemble those of an organ, leading some to liken gut bacteria to a "forgotten" organ, added to which it is estimated that these gut flora have around a hundred times as many genes in aggregate as there are in the human genome!

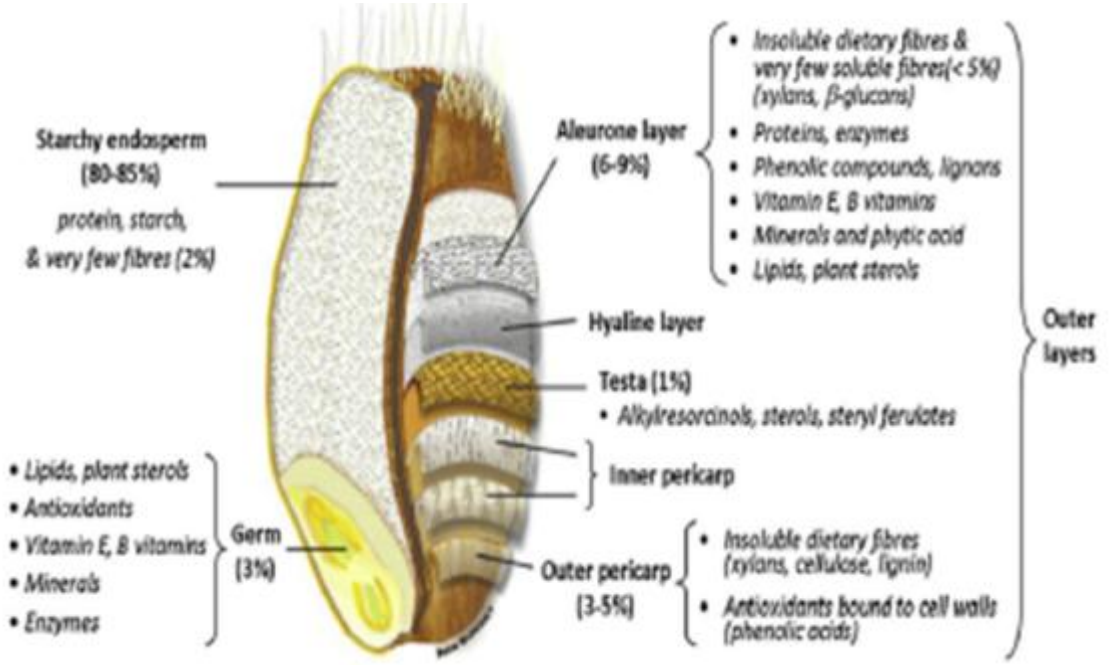


Figure 7. Histological structure of wheat grain. Adapted from Baron et al. (2007) showing bioactive components which are related to the fibre fraction of wheat and are present in the whole wheat meal but absent in refined white starch. The endosperm is mainly starch – germ high oil bran high fibre vitamins in the germ

However, a major disadvantage when it comes to exploiting the preventive merits of a wholegrain diet is that the mechanisms for health benefits remain largely unknown.

The fact that wheat, rice, and other cereals are staple foods means that they are ideal vehicles to deliver health benefits to large populations at relatively low cost. A major limitation at present is that the beneficial components are concentrated in the bran and germ (see Figure 7) which are removed by milling, and that whole grain products are less acceptable to many consumers and may have higher production costs. However, these do not need to be major barriers: increased consumer awareness and greater availability are already leading to increased consumption of whole grain products in many countries, while innovative processing can be used to improve the acceptability and reduce the production costs, such as in the 50:50 and Half and Half breads.

The work by Prof. Shewry has shown that the health benefits of wheat can also be increased by genetic improvement of the wheat grain, by exploiting natural variation, or by non-traditional approaches, such as mutagenesis or transgenesis. This combination of genetic improvement, increased consumer education and awareness, and increased availability of low cost products, should therefore contribute to improved health outcomes.

Table 4. shows the major groups of bioactive components present in the wheat grain and how manipulating their amounts and compositions can increase the health benefits of both wholegrain and white flour products.

Table 4. Major groups of bioactive compounds in wheat grain

Longer term dietary interventions on health effects of whole grain within HEALTHGRAIN			
Hypothesis	**Target group**	**Design and duration**	**Test and reference diets**
Aleurone-rich foods impact favourably on metabolic risk factors, focussing on methyl donors and related measures **(Welch et al, University of Ulster, UK)**	80 subjects healthy 45-65 year old BMI > 25	2 parallel groups 4 wk	**Wheat aleurone-rich products** vs. balanced refined wheat products incorporated into habitual diet Bread, RTE cereals, 3 portions/d (27g aleurone/d in test group)
WG wheat beneficially influences body weight reduction by stimulating satiety and by reducing the digestibility/absorption of energy providing nutrients **(Kristensen et al, University of Copenhagen, DK)**	40 + 40 subjects Postmenopausal women 45-70 year old BMI 27-37	2 parallel groups 2 week run in 12 week diet test	WG - **Wheat** vs. refined grain wheat Bread, biscuits and pasta (25% of energy intake) Calorie restricted diet (-1250 kj/d)
Metabolic merits of a WG diet are magnified by WG foods which are also low in GI **(Frid et al, Lund University, SE)**	4 X 20 subjects T2D Patients (diet treated)	4 parallel groups 4 week	Low GI/high WG wheat kernel bread High GI/high WG wheat flour bread Low GI/high WG Barley Kernel bread vs. High GI/low WG White wheat bread All bread exchanged
A diet with multiple beneficial characteristics of whole grains (WG constituents and/or low G1/11) favourably influences glucose and insulin metabolism **(Mykkanen et al, University of Kuopio, FI; and Riccardi et al, University of Naples, I)**	60 subjects per centre 50-70 year old with metabolic syndrome	2 parallel groups 12 week test diet	"Health grain" WG and/or low GI vs. refined grain diet Wheat, rye, oats and barley In different dietary background (Finland and Italy)

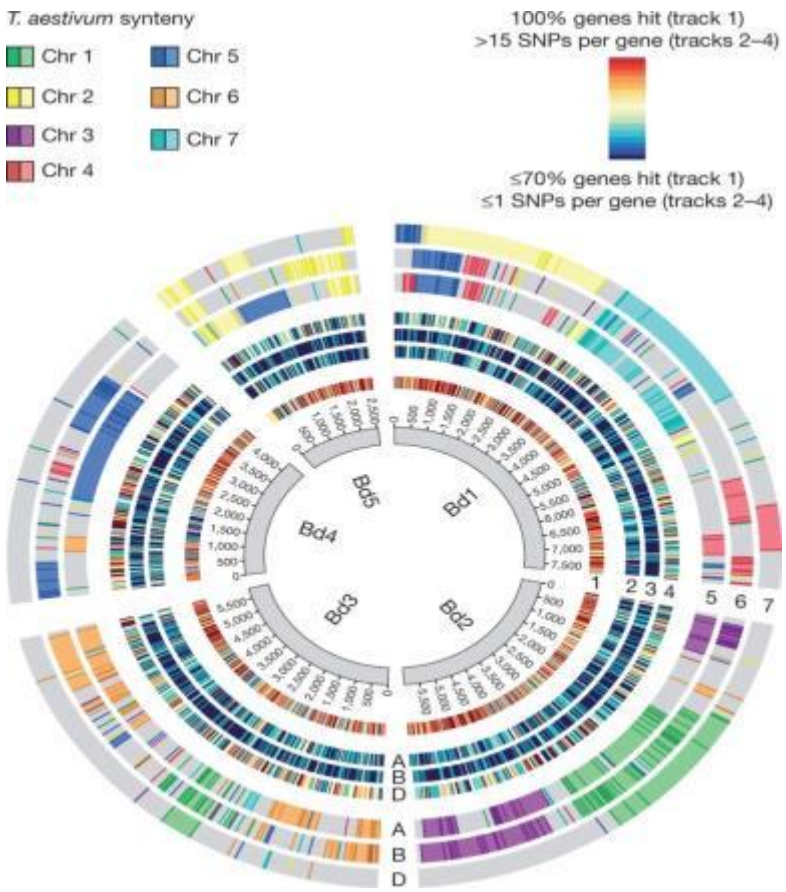
From this it can be seen that a calorie-restricted wholegrain wheat diet improved body composition and reduced fat mass (%) in over-weight women. Additionally, the studies with aleurone-rich wheat diets and supplementation with processed bran suggest that tentative mechanisms for metabolic benefits of wholegrain wheat diets may include events related to the content of methyl donors (e.g. betaine) and/or antioxidants (ferulic acid). In the case of the latter, the bioavailability and bioactivity of colonic metabolites needs to be considered. There is also evidence to hand suggesting that at least certain rye genotypes may contribute to a lowered insulin demand. Additionally, results with wholegrain barley kernel products indicate benefits on glucose tolerance mediated through colonic fermentation of indigestible carbohydrates. [xxvi]

What the HEALTHGRAIN study has shown is the ability to test tools and approaches to speed up and increase the degree of confidence associated with the gene testing and also *in vivo* and *in vitro* studies. One of the interesting aspects of the conference I attended in Taiwan was the debate and discussion around testing techniques – especially *in vivo*, which are controversial due to the ethics surrounding the use of humans in experiments, the big genetic variation between individuals and the recognition that epi-genetic factors also have an impact, and it was interesting to learn of the close relationship between the livestock research centre and the hospital in Taiwan and the IFR, JIC and Norwich Hospital in Norfolk: an area discussed in a bit more detail later in this report.

A further enhanced significant breakthrough in 2012 was where scientists from the John Innes Centre have led a project to unlock the genetic code of wheat, which is five times larger than the

human genome (Figure 8). This first analysis of the exceptionally complex and large wheat genome, published in Nature, will help wheat varieties suitable for bread making to attain higher yields and be more able to cope with disease, drought and other stresses that reduce yield. The identification of approximately 95,000 wheat genes, and establishing their relationship, lays the foundations for accelerating wheat improvement through advanced molecular breeding and genetic engineering.[xxvii]

Figure 8 : Alignment of wheat 454 reads, SNPs and genetic maps to the *B. distachyon* genome.[xxviii]



To date the very large size and polyploid complexity of the bread wheat genome have been substantial barriers to genome analysis. They sequenced wheat's large, 17-gigabase-pair, hexaploid genome using 454 pyrosequencing, and compared this with the sequences of diploid ancestral and progenitor genomes. They identified between 94,000 and 96,000 genes, and assigned two-thirds to the three component genomes (A, B and D) of hexaploid wheat. High-resolution synteny maps identified many small disruptions to conserved gene order. Specifically they showed that the hexaploid genome is highly dynamic, with significant loss of gene family members on polyploidisation and domestication, and an abundance of gene fragments. Several classes of genes involved in energy harvesting, metabolism and growth are among expanded gene families that could be associated with crop productivity. The analyses, coupled with the identification of extensive genetic variation, provide a resource for accelerating gene discovery and improving this major crop.

Wheat originated from hybridisation between cultivated tetraploid emmer wheat (AABB, *Triticum dicoccoides*) and diploid goat grass (DD, *Aegilops tauschii*) approximately 8,000 years ago. The three diploid progenitor genomes, AA from *Triticum urartu*, BB from a species that is unknown but which may be of the section *Sitopsis* (to which *Aegilops speltoides* belongs), and DD from *Ae. tauschii*, radiated from a common Triticeae ancestor between 2.5 and 4.5 million years ago, and AABB tetraploids arose less than 0.5 million years ago. Nucleotide diversity in the AABB and DD genomes

is substantially reduced compared with ancestral populations, indicating a major diversity bottleneck on the transition to cultivated lines[6].

Furthermore grass genomes show extensive long-range conservation of gene order. Nevertheless, they are highly dynamic owing to the activities of repeats that contribute to tremendous variation in genome size, changes in local gene order and pseudogene formation, particularly in larger genomes, such as those of maize and wheat. From their analysis of BAC contigs on chromosome 3B, the 17-gigabase-pair (Gb) genome was estimated to be composed of approximately 80% repeats, primarily retroelements, with a gene density of between 1 per 87 kilobase pairs and 1 per 184 kilobase pairs. Despite both the substantial knowledge of the wheat genome gained from these studies, and the central importance of the wheat crop, a comprehensive genome-wide analysis of gene content has yet to be conducted owing to its large size, repeat content and polyploid complexity.

They have analysed a low-coverage, long-read (454) shotgun sequence of the hexaploid wheat genome using gene sequences from diverse grasses. From this, they created assemblies of wheat genes in an orthologous gene family framework, used diploid wheat relatives to classify homeologous relationships, and defined a genome-wide catalogue of single nucleotide polymorphisms (SNPs) in the A, B and D genomes. These analyses provide a foundation for genetic and genomic analysis of this key crop.

The genomic resources that they have developed promise to accelerate progress by facilitating the identification of useful variation in genes of wheat landraces and progenitor species and, by providing genomic landmarks, to guide progeny selection. Analysis of complex polygenic traits, such as yield and nutrient use efficiency, will also be accelerated, contributing to sustainable increases in wheat crop production.

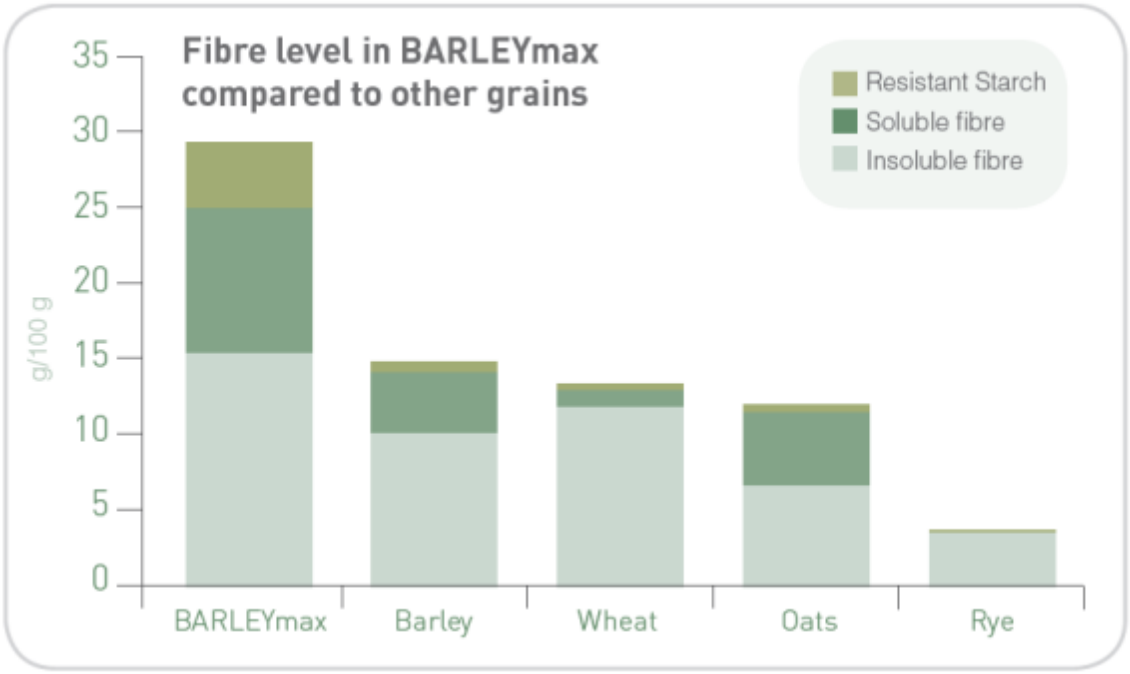
Whilst wheat is a staple food for many, suggestions have been made that wheat consumption has adverse effects on health by mechanisms related to addiction and overeating, though there is no conclusive evidence of this. However one factor that does need to be considered is that the human genetic variation has fundamentally remained the same yet our diet has changed so dramatically. Although the adverse effects of wheat on some individuals should not be ignored,[xxix] five major recent scientific reviews looking at the impact of cereal consumption on health and disease concluded that the consumption of **whole grains, the majority of which is wheat, generally exerts positive effects on health**. Thus increasing intake of whole grain for the general public, in exchange for refined foods, is good. This is different for those who have a genetic predisposition for developing celiac disease or who are sensitive to gluten and/or allergic to wheat and benefit from avoiding wheat and other cereals containing related proteins, including primitive wheats (einkorn, emma, spelt), rye and barley (about 1% of the EU and US population suffer from celiac and 5–10% have gluten sensitivity). For this sector of the population it is important that the food industry should be developing a much wider spectrum of foods, based on crops that do not contain proteins related to gluten, such as teff, amaranth, oat, quinoa, and chia. The recent development of commercial high yielding varieties of oats with various strategies being proposed to reduce exposure to gluten will address this (*Gilissen et al., 2012; Shewry et al., 2012).*

