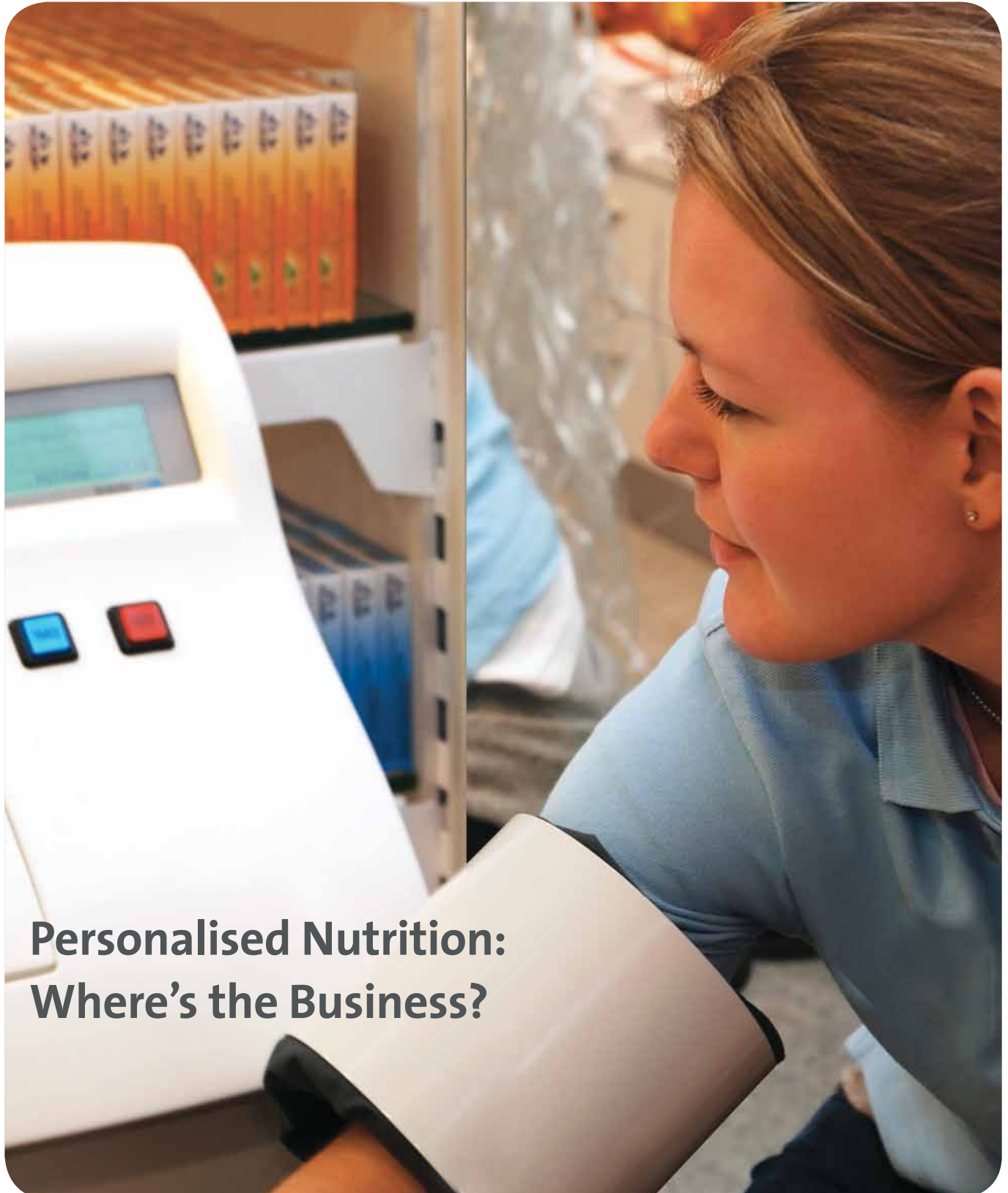# UCD Institute of Food and Health
Policy Seminar Series

MAPPING FOOD AND HEALTH TO THE PUBLIC POLICY LANDSCAPE

UCD DUBLIN

Personalised Nutrition:
Where's the Business?

Foreword

The UCD Institute of Food and Health intends to translate its research activity into both the economic and policy spheres of Irish Society. In order to advance issues of major public health significance, we have initiated a series of policy seminars in which we will bring together key international and Irish opinion formers.

'Personalised Nutrition - Where's the Business' is the fourth in a series of policy workshops held by the UCD Institute of Food and Health. The objectives of this workshop were: to bring together a multi-sectoral group to hear the various perspectives and to explore connectivity; to explore opportunities for joint research projects covering a wide range of disciplines with state funding agencies; to explore entrepreneurship possibilities in the field; and to identify both the scale and extent of business opportunities in personalised nutrition, and especially in the areas of genetic profiling, analyses of biofluids, biomarker discovery, and the development of a plethora of user-friendly sensors and software.

In this report, the papers presented on the seminar day are summarised. A video cast of the talks can be viewed at the UCD Institute of Food and Health website (www.ucd.ie/foodandhealth). I would like to thank all our speakers, the Chairs and the invited audience for their contributions to the seminar.

Professor Michael J Gibney
Director
UCD Institute of Food and Health
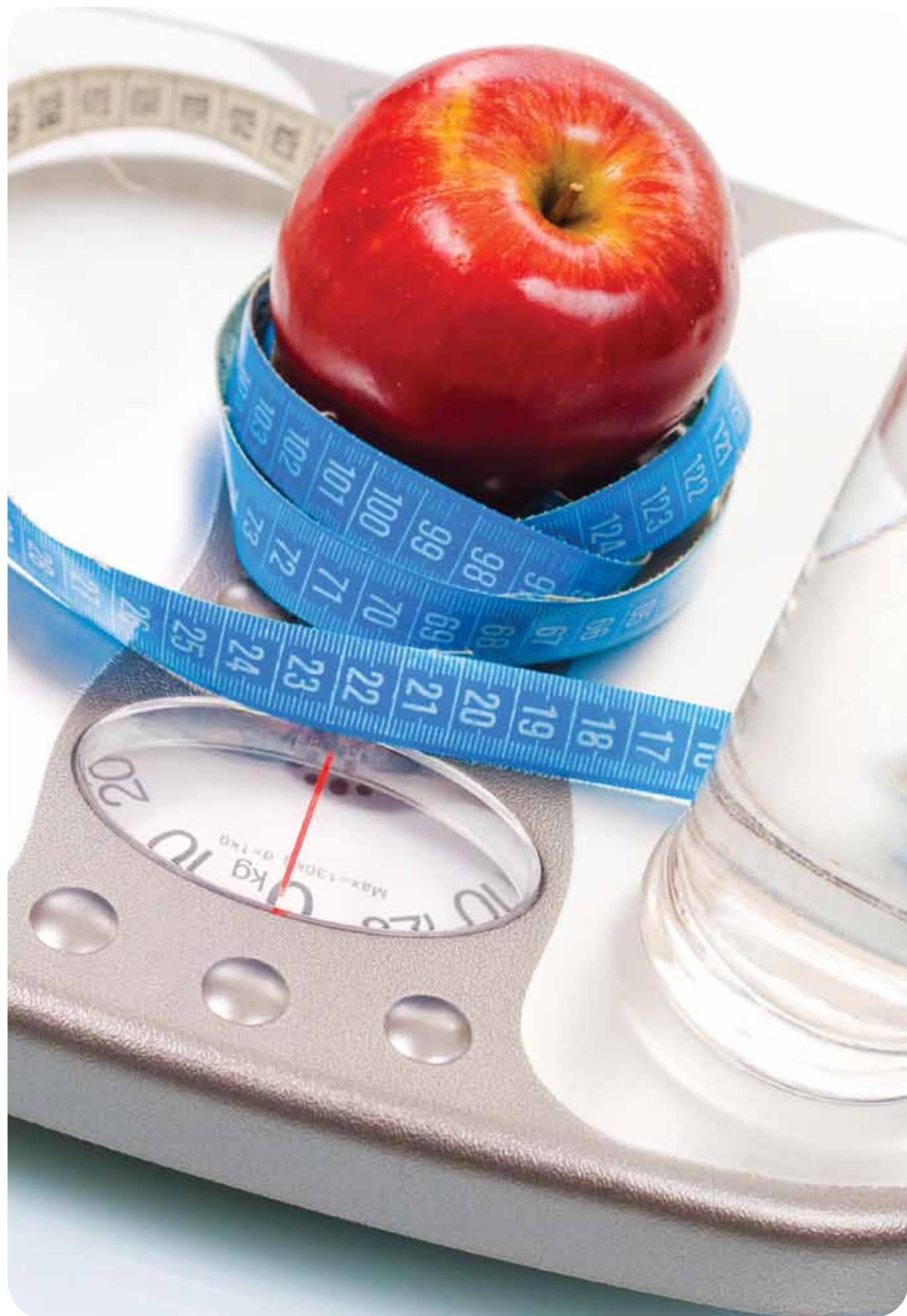
Section 1: Introduction to Personalised Nutrition

Personalised Nutrition – An Overview

Dr Eileen Gibney, Principal Investigator,
UCD Institute of Food and Health,
University College Dublin

KEY POINTS
- Personalised Nutrition has a key future role in improving the health and wellbeing of human populations.
- Personalised Nutrition can operate at different levels: none (level 0); general dietary guidelines (level 1); inclusion of individual phenotypic information (level 2); and inclusion of individual genotypic information (level 3).
- Considerable work is needed to develop Levels 2 and 3 where feedback will be given based on diet plus phenotype (Level 2) and genotype (Level 3), before such recommendations become a reality for the consumer.

The term Personalised Nutrition (PN) is not a new concept. In 2002 the Institute of Future in Palo Alto examined the potential of PN and suggested that by 2010 food choices would be based on this model. The aim is to go from population dietary advice to gene based individual dietary advice, or perhaps population sub-group dietary advice, where like-individuals are clustered and recommendations are given based on the cluster.

Personalisation of nutrition can occur at various levels and although the term is usually applied to the genetic aspects, there is plenty of scope for personalisation before this (Figure One).

At the UCD Institute of Food and Health we believe there are four levels of personalisation, which can be described as follows:

Level 0: No personalisation: based on general eating guidelines where recommendations about diet are made at a population level, with no degree of individualisation.

Level 1: Examination of and feedback of/on an individual's diet, i.e. individuals give information on their current eating habits which is analysed and feedback given on changes to be made to improve said individual's diet.

Level 2: Builds on level 1 and takes into account an individual's biochemical profile or other measurable health parameters, e.g. cholesterol or blood pressure. This gives individual feedback on diet and current physiological state, both of which impact on recommendations for dietary intake.

Level 3: Builds on levels 1 and 2, but takes into account an individual's genetic profile. Variations in genes may affect metabolism and requirements for particular nutrients in an individual's diet – the ultimate personalisation.

Figure One: **Using knowledge to optimise an individual's diet**

L0	General healthy eating guidelines
L1	Individualised dietary analysis
L2	Phenotype (biochemical profile)
L3	Genotype (genetic profile)
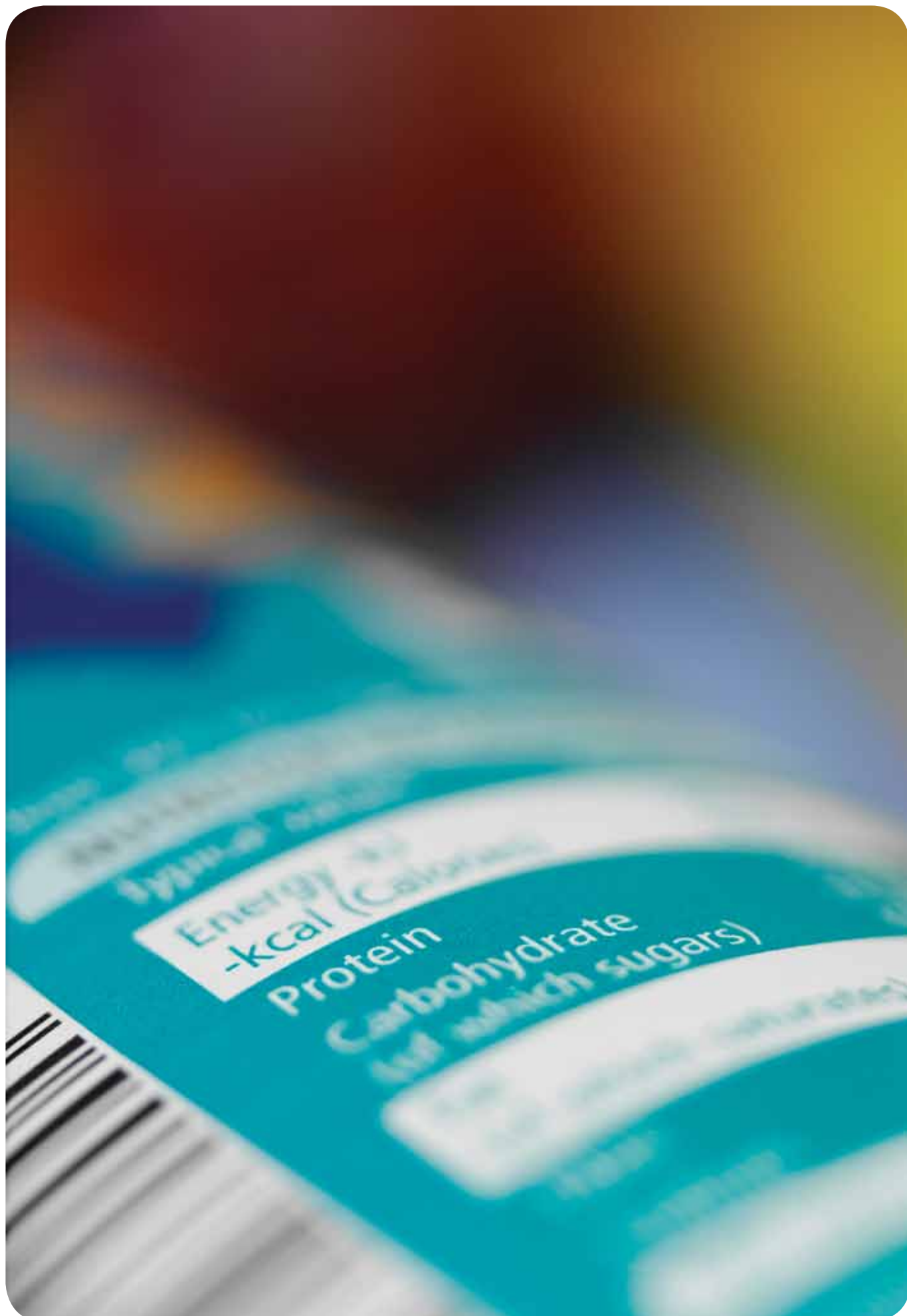
Examples of genetic variation between individuals include height, eye colour, hair colour, nutrient requirements, and a large number of other factors. Subtle variations in the genes responsible for nutrient metabolism may influence our requirement for specific nutrients and, therefore, the food choices made, i.e. will our genes decide what we put in our shopping baskets?