Furthermore, for these reasons there is much more interest in work with other cereals as substitutes for wheat or learning from research on other cereals. Attending the NIAB TAG Key Challenge Event – Biofortification and dietary choice, highlighted interesting work in a range of cereals including oats and barley and the new opportunities for oats of various end-uses (food, feed and industrial uses) such as within the QUOATS project[xxx]. Since oats and barley are relatively high in beta glucan, an immune enhancing polysaccharide located within the endosperm, there are some real opportunities, including for the farming community – but there is currently a trade-off of lower yield and higher

beta glucan. So what is needed are strong market drivers to get the whole system working as has been demonstrated by the BARLEYmax® work, a high fibre wholegrain. This project has clearly indicated that the availability of scientific evidence to support their product's health claims has played a key part in the commercialisation process. (See Case Study 3 below)

Case Study Three: The BARLEYmax® Story [xxxi]

The *Commonwealth Scientific and Industrial Research Organisation* (*CSIRO*) is Australia's national science agency, and has a long history of interest in barley as a grain with human health benefits. In the late 1990s, CSIRO researchers developed a collection of new non-GM barley grains and assessed them for their potential to improve health by delivering high levels of resistant starch and other dietary fibre components.



From this they developed a new type of barley grain that became BARLEYmax. CSIRO brought together scientists from its Plant Industry and Food and Nutritional Sciences divisions to work on understanding and substantiating the health attributes of BARLEYmax, under the CSIRO Food Futures National Research Flagship. Through an extensive programme of experimental studies, including a number of human trials, it was shown that a range of foods produced with BARLEYmax as their key ingredient had a low Glycaemic Index (GI) and also produced positive changes in a range of biomarkers of bowel health.

CSIRO formed a Joint Venture with Australian Capital Ventures Ltd to breed new BARLEYmax varieties and begin working with food manufacturers to create products containing BARLEYmax for consumers. This Food Futures Flagship development programme demonstrated that BARLEYmax not only enhances the positive nutritional attributes of a range of consumer foods, and has also been shown to improve texture and enhance flavour with a pleasant 'nutty' taste that sets it apart from other barley grains.

A further development has been SUSTagrain, developed by ConAgra Mills in the US, which is an ultra-high fibre whole grain barley. With more than 50% of its carbohydrates present as total dietary fibre and 40% of this as cholesterol lowering beta glucan, the grain has more than three times the total dietary and soluble fibre of conventional whole oats, and with less than half of the starch of most cereals and a low GI. The US Food and Drug Administration has now endorsed a heart-health label claim for barley-containing foods which has earned Sustagrain a reputation as a next generation functional food.

More work around barley has been led by the University of Bologna where they have added fractions of barley to semolina to create a pasta with increased beta glucan that may reduce heart disease – **super spaghetti,** a new functional food.

The researchers Dr Vito Verardo, University of Bologna, and Dr Ana Maria Gomez-Caravaca, University of Granada, hope to see packages of pasta labelled with the phrases "may reduce the risk of heart disease" and "good source of dietary fibre" because of the barley. In creating the new pasta, scientists first had to determine whether they could make spaghetti a "functional food" by using barley to add fibre and antioxidants. So, they developed barley flour containing the most nutritious part of the grain. The spaghetti[xxxii] made with barley flour had more fibre and antioxidant activity than traditional spaghetti made with semolina. Furthermore, adding gluten to the barley flour improved the cooking quality of the pasta, although at the expense of its antioxidant power, so there is still work to be done. The researchers believe that barley spaghetti has the adequate requirements of the FDA to warrant making health claims on the package, such as the dietary fibre, antioxidants, and vitamin E, all known to help people's hearts and digestive tracts.

Within my study travels I also visited Campden BRI and the School of Artisan Food. Campden BRI is significant in its global reach and innovation in food science and processing, such as the high-volume process of making dough in bread production, and is now used to make 80% of the UK's bread. Compared to the older bulk fermentation process, the Chorleywood Bread Process (CBP), developed in 1961, is able to use lower protein wheat, and produces bread in a shorter time; from flour to packaged sliced bread in $3^1/_2$ hours.

CBP is able to use lower protein wheat because some protein is lost during bulk fermentation of traditional bread; this does not occur to the same degree in mechanically developed doughs. The process had an important impact in the United Kingdom, as at the time, few domestic wheat varieties were of sufficient quality to make high quality bread products, and it therefore permitted a much greater proportion of lower-protein domestic wheat to be used in the grist.

Despite being a staple food in the UK for centuries, we are now seeing bread consumption falling steadily with average consumption of around 2 to 3 slices a day. As well as providing energy, mainly in the form of starch, bread contains dietary fibre and a range of vitamins and minerals. The National Diet and Nutrition Survey (NDNS) of adults suggests that it still contributes more than 10% of daily intake of protein, thiamin, niacin, folate, iron, zinc, copper and magnesium; 1/5 of our fibre and calcium intakes; and more than 1/4 of our manganese intake. Therefore, eating bread can help consumers to meet their daily requirements of many nutrients, including micronutrients, for which there is evidence of low intake in some groups, such as zinc and calcium, in the UK. Indeed since the 1950s The Bread and Flour Regulations 1998 (as amended) require that, subject to certain

exceptions, four specific nutrients in specified quantities must be added to all wheat flour, whether or not mixed with other flour. They are:

- Iron
- Thiamin (Vitamin B1),
- Nicotinic acid or nicotinamide and
- Calcium carbonate

The process of milling the wheat normally causes a loss of iron, thiamin and nicotinic acid and the purpose of this requirement is to restore these vitamins and minerals to their original levels. Calcium is added for fortification purposes. In the case of wholemeal flour, the regulations require that the levels of these vitamins and minerals are naturally present in the quantities prescribed for flour and not added. This will be because the bran and germ which is added back in wholemeal flour already contains these nutrients, so additional fortification is not required.

The challenge for farmers is thus realising the added value potential for their wheat. For many years the principle testing requirements have been the amount and quality of the protein, the HFN (Hagberg Falling Number), the SKCS number (Single Kernel Characterisation System) and the moisture content, all of which have impacts on the functionality of the end product; yet this is starting to change, for example sulphur (S). Apart from the effects on yield, the S nutrition of a crop often has a strong influence on the quality of the produce. S fertilisation has been shown to significantly improve breadmaking quality of field-grown wheat (Triticum aestivum L.) in the UK, with the loaf volumes of the same variety grown at different sites correlating better with the concentrations of grain S than grain N. Sulphur also increased gel protein content of flour; however it decreased bread's elastic strength. Breadmakers are continually looking at ways of creating fortified foods and the range of bread types has increased significantly over the last decade, such as in August 2013, with the first low carb loaf appearing in Waitrose – LivLife, with 50% less carbohydrates than ordinary bread. It contains wheat flour and butter in reduced quantities with high-protein flour from soya making up the difference, and with linseeds, sunflower and pumpkin seeds for flavour; no doubt there will be a bigger range of different breads available soon given the enthusiasm of those who experiment.

This enthusiasm and sheer love of food was so apparent in the work carried out at the School of Artisan Food where, with the Real Bread Campaign and the Slow Food Movement, the interest in this specialised master craft is apparent and there is much we can all learn from in the approach that builds on the traditions of preserving foods through fermentation, curing, pickling and smoking. At the school of Artisan Food they are teaching breadmaking, cheese making, brewing, butchery, charcuterie and preserving.

It was particularly interesting to meet with Alison Swan Parente, Chair of Trustees and Joe Piliero, Director at The School of Artisan Food, who gave me ideas and contacts to see me on my path and some wonderful food … we bought sour dough bread for quite some weeks after my visit. Whilst fridges, freezing, canning and vacuum packing have changed our preservation techniques in the home we still value the unique taste of cured foods, which the Japanese call umami; うま味 - translated to a "pleasant savoury taste", and equate it scientifically to monosodium glutamate. Umami, a savoury taste, is one of the five basic tastes (together with sweet, sour, bitter and salty) which is looked at later.

Since changing behaviour is a slow process, the benefit of changing the fibre content and nutrient quality in wheat is huge through exploiting genetic variation. In addition, using advanced breeding techniques, and not necessarily GM, it is possible to combine the qualities of high yield and high

fibre, it is only where getting knockouts that a yield deficiency will occur. A gene knockout is a genetic technique in which one of an organism's genes is made inoperative ("knocked out" of the organism). Also known as knockout organisms or simply knockouts, they are used in learning about a gene that has been sequenced, but which has an unknown or incompletely known function. Researchers draw inferences from the difference between the knockout organism and normal individuals.

While the main driver in the wheat market is to meet the requirement of the food processing industry, these major breakthroughs in the gene sequencing of wheat and the development of the largest database yet available on the content and composition of bioactive components in wheat, there is a huge opportunity for the arable sector to have a substantial beneficial impact on public health.

7c. The tomato

The development of commonly eaten fruit and vegetables, such as tomatoes, with increased levels of beneficial natural compounds helps people have healthier diets. While it is evident that a diet rich in blueberries, blackberries and blackcurrants is beneficial, it is the opportunity to improve the eating quality of tomatoes, a major component of the pizza, that can only be good.

High beta carotene, golden tomato

I have a personal interest in tomatoes. My grandfather was a tomato grower in Hampshire, carrying out some of the first glasshouse trials before the Second World War, teaching the Dutch, addressing the problems with the doodlebug bombs dropping and shattering the glass during the war, and finally giving up in the early 1950s, due to the challenges of Europe! Furthermore, my cousins were tomato breeders producing the Stonor varieties. There are around 7,500 tomato varieties grown for a range of purposes. Perhaps it was this and my conversations with Raymond Blanc that made me begin to realise the diversity and also the need to choose the right tomato for the right culinary delight, taste and experience, savouring the flavour and the memory that is important.

Tomatoes continue to be widely studied ranging from the work at the AVRDC on the tomato, looking at high beta carotene tomato adaptation trials and the search for new genes to improve carotenoids and flavonoids (there is not a tomato in Europe that does not have some AVRDC genes in them), the development of the GM tomato at the John Innes Centre, and the work at Newcastle University. And in Florida in the pursuit of the perfect tomato to create a fruit juicer, tastier and sweeter than they can find on a shelf – using smells in the jars and find a way to make them sweeter without extra sugar, through tricking the brain.

GM purple fleshed tomato

Although many of the drivers for research have been to increase yields and shelf life over the years, Prof. Cathie Martin at the John Innes Centre [xxxiii]has been working on the development of tomatoes that have been found to be tasty and stay fresh for twice as long, adding a compound high in antioxidants.

The red, blue and purple colours of many flowers and fruits are due to compounds called anthocyanins which are naturally occurring health-promoting chemicals found in high levels in berries such as blackberry and cranberry. As part of the human diet, anthocyanins and related chemicals called flavonoids protect us against a broad range of diseases such as cancers, heart disease and age-related degenerative diseases. There is also evidence that they have anti-inflammatory properties, improve vision and help prevent obesity and diabetes. Naturally occurring anthocyanin pigments are produced in the purple tomatoes and are the same as pigments produced in leaves of regular tomatoes, particularly when they are stressed. (These purple pigments are easy to see in old, dry leaves of red tomato plants).

In snapdragons, two genes are required to induce the production of anthocyanins in the flowers. Anthocyanin is completely absent in the tomato fruit; however, the two snapdragon genes, introduced into tomato using genetic modification, were able to activate the production of anthocyanins, resulting in fruit with an intense purple colour due to the very high levels of anthocyanins in both the flesh and peel of tomatoes. The genes inducing anthocyanin production are expressed only in ripe fruit, so the plants just look like regular tomatoes until the fruit start to ripen and the purple colour starts to form. There are natural varieties of purple tomatoes (Sunblack), which has anthocyanin in the skin of the fruit and not in the flesh and at levels much lower than the GM purple tomatoes. Aside from the storage benefits, cancer-susceptible mice fed a diet supplemented with a high anthocyanin tomatoes showed a significant increase in lifespan compared to animals fed a diet supplemented with regular tomatoes. The next step will be to carry out human studies with volunteers. Although not possible to be sold in this country, Prof. Martin is hoping that a tomato juice high in antioxidants will be on sale in Canada shortly. Prof. Cathie Martin plans to grow enough purple tomatoes on a Canadian farm to make 2000 litres of juice this year for research.

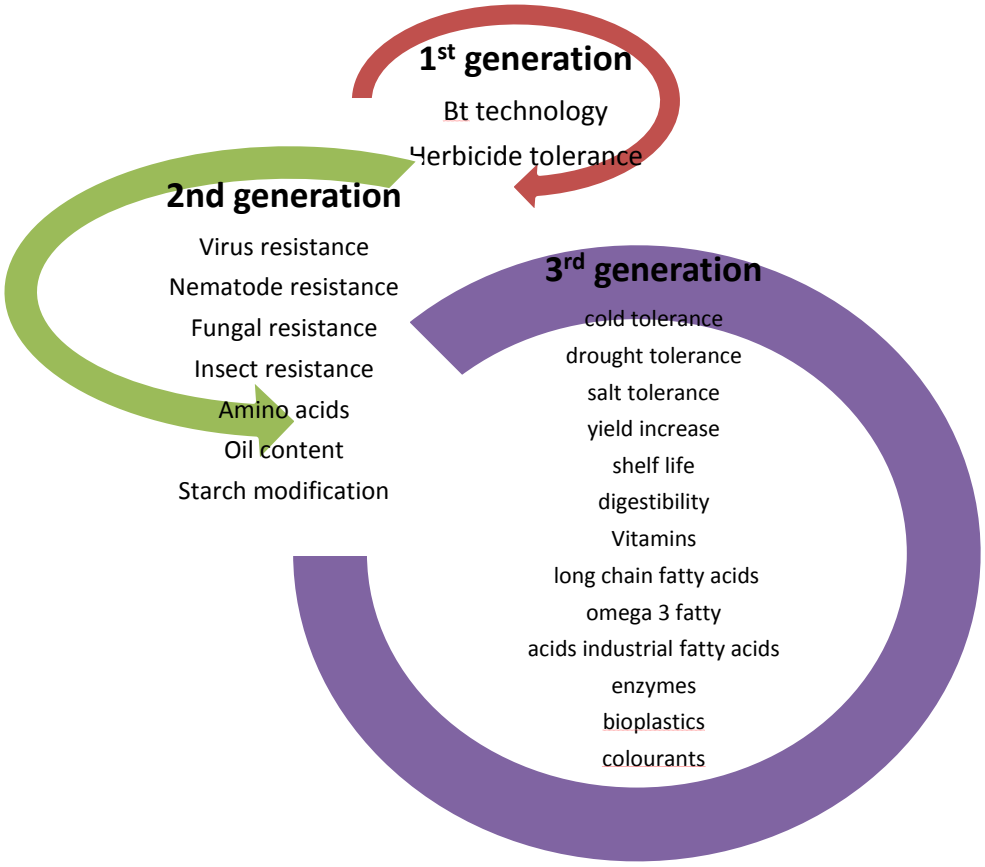
This is one of the few examples of genetic modification that offers the potential to promote health through diet by reducing the impact of chronic disease and offers benefits for all consumers. If it is successful, it may be possible to increase the levels of other naturally occurring plant nutrients with health promoting properties in tomatoes and open the door to the acceptability of GM … another discussion for another day!