Many gene-nutrient interaction studies have been published. Most of these are association studies where a genetic variation is linked to a specific trait, e.g. variation in the gene associated with increased adiposity. In contrast, relatively few intervention studies have been conducted; these demonstrate that response to a specific intervention differs according to genotype – for example, is there a genetic variation that renders an individual's blood pressure responsive or not to changes in salt intake?

As examples of gene-nutrient associations the following studies were helpful:

The TAS2R38 gene codes for a bitter tasting receptor on the tongue, existing in one of three common haplotypes deemed super, medium and non-tasters. Research suggests that super-tasters are more sensitive to the taste of sugar in foods, find fats creamier, and detect bitter substances at much lower levels compared to medium or non-tasters. To build on this, a UCD study examined the effect of genetic variation of the TAS2R38 gene on habitual food intake in Irish children[1]. This study found that although there was an influence of TAS2R38 on preference of fruit and vegetables, this did not translate into differences in food intake.

Common variation in the FTO (fat mass and obesity-associated protein) gene was studied in a population of nine year old children and demonstrated that those with an AA genotype showed increased fat mass, compared to either the TT or AT groups[2]. This association is highly significant and affects deposition of fat mass, but not lean mass in the same population. This means that those with this variation are more prone to adiposity than others, but does not reveal that this group are responsive or non responsive to specific dietary recommendations.

As examples of gene nutrient interaction studies the following studies were highlighted: 100 women were placed on four different weight loss diets for 12 months. Weight loss was analysed according to genotypes that were deemed responsive to specific diets. Those placed on a diet correct for their genotype lost more than double the weight of those on a diet deemed unsuitable for their genotype[2].

There is considerable variation in systolic blood pressure in response to changes in salt intake. This is probably linked to genetic variations in the renin-angiotensin system controlling blood pressure. A study examined the variations in the angiotensin gene, and the response of specific genotypes to specific interventions i.e. salt restriction only, exercise only, or salt restriction and exercise combined[3]. The AA and AG genotypes were responsive to all treatments. However, the GG group demonstrated no change on all three interventions. Therefore, recommendations to restrict salt intake to reduce their blood pressure would have no effect.

As part of the EU 6th Framework Lipgene project, the effect of ω-3 PUFA intake on plasma lipids was examined: 480 subjects were placed on one of four diets: (a) high saturated fat; (b) high mono-unsaturated fat; (c) low-fat, high-complex carbohydrate; and (d) low-fat, high-complex carbohydrate with ω-3 PUFA. Subjects with a CC genotype showed little variability in plasma lipids with changes in plasma ω-3 PUFA (driven by the diet they were placed on). Subjects with an A allele are responsive to changes in ω-3 PUFA intake, while the CC genotype is not. This suggests that the former individuals may show greater beneficial effects of ω-3 PUFA consumption to reduce plasma lipid concentrations than the latter.

1 Feeney. E., O'Brien, S., Scannell, A, Markey, A, and Gibney, E.R. 2011. Genetic variation in taste perception: does it have a role in healthy eating? Proceedings of the Nutrition Society, 70(1):135-143.

2 Frayling, T.M. with 40 co-authors. 2007. A common variant in the FTO gene is associated with body mass index and predisposes to childhood and adult obesity. Science, 316(5826):889-94.

3 Hunt, S.C., Cook, N.R., Oberman, A., Cutler, J.A., Hennekens, C.H., Allender, P.S., Walker, W.G., Whelton, P.K. and Williams, R.R. 1998. Angiotensinogen genotype, sodium reduction, weight loss, and prevention of hypertension: trials of hypertension prevention, phase II. Hypertension, 32(3):393-401.

4 Ferguson, J.F. with 17 co-authors. 2010. NOS3 gene polymorphisms are associated with risk markers of cardiovascular disease, and interact with omega-3 polyunsaturated fatty acids. Atherosclerosis, 211(2):539-44.

Personalised Nutrition in practice

PN is evolving rapidly and has started to come on-stream commercially. However, much of what was discussed below is still 'may be/can be' rather than 'will be'.

At level 1 personalisation (Figure One) the consumer inputs their diet, which is sent for analysis. Dietary advice is then determined and returned to the individual. After confirmation and ensuring the consumer understands the recommendations, the diet can be sent to an on-line supermarket, and food personalised to the individual's dietary needs is delivered to their door. However, with increasing personalisation and the introduction of phenotypic (level 2) and genotypic (level 3) information the situation becomes much more complex. The analysis of this information is detailed and the resulting dietary advice is, at this stage, difficult to determine and disseminate to the individual. Moreover, the recommendations given and then forwarded to the supermarket, will presume that such recommendations can be met by foods on the supermarket shelves. However supermarkets will only ever accommodate a certain number of products, not individual products for individual people. This is beyond the current model of the food industry.

Researchers at the UCD Institute of Food and Health are coordinating a new 22-partner EU Framework 7 project entitled *Food4Me*. This project will cover all aspects of PN including business, consumer acceptance, technological and legal/ethical issues. It will conduct a large proof-of-principle study examining the impact of the three levels of personalisation and compare how they impact on both compliance and effectiveness of dietary recommendations. It is envisaged that this project will help to answer many of the complexities currently clouding PN and will move the concept of PN closer to widespread implementation.

Biomarker Discovery: National Nutrition Phenotype Database

Dr Lorraine Brennan, Principal Investigator, UCD Institute of Food and Health, University College Dublin

KEY POINTS

- The Irish National Nutrition Phenotype Database, also known as the Joint Irish Nutrigenomics Organisation (JINGO)[5] database, was established to provide a comprehensive reservoir of information (physical, biochemical, genetic) gathered from approximately 7,700 people as an aid to the future development of personalised nutrition and other nutritional research initiatives.
- The database is particularly useful for the identification and validation of biomarkers and examination of the interaction between genes, diet and physical activity.
- Work on personalised nutrition within the JINGO cohort will be at the level of clusters rather than at the individual level.
- The Irish database complements the European Nutritional Phenotype Database which was launched in 2010.

A phenotype is an organism's observable characteristics or traits such as biochemical or physiological properties. Phenotypes result from the expression of an organism's genes as well as the influence of environmental factors and the interactions between the two. Traditional databases in human nutrition typically contain data on diet, physical activity, biochemistry and also measurements such as weight, height and skin-fold thickness. The National Nutrition Phenotype Database (NNPD) is much more comprehensive and explores interactions between diet, gene and phenotype with special emphasis on gene/environment interactions.

The NNPD embraces data gathered from a large number of people on: (a) intake of different food categories; (b) genetic profile; (c) detailed body composition; (d) metabolic challenges; (e) fitness testing and substrate utilisation; and (f) transcriptomic (all RNA molecules), proteomic (protein structure/functions) and metabolomic (metabolites) data. It is used in the development of personalised nutrition, in biomarker development and validation.

Biomarker discovery and validation

Two important uses of the NNPD are in biomarker discovery and validation. The latter involves both intervention and cohort studies. Of particular interest are biomarkers of dietary intake.

As an example of discovery of dietary biomarkers the following study was described: 160 subjects (85 males, 75 females) were recruited as part of a larger intervention study. Dietary data were collected from these subjects and dietary pattern analyses were conducted. Cluster analysis revealed three dietary patterns. Cluster 1 consisted of individuals with a high intake of vegetables, wholemeal bread and whole milk; cluster 2 had high intakes of yoghurt, fruit and eggs; while cluster 3 was typical of an unhealthy Irish diet with high intakes of alcohol, white bread, fat spreads, red meats and meat products. The next stage was to explore if the dietary clusters were reflected in the metabolomic data, especially compounds in the urine. The outcome was positive and phenylacetylglutamine was found to be a biomarker of vegetable consumption (Figure Two) and O-acetylcarnitine a biomarker of red meat consumption (Figure Three)[6]. Analysis indicated that O-acetylcarnitine had high sensitivity and specificity for red meat.

The next step will be to validate the biomarkers using the NNPD and an additional co-host such as NANS (National Adult Nutrition Survey). Vegetable and red meat consumption data will be compared with levels of the two biomarkers in urine. If there is a high positive correlation, then the biomarker will be validated. Research on further development of biomarkers of dietary intake will continue as part of the NNPD and the nutritype concept will also be developed i.e. profiles or combinations of biochemical markers can reflect dietary intake and people can be grouped into different nutritypes types based on their biofluid profile.

5   Joint Irish Nutrigenomics Organisation (JINGO) http://www.ucd.ie/jingo/

Use of phenotyping in personalised nutrition

So how does such detailed biochemical analysis contribute to the development of personalised nutrition? The following is a description of an analysis of a vitamin D intervention study.

Participants in the dietary intervention study, which involved a 4-week trial with vitamin D3 supplementation versus a placebo, were examined for metabolomic changes. Biofluid and faecal samples were collected at the start and finish of the study. Fourteen biochemical parameters were measured and were subjected to cluster analysis. This yielded five clusters (phenotypes) each unique to a particular biochemical compound or compounds. This led to the question 'were any of these phenotypes responsive to the dietary intervention'?

Analysis of the unclustered data showed no difference in biochemical parameters between those taking vitamin D3 and those on the placebo. However, inspection of the clustered data revealed that subjects in cluster 5 were responsive to the dietary intervention. Those on vitamin D3 had lower insulin levels, lower HOMA (homeostatic model assessment) scores (a measure of insulin sensitivity or resistance) and lower CRP (C-reactive protein) values. Inspection of other metabolomic data for the vitamin D3 cluster indicated that they had lower levels of glucose, lactate and VLDL/LDL cholesterol, and a higher glutamine level post intervention. The concept of clusters (metabotypes) will be developed further in the future and their use in personalised nutrition explored within the JINGO cohort.

A European led initiative on phenotype databases is being driven by van Ommen *et al.* as part of the challenges of molecular nutrition research[7]. A European Nutritional Phenotype Database was launched in 2010 with the aim of storing, sharing and evaluating nutritional systems-biology studies. It operates as an on-line open source database where metabolomic and nutrigenomic data can be stored, i.e. a full pipeline of nutritional studies which can be shared among research partners. Over time it will become a depository of nutrition studies which will be available to the public and will also help in future studies on gene/environmental interactions.
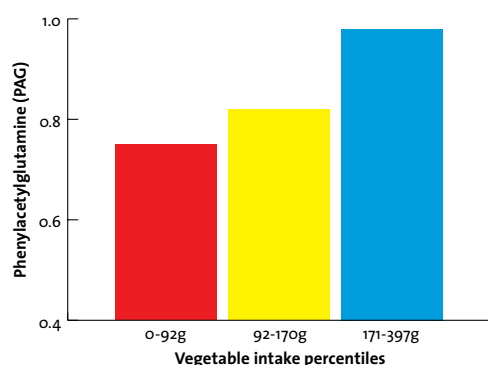
6   O'Sullivan, A. 2011. Dietary intake patterns are reflected in metabolomic profiles: potential role in dietary assessment studies. American Journal of Clinical Nutrition, 93:314-321

7   van Ommen, B. and 16 co-authors. 2010. Challenges of molecular nutrition research 6: the nutrition phenotype database to store, share and evaluate nutritional systems biology studies. Genes Nutrition, 5: 189-203.

Figure Two: **Biomaker of vegetable intake**

Figure Three: **Biomaker of red meat intake**
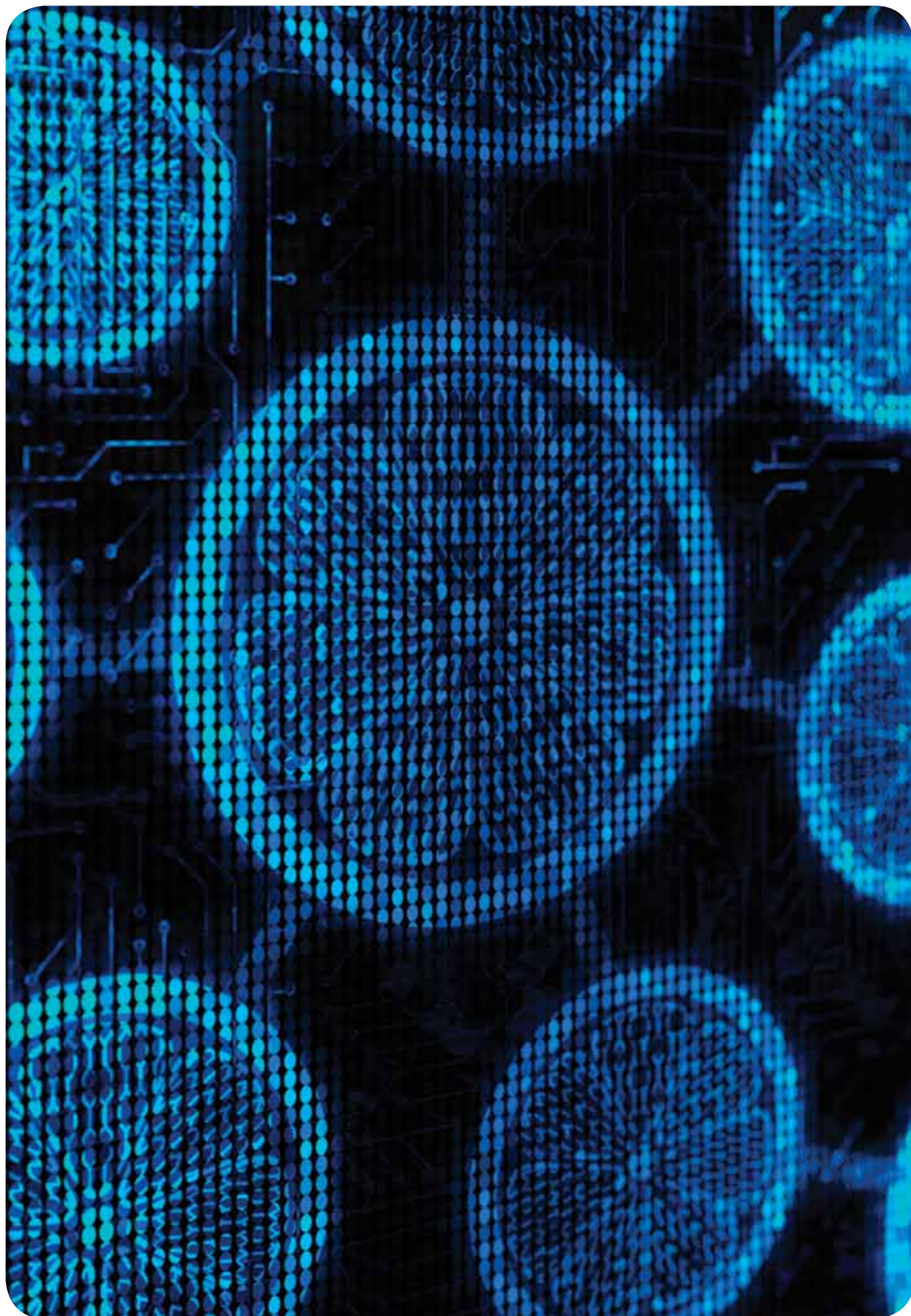
Personalised Nutrition – Risk Reduction for Cardiovascular Disease and High Systolic Blood Pressure

Professor John Scott, School of Biochemistry and Immunology, Trinity College Dublin

KEY POINTS

- About 10% of the population have an inherited variant version of the enzyme methylenetetrahydrofolate reductase, which results in elevated levels of plasma homocysteine. This is a potential risk factor for cardiovascular disease and high systolic blood pressure.
- Supplementation with riboflavin restores the function of the variant enzyme and results in a reduction of plasma homocysteine and systolic blood pressure. While the effect is known, the biochemical pathways involved have not yet been fully elucidated.
- Identification of persons with the variant enzyme via genetic testing followed by supplementation with riboflavin to restore function offers considerable potential for personalised nutrition.

The enzyme methylenetetrahydrofolate reductase (MTHFR) is responsible for the conversion of a folate co-factor into another folate co-factor. MTHFR itself has a cofactor called flavin adenine dinucleotide (FAD). It has been known for a considerable time that there is a variant version of MTHFR, i.e. flawed, which loses FAD and causes the enzyme to become very unstable and, therefore, deactivated with possible adverse effects on health.

About 10% of the population inherit two variant forms of MTHFR (genotype TT), i.e. one from each parent. Forty per-cent inherit one variant form and one good form (genotype CT) which is sufficient for the enzyme to perform its normal role, while the remainder (50%) receive two good or active forms of the enzyme (genotype CC). Those with the variant version of the enzyme express abnormal phenotypic properties and may have increased health risks as a result. Putting this in the context of personalised nutrition, alleviation of the problem would benefit about 10% of the population.

In the laboratory the normal activity of the variant MTHFR variant can be restored by adding back the cofactor FAD, i.e. the enzyme becomes stable again. However, the challenge is to restore activity *in-vivo*. The addition of FAD *in-vivo* is not feasible as it is a very large molecule and cannot be transported across cell membranes. However, riboflavin can be added as this converts to the cofactor (FAD) and restores enzyme function.

Persons with reduced MTHFR activity (i.e. those with the variant) show increased homocysteine levels in the blood (Figure Four). Raised circulation levels of this amino acid are associated with increased risk of stroke and cardiovascular events (i.e. a phenotypic expression). In reality, this is probably unlikely as circa 96% of homocysteine is bound to proteins and so is not available to 'attack' (clog) arterial cell walls. However, coincidentally another phenotypic expression associated with reduced MTHFR activity was an elevated systolic blood pressure (BP) (Figure Four)[8].

The reason for this effect is unclear but is likely to be linked to an unknown pathway between folate and BP. This may have major potential for personalised nutrition in that restoring MTHFR enzyme function could be a new route to reducing systolic BP in the 10% of the population with the variant gene.

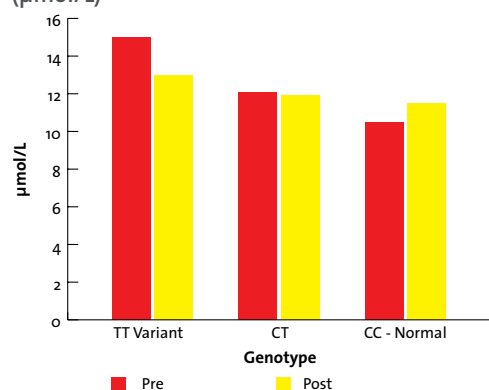FIGURE FOUR: **Plasma homocysteine (μmol/10L) [8] and systolic blood pressure levels (mm) in humans**
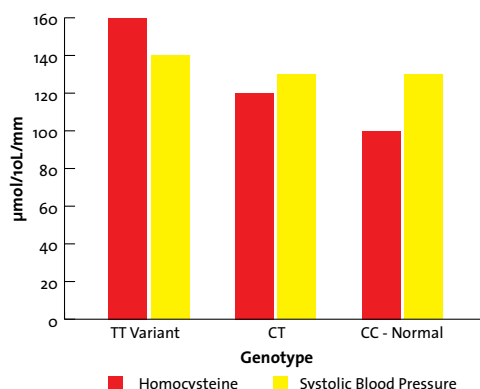
8   McNulty, H., Dovey, L.C., strain, J.J., Dunne, A., Ward, M.,Molloy, A.M., McAnena, L.B., Hughes, J.P., Hannon - Fletcher, M. and Scott, J.M. 2006. Riboflavin lowers homocysteine in individuals homozygous for MTHFR 677C - I polymorphism. Circulation 113: 74 - 80

Plasma homocysteine levels were lowered by the use of riboflavin in TT genotype persons, presumably because the MTHFR function was restored by riboflavin. If in the future it is conclusively proven that reducing plasma homocysteine improves cardiovascular health then dietary supplementation with riboflavin could be of benefit to genotype TT persons.

An initial small scale trial using riboflavin and a placebo showed that supplementation with riboflavin also significantly reduced systolic BP in genotype TT persons and gave a small non-significant reduction in CT and CC genotypes (Figure Five). In view of this, a larger trial was conducted concentrating on genotype TT persons only.

This involved extensive screening as only 10% of the population are of the TT genotype. The TT persons were randomised into two groups with the same BP and were given riboflavin or placebo for 16 weeks. Riboflavin had a marked reducing effect on systolic BP in comparison with the placebo (Figure Six). The trial was brought back on-stream in 2008 and the previous participants were contacted and took part again. Those on riboflavin in 2004 were now given the placebo and vice-versa, and again the beneficial effect of riboflavin in reducing systolic BP was found (Figure Six).

The level of reduction (10-15mm) is similar to the level achieved by taking BP medication and is much larger than that obtained by reducing weight. The biochemical reactions responsible for the effect are not yet elucidated and require further study.

Figure Five: **Effects of riboflavin (1.6mg/d for 16d) on plasma homocysteine levels in humans (μmol/L)**

Figure Six: **Effect of riboflavin (1.6mg/d for 16d) on systolic blood pressure levels in humans (mm)**
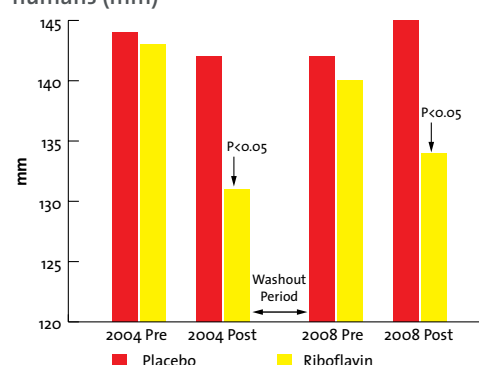
Personalised Nutrition: - Risk, Benefit, Whatever?
The Consumer Perspective

Dr Barbara Stewart-Knox, Senior Lecturer in Biomedical Sciences, University of Ulster Coleraine

KEY POINTS
- A substantial number of European consumers appear to be favourable to the idea of genetic testing for the purpose of nutritional intervention.
- Individuals who report a health condition have more favourable attitudes to nutrigenomic intervention.
- Those who have unfavourable attitudes to nutrigenomics indicate concern about how personalised foods will be developed and how personal information will be used.
- These findings are encouraging for the development of novel interventions combining nutrition and genetics, provided individual and inter-EU country differences in attitudes to nutrigenomics are considered and the handling of information is regulated.

Public acceptance of nutrigenomic technology and how perceived issues are dealt with are considered important determinants of the future success or failure of the personalised nutrition approach to health promotion. There is a dearth of research into public opinion of functional and/or nutritional genomics. Consumer uptake or rejection of personalised nutrition is driven by ethical, legal and social issues. Individual and cultural differences in preferences and requirements are also of major importance.

Two studies were described on European consumer attitudes to personalised nutrition and their perceived requirements of health promotion interventions.

The first study involved a series of focus group discussions with consumers and interviews with stakeholders in Great Britain and Portugal[9]. A questionnaire seeking information from consumers regarding demographic details; health issues, such as awareness of the metabolic syndrome (obesity) and barriers to healthy lifestyle; food technological issues; uptake of functional foods; attitudes to nutrigenomics; and anthropometric assessment including body mass index and waist circumference was also completed.

Results from this study indicated that definitions of health were varied and went beyond the biomedical definition (disease free, physical fitness etc) to include function and psychological well-being.

Comments concerning nutrigenomics included: "I'd love to know more about the subject"; "What you don't know can't harm you"; "Think of the insurance"; "I might not like what they have to say"; "You could modify your diet, if you needed to, and modify your lifestyle or take advice".

Comments from stakeholders included: "Just because we can use nutrigenomics doesn't mean we should" (Academic); "It adds a huge layer of ethics and practice" (Academic); "As the law stands currently, very few biodata are allowed to be taken into consideration and this is not anticipated to change in the short to medium term" (Insurer).

In the second study a representative survey of over 6,000 participants was conducted in France, Germany, Italy, Great Britain, Portugal and Poland[10].

The findings from this study suggest that consumers may want PN for a number of reasons including disease prevention, making healthy dietary changes, tailored health messages, peace of mind, and more healthy eating habits in pregnancy. Sixty seven percent of consumers interviewed were willing to undergo genetic testing for general interest or specifically to follow a diet tailored to needs, 24% were unwilling to be tested and 11% did not know.

9 Ghosh D. 2009. Future perspectives of nutrigenomics foods: benefits vs risks. Indian Journal of Biochemistry & Biophysics, 46:31-36.

10 Stewart-Knox, B.J., Gilpin, S., Parr, H.J., Bunting, B., Pinhao, S., de Almeida, M.D.V. 2006. Attitudes to personalised nutrition in Europe. Public Health Nutrition, 9:78

TABLE ONE: **Attitudes towards tests for nutrigenomics across six European countries**

	🇫🇷	🇬🇧	🇩🇪	🇮🇹	🇵🇱	🇵🇹
Have test done for general interests (%)	44	38	35	34	33	49
Have test done to follow a personalised diet (%)	29	59	13	38	21	26
It's good to know if you are generally at risk (%)	55	54	40	61	44	66
Changing my lifestyle is enough to get benefit (%)	7	6	16	6	5	3
Live life to the full and don't worry about tests (%)	5	4	8	6	7	3
No interest in eating food based on my genetic profile (%)	7	3	12	4	5	4

When asked 'if it is good to know if you are genetically at risk', 53% of the total sample said 'yes'. Interviewees from Poland and Germany were the least likely to want to undergo genetic testing and/or to follow a personalised diet. (Table One)[11]. Only 7% said that 'changing my lifestyle is enough to get benefit'. Only 5.4% responded 'yes' to the question 'live to the full and don't worry about tests' and 5.8% to the question 'not interested in eating food based on my genetic profile'(Table One). There was virtually no difference in response from males and females to all the questions. Those aged 65 years and older responded more positively than the other age groups to most of the questions.