Further good news about the tomato is highlighted by research from Dr Kaijun Nui from China's Tianjin Medical University stating that, whether they are sliced, chopped or in soup, eating a tomato a day can cure depression. They are packed with lycopene, an antioxidant that reduces stress and repairs damaged brain cells. Analysing the diets and mental health of 1000 over-70s in Japan, the study showed those eating at least two tomatoes a week were happier, potentially having positive effects for a country where the population is ageing and depression growing. While researchers are not sure why lycopene, which gives tomatoes their deep red colour, directly affects the mind, currently eating other healthy foods such as cabbage, carrots and pumpkins, has no effect on the psychological well-being, so more work needs to be done.

Interestingly, it was evident from the discussions I had in Taiwan that 'black' food was culturally considered good and had been proven too - perhaps there is something here?

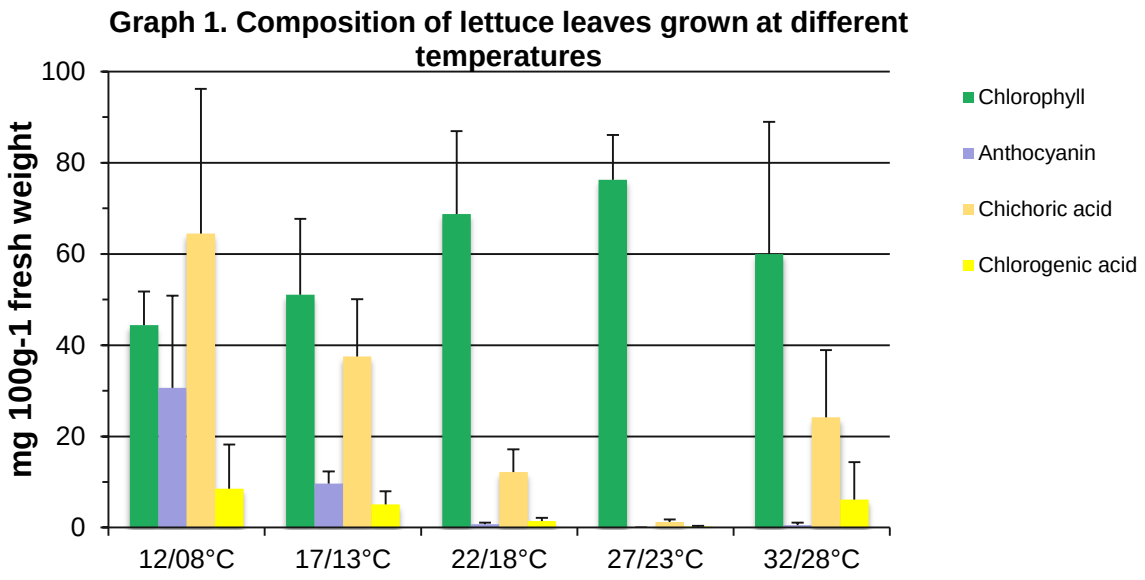
From the genetic modification work that is currently being carried out in Asia many of the traits and stacked traits are to do with agronomic features of plants and not nutrient benefits to humans. The tomato GM work potentially opens the door to consider acceptability among the general public and it will be interesting to see how the discussions are formed over the coming years, as shown by the discussions in Taiwan (Figure 9).

Figure 9. The Development of Biotechnology
(discussions in Taiwan)



Tomatoes produce anthocyanins when under stress and it was fascinating to learn of the counterintuitive work of Danish researcher Dr Kirsten Brandt, at the human nutrition centre, Newcastle University. They have been doing some very interesting work on storage, waste, nutrition, agronomy and challenging the norm on setting up trials. They have looked at work on the shelf life of tomatoes clearly demonstrating that where tomatoes are kept at 10°C to 14°C their taste and quality is poorer than where tomatoes are kept out of the fridge at room temperature. They have also studied the relationship between disease and stress in plants; something that the conference in Taiwan also reflected, in that when a plant is under stress it is more nutrient dense.

Particularly interesting has been their work on lettuce, as shown in Graph 1, whereby at the optimal temperature for plant growth there is the lowest secondary metabolites, such as anthocyanin, chichoric acid and chloregenic acid. It demonstrates that where plants are under stress they are healthier than when under no stress at all.



Dr Brandt highlighted that increasing the *content* of biologically active compounds in fruits and vegetables by 12% could be equivalent to increasing the *intake* of fruits and vegetables by the same 12%, based on findings of Dutch researchers looking at how the CAP could be used to impact health specifically through increasing fruit and vegetable consumption. At Newcastle they have also carried out work on trial design and a range of fruit and vegetables, much of it challenging the way of thinking; addressing 'counter intuitive' issues on how often we grow, store and eat fruit and vegetables in the same way.

Stepping across the pond, Professor 'Jay' John Warner Scott, University of Florida, is a prolific breeders of new tomatoes and has developed more than 30 varieties. Each year he grows several hundred different varieties of tomatoes, called "parent lines," in test plots. His goal is to find plants with complementary traits - one may have disease resistance but low yields, another high yields but weak immunity - and crossbreed them hoping that some of the offspring will carry the best traits of both parents. One in particular is Tasti-Lee, combining Florida 7907, known for its sweetness, but is too spherical; and the Florida 8059 grown for its hardness and shape (Florida growers like their fruits to have defined shoulders and slightly flattened bottoms), to create the Florida 8153 in 2002. Working commercially with Whitworths in February 2010, Tasti-Lee began appearing in 16 Whole Foods stores in Florida. Within two years, major chains across the country were stocking the variety.

Another Professor at Florida is Professor Harry Klee, who has a different approach to growing a tomato, starting with the consumer rather than the breeder. He has two goals, one to define what a good-tasting tomato is, and two to find the genes that control the processes that make good taste and breed them back into tomatoes. He has done this through bringing together psychologists, food scientists, statisticians and molecular biologists. Using the traditional breeding techniques of cross-pollinating plants and sorting through thousands of their offspring, Professor Klee is convinced that tomato breeders took a wrong turn 50 years ago, focusing on yield, size and appearance, for the grower is not paid for flavour or nutritional quality. This created a disconnect between what growers want and what consumers expect.

Neglected for a half century, the genes that once gave commercial tomatoes taste have become lost. To rediscover those genes, tasting panels work their way through 150 varieties of non-hybrid heirloom tomatoes from 50 years ago. Tomato flavour is based on a combination of sugars, acids and volatiles (chemicals we can smell, often at minute levels measured in a few parts per billion).

Having the right balance of sugar and acids provides a foundation on which tomato taste can be built, but since most of what we perceive as flavour is actually aroma, it is the 15 or 20 volatile compounds that have the biggest impact on tomato taste. These include: cis-3-hexenal, beta-ionone, beta-damascenone, I-penten3-one, 2+3 methylbutanal, 2-isobutylthiazole, I-nitro-2, methyl salicylate and phenylacetaldehyde. Of these, perhaps a half-dozen are critical and make a tomato taste like a tomato. Thus there are many different compounds that are all synthesised by different chemicals independent of each other, so there is a huge scientific problem to solve and they have identified 50 genes that affect flavour. For example, beta-ionone, smells like juicy fruit gum, 2-phenylethanol like rose scent, cis3-hexenol like freshly cut grass and beta-damascenone resembles the woody and fruit-flavour associated with grapes and wine. While none of these volatiles smell like a tomato, Professor Klee believes that all of them have to be present to deliver the fruit's signature flavour.

Through this work and using taste panels they have identified which volatiles, in what concentrations, make a tomato taste good and it is the small heirloom, Cherry Roma, the epitome of the tomato's sweetness and tartness, that is a winner. Using the top 20 varieties that have consistently scored highly, and a gas chromatograph, he has identified the volatiles to be beta-ionone. Then working with a 'blueprint' for the perfect taste they have searched for the specific genes to reproduce that blueprint and produce beta-ionone and each of the other desirable chemicals. Professor Klee has now discovered about half of the volatiles he thinks must be present in a good tomato. Once all of them have been found, they will be a tool kit that breeders can use to reintroduce tasty traits into industrial-grade fruits.

Ripe tomatoes, which are rich in umami components.

And thus for tomatoes there is yet again another set of astonishing research that challenges our thinking and could provide excellent opportunities for farmers.

7d. Cheese

And now to the final ingredient of the pizza – cheese. At home our milk goes into cheese production for Dairy Crest at their creamery in Davidstow, Cornwall, of which Cathedral City is the top selling cheddar brand in the UK. From Cornwall, the cheese moves to a centre in Nuneaton, Warwickshire, where it is matured, cut and wrapped before being distributed to retail customers.

So it was good to meet with Mark Litherland the technical services manager and Sarah Dean from Dairy Crest to understand more about some of their requirements in the cheese making process. Cheese is a natural food source and is a great source of calcium, which is essential for maintaining strong teeth and healthy bones. Other key nutrients found in cheese include protein, Vitamin B12 (which is crucial for red blood cell formation, normal cell division and normal function of the immune system) and phosphorus which helps maintain normal bones and teeth. However, there is increasing pressure for the cheese makers to reduce the saturated fat content in cheese and there might be other opportunities to increase the health profile of cheese and potentially benefit livestock health at the same time.

In the production of cheese the steps are principally the same; it is the order and length of time in these steps that alters the texture and composition of the cheese. Cheese is principally a living organism and what makes the difference is how quickly acid produced in the cheese has an impact; in Cheddar for example the acid development is $1^{1}/_{2}$ hours and in Stilton some 20 hours. The real skill lies in the cheese making in order to provide the consistency, quality, texture and taste, required of the consumer. The calcium content is of course crucial as it is used in the cross link in the protein for the coagulation process, but poor winters and feed quality can all impact the quality of the cheese. Furthermore, manganese and magnesium are important in the cheese processing, but are not measured either by the processor or indeed the farmer. The cheese makers know the variations in the seasons and adjust the process accordingly. For a farmer the specifications for the milk fall within set parameters of butterfat and protein, bacteria count and, of course, being free from antibiotics. It could be that there is a need to start looking in more detail at factors, such as manganese and magnesium, to find the win-wins for both farmers and the cheese makers.

More work has been done looking at saturated fat in the cow's diet and the benefits around a reduced fat cheese, which is currently processed through reducing the butterfat in the cheese making process rather than the diet or milk specifications. In spite of concerns over saturated fatty acid consumption, evidence shows that greater consumption of dairy improves health in humans, including reduced relative risk of Cardio Vascular Disease (CVD). Work at Reading University has shown that men consuming larger amounts of milk had a lower body mass index and reduced blood pressure and men consuming more dairy products (milk, cheese, cream) had less arterial stiffness; but although greater butter consumption may be detrimental, dairy can be part of a healthy, balanced diet at all stages.[xxxiv] For example, research shows how milk and meat from grass-fed animals has a lipid composition which is intuitively more 'healthy' than from non-grass-fed livestock. This was shown in a study by Couvreur (2006), which progressively replaced maize silage with fresh grass in the diet of Holstein cows. The effect on milk fatty acids was measured. The 'bad' saturated fats declined and the good fatty acids increased. A further study looked at pasture-fed lamb and beef *(McAfee et al. (2001)*) from animals finished on grass or concentrates, and gave them to 40 healthy volunteers. Each week these people ate in place of their normal ration of red meat, 250 g of beef mince, one 200 g sirloin steak and four small lamb medallion pieces (240 g total). The grass-fed meat increased the amount of beneficial fatty acids in the blood of the volunteers, but it is not known if long term consumption would lead to the reduced risk of CVD.

Marks and Spencer have led on this, launching their 'better for you' milk in 2011. Together with some of their farmers and Reading University they have carried out trials to look at the impact of changing some of the feeds given to cows, lowering the saturated fat content and improving the health and wellbeing of the cows. Aside from reducing the saturated fat in the diet by up to 8%, palm oil has also been removed from the cow's diets and replaced with linseed.

Milk saturated fat levels naturally drop when cows go out to grass and increase at housing. Furthermore, there is a huge range in saturated fat levels on individual farms, from 58% up to more

than 70%. This natural fluctuation is due to oil levels in the grass, and specifically omega 3 fatty acids. Omega 3 fatty acids in grass are anti-carcinogenic, anti-inflammatory and also reduce saturated fats in milk. The main aim has thus been to mimic spring grass growth in the ration. Overall, extruded linseed is currently seen as the quickest and most effective way to reduce saturated fats and could improve cow fertility and general health, but it is costly and it could be that whole rapeseed and extruded rapeseed could have a similar effect.

Initial trial work was carried out to assess the effects of feeding linseed and what the optimum levels of inclusion were. At an inclusion rate of 1.5kg a head, gut condition was compromised. The target of a saturated fat level lower than 69% was based on what levels were achievable on farm, without compromising cow health. Generally, in some herds, when palm oil products are removed from a ration, saturated fat levels will drop. There is no set oil level to ensure low saturated fat levels, but when the oil level is 8% or less, scouring can be a problem. The key is to have a quality, consistent and well-balanced ration and use common sense when it comes to the type of ingredients.

This is a good starting point and further work by the Scottish Rural University College (SRUC), NMR and Marks & Spencer is now taking place to help understand what other factors influence milk saturated fat levels. The aim is to understand how fatty acid profiles can be used to predict animal health and welfare, latitude effects on fatty acid profile and how body condition score correlates to fatty acid data.