Analyses were conducted within the whole sample and within each of the six countries to determine patterns in attitudes to nutrigenomics, and to identify consumer segments defined by attitudes to nutrigenomics. Within the group of approximately, 6,000 participants 3.5% were identified as 'sceptics', 46% as 'don't care', and 50.5% as 'keen'.

- More than a third of sceptics (35%) agreed it is good to know genetic risk. Of those that did not agree, fewer than 15% cited lifestyle reasons. More than a third were concerned that foods could be genetically modified (GM), while more than half were concerned as to how the gathered information would be used/controlled.
- In the 'don't care' category fewer than 5% agreed it is good to know genetic risk. Of those that did not agree, 10-15% cited lifestyle reasons. None of this group cared how the gathered information would be used/controlled.
- More than 95% of the 'keen' group agreed that it is good to know genetic risk. Of those that did not agree, 2% cited concern that foods could be GM.

11   Stewart-Knox, B.J., Bunting, B., Gilpin, S., Parr, H.J., Pinhao, S., de Almeida, M.D.V. 2009. Attitudes toward genetic testing and personalised nutrition in a representative sample of European consumers. British Journal of Nutrition, 101:982-989.

1.Electronics Sector
Measure, Monitor and Motivate Users Towards a Balanced Diet

Dr Gijs Geleijnse, Senior Scientist, Human Experiences and Interaction, Philips Research

KEY POINTS
* DirectLife is a device and service for measuring physical activity and converting it into caloric usage by the day, hour or minute. A feedback loop is a critical part of the service.
* Measuring daily food intake can be conducted using wearable electronic devices. This may be the way forward but in order to gain consumer acceptance such devices must be neat, not cumbersome and not conspicuous in order to gain consumer acceptance. A similar feedback loop may be desirable.

Using electronic devices to monitor health and well-being is an emerging major development within Philips. In recent years, Philips has reinvented itself into a company that focuses on health and well-being. This is against a background of an ageing population, increased consumer empowerment and sustainable lifestyles, climate change and sustainable

development, and the rise of emerging markets such as the Asian market. These feed into the Philips circle for healthcare, consumer lifestyle and lighting (Figure Seven).

End-user input is at every stage of the Philips innovation process. Insights on needs and aspirations are gathered by listening, watching and engaging end-users and customers. Multiple solutions are created by in-house marketing, research and development, and by design teams who collaborate with external specialists. Conclusions are validated with end-users and customers, both globally and locally. Product creation processes continue and there is 'outside-in' thinking throughout, together with 'experiential' and 'simplicity' testing.

Two important growth areas for the personalised nutrition domain can be home healthcare (healthcare sector) and lifestyle management (consumer lifestyle sector). Of which, Directlife is an example.

DirectLife is a consumer product-service combination that assists the user to increase his/

FIGURE SEVEN: **Philips healthcare consumer lifestyle and lighting circle**
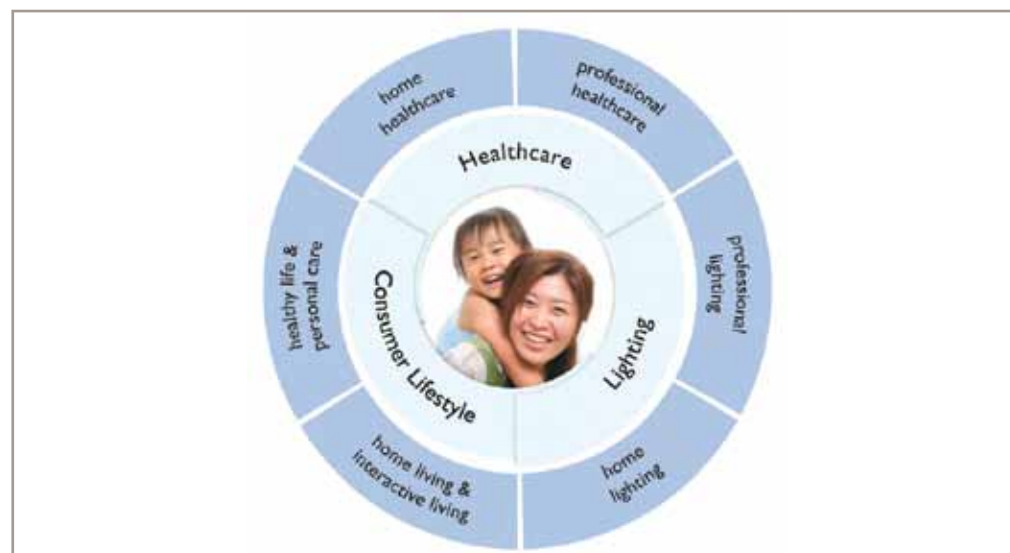
her physical activity levels under the headings 'track your activity', 'monitor your progress', and 'receive motivating feedback'. DirectLife measures physical activity and converts it into caloric usage by the day, hour or minute. It gives tailored multiple feedback and will give insights into details such as 'likes to w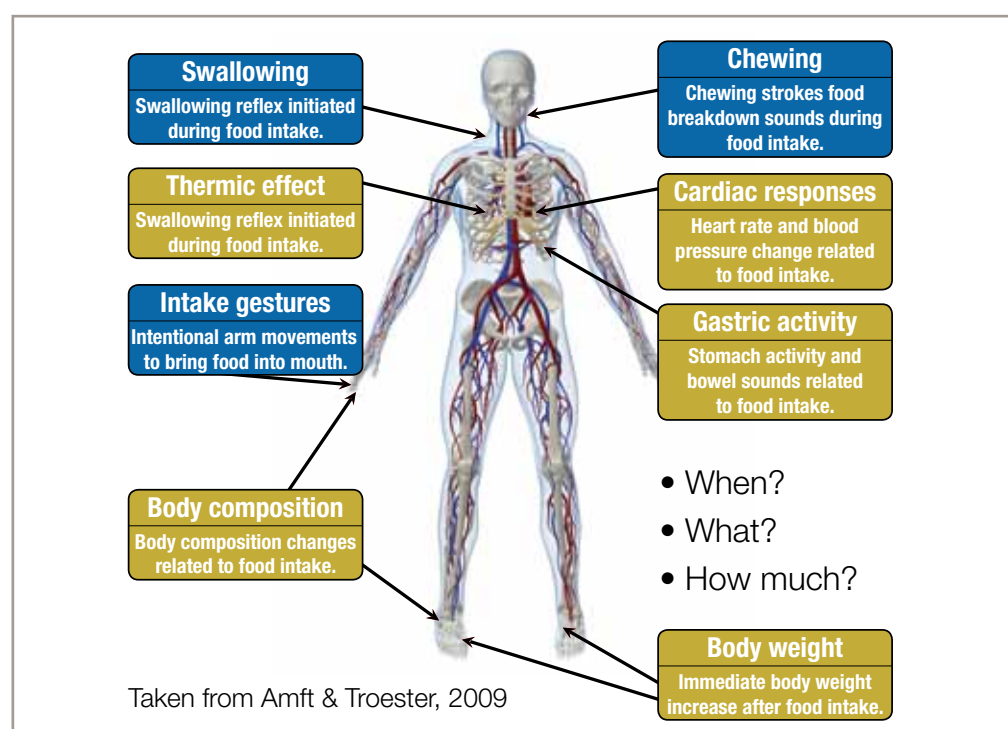ork weekdays', or 'likes to lie on the couch on Saturdays'. Having a feedback loop for physical activity and caloric expenditure is a critical part of the technology.

In the weight-management eating-habits application, emphasis is on 'measure, monitor and motivate'. The practical sequence is measure daily food intake, monitor nutrients and calories, and motivate by assisting with future meal design/planning. Measuring daily food intake has traditionally been conducted using food diaries. Consumers frequently find this boring and difficult.

However, electronic devices are available that enable this to be done, i.e. wearable sensors for measuring a number of parameters relating to food intake (Figure Eight), for example, a neck brace for measuring swallowing, which in turn relates to food intake. Combining solutions gives a complete overview. This is the key and operates on three levels, i.e. food-activity-human. 'Activity' incorporates buying and storing food, cooking, eating and drinking, digestion, and going to the toilet.

Philips is interested in solutions to create a measure-monitor-motivate feedback loop for nutrition. This is proceeding along two tracks, i.e. full day and targeted situations (evening meal). The research and development is ongoing and requires contributions from multiple disciplines; solutions must also be across many disciplines.

Figure Eight: **Using a wearable sensor**

Swallowing
Swallowing reflex initiated during food intake.

Chewing
Chewing strokes food breakdown sounds during food intake.

Thermic effect
Swallowing reflex initiated during food intake.

Cardiac responses
Heart rate and blood pressure change related to food intake.

Intake gestures
Intentional arm movements to bring food into mouth.

Gastric activity
Stomach activity and bowel sounds related to food intake.

Body composition
Body composition changes related to food intake.

• When?
• What?
• How much?

Body weight
Immediate body weight increase after food intake.

Taken from Amft & Troester, 2009

Insights into 'Personalisation Technology' and its Application in Consumer Health

Ciaran McCourt, Business Development Director, BiancaMed

KEY POINTS

- Chronic restriction of night-time sleep duration appears to cause hormonal changes that slow metabolic rate thus making habitual short sleepers more likely to gain weight, and to gain weight faster over time, than individuals with longer nightly sleep durations.
- The BiancaMed SleepMinder is placed beside the bed and points towards the patient/user, but there is no physical contact. A motion sensor outputs signal formation/digitisation and proprietary algorithms create a personalised sleep and respiration analysis for medical and consumer use.
- Future challenges will centre round 'who pays', proving efficacy, and further development of the technology. Market size in relation to payback for the inventor/innovator is also important.

Sleep duration versus obesity

Recent epidemiological evidence links "short sleep" with long-term weight gain. Chronic restriction of night-time sleep duration appears to cause hormonal changes that slow metabolic rate (i.e. reduces the rate at which calories are burned), thus making habitual short sleepers more likely to gain weight, and to gain weight faster over time, than individuals with longer nightly sleep durations[12].

Nowadays people are sleeping less and this is creating new health and performance issues. A recent study on child obesity found that, lack of sleep was a bigger risk factor for overweight and obesity than any other known contributor, including parental obesity, family income, or time spent in front of the television or computer. Short sleep duration is associated with reduced leptin, elevated ghrelin, and increased body mass index[13]. Leptin is a protein which regulates

energy intake and ghrelin a protein which stimulates hunger.

In BiancaMed's application the information translates into an objective report giving details on sleep characteristics. An example of personalised sleep characterisation output is: sleep duration (7.5h); sleep efficiency (80%); sleep latency (25 min); awake after sleep onset (50 min); and for respiration: sleep disordered breathing events (35 events/hour); low breathing events (apnea) (32 events/hour); breathing rate (15 breaths/min).

The advantages of personalised technology include: the ability to capture, track and monitor sleep patterns and to give the customer information in order to engage them in an effective manner.

1. Capture, monitor, track:
- Measurement – counters self reporting
- Access to information heretofore impossible to get
- Examples are low breathing events/sleep efficiency; latency; movement; respiration

2. Knowledge
- Awareness
- Bio-feedback
- Lowers feedback
- Examples include: feedback to user/carer; sleep report; sleep quality compared to averages

12 Patel, S.R., Ayas, N.T., Malhotra, M.R., et al. 2006. Association between reduced sleep and weight gain in women. American Journal of Epidemiology, 164(10): 947-954.

13 Taheri, S., Lin, L, Austin, D., Young, T. and Mignot, E. 2004. Short sleep duration is associated with reduced leptin, elevated ghrelin, and increased body mass index. PLoS Medicine, 1(3), e62

Non contact connection via
Bluetooth for remote monitoring
Or
Embedded processing for
realtime respiration information

- Place SleepMinder beside bed and point towards patient/user
- No physical contact
- Proprietary algorithms separate into movement, breathing
  and heart beat (not analysed).
- Create a Personalised Sleep and/or Respiration Analysis for
  medical and/or consumer usage
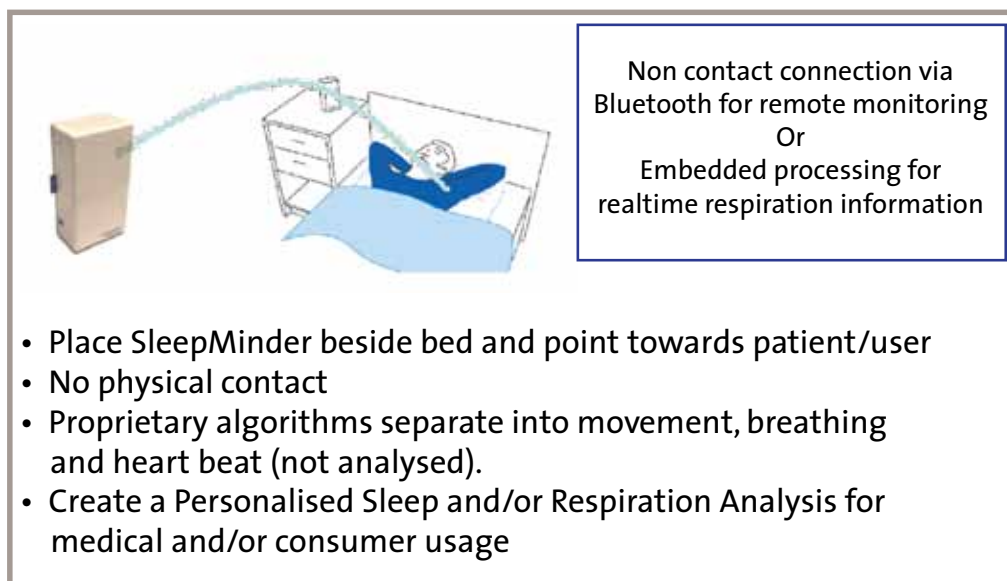
3. Efficacy
- Bio-feedback
- Devices + web

4. Engagement
- Personalisation facilitates greater
  engagement by patients
- Incentives and engagement in social media
- Examples are where conditions exist e.g.
  apnea - go to doctor; or insomnia - go on-line
  at CBT sleep hygiene

Participants who received the Internet
intervention for insomnia significantly improved
their sleep, whereas the control group did not
show a significant change[14].

Future challenges will centre round 'who pays',
proving efficacy, and further development of
the technology. Payment may be by the user or
there may be a 'free content'. In the UK the NHS
has paid for an on-line based platform to help
people with mental health issues. Relatively few
studies have been conducted on efficacy so more
are needed. Developments in the technology
will include commoditising, i.e. will we build our
own technology or incorporate it into someone
else's technology?

Future trends in the nutrition personalisation
space will be along four evolving pillars:
- Devices: these need to be scalable;
  outsourcing to individuals will become the
  norm e.g. telemedicine.
- Biofeedback: this will embrace personal
  information on genomics/genetics and on
  chronic conditions such as diabetes.
- Social media: e.g. the use of incentives to
  encourage consumers to change their habits.
- Mobility and interoperability: this includes
  the ability of diverse systems to work
  together to ensure that there is not a
  multiplicity of devices but that existing ones
  speak to each other i.e. mobile phone, blood
  pressure monitor, sleep monitor, pedometer,
  weighing scales etc. The whole system will
  be dynamic and will feedback based on the
  person's health progress.

Personalisation technology is getting more
sophisticated and it is estimated that the
market in personalised mobile health will be $7
billion by 2015[15].

14 Ritterband, L.M., Thorndike, F.P., Gonder-
    Frederick, L.A., Magee, J.C., Bailey, E.T., Saylor,
    D.K. and Morin, C.M. 2009. Efficacy of an
    Internet-based behavioural intervention
    for adults with insomnia. Archives of
    General Psychiatry, 66(7): 692-698

15 Mobile Health Market Report (2010-2015).
    2010, research2guidance

Applications Using TRIL Sensing Systems

Dr Brian Caulfield, Director, Technology Research for Independent Living (TRIL)

KEY POINTS
- TRIL aims to achieve a better understanding of the issues facing the older population, to provide new insights into the ageing process, and to ascertain what determines the capacity for independent living.
- TRIL has designed systems for gait analysis and falls risk assessment; alleviating social isolation and loneliness; integrating lifestyle management systems for individuals with particular health problems; and facilitating smart regular exercise programmes.
- Developing and evaluating new assessment or intervention protocols that make judicious use of technology will deliver more effective and efficient health and social care models.

Technology Research into independent Living (TRIL) was established in 2007 and is a multi-disciplinary research centre in collaboration with UCD, TCD, NUIG and Intel Digital Health, with funding support from the IDA.
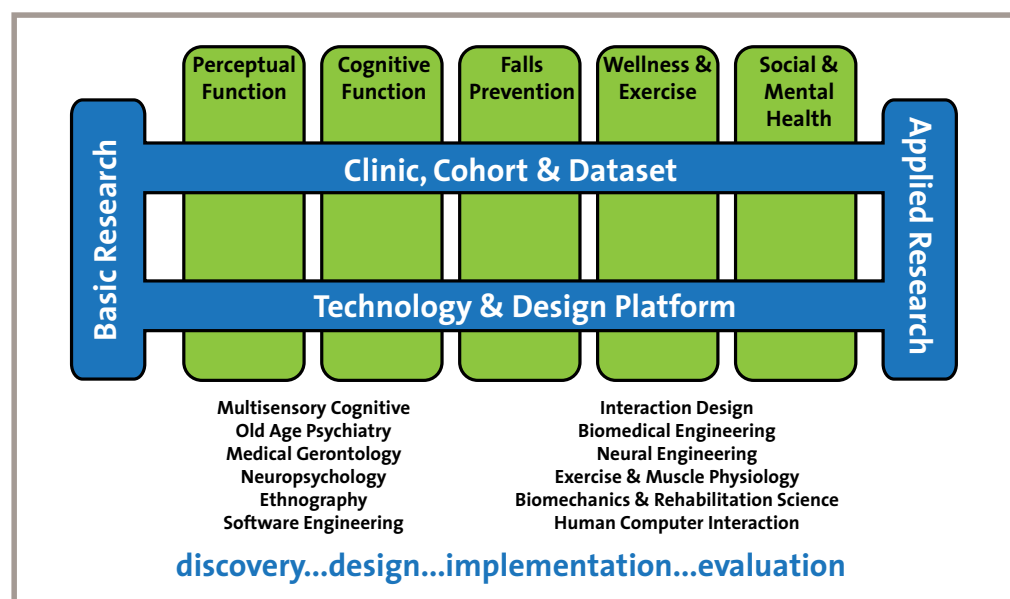
The TRIL research and development platform (Figure Ten) embraces discovery, design, implementation and evaluation stages, running from basic to applied research across five pillars each dealing with health and wellness in older people.

From the beginning TRIL's activities have been driven by three philosophical underpinnings:
- Following a model of clinically informed technology development rather than a technology push model.
- Involving all relevant stakeholders in the design process including end users and healthcare professionals who will implement technology enabled protocols.
- Always striving towards final deployment and evaluation of technology enabled assessment or intervention protocols in real homes, rather than a laboratory or smart home environment.

Figure Ten: **The TRIL R&D platform**

Basic Research

| Perceptual Function | Cognitive Function | Falls Prevention | Wellness & Exercise | Social & Mental Health |

Clinic, Cohort & Dataset

Technology & Design Platform

Applied Research

Multisensory Cognitive
Old Age Psychiatry
Medical Gerontology
Neuropsychology
Ethnography
Software Engineering

Interaction Design
Biomedical Engineering
Neural Engineering
Exercise & Muscle Physiology
Biomechanics & Rehabilitation Science
Human Computer Interaction

discovery...design...implementation...evaluation

Below are three examples of development in TRIL

1. Gait analysis and falls risk assessment in the elderly

This TRIL motion analysis platform involves the development, validation and utilisation of wireless sensing gait analysis applications using the Shimmer sensor platform. Aspects of gait were evaluated that were previously only possible using expensive laboratory equipment deployed in specialist facilities by highly qualified personnel.

Gait measurement applications can be conducted by healthcare workers not familiar with biomechanics or motion capture technology, by providing them with a simple application method with a user friendly interface.

The wireless motion sensing platform has no clinical utility unless it has high measurement validity and can provide clinicians with meaningful clinical data that can be used to trigger suitable remedial interventions. The TRIL motion analysis platform performs very well against gold standard laboratory measures of temporal and spatial gait variables, and is a significant improvement on existing Falls Risk Assessment protocols available to geriatric medicine specialists.

A targeted therapeutic biofeedback system has been developed and implemented to address falls risk, thus providing a technology-enabled solution that can be deployed outside an acute hospital setting.

2. Alleviating social isolation and loneliness

The project Building Bridges examines the potential role of technology in alleviating social isolation in the older population. Loneliness has a negative impact on mental and physical health and is associated with illnesses such as depression, hypertension, and disordered sleep patterns. Building Bridges can bring the power of social networking over the Internet to an older population who may not be comfortable in an ICT environment. This involves a user-centred design approach to develop a concept and software interface that is easily used by older adults with little or no computer knowledge.

The system is designed to provide opportunities for group interaction with other seniors. This is achieved through daily 'broadcasts' followed by a 'group chat'. Users can initiate one-to-one or group (up to six people) phone calls and send messages.

3. Personalised exercise (Stepping Stones System)

For many, regular participation in exercise activities does not fit into daily life and so novel strategies to encourage participation are required. TRIL has designed the Stepping Stones System which is a small smart exercise platform (step up – step down) located in the workplace or the home. It is a cardiovascular exercise application with motivational user feedback interface and is based on short periods of intense exercise (3 min/3 times daily) rather than on long duration treadmill type exercise.

2. Diagnostics Sector
Challenging Biology – Improving Public Health

Dr Christine M'Rini, Scientific Director, Institut Mérieux

KEY POINTS
- In the future the Mérieux group will focus more on a global, multidisciplinary and integrated approach aiming at better monitoring (of Personalisation), management and patient care. Personalised nutrition can be included in this scope.
- One challenge is to develop and validate biomarkers that are able to profile not only the disease and/or the physiological status of the patient but the individuals themselves and their relationship with their environment (including their relationship with nutrition and diet).
- Developing a successful biomarker in the market place can take time and the success rate is foreseen as low as 1 in 1,000.
- Profiling people and disease is not just about biological parameters. The future of diagnostic tools could change from hard equipment and reagents to algorithms coupling biological analyses with physical and/or imaging, and/or clinical information.

Institut Mérieux uses a global, multidisciplinary and integrated approach to solve issues focused on patient wellbeing. This is developed along four lines:
- a new approach using personalised medicine and patient care management;
- locating healthcare settings at the point of care;
- making use of the technological revolution and integrating diverse types of analyses around the same patient (e.g. omics, proteomics, transcriptomics, metabolomics.); and
- using best-fit solutions for countries with different genetic backgrounds or for developing countries,.

Personalised nutrition needs accurate biomarkers with a range of functions. Individual and sub-group biomarkers will tell which family you belong to e.g. high or low blood lipids, these will help verify the impact of nutrition. Efficacy, disease and health condition biomarkers will help achieve the goal of personalised healthcare. However, being realistic, biomarkers of "good health" and wellbeing may be out of reach, at least in the short term.

Developing Biomarkers for personalised nutrition is a challenge. To date there are few if any but research on the topic continues apace. Progress is along three lines: data integration/clinical validation of biomarkers of interest including clinical and methodical studies, compliance with good practices, and ethics, and cost/benefit analysis; evolution of concepts embracing a unique biomarker versus multiple biomarkers [multi-parametric, i.e. data integration, bioinformatics, biology of systems, intellectual property; final data processing and communication (e.g. mobile phones)]; and a rapid evolution of technologies including transcriptomics, proteomics, metabolomics and human and metagenome sequencing used traditionally for discovery that could move to the patient's bedside and to a more routine utilisation.

With diagnostics and biomarkers there are a number of options when it comes to development:
- Research use only: This embraces open and multiplexed platforms assaying biomarker profiles.
- *In-vitro* diagnostics: Specific biomarkers whose role has been scientifically demonstrated in human clinical trials and whose analytical mode has been demonstrated to be reproducible, robust and standardised.

Successful biomarker programmes draw on information/data inflows, samples, budgets

and expertise, as well as communication and information networks. In practice a biomarker may be more difficult to bring to clinical use than a new drug.

Developing a biomarker is a complex procedure with many steps (Figure Eleven).

To achieve the transfer of a biomarker from scientific idea to the patient side, many technological components need to be developed in parallel. Expert systems will be used to process and analyse the raw data and to deliver results with a high degree of confidence for clinical use. In addition, point-of-care utilisation of biomarkers may be essential for effective personalised management of the patient, as it could be for personalised nutrition.

The efficacy and validity of each of these components/steps also needs to be demonstrated in parallel and in addition the relevance of the biomarker's demonstrated.

It can take up to 30 years to develop a successful biomarker, e.g. PSA for prostate cancer; 10 years for researchers to identify a suitable candidate; 10 years for companies to develop the correct analytical tools and to validate/demonstrate the biomarker; and 10 years for the market to accept it.

The future will see a number of biomarkers for different human conditions coupled with clinical information to produce an algorithm that will help people assess their health status. Moving from biomarker research to routine application *in-vivo/in-vitro* will present a challenge as validation is more difficult in the former.

FIGURE ELEVEN: **Development of a Biomaker**
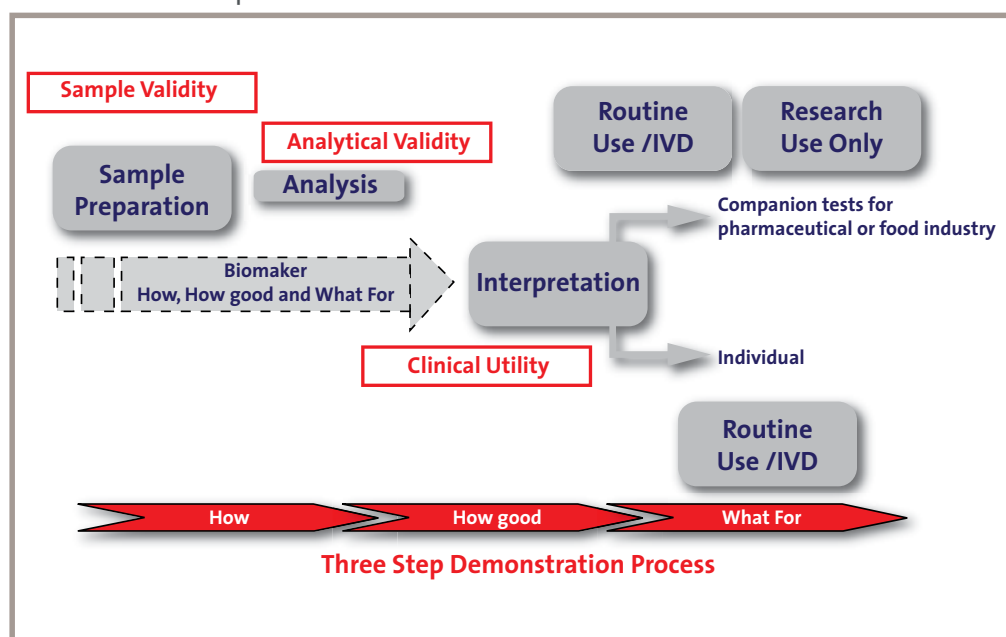
The Bioindex System

Dr Thomas E. Gundersen, Managing Director, Bioindex

KEY POINT
- Bioindex provides an on-line service aimed at addressing the incidence of chronic diseases via a healthier lifestyle for consumers.