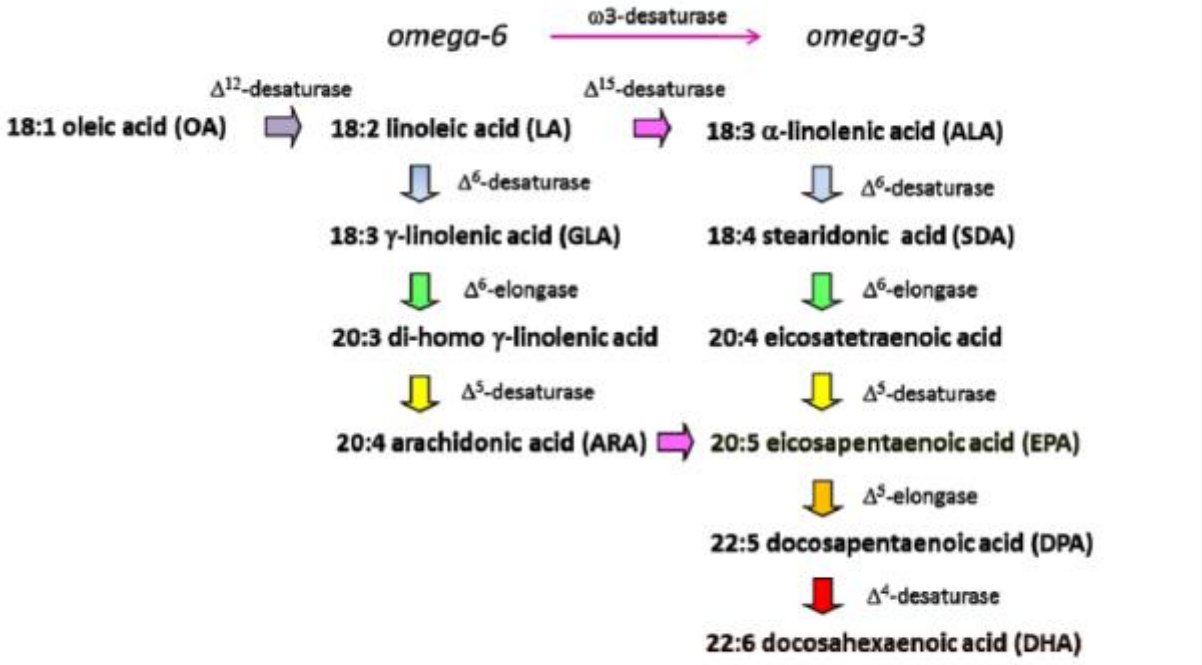
Pasture-fed commercial cattle finished solely on grazed grass and grass red clover silage (Sara Gregson)

Butchers have long known the value of the personal relationship they have with their suppliers and their customers and now more and more people, from the Slow Food movement to farm shops, farmers' markets and on-line sales, are recognising the value of selling the nutrition story behind the food they sell - such as for special diets, sportsmen and athletes - especially associated with a reduction in saturated fats and an increase in omega 3 (*see Appendix A on page 76*). Increasingly

athletes are working with personal nutritionists; for example the IBF middleweight champion, Darren Barker, eats 40% protein, 40% carbs, 20% fat and lots of water. It is a good balance, with hardly any processed foods and most of his sugar from fruit.

Over the last 12 months significant new work is taking place around omega-3, such as at Bristol University in the diets of chickens and guinea pigs to reduce bone breakages and osteoarthritis and the potential carry over to humans,[xxxv] and at the Rothamsted Research where they have applied to Defra to conduct a field trial of Camelina plants that have been genetically modified to produce omega-3 oils (See Figure 10). At Rothamsted the trial led by Professor Johnathan Napier[xxxvi], will test whether GM Camelina sativa plants are able to make significant quantities of omega-3 long chain polyunsaturated fatty acids (LC-PUFAs) in the seed of the plant under field conditions. The omega-3 LC-PUFAs that are beneficial for health are eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). They modulate both metabolic and immune processes and confer the health benefits in areas of CHD and neurodevelopment; the challenge is that not all omega-3 fatty acids are equivalent[xxxvii]. Plant sources of omega-3, e.g. flax seed, do not produce EPA and DHA; instead they produce shorter chain omega-3 fatty acids such as a-linolenic acid (ALA), which does not show the same benefits associated with EPA and DHA.

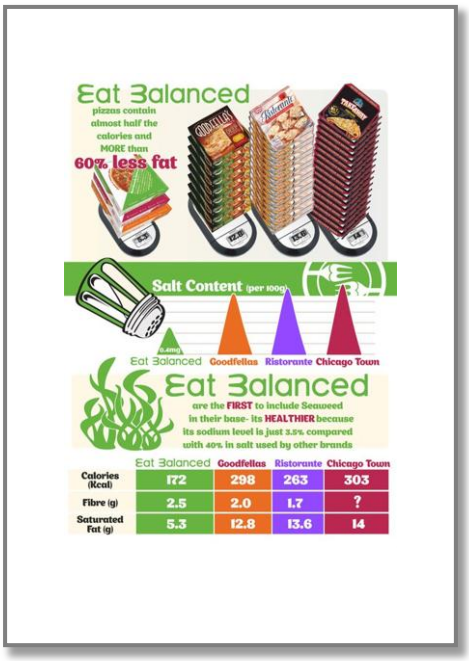
The researchers have used synthetic gene sequences involved in the biosynthesis of omega-3 LC-PUFAs that have been optimised in order to be functional in Camelina plants. These synthetic sequences are based on the sequence of genes found in photosynthetic marine organisms, and other lower eukaryote species such as mosses and oomycetes, with a view to producing feed for fish. They have produced three varieties of plants; one where four synthetic genes have been introduced into the plant, one where five genes have been introduced in the plant, and one where seven synthetic genes have been introduced into the plant. The reason why this number of synthetic genes needs to be introduced into the plant is that the synthesis of omega-3 LC-PUFAs requires multi-step processes. In order to achieve maximum production of these oils in the seed of Camelina plants the breakthrough work is to help the internal biosynthetic machinery of the plant to shift from ALA towards the production of EPA and DHA added. With growing pressures for the UK's ability to source protein for livestock this work will be invaluable.



It is crucial that omega-3 and omega-6 are in balance in the diet. Western diets generally provide a 10 to 20-fold deficit in omega-3 PUFAs compared with omega-6, and this is thought to have contributed to the marked rise in incidence of disorders of modern human societies, such as heart disease, colitis and potentially osteoporosis. Many of our food production animals, fed on grains rich in omega-6, are also exposed to a dietary deficit in omega-3, with perhaps similar health consequences. Bone fragility due to osteoporotic changes in laying hens is a major economic and welfare problem, with recent estimates of breakage rates indicating up to 95% of free range hens suffer breaks during lay. And this work at Bristol University demonstrates clear benefits of n-3[xxxviii] supplementation in reducing the signs of osteoarthritis (OA) in a naturally occurring model of disease. They believe that a high n-3 diet has the potential to reduce signs of OA in both cartilage and sub-chondral bone, further studies are needed to determine the influence of n-3 on established disease, and also to confirm these effects in human OA.

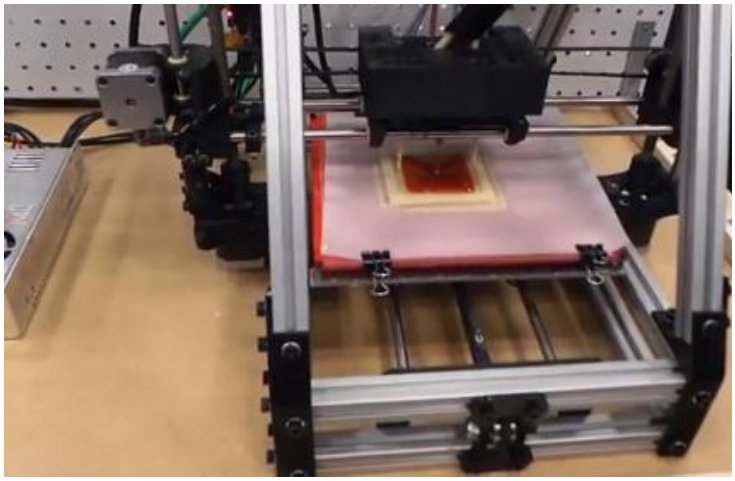
8. Choosing the right ingredients - the ultimate pizza

I have looked at the adjustments that can be made to the individual components of the pizza, but work has also been done on the 'whole pizza'. At the Glasgow Royal Infirmary I met with Professor Mike Lean and Dr Emilie Combet-Aspray who have been working on the world's first nutritionally-balanced pizza. They analysed existing pizzas on the market and found them to be nutritionally poor, so they worked with Donnie Maclean, MD of food company Eat Balanced, to design a range of new pizza recipes which all meet nutritional targets for a healthy meal (30% of one's daily intake), and also contain 30 % of vitamin and mineral needs.

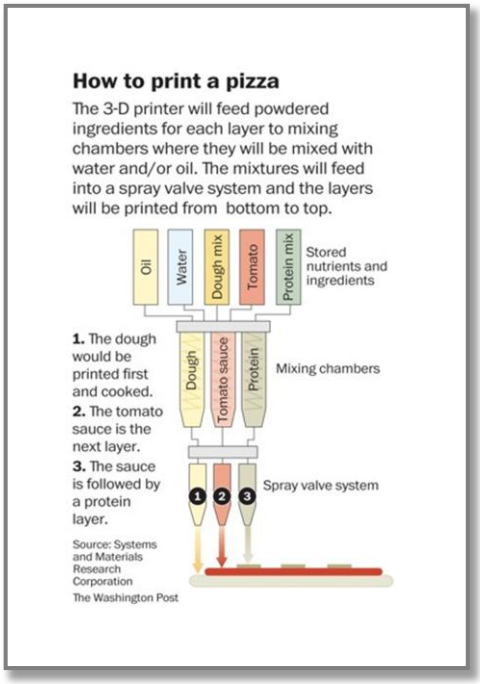


The pizzas created have familiar toppings such as ham & pineapple and spicy chicken but have certain additions to make them healthier. For example, the pizza base is flecked with seaweed which has a much lower sodium content, and minerals such as iodine and vitamin B12, while red pepper incorporated into the tomato sauce increases vitamin C levels. The pizzas are frozen to preserve the vitamins and also contain magnesium, potassium, folates and vitamin A. The pizza gives a complete meal with all the nutrients in it for 30 % of the daily requirement for good health. Again their message was clear – eat a balanced diet.

And then finally there is the ultimate 'modern' pizza.



A 3-D pizza printer



In May 2013 a mechanical engineer received a $125000 grant from NASA to build a prototype of his 3D food printer. Anjan Contractor, a senior mechanical engineer at Systems and Materials Research Corporation (SMRC), based in Austin, Texas, received the grant from the space agency to build a prototype of his food synthesizer. NASA hopes the technology may one day be used to feed astronauts on longer space missions, such as the roughly 520 days required for a manned flight to Mars. Manned missions to destinations deeper in the solar system would require food that can last an even longer amount of time and it is estimated that could be a shelf life of 30

years. In January 2014 it appears they have been successful. The printers lay out all the starches, proteins, fats, texture, and structure, and the inkjet sprays on the flavour, smell, and micro-nutrients at the end; it then takes about 70 seconds to cook the pizza.

9. Taste

As has been shown by the tomato work of Prof. Klee, taste is a strong attribute for the food we choose to eat. Flavours are a combination of taste and odours, which float up through the back of our mouths to activate a suite of smell receptors in the nose. A simple trick is to hold your nose while tasting a jelly bean. You can tell it is sweet but not what flavour it is. Then unplug your nose. There are many different factors that humans use to determine if a food is acceptable to eat or not, but taste is at the centre. That said it is the combination of all the factors shown in Diagram 2 below that ultimately we need to look at when trying to encourage more healthy diets and change behaviour in the long and short term.

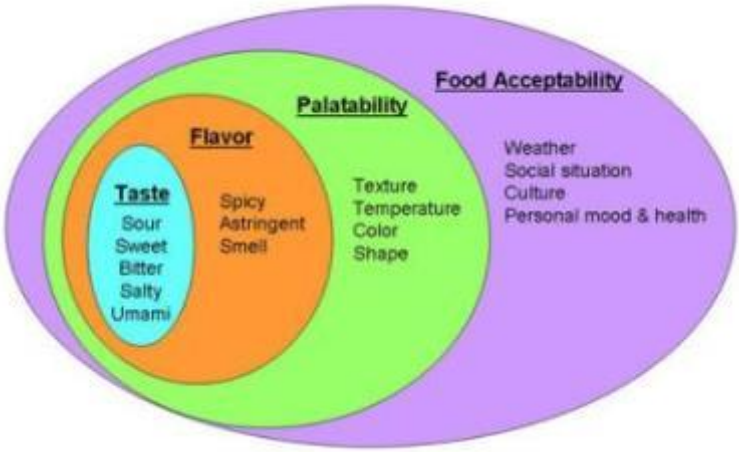


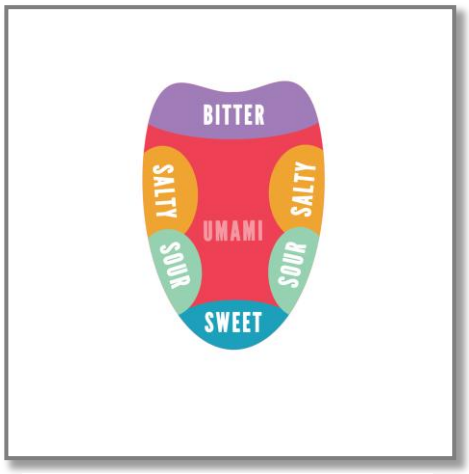
Diagram 2 : The different factors humans use to determine if a food is acceptable to eat or not, taste is at the centre.

Professor Linda Bartoshuk at Yale University researches the sense of taste, looking at clinical taste disorders and in the genetic variations in taste abilities. Clinical problems encountered in the taste system are of two sorts: 'phantom tastes', that cannot be abolished, and 'taste losses'. Their investigations into genetic variation show that bitter and sweet substances in particular do not taste the same to everyone. For example, saccharin tastes bitter only to some individuals while others taste it as pure sweet. Sucrose is sweet to everyone but the degree of sweetness varies. Individuals who find saccharin to be bitter also taste sucrose to be nearly twice as sweet as other substances which taste bitter to some people. Prof. Bartoshuk has tested hundreds of volunteers with a host of chemicals found in food. About one in four, she discovered, qualified as 'supertasters'.

To find what made them special, Prof. Bartoshuk[xxxix] studied the tongue's anatomy. She found that people have different numbers of fungiform papillae, with tongue topography ranging from, say, sparse cactus-pocked deserts to lush lawns. To qualify for supertaster status, which is a genetically inherited trait, a person has to have wall-to-wall papillae on their tongue and also have an ability to readily taste PROP, a bitter synthetic compound also known as 6-n-propylthiouracil, which is used as a thyroid medication. She had learned that phantoms are actually caused by nerve damage: properly functioning taste nerves, in particular the chorda tympani nerve that runs from the tongue through the middle ear to the brain, inhibit one another. If the inhibitory nerve is damaged, taste phantoms can result. Prof. Bartoshuk had been testing the effects of anaesthesia on these phantoms. Just about the same time, a Yale Medical colleague referred a man with Burning Mouth syndrome to her because no traditional treatments helped him. She used an anaesthetic on the man and his pain doubled, causing Prof. Bartoshuk to realize that Burning Mouth is actually a central nervous system pain phantom.