Bioindex was established in 2006 as a joint venture between the technology transfer office of the University of Oslo and the private company AS Vitas. Its first products were launched in 2009 in the form of a service aimed at addressing the incidence of chronic diseases via the promotion of a healthier lifestyle for consumers.

Chronic diseases are caused by factors which are genetic, environmental (smoking, diet, lack of physical activity), and coincidental. If smoking, diet and lack of physical exercise risk factors could be eliminated then coronary heart disease and Type 2 diabetes would be reduced by 80% and cancer cases by 50% resulting in an increased lifespan of 15 years[16].

Bioindex operates an on-line service where customers can buy six products relating to heart health, Type 2 diabetes, cancer risk, brain health, bone health and omega - 3 fatty acid levels. These are also available in a combined product called Total Bioindex (Figure Twelve).

Data on diet, age, physical activity, blood pressure, lifestyle and smoking are collected from customers via a web based questionnaire. The customers also supply a blood sample via a supplied kit (Figure Thirteen), which is then returned to the Bioindex laboratory and analysed for biomarkers and biochemical parameters including cholesterol, glucose and biomarkers for fruit, vegetable and fish intakes. These data are inputted into an algorithm which assesses the risk of the individual developing a range of chronic diseases 10-15 years hence.

Customers can download their own results on-line and feedback advice is given on how to change eating habits and lifestyle as a route to lowering the risk of developing chronic diseases. The system is dynamic in that it constantly updates personal advice based on the latest information sent by the customer and the

Figure Twelve: **The seven Bioindex products**

16 Chronic Illness, World Health Organisation, 2008

outcomes from the most recent blood sample analyses. All databases are totally secure.

Following its initial launch during which, traffic to the Bioindex website was high and demand for the products was good, over time sales fell to a level where advertising costs were too high relative to sales. A review and evaluation of the service and its marketing indicated a number of factors which may have contributed to the fall off in sales:

- The products were too focused on serious sickness/illness.
- Customers did not want to know their current or future health status.
- Customers did not like taking their own blood samples.
- Bioindex products relate to something happening in 10 – 15 years time.
- Dietary and lifestyle advice may seem too ordinary, boring and academic.

Bioindex is currently considering a number of steps/initiatives to boost its business. Bioindex is now merged with the Vitas Company, however,

Bioindex will continue as a brand. Partnerships with Aker BM and several other functional food producers are still active. The website will be updated to reflect a new product line of single tests rather than groups of tests as was the case in Total Bioindex. Additional tests will be added to the list.

VITAS As continues as a member of the EU Food4Me project and is involved in a consortium preparing a second EU project application. This will embrace clinical studies relating to nutrition and cognitive skills, nutrition and autism.

FIGURE THIRTEEN: **Taking a blood sample**

3. Software "Personalised Wellness"

Rick Weiss, President, Viocare Inc.

KEY POINT
· Viocare has a number of products developed to allow new approaches in measuring dietary intakes and the analysis of nutritional information.

The software industry has a pivotal role in the development of personalised nutrition as it allows new approaches in measuring dietary intakes to be brought on-stream. It also supports new methods in the analysis of nutritional information. Viocare Inc is at the forefront of these developments and has a number of products including the VioScreen food frequency questionnaire, the Mobile Food Intake Visualization and Voice Recognizer (FIVR), and the VioWell programme.

Accurate nutritional assessment is key to the development of personalised nutrition. Nutritional assessment techniques include food records both, estimated and weighed; 24 hour diet recalls; questionnaires/surveys, i.e. food frequency questionnaires; and metabolic feeding studies.

Viocare has developed a number of tools.
1. VioScreen food frequency questionnaire[17]: The questionnaire features a graphical, web-based, food frequency questionnaire method for data collection. Once complete the reported foods consumed are converted to nutrient intakes using appropriate food composition databases.

The use of images and list of commonly consumed foods attempt to make this a consumer friendly tool.

FIGURE FOURTEEN: **Cereals and breads selection pictures**

17 Developed through a National Cancer Institute grant (R44 CA097560) and based on the Fred Hutchinson Cancer Research Centre's food frequency questionnaire (WHI, Select).

18 Funded through a National Heart, Lung, and Blood Institute grant (U01 HL091738)

Analysis of the responses generates reports on nutrient intake and food use patterns suitable for a variety of clinical counselling and research applications. It benchmarks dietary behaviour against recommended dietary guidelines. It analyses by food type, e.g. confectionery, for simplified planning. It suggests foods to overcome identified dietary deficiencies and creates an overall personalised dietary profile.

2. Mobile Food Intake Visualization and Voice Recognizer (FIVR[18]): The classification and segmentation of foods is performed using both colour and texture features. The FIVR system embraces a number of elements: a mobile phone that captures food intake in real-time; camera and voice recording before and after eating; and speech recognition, personalised database, and computer vision techniques to determine the food items and portions eaten. The system is fast, cheap, robust and non-repetitive.

The FIVR system captures images and speech from a mobile phone. Computer vision processing on servers inputs the images, gives food classification and segmentation, estimates volume/portion intakes, and generates food intake reports that embrace both user and dietitian databases.

Segmentation and classification of foods utilises texture, colour, shape, etc, to segment images according to local-area similarities. Many foods can assume different shapes but maintain constant colour/texture e.g. green beans, mashed potatoes, chilli. However, some foods have little texture but yet have characteristic colour and/or shapes e.g. a bowl of tomato soup. Segmentation and classification is aided by speech recognition and by characterisation of every pixel in the image. Final classification is obtained by comparing against images in a database.

Currently the FIVR system is trained to recognise over 200 different food types and the system has been tested with 322 food plates. The outcomes are then sent to a smart phone which informs the user on diet and dietary targets (Figure fifteen)

Figure Fifteen: **Example of data migration to a smart phone**
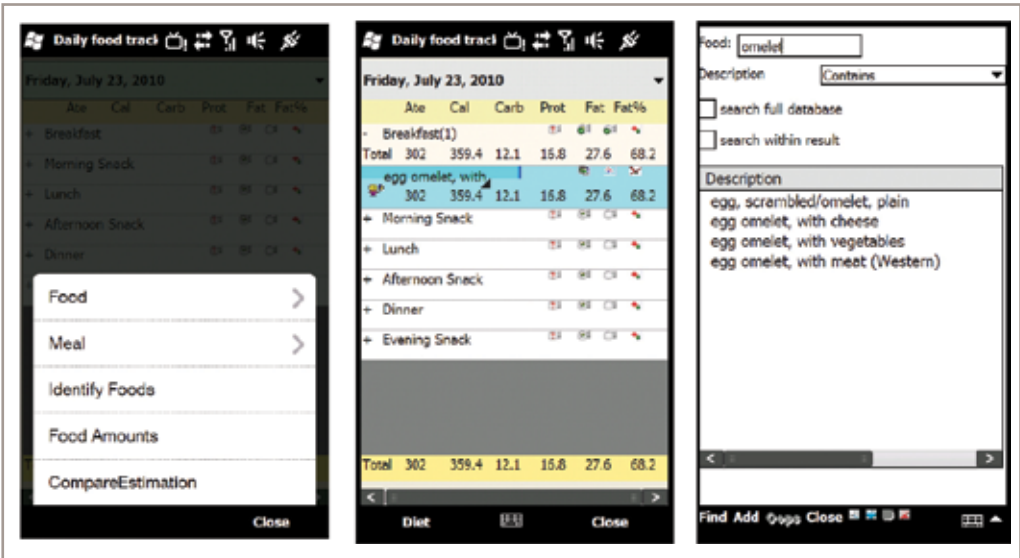
3. VioWell Programme: This is a scientifically-based and personalised wellness programme that combines web technology with one-on-one counselling to help participants develop and maintain healthier lifestyles. This is based on assessment (where am I now?), planning (what I need to do to be healthy?) and tracking (how am I doing?). The assessment yields goals that are incorporated into planning and an action plan. The tracking component will feedback leading to a modified plan and to re-assessment, (have I moved forward from the previous assessment?)

The four VioWell assessment tools consist of a series of questions. These web-based, self-administered questionnaires offer a quick and effective way to capture critical health, lifestyle, physical activity, and dietary information. The assessments take 1-1.5 hours to complete. The first health screening questionnaire asks about current health status, lifestyle factors, eating habits, weight, attitudes towards diet, and levels of physical activity. The second questionnaire identifies barriers to an individual's healthy lifestyle, while a third determines current levels of physical activity. The final questionnaire records foods eaten over the last three months.

Each customer is assigned to a wellness partner who reviews progress and modifies goals and plans according to needs and successes. The VioWell programme also embraces motivation and social connectedness e.g. rewards for healthy choices and activities; engagement with local community; peer networking, forums and blogs.

Smart Software for Food Choice

Dr Ben van Ommen, Director,
Nutrigenomics Organisation (NUGO)

KEY POINTS

- Laboratory/clinic testing and sensor/ gadget/software technology that delivers personalised nutrition information on-line, and the subsequent follow-up dietary, lifestyle and other advice, represents a huge volume of potentially remunerative business for companies.
- Smart phones will be at the centre of the personalised nutrition revolution and will give real-time outputs on wellness, required dietary modification, need for medical intervention, and future disease risk.
- Requirements for delivery of personalised nutrition include open innovation agreements, a proper regulatory climate, reliable information, and a health care system focused on optimal health.

To date most contact between dietitians and the public has been in the realm of general dietary advice and the translation of information in the food pyramid to food products so that consumers will improve their diet. However, the quantum step forward is the provision of dietary advice and services on a personal (individual) rather than on a population basis. The difference between the two approaches is that a diagnosis is required for the latter with the marketing and selling of a service.

The opportunity for the development of software to facilitate personalised nutrition is immense, as is the financial gain by the inventors and those conducting the services associated with its delivery. For example, Google has developed a health portal that enables individuals assemble their health/wellness status in real time by helping them store and manage their medical records on-line e.g. blood pressure, blood sugar, exercise, calories burned, heart rate, height, hours slept and body mass index. Individuals can add information,

import data (e.g. test results for biochemical parameters), or explore tools to get maximum output/feedback from their health information. The whole system operates via a Smart phone. CardioTRAINER is an example of software available on a smart phone that can log an individual's exercise taken over a week going to and from his place of work, the distance travelled each day, and the duration of the exercise.

Determining one's genetic makeup and identifying one's potential health outcomes in no longer just a notion of science fiction. Genetic testing on saliva is available and can be done for as little as $100 revealing the individual's risk of developing a range of diseases/conditions. The individual's risk can be then be compared with the average risk, the latter being based on a large number of individuals.

The business potential in the arena for personalised nutrition is huge. But where do you start? Opportunities for business must be looked at as 3 and 10 year scenarios:

In three years individuals will...
- have access to all of their relevant genetic variations for less than €100.
- access a series of (home-based) diagnostics connected to the internet.
- spend five minutes each week to update personal health information.

In ten years...
- individuals will have access to their genome information.
- personal diagnostics will be integrated with on-line monitoring and electronic medical records, with Internet-based primary medical advice.
- nutritional science will have tackled/confronted the complexity of gene-diet interactions.

Laboratory testing and 'sensor/gadget' technology to deliver the above personalised information on-line, and the follow-up dietary, lifestyle and other advice represents a huge volume of remunerative business for the companies involved.

Requirements for delivery for businesses who want to enter this space are fourfold:
1) Open innovation agreements, standards and formats coupled with only one 'gadget' and one portal.
2) A proper regulatory climate that empowers the individual and protects the vulnerable.
3) Reliable information embracing an unbiased scientific knowledge base; optimal integration of electronic medical records with personalised health monitoring; and algorithms translating individual phenotypes into individual dietary requirements.
4) A health care system focused on optimal health, i.e. investment in health optimisation and prevention; and an integrated approach requiring multiple stakeholders moving together.

4. Food Industry
Corporate Wellness Programmes and Personalised Nutrition

Dr Jo-Ann van Geest, Product Manager Web Based Products, DSM Personalised Nutrition

KEY POINTS

- Occupational health and health at work are important for DSM. Vitality@DSM is one way to engage employees while working on a sustainable culture of health.
- GPNS™ is a comprehensive nutrition-based health and wellness programme that engages and empowers employees to make simple dietary and lifestyle changes that can significantly improve their health. Results to date from a pilot study have been positive and the outcomes are being built upon with a view to rolling out the initiative across all employees of DSM at the different global worksites.

The mission at DSM is to create brighter lives for people today and for the generations to come. This is done by connecting DSM unique competences in life sciences and materials sciences to create solutions that nourish, protect and improve performance.

Global health management for employees with DSM includes occupational health and embraces prevention, primary care and promotion. The Vitality@DSM programme is an enterprise-wide initiative to invest in the health and well-being of DSM's employees.