Her discovery of supertasters also came about in a circumstantial matter. She was actually using the bitter-tasting chemical phenylthiocarbamide (PTC) to revisit an old taste blindness phenomenon (which was discovered in 1931 when DuPont chemist Arthur Fox dropped a bottle in the lab, releasing a cloud of PTC dust which his lab mate could taste, but he couldn't). She realized that not only did some people have stronger reactions to PTC, they had stronger reactions to all kinds of tastes. However, Prof. Bartoshuk did not have adequate scales to measure this new taste phenomenon. If two people rate a cookie as 7/10 on sweetness, how do you know that they are both the same seven? Her next step was to look at dietary choice. How does taste affect diet and weight? Since supertasters taste everything more intensely, much food is too sweet, salty, sour, or bitter. So, supertasters are actually more likely to be skinny than regular tasters, but the effect is very small. Prof. Bartoshuk stated that weight is normally distributed, which means that many factors play a role. One genetic difference (which is all that being a supertaster is) is not enough to have a wide effect on weight across the population.

But Prof. Bartoshuk has identified one other piece of the weight puzzle: people with a history of ear infections are more likely to be overweight. She hypothesizes that, like taste phantoms and Burning Mouth, this could be due to nerve damage. Because the chorda tympani nerve passes through the middle ear, it can be damaged by ear infections or other upper respiratory problems. As with Burning Mouth, this damage can result in the lack of the nerve's inhibitory function, in this case causing the nerve not to inhibit tactile sensations, making fats all the more rich and creamy, leading to a change in dietary choices and, consequently, weight. Taste sensitivity may also affect health. According to recent studies, supertasters have better cholesterol profiles than the norm, helping reduce their risk of heart disease. Yet supertasting may also have a downside. Some scientists have speculated that supertasters don't eat enough bitter vegetables. A group of vegetables that AVDRC has worked on extensively to assess their nutrient values may help to protect against various types of cancer. Adam Drewnowski, a nutrition scientist at the University of Washington, says a dollop of butter or maybe a splash of cheese sauce may be all a supertaster needs to find spinach or broccoli palatable. Still, the new data intrigues medical researchers, who don't usually consider taste an inherited factor in disease risk, which opens up another door on trying to understand the impact of different food types on each other and their impact on bioavailability.



The taste zones on our tongue

Each smell tingles a different constellation of neurons in the brain, and with experience we learn what these different patterns mean. Nature may dictate whether or not we are supertasters, but it is nurture that shapes most of our food preferences. Beyond genes, and even learning, lies a more ineffable aspect of taste: its emotional content. Certain foods can bring back unpleasant experiences; it may take only one rotten fishcake to put you off fish for life. Other tastes unlock happy memories, a romantic dinner, a family meal, etc. It is the impact of all this to an extent that researchers are still trying to understand, just by learning which foods are safe to eat while in the security of our mother's arms, that may be the source of some of our most enduring desires.

With the studies from Professors Bartoshuk and Klee, as we understand more those foods and flavours that we desire, we can start to match these against what we should eat and thus help reformulate our foods to develop more 'health by stealth'. A further example impacting taste is shown by 'The miracle berry[xl]' which takes away the tongue's ability to recognise bitterness and sourness; sour things taste sweet for 20–30 minutes. The key to the miracle fruit's ability to turn

sour things sweet lies in a glycoprotein called miraculin. The protein has sugars attached to it that can only be accessed when a sour food is eaten. When the sugar pops into the sweet receptors on the tongue, they stimulate a cascade of molecular events resulting in an electrical signal in the nerve. The action's potentials propagate along the nerve carrying a message of sweetness to the brain. The sourness isn't being converted into sweet; its taste is being overwhelmed by the sugars in the protein!

As I mentioned, this whole area of food science in its broadest sense is a growing and exciting area. Aside from the real need to improve nutrition for the majority there are some other exciting developments in berries, broccoli, blush oranges and sweet potatoes in developing countries. Prof. Sir Gordon Conway has been involved in the Harvest Plus project where the orange-fleshed sweet potatoes have been grown providing a rich source of beta-carotene and vitamin A.

With Harvest Plus the focus on nutrition is so strong that it has driven the success of the work on the sweet potato. The challenge in the UK is getting in to that market. Many small farmers I met growing for box schemes and farmers' markets would have loved to grow more fruit and vegetables, but simply could not sell it.

The diets of the poor in developing countries usually consist of very high amounts of staple foods (such as maize, wheat, and rice) but few micronutrient-rich foods such as fruits, vegetables, and animal and fish products. Biofortified crops, which have been bred to have higher amounts of micronutrients, can help provide these needed vitamins and minerals. They can be effective in reducing hidden hunger as part of a strategy that includes dietary diversification, supplementation, and commercial fortification, among others.

Harvest Plus is using biofortification to breed new varieties of food crops that contain higher amounts of nutrients to improve nutrition and public health. From 2007-2009, HarvestPlus and its partners disseminated orange sweet potato to see if Vitamin A Deficiency could be reduced. Orange Sweet Potato is now being planted and eaten by over 126,000 farming households in Uganda alone, under a project led by HarvestPlus.

Some two billion people worldwide do not get enough vitamins and minerals in their diets. This can negatively affect their cognitive and physical development and increase their vulnerability to infectious diseases and this work has had a huge positive impact to address widespread hunger and malnutrition. Other key innovations for agriculture, such as drought-tolerant maize, Fertilizer Deep Placement (FDP) technology, and cell phones are now also being used and developed within the project. Such innovation delivers, but it is driven by the genuine crisis of poverty and hunger. What will it take for the developed world to sit up and address the obesity issue that is here now?

10. A little bit on epi-genetics

Just when I thought I had got to grips with some of the pathways for food and nutrition, I was introduced to epi-genetics!

Diabetes is a disorder in which the blood glucose levels remain too high. It can be treated by injecting insulin. The extra insulin allows the glucose to be taken up by the liver and other tissues, so cells get the glucose they need and blood-sugar levels stay normal. (*see Appendix B on page 77*). Insulin is like a truck that moves parcels of energy around the body and, when there is more fat, its ability is compromised and the body suffers. Unlike behaviour or stress, diet is one of the more easily studied areas, and therefore more effective for studying environmental factors in epigenetic change. The nutrients we extract from food enter metabolic pathways where they are manipulated, modified and moulded into molecules the body can use. One such pathway is responsible for making methyl groups - important epigenetic tags that silence genes.

Familiar nutrients like folic acid, B vitamins and SAM-e (S-Adenosyl methionine, a popular over-the-counter supplement) are key components of this methyl-making pathway (Diagram 3 and Table 5). Diets high in these methyl-donating nutrients can rapidly alter gene expression, especially during early development when the epigenome is first being established.

Regulating glucose in the blood
Glucose is needed by cells for respiration. It is important that the concentration of glucose in the blood is maintained at a constant level. Insulin is a hormone produced by the pancreas that regulates glucose levels in the blood.

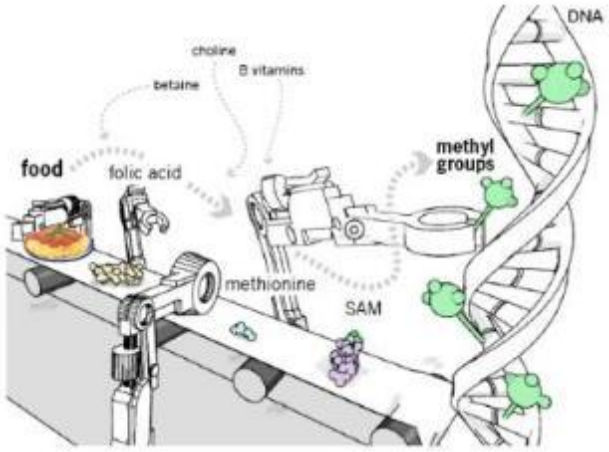


Diagram 3. Nutrients from our food are turned into methyl groups along a pathway: the pathway is made up of many players that manipulate molecules into methyl groups and ultimately put them on our DNA.

Table 5 The nutrients that affect our epi-genome and the foods they come from

Nutrient	Food Origin	Epi-genetic Role
Methionine	Sesame seeds, brazil nuts, fish, peppers, spinach	SAM synthesis
Folic Acid	Sunflower seeds, baker's yeast, liver	Methionine synthesis
Vitamin B12	Meat, Liver, shellfish, milk	Methionine synthesis
Vitamin B6	Meat, whole grain, vegetables, nuts	Methionine synthesis
SAM-e	Popular dietary supplement pill; unstable in food	Enzymes transfer methyl groups from SAM directly to DNA

Choline	Egg yolks, liver, soy, cooked beef, chicken, veal and turkey	Methyl donor to SAM
Betaine	Wheat, spinach, shellfish, and sugar beet	Break down the toxic by-products of SAM synthesis
Resveratrol	Red wine	Removes acetyl groups from histones improving health (in lab mice)
Genistein	Soya products	Increased methylation, cancer prevention, unknown mechanism
Sulphoraphane	Broccoli	Increased histone acetylation turning on anti-cancer genes

Even your mother's diet during pregnancy and what you are fed as an infant can cause critical changes that stay with you into adulthood. Animal studies have shown that deficiency of methyl-donating folate or choline during late foetal or early postnatal development causes certain regions of the genome to be under-methylated for life. For adults, a methyl deficient diet still leads to a decrease in DNA methylation, but the changes are reversible with resumption of a normal diet.

So if a pregnant mother's diet can affect the child's epigenetic outcome, can the father's diet do the same? Quite possibly, according to scientists who delved into the well-kept, historical records of annual harvests from a small Swedish community. These records showed that food availability between the ages of nine and twelve for the paternal grandfather affected the lifespan of his grandchildren. But not in the way you might think. Shortage of food for the grandfather was associated with extended lifespan of his grandchildren. Food abundance, on the other hand, was associated with a greatly shortened lifespan of the grandchildren. Early death was the result of either diabetes or heart disease. Could it be that during this critical period of development for the grandfather, epigenetic mechanisms are "capturing" nutritional information about the environment to pass on to the next generation?

As we better understand the connections between diet and the epigenome, the opportunity arises for clinical applications. Just as mapping our gene variations gives us a window into our personalised medical needs, so might a profile of one's unique epigenome. Formed through a lifetime of experiences, beginning in the womb, our epigenome may provide a wealth of information about how to eat better. Enter the future field of nutrigenomics, where nutritionists take a look at your methylation pattern and design a personalised nutrition plan. We are not quite to that point yet, but our doctor can already tell a lot about our disease risk by looking at our family health history.

While not a popular political intervention, personalised nutrition is becoming increasingly recognised as an opportunity to optimise health. Indeed I was involved in a lengthy discussion on personalised 'microchips', not potatoes for the microwave, but one inserted under your skin, to record your own diet, and associated health. All too often people only look at changing their diets when they are unwell, or during some other life changing intervention such as when pregnant, or cooking for themselves for the first time. When epi-genetics determines so much with our health we could be far more planned and strategic in altering diets at key stages in our lives: as a baby, under 5, puberty, reproduction, pregnancy, significant birthdays; it would be money well spent. Being 50 this year made me question why I am not called in for a check-up. There is not one doctor I met that does not think more could be done. Prof. Wilkins talked about how important the circumference of your waistline is (you should be taller than twice the circumference of your waist); all doctors need is a tape measure. Then there is the difference between apple and pear shapes – the deposition of fat around your waist is hard to shift. **Change involves better information, more communication and an effective plan that is stuck to.**

11. Behaviour change and education

One social science that has always interested me is that around perceptions and changing behaviour. With food, the over-arching solution to reducing NCD is eating a balanced diet, exercising regularly and drinking plenty of water. New York Times Magazine contributor and author Michael Pollan sums up the simple rules of eating in his book 'Food Rules'[xli], addressing the questions: **What should I eat? (Eat Food); What kind of Food should I eat? (Mostly Vegetables) and How should I eat? (not too much).**

Yet we continue to find excuses why we cannot eat that balanced diet. Table 6 below looks at some of the consumer barriers to choosing nutrient-rich food and beverages.

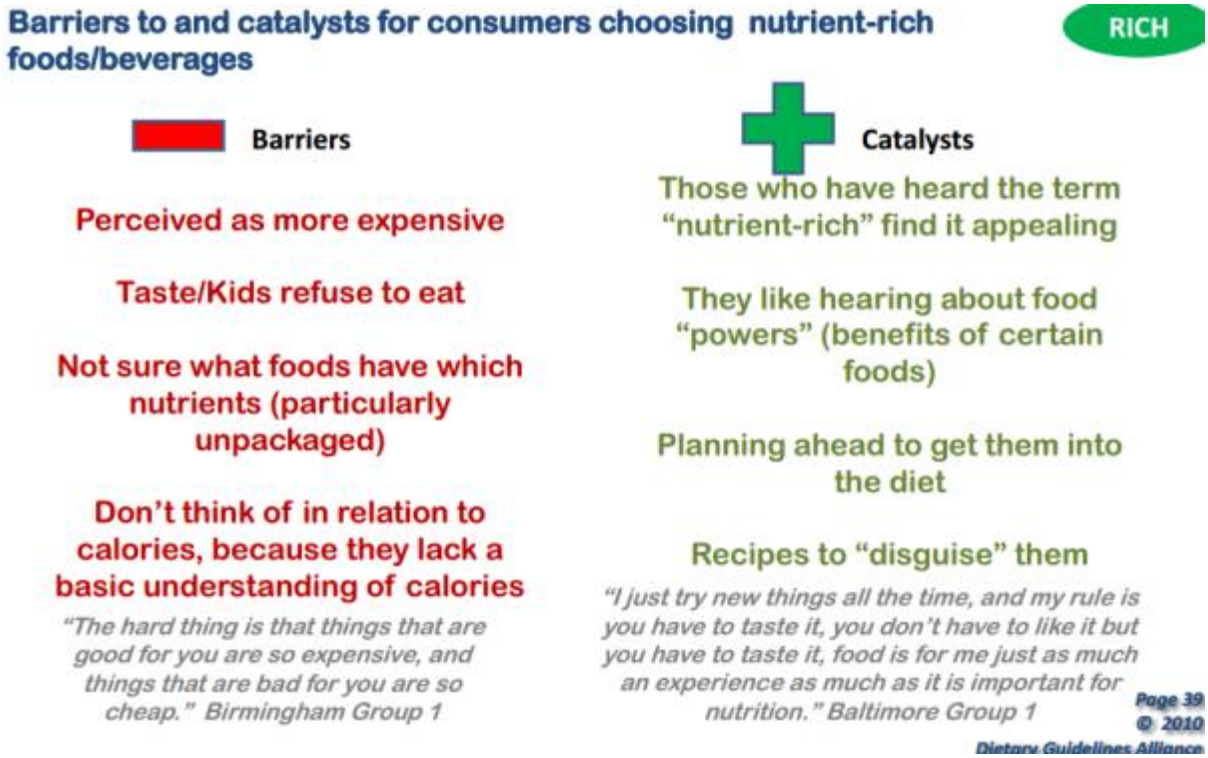


Table 6 Barriers & Incentives

Many programmes and campaigns to change eating habits have met with costly, disappointing short-term results. The adoption of functional foods, for example, has been slow, since we are wary of trying unfamiliar foods that appear unfamiliar.[xlii] This is not new. In World War II we can find some of the solutions. In America during this time much of the domestic meat supply was being shipped to feed soldiers and allies, leaving the US short of protein. The challenge was to encourage the Americans to eat offal, feet, ears, and cow heads. To accomplish this the Department of Defence enlisted Margaret Mead, Kurt Lewin, psychologists, sociologists, anthropologists, food scientists, dieticians and home economists to determine how dietary change could be accomplished. They established a **Committee on Food Habits**. They addressed the perceptions of change looking to balance the encouraging forces and discouraging forces (barriers and incentives). It was important to first remove the reasons why they should say 'no' before giving people nutritional or patriotic reasons to say 'yes'. With any efforts to change behaviour unless barriers to consumption are removed, promotional incentives would be wasted (Figure 11).

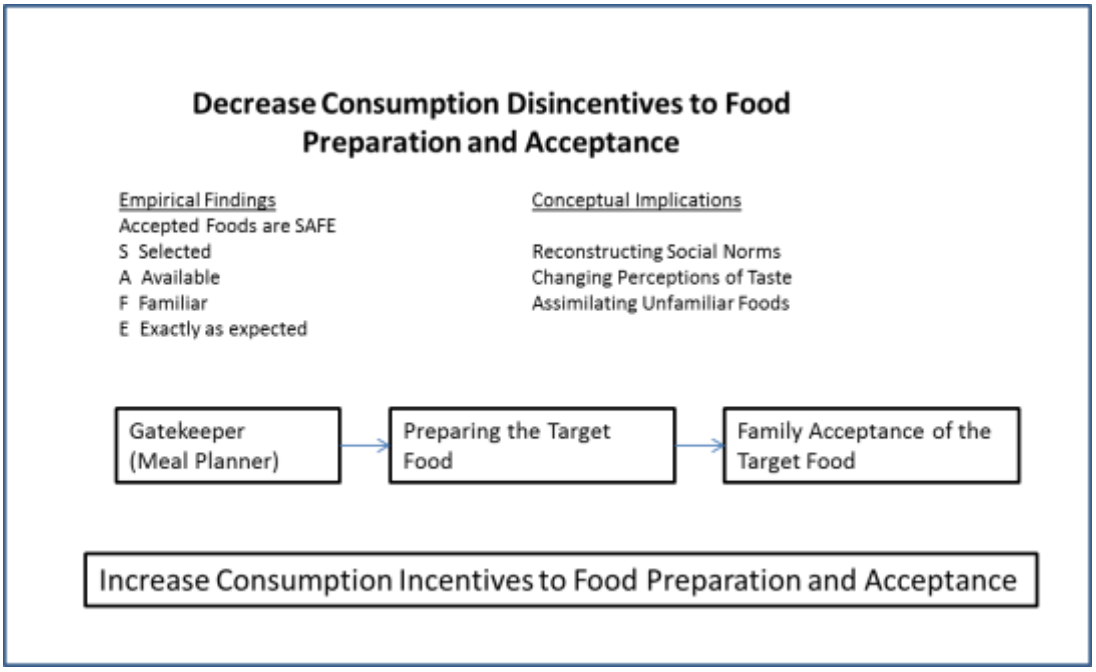


Figure 11. Gatekeeper focused framework of food acceptance

They also suggested that larger issues: social norms, perceptions of taste and assimilation of variety, all influenced human behaviour. It was also important to identify the 'gatekeeper' within households, since they control what food is selected, purchased, prepared and served. Indeed it is estimated that 72% of food decisions by families are made directly or indirectly by the primary shopper and much of this is around habitual purchasing decisions, influenced occasionally through promotions, TV programmes and children's pester power.

Another issue that is critical is linking the **attribute** of a food with the **consequence** of eating it, good and bad! Promoting a product low in cholesterol is less effective than saying it can help reduce the chances of heart disease. One of the key implications for practitioners is that education strategies based on **attribute knowledge** of healthful products are not likely to change long-term behaviour. **It is essential to link food attributes with personal health consequences when communicating with the public.**

Much of the disconnection between nutrition education and behaviour change can be attributed to ineffective targeting. Rather than approaching all people in a generic, one-size-fits-all manner, it is important to realise that some groups are more predisposed to some messages and interventions than others. It is evident that tastes can be segmented, such as those who prefer more savoury foods than sugary ones and vice versa, and how nutrition education and marketing campaigns can become more efficient and effective by taking these different tastes into account. (As shown in Figure 12 on next page).

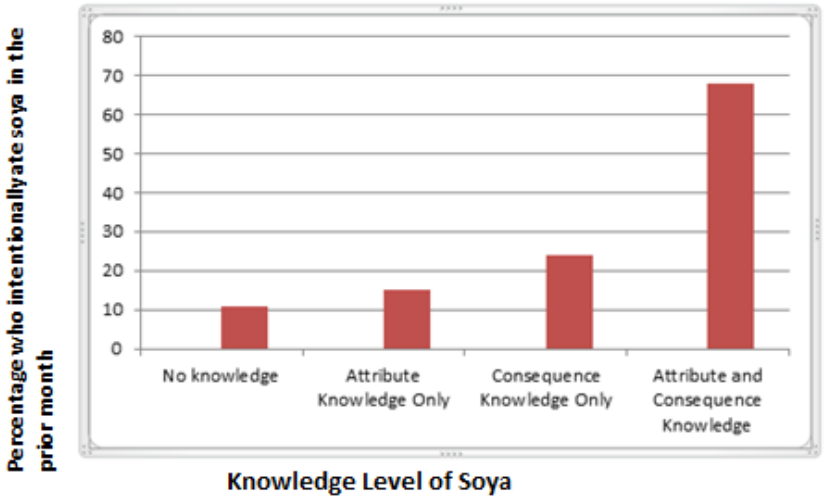


Figure 12. Having both attribute and consequence knowledge dramatically increases a consumers' willingness to eat a functional food

There is strong evidence that those who are more 'fruity' prefer sweet snacks, rather than the savoury snacks favoured by vegetable lovers … though this was completely disproved when I tried it out at a ladies dinner!

Thinking about taste and changing behaviour around food and diet is hard when the perception is that a certain food is unacceptable. Familiar preparation, appearance and taste portfolios all influence taste, and working out ways that clearly break habits is hard. Add to this is the act that people learn in different ways, individuals receive and assimilate information in different ways and our culture also has an impact on our food choices. In the Western world those habits and familiarity are built on our resistance to risk and familiarity. **Where food is readily available we could do more such as substituting high fat foods with low fat foods, substituting sweet snacks with fruit, starches with vegetables or meat protein with soya or pulse protein, or even reducing the proportion of meat in processed foods.**

With many food decisions being grounded in our culture, how do we know that the western world will not adopt the Chinese and Asian values and food culture in the future? Currently the stigma in Asia associated with the perceived wealth of Western fashion and food means that meat consumption is increasing there. Understanding cultures is important since some cultures view food exclusively as providing nutrition (utilitarian cultures) whereas others have a greater predisposition for the complexity of preparation and for the process of savouring food (hedonic cultures). **This is important in marketing nutrition and develops change because it improves our understanding of how to integrate new foods into different cultures and improve health.**

The likelihood of an unfamiliar food being integrated into a culture depends on whether the context of a culture is high or low. Higher context cultures, such as those in Latin American and Asia, focus heavily on personal relationships and social interactions. In contrast lower context cultures such as those of many western nations focus on individualism and achievement. Table 7. describes how a culture's context can affect how people make decisions.

Area of impact	Higher Context Cultures	Lower Context Cultures
Personal Choice	• Strong preference towards cultural traditions and practices • Desire for many close personal relationships with family, friends, co-workers and clients • Tendency to use multiple forms of communication at once (eg tone of voice, timing, facial expressions and choice of words) • Focus on meaning that is implicit in relationships and situations • Placement of emphasis on the group (eg collectivism)	• Strong preference towards individual decisions and preferences • Lack of strong cultural pressure to follow tradition • Tendency to use explicit and straightforward communication (eg complete, accurate and appropriate work choice) • Placement of emphasis on the individual • Willingness to change cultural patterns
Food Choice	• Value placed on traditional food dishes • Considers food presentation and texture to be as important as taste • Preference for complex and involved food dishes • Unwilling to try foreign and not culturally accepted foods • Tendency to favour taste over nutrition	• Value place on functional, practical, nutritional foods • Preference for simple, quick food choices • High willingness to accept new foods and adapt personal eating habits accordingly

Table 7 : Characteristics of Higher and Lower context cultures[xliii]

12. Changing perspectives

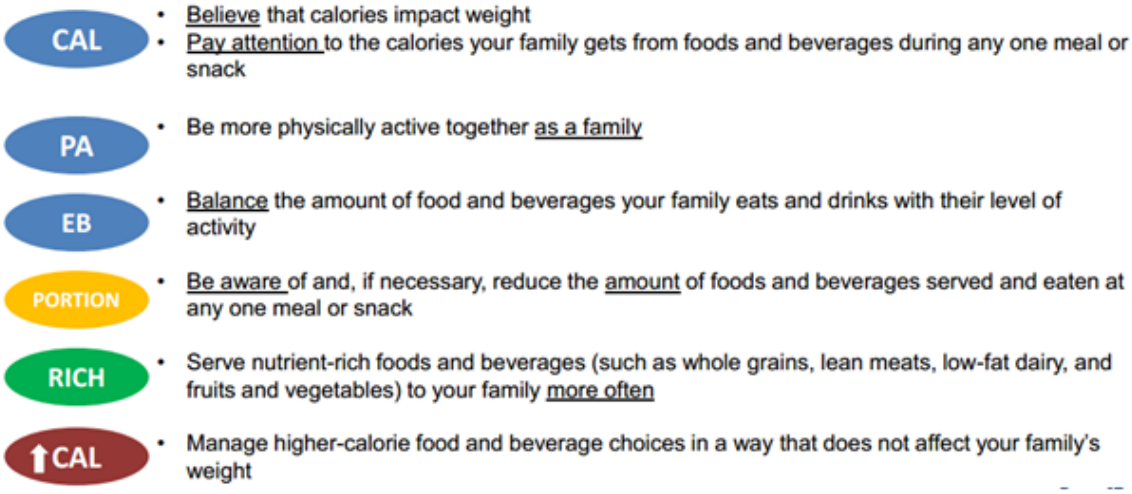
As has been highlighted, different people have different predispositions to different foods, based around culture, taste, history, etc. (See Table 8). Knowing a person's taste profile will help a dietician design a nutritional plan and a nutritional message will be heard. Since fruit lovers tend to prefer sweet snacks, so it is best to encourage them to eat fruit snacks instead of cookies. Rather than changing behaviour, realise that some people are more likely to change their eating behaviours than others. **In general nutritional messages are most effective when you target a specific population with a quantitative but personal message.**

Given the fact that nutrition knowledge is power, we are only 7 meals away from anarchy and in 2008 there were over 100 food riots globally. Sometimes it is assumed that once people know that food is nutritious, they will consume it. Too much day-to-day contact with highly salient nutritional knowledge may lead some to believe that simply passing on this knowledge will induce change. These approaches are generally unsuccessful, like knowing that doing 50 press-ups every morning is good for us – and then not quite doing that. Unfortunately some people will not eat better even if they pass a nutritional quiz and in fact at times there is an inverse relationship. Increasing evidence is moving to an approach of **understanding taste and then nutrition**. A good dietician or health care professional understands that nutrition education will solve nutrition problems only when it is **relevant to one's personal circumstances and appealing to one's individual tastes.**

	Perspective	
Profession	**Backward - Looking**	**Forward Looking**
• Dieticians and healthcare professionals • Public policy officials and food aid administrators • Brand managers • Researchers and academics	• Nutritional knowledge is power • Food aid is food eaten • Marketing nutrition is like marketing soap • Here's the data	• Understand taste, then understand nutrition • Persuade then provide • Half taste, half perception • Rigour and relevance

Table 8. Speeding forward and changing perspectives

Work in the US has incresaingly looked at messages as illistrated below by the Dietary Guidelines for Americans. See chart on next page.



Dietary guidelines for Americans

Messaging is complex and often hard to achieve, such as eating 5 fruit a day or walking 9000 steps a day, especially if you are only achieving 1 or 2 fruit and vegetables a day, food on the hoof and 2000 steps. Targeted specific and more achievable messages are critical, such as one more fruit or veg a day or walk 500 more steps a day and against a background of pressure on the shopping basket. News in the Times in November 2013 from the Institute for Fiscal Studies (IFS) showed fruit and veg left on shelf as families tried to cut costs. Analysis suggests that cash-strapped households replaced fruit and vegetables with cheaper, fatty food because of a combination of rising grocery bills and stagnant incomes. In particular families with young children are buying unhealthy foods. Melanie Luhrmann, a research associate at the IFS, said they were surprised to find that there has been a substantial decline in total calories purchased at a time when obesity has increased. This does not mean that poor diets play no part in rising obesity, but understanding the interaction between diet and physical activity is crucial.

In 2013 families with young children were buying 6 g of sugar more per day than six years ago and getting only 10.2% of their calories from fruit and vegetables, down from 11.4% in 2005 to 2007. Pensioners are buying 2 g more of saturated fat. In 2012, the UN conference on sustainable development, Rio+20, referred to non-communicable diseases (NCDs) as "one of the major challenges for sustainable development in the 21st century", emphasising the fundamental link between health and development. The costs of NCDs are increasingly a burden in low-income and middle-income countries, affecting people in the prime of their lives and putting more pressure on already stretched health systems and government and family budgets.

The significance of the developmental consequences of NCDs is not yet sufficiently understood. However, increasing global attention is being given to NCDs at the political level and among other stakeholders outside the health system. In 2011, the UN General Assembly adopted the political declaration on Non-Communicable Diseases, which sets global priorities to tackle NCDs. In May, 2012, the **World Health Assembly approved a global target of a reduction in NCD-associated premature mortality by 25% by 2025.** The 2012 UN resolution on global health and foreign policy also recognises the need to address these diseases.

To meet such targets action from the health sector, led by WHO, is crucial, as are robust partnerships between the health and other sectors to tackle the underlying social, economic, political, environmental, and cultural determinants. Multisectoral partnerships can build on the

knowledge gained and partnerships forged for the global response to the AIDS epidemic. Promises are easy to make, but harder to deliver and even more difficult to monitor. In the political declaration from the UN high-level meeting on non-communicable diseases in September, 2011, heads of state made many welcome promises. But how should the global community ensure that these commitments are adhered to? How can all partners who support the political declaration be mobilised to ensure that tangible progress is being made on the commitments? In one word, the answer lies in accountability. Only by establishing a rigorous, independent accountability mechanism will we be certain that the goal of a 25% global reduction in mortality from NCDs by 2025 is on track to be met. But this will be a challenge when so many other global government targets have slipped and what does the idea of independent accountability mean?

With the new CAP reform, it is evident that food nutrition is not a core or stated objective. There is potentially so much opportunity to grow our food production and link it in with health programmes and the school foods programme in milk and fruit and vegetables. At the Oxford Farming Conference 2014, Owen Paterson called for an increase in British fruit and veg - plausible and laudable objectives, but let us make sure it is in a holistic and reasoned approach to long term joined up strategy with some high level commitment and leadership.

We have seen the efforts of Jamie Oliver who does not do things by halves. His food Revolution Day has engaged many people across the globe, connecting with food and cooking. There are some great initiatives and some huge opportunity for the farming sector to be much more involved in providing the food![xliv] In 2013 communities and 75 countries came together to share cooking skills at street markets, cooking classes, dinner parties and potluck suppers. Where we have more people dying from diet-related diseases by eating too much, than from eating too little, we have lost our way with our relationship with food; we need to get back on track before it is too late.