The Vitality@DSM programme embraces the transition from living in a system of "Managed Care". to a sustainable "Culture of Health". DSM Vitality checkpoint is a web-based tool with four pillars: nutrition, activity, recovery, and mindset (Figure Sixteen). It operates via a three-pronged approach: individual risk profile, review with coach, and individual coaching, if required. These in turn feed into a Global Personal Nutrition System (GPNS™). GPNS™ is a comprehensive nutrition-based health and wellness programme that engages and empowers employees to make simple dietary

Figure Sixteen: **Vitality@DSM: four web based tool pillars**

| Nutrition | Activity | Recovery | Mindset |
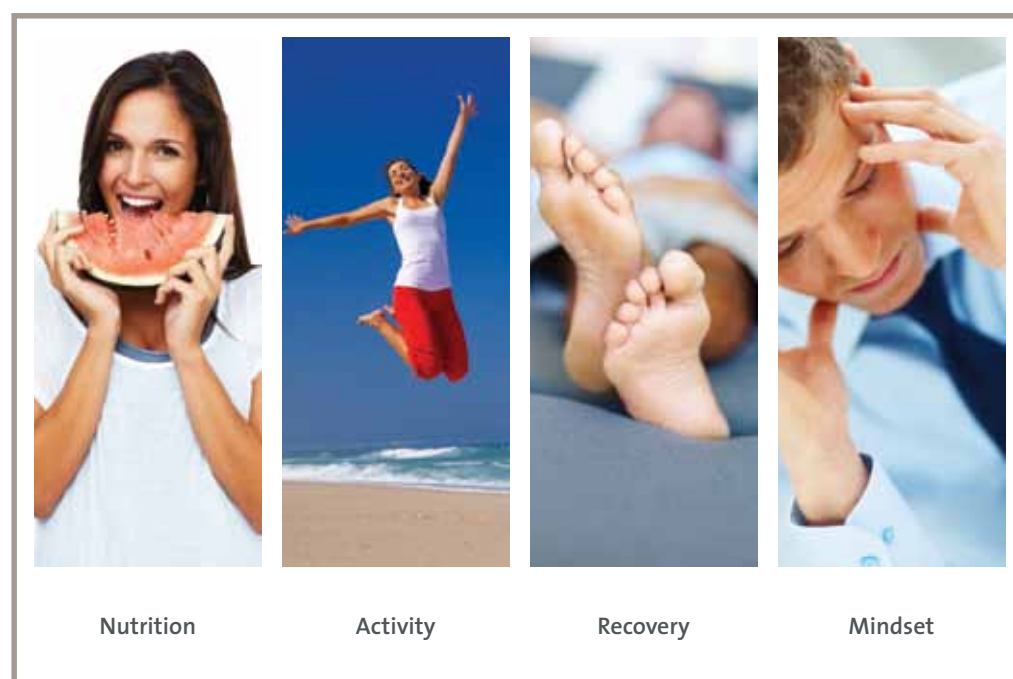
and lifestyle changes that can significantly improve their health. It has an international, multilingual set up and is workplace based.

The development strategy for GPNS™ is based on four pillars: health care is high on the priority list of company executives; US based workers spend more on health than workers in other developed countries; the cost of poor employee health is very high for a company; and return on company investment in worker health care is good.

Behaviour is the primary determinant of health followed by genetic aspects, social environment, access to and quality of care, and finally physical environment[20].

There are nine programme elements within the GPNS™ system has:

- *Biometric screening:* Personal health insights delivered by certified health professionals, including BMI, body composition, blood pressure, cholesterol, etc.
- *Health assessment:* A comprehensive questionnaire providing employees with health insights and management with health and behavioural metrics for a population.
- *Nutrition assessment:* A comprehensive questionnaire translating eating behaviour into nutritional insight completed by both the employee and his/her coach.
- *Wellness portal:* Proprietary website through which a participant can communicate with his/her coach, privately store health information, create personal goals, track progress etc.
- *E-mail coaching:* Electronic messaging between GPNS™ participant and his/her coach.
- *Telephonic coaching:* A personalised,

FIGURE SEVENTEEN: **The GPNS wellness portal**

20 McGinnis, J.M., Williams-Russo, P. and Knickman, J.R. 2002. Optimal health is the desired output of a health care system. Health Affairs, 21 (2): 78-93

protocol-driven set of telephone interactions designed to help participants identify and reach health goals.

- *Wellness messaging:* A catalogue of electronic and hard copy communication pieces that clients use to help stimulate greater participation in GPNS™ and to continue to educate employees about health.
- *Challenges:* Group and individual-based contests that help employees pursue health goals. Also an effective recruiting tool for coaching.
- *Day with the health coach:* One-on-one, in-person meeting with a GPNS™ health coach to help participants achieve their individual goals (typically 8 -10 meetings in a day).

All of these are incorporated into four interactive stages: health insights, screening and diagnostics, health goals, advice and motivation. (Figure 17)

Results from the first year of the programme showed that out of 166 employees 52% availed of coaching, 72% of the motivation programme, and 74% used the GPNS™ portal. This exceeded the corresponding targets of 46, 20 and 58% for each element. About 97% of the test population (102 persons) either improved or retained their BMI; 77% either improved or stabilised their blood pressure; and 85% either improved or had stable HDL cholesterol.

Improvements in weight management showed average reductions of >9kg in weight (~5% of total weight), 2.3% reduction of body fat, 1.8 inches reduced around the waist, and 1.4 points improvement in BMI. Blood pressure status also improved (27% improved blood pressure by 1 or more risk categories; 52% of pre-hypertensives dropped to normal; 50% of stage 1 blood pressure dropped to pre-hypertensive; 75% of stage 2 blood pressure dropped 1-2 categories).

Over 84% of respondents participated in at least one GPNS™ activity. Two-thirds to three-quarters of all participants surveyed agreed the GPNS™ programme increased their knowledge of nutrition, as well as increasing awareness surrounding their own empowerment toward achieving healthy behaviour and self improvement. About 91% of the employees felt that the GPNS™ wellness programme was a valued employee benefit, with over 33% stating it was an extremely important element of their benefits package.

The Nestlé Institute of Health Sciences Vision for Personalised Nutrition

Dr Ed Baetge, Director, Nestlé Institute of Health Sciences

KEY POINTS

- The mission of the Nestlé Institute of Health Sciences (NIHS) is to create and deliver world class excellence in biomedical research in order to better understand health and disease.
- The seven research pillars of the NIHS programme are integrated to produce a smooth transition from research to science based nutrition.
- The implementation of the Nestlé vision for personalised science-based nutrition is targeted for 2020.

By 2020 one in five persons will be over 65 years of age and 70% of developed countries will have more people aged 50 years of age or older than under 50 years. China alone will have more than 200 million people above the age of 65 years. These figures clearly point out that current healthcare systems need to be much better adapted to the needs of older populations than currently is the case.

Allied to these facts by 2020 one in five persons will be overweight or obese. This equates to 120 million people in the USA and to 20% of people less than 18 years of age in China. There will be a major need to treat increasing co-morbidities such as cardiovascular disease and diabetes. In the USA 5-10 trillion will be spent on healthcare equating to more than 16% of GDP. National per capita health expenditures in the USA will reach $14k. This means that radical ways of containing costs and/or increasing available funding will be required.

The mission of the Nestlé Institute of Health Sciences (NIHS) is to create and deliver world class excellence in biomedical research to better understand health and disease as influenced by genetics, metabolism and environment. The goal is to translate this knowledge into personalised science based nutrition, based on the following:

1) Establish regenerative, genomic and metabolomic platforms to model cellular function in health and disease.
2) Develop cellular models that simulate genetic, metabolic and physiological

FIGURE EIGHTEEN: **Core scientific platform integration**
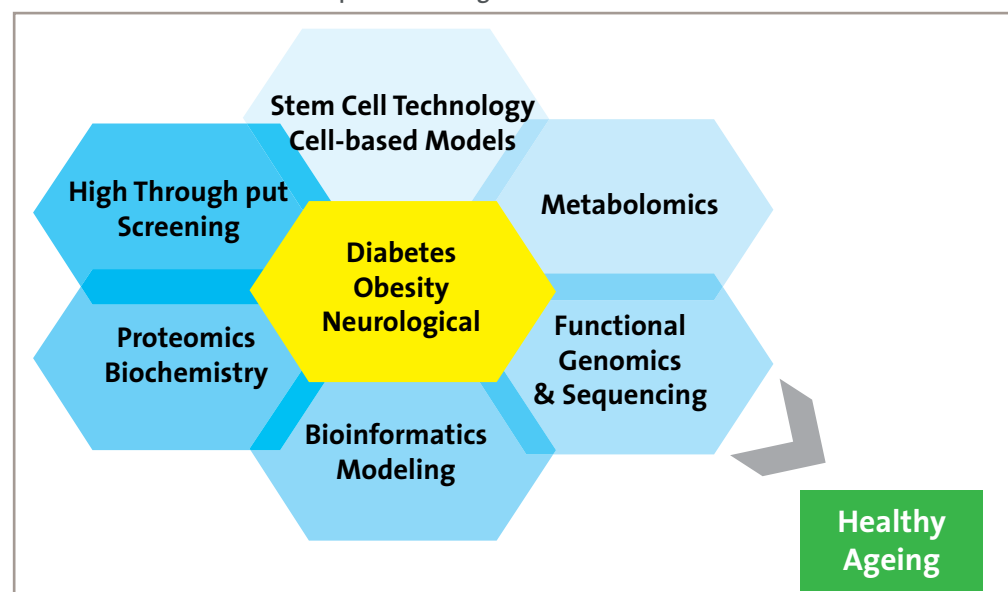
characteristics of common chronic diseases.

3) Identify and discover nutritional intervention or biomarkers that modify or predict these molecular, cellular and physiological disease mechanisms.

Chronic diseases are the core of the NIHS scientific programme and are influenced by the environment, genetics, metabolism and lifestyle. Researchers are adopting the tools of bioinformatics and pharmaceuticals to study and interpret the ever-growing body of data on the interplay between diet and genes. The research and translational model system has at its core the determination of the proteome, transcriptome, genome, epigenome and metabolome of control and diseased cells (pancreatic, hepatic or adipose cells) both normal or young and stressed or old. In other words, nutrigenomics is the driver of the core programme.

This approach adopted a large pool of data which is subjected to bioinformatic treatment. This gives information on disease phenotype, pathway(s) and biomarkers and leads to the final step of screening molecules that have to achieve GRAS (generally recognised as safe) status for use in food. Core scientific platform integration is shown in Figure Eighteen.

The pathways from research to science based nutrition are driven from the outputs generated from the core platform (Figure Nineteen). The seven pillars of the core programme feed into modelling, identification (of signatures), and compound screening elements. The two final outputs from the system are personalised science based nutrition, and nutritional strategies, products and clinical programmes.

The future programme of the Institute will take place in three phases. By 2012 core platforms and basic scientific strategies will be in place. By 2015 basic biomedical outputs will have been developed and translated for Nestlé Health Sciences Institute and the entire Nestlé group, resulting in the publication of high impact science. By 2020 the Nestlé vision for personalised science based nutrition will be in place.

Figure Nineteen: **From Research to Science Based Nutrition**
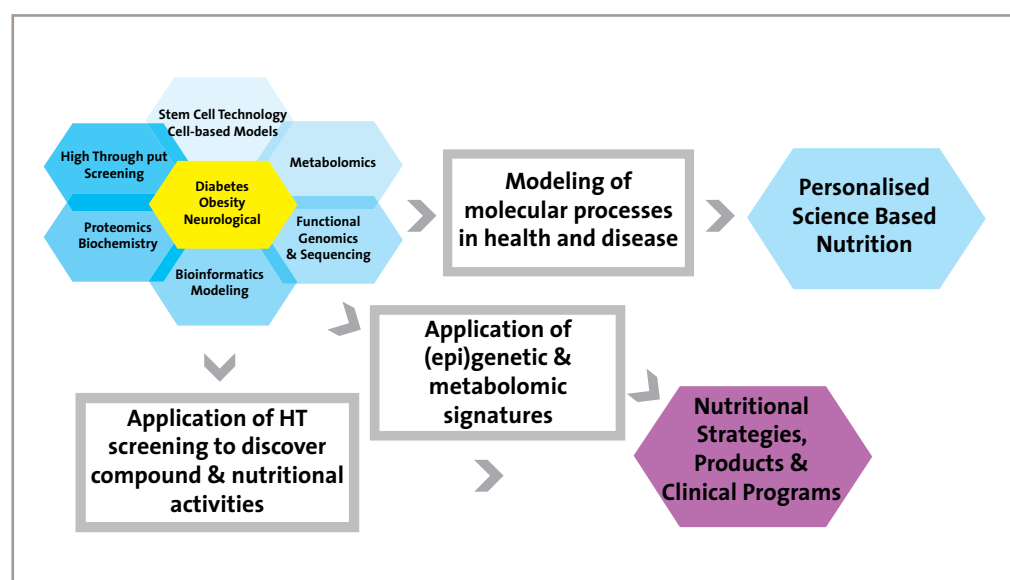
Forum Discussion

The main focus of the seminar was on identifying the business avenues and outlets in the area of personalised nutrition (PN) and on who might bring PN to the market place to realise a profit. A number of areas were discussed in relation to these issues.

The burden of healthcare is increasing in developed countries and will further increase as people live longer, and the impact of obesity and its downstream diseases becomes even greater. In time, these may force governments to include elements of PN in their national health programmes in order to improve Public Health. At the level of the individual, some consumers may opt for PN out of self interest and the potential to reduce disease risk. Others may not wish to know if they are at increased risk of contracting a particular disease, especially one for which there is no known cure.

A number of elements of PN were discussed that are currently suitable for commercial exploitation. For example, researchers in the US have been able to pinpoint the best weight reduction diet for a given individual genotype and it is likely that some companies, particularly those in the weight loss space, may want to develop this type of technology and implement it. People will be screened and put on a diet which will work for them. A second example is blood pressure where it is now known that blood pressure of certain individuals will not respond to a reduction in salt intake, while that of others will. If this information is available to the general practitioner he/she can advise the patients accordingly.