Attempts to increase public awareness of appropriate ways to eat more healthily have not led to significant changes in patterns of food purchase and consumption. We need further systematic research and innovative approaches, building on existing activities, such as the EU research project INPROFOOD, but we also need action. *INPROFOOD* is determined to tackle this hugely ambitious task during 3 years of intensive activities. Their aim is to foster dialogue and mutual learning between:

- Industry;
- Academia;
- Civil society.

The research is already in the early stages of developing innovative approaches (technical and social) for dealing with the food and health challenge.

Then of course there are the successful industry-wide initiatives such as Open Farm Sunday and Open Farm Schools Day led by LEAF (Linking Environment and Farming) and supported strongly by the industry and the BNF (British Nutrition Foundations) Healthy Eating Week, alongside the Schools Food Project and work such as Food For Life. In spring 2013 SUSTAIN launched the children's future fund proposing that it, funded by a sugary drinks duty, could pay for programmes to improve children's health and protect the environment they grow up in. Pointing to the annual £6 billion NHS bill to treat dietary related illnesses, part of the children's future fund recommended the introduction of a sugary drinks duty for the UK which, for example, at 20p per litre would raise around £1 billion a year which could be put to good use. Furthermore, from April 2013, the National Heart Forum became the UK Health Forum. This signified the wider focus of the forum's work in the UK and internationally across a range of preventable NCDs that share common risk factors and determinants.

All these add up to help engage and encourage change and have an important role to play in the fight against chronic diseases and health-related problems that are directly related to poor nutrition and inadequate fruit and vegetable consumption. In June 2013 the UK Government launched the Global Panel on Agriculture and Food Systems for Nutrition chaired by Prof. Sir John Beddington, and John Kufuor, former President of Ghana, and hosted by the London International Development Centre (LIDC). It will review research evidence and provide global leadership for investments and policies in agriculture that will support nutrition and help eradicate hunger. Focused globally, this work notes that 165 million children alive today will have their future potential stunted due to lack of adequate food. Providing better nutrition to mothers and infants in the first 1,000 days is essential to give these children a better start in life. The benefits of interventions that directly tackle nutrition are well documented, but broader measures are urgently needed to address the global burden of under-nutrition and under-five mortality. In this work agriculture is seen as critical for improving livelihoods and tackling food and nutrition security. It plays a key role in producing nutritious foods and making them available to consumers through the food value chain, resulting in better nutritional outcomes. It is also an important source of income for farmers and farm workers enabling them to provide their families with better quality nutrition; but what is really needed is truly strong leadership in tackling this issue.

13. Conclusion and Recommendations

1. Agriculture drives economic development in many countries and is essential to improving nutrition and how future policy for feeding 9 billion is fashioned.

2. Food and health is a highly complex societal challenge and public engagement in research requires ever more focus. Over the past decade, most EU Member States have identified food and health as key priorities, yet it is not linked to what we produce, or education, or health policy in an integrated and considered way in response to increases in obesity and diet-related chronic diseases such as diabetes and cardiovascular diseases amongst their populations.

3. Without a doubt, Non-Communicable Diseases account for the greatest healthcare and social burden of disease. I have only just started to understand the complexity of getting to grips with more sustainable diets and what farmers can learn from science to improve the nutrition of our food. However, as farmers learn and take part in making changes they cannot do it in isolation from the market; government policy, education and health programmes all need to focus with nutrition as the goal – indeed to reach the target of 25% reduction in NCD premature deaths by 2025.

4. Public health and private organisations clearly agree that a compelling emotional benefit was needed to motivate consumers to eat more fruits and vegetables and that messaging needed to be used consistently. It is repeatedly shown that resolving this public health issue depends on the efforts and success of many stakeholders who impact food choices and eating habits:

    - Nutrition education, promotion, and marketing groups
    - Growers, farmers, processors, and supermarket retailers
    - Restaurants and other food service establishments
    - Schools, child care, and other institutions feeding children and adolescents
    - Workplaces
    - Health care community
    - Local and national governments

5. There is a huge disconnect between knowledge and action; even the people who have adequate awareness of healthy diet and eating habits do not necessarily act on it due to wider cultural and institutional factors. Concerns over food safety and the need for more variety, healthy and nutritious food have driven innovation in quality standards. The demands of both consumers and the food and drink processors have led to many changes in recent years. Access to the most advanced developments in agricultural science and technology will be essential to meet the challenge of maintaining and improving the nutritional and health properties of our crops and livestock. When the majority of families are eating from a routine list of the same 10 meals, more diversity is key, but such changes are in the long term.

6. Each day we are bombarded by dozens of conflicting messages about food. Sometimes health professionals cannot even agree on what we should eat for optimal health. One thing they can agree on: eat more fruits and vegetables and eat more whole grains. The scientific evidence is clear, and overwhelming. These foods can help maintain a healthy weight, and help reduce the risk of diet-related chronic diseases. The real risk is that farmers lose the opportunity for their businesses which, with volatile weather and global markets, could

mean they end up just growing the raw materials, and food either being fortified post farm gate or supplemented with vitamins.

7. It is increasingly clear that we do not need vitamin supplements, except in rare cases like expectant mothers; we easily get enough of the vitamins we need from the food we eat; especially since those who buy supplements tend to be the worried well. The global vitamins and supplements industry is worth over $68 billion (*2010 Euromonitor*). In the UK this is predicted to be £389m (€466m) in 2015-2016 – how much better it would be for farmers to be getting a cut of that through demonstrating the importance of nutrition in the diet.

Table 9 : The main conclusions – we can all play a part

	NOW	1 – 5 YEARS	5 – 10 YEARS	GOAL
ALL	**4. WORK TOGETHER TO DEVELOP A FULLY INTEGRATED FOOD PLAN BASED AROUND NUTRITION** - Community based and with people, and ideas we would usually not choose to work with **5. EMBED HEALTH AS A VALUE WHEN WE BUY FOOD** **6. WE NEED TO CREATE MORE DIVERSITY – IN OUR FOOD AND IN OUR FARMING**			**A 25% REDUCTION IN NON-COMMUNICABLE PREMATURE MORTALITY BY 2025 (World Health Assembly)**
Farmers	➢ All agricultural courses should ensure that students carry out basic human food nutrition education ➢ There is a great opportunity for farmers to link more effectively with the general public – Open Farm Sunday and Open Farm Schools days are very successful, but there is more scope for deeper and more meaningful connections for farmers and the local community around food.	➢ Reinstate farming's ownership of food – *food not commodities* ➢ Get healthy! ➢ The market place is starting to gear up to require nutrient benefits, it is more urgent in developing countries, but it will come to the Western world with the potential to improve opportunities for farmers and breakthroughs in processing – be part of it in order to benefit from added value opportunities ➢ Look at your business and identify your long term goals for food production and nutrition	➢ Consider the niche opportunities for your business in the development of fortified foods and bio-fortification ➢ Adopt more sustainable farming approaches and get closer to your market, such as LEAF Marque	
Researchers	➢ Be open to new ways of thinking, the amount of times I heard 'counter intuitive' results was amazing ➢ Look at the opportunities for Apps for individuals and doctors on improving health	➢ Develop new more integrated approaches to health and diet that links in with farm production. It appears we have only just started to get to grips with the breeding pathways, the single issue nutrients, epi-genetics, how foods interact in vitro and in vivo, our gut organisms and so much more is needed to be done to understand how we can deliver 'health by stealth'.	➢ Understanding more around behaviour change is critical, social scientists and psychologists are essential in how we move things forward	
Consumers	➢ Learn to love food more, including its values and culture – the story behind our food	➢ Eat a balanced diet – one more fruit and vegetable per day per year ➢ Consider your food habits and reflect on change	➢ Get involved in government, industry and school initiatives, such as Open Farm Sunday and Open Farm Schools Days	

Doctors	➢ Be more pro-active in supporting and monitoring health – weight, wee and waist should be measured during significant milestones in people's lives	➢ Consider the opportunities for your role in local community actions, at the GP or hospital	➢ Work alongside nutritionists to improve health
Retailers and processors	➢ Health is a pre-competitive issue – we need to work together to market messages and improve performance	➢ Work with farmers to deliver the best and right raw nutrient appropriate materials – the whole package of food delivers vitamins and nutrients more effectively	➢ Your marketing and analytical skills will be increasingly important in helping deliver change among all ages
Policy	➢ Be bold in the food debate – with strong leadership ➢ Much as it greaves me to say – it is not all about farming! Neither is it all about multinational food corporations. We need a food, health and nutrition, what we know and a radical rethink our approach and who is involved. (farmers have often been excluded)	➢ Build up a team and pilot a new approach to a fully integrated, community based health and wellbeing plan, built around nutrition	➢ Promote and support the pilot, built around simple and inclusive messages and community drive

14. So where next?

The big challenges will continue to be around how, with limited resource availability, we reconcile the need to provide the appropriate nutrition for the projected world population growth. The issues around where food is produced and consumed, the level of food consumption by people in different parts of the world, and the composition of what they eat will continue to be high on people's agenda. There will be significant implications for the cost of food as demand outstrips supply, and there is a good opportunity for sophisticated food companies to help resolve some of these problems, but it is essential that farmers are seen as part of the answer too.

We will see the development of new technologies, essential to deliver the answer, is needed. The role of science in food must become more important at all stages of the supply chain from genetics right the way through to innovations in the home.

The place of food is much more important than just sustenance, particularly in different parts of the world. Factors such as taste, enjoyment, wholesomeness and how integrated is the fabric of society, culture and family life are equally important. It is crucial that we get this balance right as we move forward. There are so many unanswered questions that my study has turned up – more research, technology and development are needed and bold leadership is essential now to develop a culture that is right to improve diets, nutrition and the role that farmers have to play in it.

… And for me: a balanced diet, more exercise and the occasional treat and of course the pursuit of more answers on how can farmers learn from science to improve the nutrition of our food! Within the activities of LEAF there is scope for our work to play a significant role in the future and in developing and promoting more sustainable diets.

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15. Glossary of Terms

Biofortification

Biofortication is breeding crops to increase their nutritional value, either through conventional selective breeding, or through GM. Biofortification differs from ordinary fortification because it focuses on making plant foods more nutritious as the plants are growing, rather than having nutrients added to the foods when they are being processed. Biofortification is seen as an upcoming strategy for dealing with deficiencies of micronutrients in the developing world.

Functional Foods

A **functional food** is a food given an additional function (often one related to health-promotion or disease prevention) by adding new ingredients, or more of existing ingredients. The general category of functional foods includes processed food or foods fortified with health-promoting additives, like "vitamin-enriched" products. Products considered functional generally do not include products where fortification has been carried out to meet government regulations and the change is not recorded on the label as a significant addition ("invisible fortification"). An example of this type of fortification would be the historic addition of iodine to table salt, or Vitamin D to milk, done to resolve public health problems such as rickets. Fermented foods with live cultures are considered functional foods with probiotic benefits. Functional foods are part of the continuum of products that individuals may consume to increase their health and/or contribute to reducing their disease burden. Functional foods are an emerging field in food science due to their increasing popularity with health-conscious consumers and the ability of marketers to create new interest in existing products.

The term was first used in Japan in the 1980s where there is a government approval process for functional foods, called Foods for Specified Health Use. It is estimated by BCC Research that the global market of the functional food industry will reach $176.7 billion in 2013.

NCD

A **non-communicable disease,** or **NCD**, is a medical condition or disease, which by definition is non-infectious and non-transmissible among people. NCDs may be chronic diseases of long duration and slow progression, or they may result in more rapid death such as some types of sudden stroke. They include autoimmune diseases, heart disease, stroke, many cancers, asthma, diabetes, chronic kidney disease, osteoporosis, Alzheimer's disease, cataracts, and more. While sometimes (incorrectly) referred to as synonymous with "chronic diseases", NCDs are distinguished only by their non-infectious cause, not necessarily by their duration. The World Health Organization (WHO) reports NCDs to be by far the leading cause of death in the world, representing over 60% of all deaths.

Nutraceuticals

Food, or parts of food, that provide medical or health benefits, including the prevention and treatment of diseases. Dr Stephen DeFelice, Foundation for Innovation in Medicine.

Nutraceuticals include the following:

Dietary Supplements including botanicals:

- Vitamins, minerals, co-enzyme Q, carnitine
- Gingsing, Gingko Biloba, Saint John's Wort, Saw Palmetto

Functional Foods:

- Oats, bran, psyllium and lignin's for heart disease and colon cancer
- Prebiotics - oligofructose for control of intestinal flora
- Omega-3 milk in prevention of heart disease
- Canola oil with lowered triglycerides for cholesterol reduction
- Stanols (Benecol) in reduction of cholesterol adsorption

Medicinal Foods:

- Transgenic cows and lactoferrin for immune enhancement
- Transgenic plants for oral vaccination against infectious diseases
- Health bars with added medications

Nutrigenomics

Nutrigenomics is the study of how different foods may interact with specific genes to increase the risk of common chronic diseases such as type 2 diabetes, obesity, heart disease, stroke and certain cancers. Nutrigenomics also seeks to provide a molecular understanding of how common chemicals in the diet affect health by altering the expression of genes and the structure of an individual's genome. The premise underlying nutrigenomics is that the influence of diet on health depends on an individual's genetic makeup.

SAM

***S*-Adenosyl methionine** (**SAM-e**, **SAMe**, **SAM**, **AdoMet**, **ademetionine** is a common co-substrate involved in methyl group transfers. The methyl group (CH_3) attached to the methionine sulphur atom in SAM is chemically reactive. This allows donation of this group to acceptor substrate in transmethylation reactions. More than 40 metabolic reactions involve the transfer of a methyl group from SAM to various substrates, such as nucleic acids, proteins, lipids and secondary metabolites.

16. Bibliography

Artusi, P. (2011), Science in the Kitchen and the Art of Eating Well, University of Toronto Press.

Blair, R. (2012), Organic Production and Food Quality, A Down-To-Earth Analysis, Wiley Blackwell.

Blanc, R. (2008), A Taste of My Life, Bantam Press.

British Nutrition Foundation (2013), Nutrition and Development, Short and Long Term Consequences for Health, Wiley-Blackwell.

British Society of Animal Science and the Association of Veterinary Teaching and Research Work (2012), Advances in Animal Biosciences, Healthy Food from Healthy Animals, Cambridge University Press.

Campden and Chorleywood Food Research Association Group, (2008), Nutritional Status of Fruit and Vegetable Crops – A Review.

Campden and Chorleywood Food Research Association Group, (2013), Scientific and Technical Needs of the Food and Drink Inudstry.

Caws, M. (2013), The Modern Art Cookbook, Reaktion Books.

Cooper, D. (2012), Convergence with Nature, A Daoist Perspective, Green Books Ltd.

Drummond, J. C. and Wilbraham, A. (orig. 1939, updated 1991), The Englishman's Food, Five Centuries of English Diet, Pimlico

Food and Agriculture Organisation (2013), The State of Food and Agriculture, Food Systems for Better Nutrition, FAO.

Food and Fertilizer Technology Center for the Asian and Pacific Region (2013), General Information.

Food and Health Network, Institute of Food Research.

Gore, A. (2013), The Future, Random House

Harding, S. (2013), Animate Earth, Science, Intuition and Gaia, Green Books Ltd.

Harvey, G. (2006), We Want Real Food, Constable.