An example of 'health and wellness' software/procedures was discussed. This involves a relationship between consumers, a software company, and a supermarket. The dietary requirements of individuals for good health and wellbeing are identified, relayed to the supermarket, which in turn supplies the required foods for the diet in question. It was stressed that the cost of the software tools is very small relative to the cost of disease. The fact that Philips is selling their DirectLife PN software is indicative that a market exists for electronic devices and phenotyping.

There was consensus that niche markets are much more likely to bring PN on-stream at an early date rather than focusing on mass markets. The increase in company alliances for delivering PN was also noted;. for example, alliances of food, electronic and retail companies.

Payback for providers of PN programmes is manifold and will come from on-line systems (users log on, pay, and engage); payments for biochemical tests on biofluids; genetic profiling of individuals; purchase of software, sensors, Smart phones and other devices by PN users; and updating dietary and lifestyle advice to users by health professionals based on feedback from the most recent test results for individuals.

The forum concluded with a discussion on how likely PN will succeed in the market place, where it currently stands and where is it likely to go. The consensus in relation to the four levels of PN was:

- Level 0 is already operational. For example, the EU FP7 project is an interactive, internet-based resource designed to support the teaching of nutrition and food safety elements.
- Level 1 is currently achievable and is ready for launch. Level 1 is based on examination and feedback of/on an individual's diet, i.e. individuals give information on their current eating habits which is analysed and feedback given on changes to be made to improve the individual's diet.

- Level 2 has still some way to go before universal launch. Level 2 builds on level 1 and takes into account an individual's biochemical profile or other measurable health parameters, such as cholesterol or blood pressure. It embraces metabolomics, electronic sensing devices, and other aspects.
- Level 3 is at least 10 years from application. Level 3 builds on levels 1 and 2, but takes into account an individual's genetic profile. Establishing this for an individual still poses some difficulties and is costly. Variations in genes may affect metabolism and requirements for particular nutrients in an individual's diet.

Based on the above it was agreed that the immediate priority is to focus on full implementation of level 1 before advancing to the application of levels 2 and 3.

The Forum agreed that the government should prioritise PN in the national research agenda. The long-term benefit in the reduction of health care costs as a result could be immense.

UCD Institute of Food and Health
Policy Seminar Series

MAPPING FOOD AND HEALTH TO THE PUBLIC POLICY LANDSCAPE

Personalised Nutrition: Where's the Business?

The objective of the UCD Institute of Food and Health policy seminar series is to connect its research interests to national and international policy development. In this policy seminar there will be a unique opportunity to hear leading international and national experts share their views and research in the new and exciting area of Personalised Nutrition. The seminar will not only hear from experts from the food and health sector but also from leading organisations in the technology area. Discussions will help mould the development of activities within the healthy living space and debate how these will impact on the development of policy. The seminar will also highlight the unique multi-sectoral opportunities that exist in this arena.

Date: Monday 14th March 2011

Venue: William Jefferson Clinton Auditorium, UCD Global Irish Institute

Rick Weiss is the President and Founder of Viocare, Inc., a wellness information technology company that develops innovative and scientifically-proven dietary and physical activity assessment and behavioural change systems for researchers, clinicians, and wellness counsellors.

Mr. Weiss has been the Principal Investigator on 19 National Institutes of Health grants and contracts, valued at over $8 million. These projects have formed the basis of Viocare's product line including a wellness program for counsellors, VioWell; an electronic dietary history questionnaire, VioScreen; and a community wellness portal for diabetes/obesity prevention, Princeton Living Well (PLW). One aspect of PLW is an incentive system that rewards consumers for their wellness efforts with products and services from local businesses. Viocare is working on several mobile applications including the "Mobile Food Intake Visual and Voice Recognizer" (FIVR) for the NIH Genes, Environment and Health Initiative to develop an accurate, inexpensive, and convenient new dietary assessment tool using a mobile phone. Viocare's systems have been used by major research and clinical organizations such as the Mayo Clinic, Brigham and Women's Hospital, Eli Lilly, FDA, USDA, and NIH.

Viocare received the 2011 Tibbetts Award. This prestigious award, presented by the U.S. Small Business Administration, honours companies that have advanced technological innovation and stimulated economic growth and individuals that show excellence in owning and operating an influential business. Mr. Weiss received the Princeton Regional Chamber of Commerce Entrepreneur of the Year award for 2010 and two New Jersey Small Business Development Center Success Awards (1998, 2005). He has presented at major healthcare conferences and published in peer reviewed journals about new techniques for dietary assessments.

Mr. Weiss received a BS in Electrical Engineering and Math with honours from Carnegie Mellon University and a MS in Electrical Engineering and Computer Science from Princeton University. He started his career working at Bell Labs and held management positions at Digital Equipment Corporation, and Squibb.

Dr Thomas E. Gundersen graduated from University of Oslo, Department of Chemistry in 1995 with a master degree in analytical chemistry and later with a PhD on retinoids and embryonic development from the Medical Faculty, University of Oslo in 2007. Alongside his master studies on automated assays for nutrient determination in biological samples, Dr. Gundersen founded, in collaboration with Professor Christian A. Drevon and Professor Rune Blomhoff, the analytical contract laboratory Vitas in 1994. Dr. Gundersen has been the Managing Director of this GMP certified CRO since 2002 and has published numerous papers within the field of biomarker analysis. Vitas offers an advanced high throughput chemical analytical service towards; primary health care, biotech and pharmaceutical industry, food producers, hospitals and academia. Vitas developed at a very early stage a number of assays on samples collected as dried blood spots (DBS). In 2006 Vitas established together with the technology transfer office at the University of Oslo, the daughter company Bioindex with Dr. Gundersen as Managing Director. Bioindex offers on a commercial basis analysis of important biomarkers from the DBS platform and returns via a web based e-commerce and reporting system, blood values, disease risk scores and personal nutritional advice directly to the consumer.

Dr Barbara Stewart-Knox is a Senior Lecturer and among the founder members of the Northern Ireland Centre for Food and Health (NICHE) at the University of Ulster, Coleraine. Research interests are concerned with psycho-social factors related to diet and health, including consumer attitudes to food related issues using mixed methodologies. Barbara has been a principal investigator of several previous externally-funded projects including the FP6 LIPGENE project which explored consumer attitudes toward intervention to prevent and treat metabolic syndrome as well as associations between psychological well-being, obesity and the metabolic syndrome.

Jo-Ann van Geest has worked for the past 15 years at DSM and formerly at Gist-brocades in several positions. She has worked in areas of Research and Development, Global Technical Sales and New Business Development within several Business Units of DSM. She is currently Product Manager at DSM Personalized Nutrition and is involved in the Product Development of their Global Personal Nutrition System - a corporate employee wellness program with personal lifestyle coaching and focus on nutrition. Jo-Ann van Geest holds a Master in Food Science degree from the University of Wageningen.

Dr Lorraine Brennan graduated from Trinity College Dublin in 1995 and received a Marie Curie Fellowship to carry out her PhD studies in the University of Southampton, UK. In 1998 she commenced a Marie Curie post-doc, in ITQB, Lisbon, Portugal. In 2000 she received a Conway Fellowship and returned to Ireland to initiate work in cellular metabolism in UCD. In 2005 she was appointed a lecturer in Biochemistry. In 2007 she joined the School of Agriculture, Food Science and Veterinary Medicine as a lecturer in Nutritional Biochemistry and is currently a PI in the Institute of Food and Health in UCD. She currently leads a vibrant research group whose primary focus is the application of metabolomics in nutritional research.

Dr Ben van Ommen is Principal Scientist with TNO, one of the largest independent research organisations in the area of nutrition world-wide. He is also director of the TNO systems biology program and leading the activities on nutrigenomics, nutritional systems biology, personalized health and personalized medicine.

His research applies systems biology to metabolic health and metabolic disease, focusing on understanding all relevant processes involved in maintaining optimal health and causing specific disease sub-phenotypes, developing new biomarkers and treatment strategies.

Ciaran McCourt is currently Business Development Director for BiancaMed, an indigenous Irish technology company, which developed the world's first non contact bio-motion sensor for sleep and respiration detection.

He has a business background in consumer wellness technology specifically around nutrition and was founder of eDiets Europe, which was sold to Tesco.com and remains the largest independent online nutrition company employing about 40 people in Dublin. He was former CEO of MiLife, a Unilever spin out nutrition and fitness technology company.

Dr Brian Caulfield is the Director of the TRIL Centre, a multidisciplinary research centre based in Dublin that aims to develop new technology enabled models of care for the ageing population. He is also a PI in the CLARITY Centre for Sensor Web Technologies and the leader of the Stim-XDP research group in UCD. Dr Caulfield has a background in clinical

Physiotherapy and his research interests cover a wide area based around using technology in the assessment and enhancement of human function in health and sport. He has co-authored over 130 academic publications and 6 patent documents and has multiple collaborations with industry in the SME and MNC sectors.

Prof John Scott is a Senior Fellow at Trinity College Dublin, Associate Professor of Biochemistry and Professor of Experimental Nutrition. He was Bursar to the College from 1977 to 1980. He is a world renowned expert in Folate and Folic Acid and has been on the advisory boards for such bodies as the UK Department of Health, the EU Nutritional and Energy Intake for the EU, the UK Committee on Medical Aspects of Food and Nutrition Policy (COMA) Folic Acid Group, the National Academic of Sciences Dietary References Intakes, the UK group to review Dietary Reference Values for Folic Acid, the Irish Food Safety Authority and the FAO/WHO Consideration on Human Vitamin and Mineral Requirements. John has won international prizes such as the Lederle Award (1997) by American Society for Nutritional Science; the Gowland Hopkin Medal in Germany, 1997; David Hawkins Lecture; Canada, 1997; the International Award for Modern Nutrition, Switzerland 1999 and the Provost's Award for Outstanding Contribution to Teaching and Learning, Trinity College, Dublin 2001. He has been awarded Honorary Degrees from the University of Ulster at Coleraine in 2004 and the University of San Paulo, Madrid, 2005.

Dr Emmanuel E. Baetge is the director of the new Nestlé Institute of Health Sciences, located at the Swiss Federal Institute of Technology in Lausanne (EPFL). The Institute, which will form part of Nestlé's extensive R&D network, is to play the lead role in breaking new scientific ground in the field of personalized science based nutrition for the maintenance of health and prevention of chronic diseases.

Dr. Baetge is a pioneer in the use of regenerative medicine for the treatment of diabetes and has an international reputation as an authority in the fields of neuroscience, gene therapy and metabolic diseases. From 2001-2010, Dr. Baetge was Senior Vice President and Chief Scientific Officer at ViaCyte in San Diego, California, leading its human stem cell project. During his 9 year tenure he has built a scientific and patent portfolio from the ground up, creating the foremost diabetes stem cell therapy company. Prior to joining ViaCyte, Dr. Baetge was Chief Scientific Officer at Modex Therapeutics in Lausanne from 1997-2001. Modex developed a personalized adult stem cell therapy product for the treatment of chronic ulcers. Before Modex, Dr. Baetge held management positions at CytoTherapeutics Inc. (from 1992-1997) and Bristol-Myers Squibb (from 1987 to 1992).

He holds a Ph.D. in molecular neurobiology from Cornell University and carried out postdoctoral work at Cornell University and the Howard Hughes Medical Institute in Seattle, Washington. Dr. Baetge has published in the fields of cell and gene therapy in leading international journals worldwide. He is also inventor on a wide range of issued patents covering cell, gene and device technologies.

Dr Eileen Gibney obtained her PhD from the University of Cambridge in 2001 and joined UCD as Lecturer in Nutrition and Genetics in 2005. She is currently researching many aspects of Food and Health and is a key member of the UCD Institute of Food and Health. Her key interest lie in the area of personalised nutrition and recent work include a project

examining the `Genetics of Food Choice in Irish children and their parents. Other areas of interest include functional effects of novel foods, and nutrient - epigenetics relationships. Eileen has worked on several human intervention trials, including a hospital based clinical trial examining the effect of supplementation on biomarkers of colorectal cancer, and more recently examination of extracted polyphenols as markers of inflammation. She also has considerable experience in collecting, collating and analysing dietary intake data, examining the dietary intake of 2500 students in the Trinity Student Study, and more recently involved in both the National Adult and Nutrition Survey (NANS) and National Phenotype Database.

Dr Gijs Geleijnse received his M.Sc. degree with honours in computer science from Eindhoven University of Technology (TU/e) in 2004, specialising in formal methods. In the same year, he joined Philips Research as a Ph.D. candidate, working on natural language processing algorithm applied to web content. In 2008 he successfully defended his Ph.D. thesis at the department of industrial design at TU/e. His recent work as a senior scientist in the Human Experiences and Interaction department at Philips Research focuses on technology to support health behaviour change, including physical activity and dietary intake. His work led to various scientific publications, patent applications and patents.

Dr Christine M'Rini has almost 20 years working experience in clinical and health science research activities. She is currently the Scientific Director of the Institut Mérieux, a holding composing 5 companies (bioMérieux, Transgène, MérieuxNutriScience, ABL-Mérieux and Mérieux Development), present in approximately 40 countries and dedicated to the fight against infectious diseases and cancers, in the fields of diagnostics, immunotherapy and food safety. Christine is responsible for transversal R&D programs, at the interface of the group companies, and also contributes to their mid- and long-term strategy for Innovation. She is Vice-President of ARIIS and President of the Scientific Council of ARIIS (French national professional association for innovation and R&D activities of the health dedicated industry diagnostics industries), and a member of many international boards and scientific committees. In addition to numerous publications and presentations, Christine has also coordinated and/or been a member of European-funded grants or initiatives. Between 2006-2008, she was on secondment to the French ministry of foreign affairs as Deputy Counsellor and then Head of the Section for Science and Technology at the French Embassy in China.

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