HRH The Prince of Wales's Food and Farming Summer School (July 2013), Course Materials.

International Society for Nutraceuticals and Functional Foods (ISNFF), (2013), An International Conference and Exhibition on Nutraceuticals and Functional Foods 2013, Symposium Papers November 5-9, 2013, Taipei, Taiwan.

Journal of Food Composition and Analysis (2013), Elsevier.

Lawrence, F. (2008), Eat Your Heart Out, Penguin.

Linford, J. (2014), The Creamery Kitchen, Ryland Peters.

Livestock Research Institute, Council of Agriculture, Executive Yuan, (2013), General Information.

McCandless, D. Information is Beautiful, Collins.

Pollan M.(2009), Food Rules An Eaters Manual, Penguin.

Pollan M.(2008), In Defence of Food, Penguin.

Price, W. A. (orig. 1939, updated 2012), Nutrition and Physical Degeneration, Price-Pottenger Nutrition Foundation.

Salatin, J. (2012), Folks, this Ain't Normal, Hatchett Book Group.

Schumacher, D. (2011), Small is Beautiful in the 21st Century, Green Books Ltd.

Wansink, B. (2007), Marketing Nutrition, Soy, Functional Foods, Biotechnology and Obesity, University of Illinois.

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18. Appendix A

Dr JohnTarlton Bristol University[xlv]

Omega-3 and omega-6 are types of essential fatty acids - meaning we cannot make them on our own and have to obtain them from our diet. Both are polyunsaturated fatty acids that differ from each other in their chemical structure. In modern diets, there are few sources of omega-3 fatty acids, mainly the fat of cold water fish such as salmon, sardines, herring, mackerel, black cod, and bluefish. There are two critical omega-3 fatty acids, (eicosapentaenoic acid, called EPA and docosahexaenoic or DHA), that the body needs. Vegetarian sources, such as walnuts and flaxseeds contain a precursor omega-3 (alpha-linolenic acid called ALA) that the body must convert to EPA, and DHA. EPA and DHA are the building blocks for hormones that control immune function, blood clotting, and cell growth as well as components of cell membranes.

By contrast, sources of omega-6 fatty acids are numerous in modern diets. They are found in seeds and nuts, and the oils extracted from them. Refined vegetable oils, such as soy oil, are used in most of the snack foods, cookies, crackers, and sweets in the American diet as well as in fast food. Soybean oil alone is now so ubiquitous in fast foods and processed foods that an astounding 20 percent of the calories in the American diet are estimated to come from this single source.

The body also constructs hormones from omega 6 fatty acids. In general, hormones derived from the two classes of essential fatty acids have opposite effects. Those from omega-6 fatty acids tend to increase inflammation (an important component of the immune response), blood clotting, and cell proliferation, while those from omega-3 fatty acids decrease those functions. Both families of hormones must be in balance to maintain optimum health.

Many nutrition experts believe that before we relied so heavily on processed foods, humans consumed omega-3 and omega-6 fatty acids in roughly equal amounts. But to our great detriment, most North Americans and Europeans now get far too much of the omega-6s and not enough of the omega-3s. This dietary imbalance may explain the rise of such diseases as asthma, coronary heart disease, many forms of cancer, autoimmunity and neurodegenerative diseases, all of which are believed to stem from inflammation in the body. The imbalance between omega-3 and omega-6 fatty acids may also contribute to obesity, depression, dyslexia, hyperactivity and even a tendency toward violence. Bringing the fats into proper proportion may actually relieve those conditions, according to Joseph Hibbeln[xlvi], M.D., a psychiatrist at the National Institutes of Health, and perhaps the world's leading authority on the relationship between fat consumption and mental health. At the 2006 Nutrition and Health Conference sponsored by the University of Arizona's College of Medicine and Columbia University's College of Physicians and Surgeons, Dr. Hibbeln cited a study showing that violence in a British prison dropped by 37 percent after omega-3 oils and vitamins were added to the prisoners' diets.

In general, however, you can cut down on omega-6 levels by reducing consumption of processed and fast foods and polyunsaturated vegetable oils (corn, sunflower, safflower, soy, and cottonseed, for example). At home, use extra virgin olive oil for cooking and in salad dressings. Eat more oily fish or take fish oil supplements, walnuts, flax seeds, and omega-3 fortified eggs.

19. Appendix B

How insulin gets into the blood

How insulin get into the blood. The hormone (dark blue) is carried to the cell surface in a bubble-like compartment, called a vesicle. When the vesicle binds with the cell membrane, it pops open and releases the insulin.
(Courtesy of the Nobel Prize)

In May 2013 three scientists shared the Nobel Prize in Physiology or Medicine. The winners include two Americans — James Rothman of Yale University and Randy Schekman of the University of California, Berkeley — and the German-born Thomas Suedhof of Stanford University. Both Schekman and Suedhof are also investigators at the Howard Hughes Medical Institute. Bioengineers have already harnessed the discoveries to manufacture new vaccines and improve the quality of insulin for diabetics.

Their discoveries took place over the course of 30 years. The work got its start with a few simple experiments in cells of yeast. In the 1970s, biologists already knew that cells weren't just sacks of fluid. Rather, they contain sophisticated highway systems that shuttle material from one compartment to the next. This cargo moves around cells in bubble-like compartments called vesicles. In a healthy cell, some of these vesicles make their way to the cell's surface, where the material is released outside the cell. That's one way that cells communicate with each other and with organs in the body. In 1976, Schekman, a new professor at the University of California, Berkeley, had recently found mutant yeast cells that had faulty transport systems. The cargo just piled up at the cell's surface, like cars stuck in a traffic jam. By figuring out which genes were defective in these yeasts, Schekman discovered dozens of components that built and controlled the cell's transport system. But there were still many pieces missing. In particular, it wasn't known how a cargo vesicle knows *where* to go on the cell's surface and then *when* to dump out its contents. *"Imagine hundreds of thousands of people who are travelling around hundreds of miles of streets. How are they going to find the right way? Where will the bus stop and open its doors so that people can get out?,"* said Nobel committee secretary Goran Hansson on Monday. "*There are similar problems in the cell, to find the right way ... and out to the surface of the cell.*" Take for instance two neurons in your brain. One neuron communicates with another by secreting neurotransmitters, such as dopamine and serotonin. But a neuron must release the neurotransmitter at a particular place — and at the right time. Otherwise the message will never make it to the second neuron, or the signal will get scrambled. That's where Rothman and Suedhof's research comes in. In the 1980s and 1990s, Rothman, now 62, figured out there is a signal on the vesicle's surface that helps it dock at just the right place on the cell's surface. The process works a bit like a zipper: a protein on the vesicle zips up with another one on the cell's membrane to position the cargo in the correct location. Then a few years later, Suedhof identified the trigger mechanism that dumps the neurotransmitter outside the cell at just the right time by unzipping the two proteins. This transport system has served as the foundation of modern cell biology and neuroscience. And breakdowns of the process are involved in a vast range of diseases, including Alzheimer's, cystic fibrosis, muscular dystrophies and some autoimmune disorders.

20. References

[i] www.leafuk.org & www.farmsunday.org
[ii] www.foodafactoflife.org.uk
[iii] http://www.hscic.gov.uk/catalogue/PUB10364
[iv] https://smartswaps.change4life.co.uk/
[v] http://www.noaw2014.org.uk/news/new-report-treat-obesity-like-smoking-face-obesity-costs-exceeding-50-billion-2050/
[vi] http://ec.europa.eu/agriculture/sfs/index_en.htm
[vii] National School Lunch Program, part of the Healthy, Hunger-Free Kids Act (2010) http://www.newsmax.com/US/obama-healthy-lunch-program/2013/08/29/
[viii] http://thefastdiet.co.uk/
[ix] http://www.bbc.co.uk/news/magazine-25498742
[x] www.leafuk.org
[xi] Burlingame, B. & Dernini, S. 2010. Sustainable diets and biodiversity: directions and solutions for policy, research and action. Proceedings of the International Scientific Symposium "Biodiversity and Sustainable Diets United against Hunger", 3–5 November 2010, FAO Headquarters, Rome. Rome, FAO and Biodiversity International.
[xii] FAO 2013. The state of food and agriculture 2013. Food systems for better nutrition.
[xiii] HarvestPlus. 2011. Breaking ground. HarvestPlus Annual Report 2011. Washington, DC, HarvestPlus.
[xiv] Reardon, T. & Timmer, C.P. 2012. The Economics of the Food System Revolution. The Annual Review of Resource Economics, 4: 225–264.
[xv] World Bank. 2006. Repositioning nutrition as central to development: a strategy for large scale action. Directions in Development. Washington, DC.
[xvi] WHO. 2011. Global status report on non-communicable diseases. Geneva, Switzerland.
[xvii] Bloom, D.E., Cafiero, E.T., Jané-Llopis, E., Abrahams-Gessel, S., Bloom, L.R., Fathima, S Feigl, A.B., Gaziano, T., Mowafi, M., Pandya, A., Prettner, K., Rosenberg, L., Seligman, B., Stein, A.Z. & Weinstein, C. 2011. The global economic burden of non-communicable diseases. Geneva, Switzerland, World Economic Forum.
[xviii] Croppenstedt, A., Barrett, C., Carisma, B., Lowder, S., Meerman, J., Raney, T. & Thompson, B. 2013 (forthcoming). A typology describing the multiple burdens of malnutrition. ESA Working Paper No. 13-02. Rome, FAO.
[xix] Prof. Kevin Fenton, Director of Health and Wellbeing at Public Health England.
[xx] Prevalence and Control of Diabetes in Chinese Adults: Yu Xu, PhD[1]; Limin Wang, PhD[2]; Jiang He, MD, PhD[3]; Yufang Bi, MD, PhD[1]; Mian Li, PhD[1]; Tiange Wang, PhD[1]; Linhong Wang, PhD[2]; Yong Jiang, MS[2]; Meng Dai, BS[1]; Jieli Lu, MD, PhD[1]; Min Xu, PhD[1]; Yichong Li, MS[2]; Nan Hu, MS[2]; Jianhong Li, MS[2]; Shengquan Mi, PhD[2]; Chung-Shiuan Chen, MS[3]; Guangwei Li, MD, PhD[4]; Yiming Mu, MD, PhD[5]; Jiajun Zhao, MD, PhD[6]; Lingzhi Kong, MD[7]; Jialun Chen, MD[1]; Shenghan Lai, MD, MPH[8]; Weiqing Wang, MD, PhD[1]; Wenhua Zhao, PhD[2]; Guang Ning, MD, PhD[1]; for the 2010 China Noncommunicable Disease Surveillance Group
[xxi] Personal meeting with Professor Susan Jebb, Oxford University.
[xxii]http://www.dailymail.co.uk/femail/article-2221066/Winter-health-Immunity-boosting-diet-micronutrients-Dr-Joel-Fuhrmans-book-Super-Immunity.html#ixzz2qIZxkD4p
[xxiii] Developing new types of wheat with enhanced health benefits (2012) Peter R. Shewry, Gilles Charmet, Gerard Branlard, Domenico Lafiandrac, Szilveszter Gergely, Andras Salgo, Luc Saulniere, Zoltan Bedo, E.N. Clare Mills and Jane L. Ward
[xxiv] Cereal grains for nutrition and health benefits: Overview of results from in vitro, animal and human studies in the HEALTHGRAIN project (2011) Inger Bjorcka, Elin Ostmana,*, Mette Kristensenb, Nuria Mateo Ansonc, Ruth K. Priced, Guido R.M.M. Haenenc, Rob Havenaare,

Knud Erik Bach Knudsenf, Anders Fridg, Hannu Mykkanenh, Rob W. Welchd and Gabriele Riccardii Applied Nutrition and Food Chemistry, Dept. of Food Technology, Engineering and Nutrition, Faculty of Engineering, Lund University, P.O. Box 124, SE-221 00 Lund, Sweden

[xxv] Bread in the diet: consumption and contribution to nutrient intakes of British adults. (2008). Toni Steer, Chris Thane, Alison Stephen and Susan Jebb on behalf of the RISCK Study Group MRC Human Nutrition Research, Cambridge, UK Proceedings of the Nutrition Society (2008)

[xxvi] Ross, A. B., Bruce, S. J., Blondel-Lubrano, A., Oguey-Araymon, S., Beaumont, M., Bourgeoise, A., et al. (2011). A whole-grain cereal rich diet increases plasma betaine, and tends to decrease total and LDL-cholesterol compared with a refined-grain diet in healthy subjects. British Journal of Nutrition, 105, 1492-1502.

[xxvii] analysis of the bread wheat G gnome using whole genome shotgun sequencing. Nature, 10.1038/nature 11650

[xxviii] R Brenchley *et al. Nature* 491, 705-710 (2012) doi:10.1038/nature11650

[xxix] Brouns, F.J.P.H., et al., Does wheat make us fat and sick?, Journal of Cereal Science (2013)

[xxx] www.quoats.org

[xxxi] The BARLEYmax Better Nutrition Report CSIRO and Australian Capital Ventures Ltd.(2009)

[xxxii] American Chemical Society's *Journal of Agricultural and Food Chemistry*.

[xxxiii] Anthocyanins Double the Shelf Life of Tomatoes by Delaying Over ripening and Reducing Susceptibility to Gray Mould Yang Zhang, Eugenio Butelli, Rosalba De Stefano, Henk-jan Schoonbeek,1 Andreas Magusin, Chiara Pagliarani, Nikolaus Wellner, Lionel Hill, Diego Orzaez, Antonio Granell, Jonathan D.G. Jones, and Cathie Martin. Current Biology 23, 1094–1100, June 17, 2013 Elsevier Ltd

[xxxiv] Milk, Composition, Dairy Foods and Human Health

[xxxv] Reduced bone breakage and increased bone strength in free range laying hens fed omega-3 polyunsaturated fatty acid supplemented diets (2012). John F. Tarlton, Lindsay J. Wilkins, Michael J. Toscano, Nick C. Avery, Lynda Knott. Elsevier Inc.

[xxxvixxxvi] Conversation with Professor Johnathan Napier

[xxxvii] Long-chain omega-3 fatty acids: time to establish a dietary reference intake. (2013) Michael R Flock, William S Harris, Penny M Kris-Etherton**.** Nutrition Reviews**,** Volume 71, Issue 10, pages 692–707, October 2013

[xxxviii] Regulation of osteoarthritis by omega-3 (n-3) polyunsaturated fatty acids in a naturally occurring model of disease L. Knott y, N.C. Avery, A.P. Hollander, J.F. Tarlton

[xxxix] Observer *V*ol.23, No.6 July/August, 2010

[xl] http://calorielab.com/news/2008/07/22/miracle-fruit-mystery-why-rare-fruit-not-available-in-us/#sthash.BIsnwdmp.dpuf

[xli] Food Rules and Eater's Manual. (2009) Michael Pollen.

[xlii] Marketing nutrition; Soy Functional Foods, Biotechnology and Obesity Wnsink B. (2007).

[xliii] Wansink, Sonka and Cheney (2002). A cultural hedonic framework for increasing the consumption of unfamiliar foods: soy acceptance in Russia and Columbia. Review of Agricultural Economics (2002).

[xliv] http://www.jamieoliver.com/us/foundation/jamies-food-revolution/school-food

[xlv] Conversation with Dr John Tarlton Bristol University

[xlvi] http://www.fabresearch.org/545