Future Challenges and Present Ethical Considerations in the Use of Personalized Nutrition Based on Genetic Advice

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ARTICLE INFORMATION

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NUTRITIONAL RECOMMENDATIONS DIRECTED toward the general population are based mainly on estimated average nutrient requirements for a target group. These norms intend both to meet the needs of most individuals in a community and to prevent common diseases, such as obesity, diabetes, and cardiovascular problems. Personalized nutrition guidelines are currently focused on people with metabolic disorders. Infants with inborn errors of metabolism (eg, maple syrup urine disease, phenylketonuria) or adults carrying specific genetic monogenic disorders (eg, familial hypercholesterolemia, hypolactasia) benefit from genetic-based dietary advice.

Current management of nutritional and metabolic diseases is based mainly on clinical examinations and dietary advice. However, as a result of the Human Genome Project, genetic tests have emerged in the last few years. This progress in genetic technologies is contributing to the extension of this practice to other diseases with gene-related backgrounds in order to individualize the dietary prescription under genetic premises. Decreased costs and increased analytical speed have boosted the commercialization of robust genetic testing for clinician and consumer use. However, important concerns must be addressed, such as validity and correlation with specific nutritional diseases, target population, and the inter-relationships of single genetic variants with unknown, compensatory genetic mechanisms or nutrient–gene interactions.

Nutrigenetics envisages dietary personalization through a genetic “reading” of nucleotide sequence and polymorphisms (single-nucleotide polymorphisms [SNPs]) in order to offer an individualized dietary prescription. This approach is based on the detection of those genetic variants (alleles) that can influence the patient’s development of nutrition- or metabolism-related diseases. Knowledge of genetic traits can complement the data collected by the registered dietitian (RD) and other health professionals concerning anthropometrics, biochemical analyses, and dietary assessment. Also, it would contribute to more deeply customized recommendations for dietary and lifestyle modifications. Genetic variations can predict susceptibility to health problems caused by poor diet or detrimental lifestyle habits. Therefore, nutrigenetics represents a promising preventive tool in primary care by providing early information to RDs about environmental and genetic interactions influencing obesity and other nutritionally related diseases. In fact, it is an instrument for delaying or preventing disease onset through personalized dietary advice.

Diverse companies are considering the potential of this applied nutrition field and a number of genetic test panels have emerged in the last 10 years. Most of them are marketed using the internet through affordable direct to consumer testing because it is considered a good medium to reach people and showcase new technology. However, this system of publicity and sale involves ethical concerns because the web is open and the seller could offer services and information with insufficient scientific accuracy or exclusively with commercially driven interest. Direct to consumer testing could also provide biased information to clients with not enough knowledge. These new tools are worthless without adequate interpretation and subsequent translation into colloquial language by trained RDs. These professionals should have the ability to assess and recommend the best genetic test by evaluating the assayed genetic variants, price, available information, quality, and other values related to nutritional interactions.

The aim of this commentary is not only to provide an overview of the genetic test panels currently available in the US and European markets, but also to provide information about the analyzed genetic variants and the scientific evidence relying on these variants in order to help RDs and other nutrition and health professionals choose suitable products and use the information provided critically.

To develop this search, a systematic review of the websites of genetic diagnostic laboratories was performed during 2012. Apart from general Google pages, we used specialized search engines (such as the National Center for Biotechnology Information and SNPedia) and biomedical research partnerships (eg, ASEBIO, in Spain). To interpret raw data, the matches and mismatches between genes analyzed in Spain and the United States were specifically checked.
<table>
<thead>
<tr>
<th>Gene</th>
<th>Name</th>
<th>Present SNPs&lt;sup&gt;a&lt;/sup&gt; with scientific evidence (risk allele)</th>
<th>Related metabolic function or disease</th>
<th>Laboratories/company</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABCC8</td>
<td>ATP&lt;sup&gt;b&lt;/sup&gt;-binding cassette, subfamily C, member 8</td>
<td>NA&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Familial hypoglycemia&lt;sup&gt;8&lt;/sup&gt;</td>
<td>LABGENETIC; Athena Diagnostics; Correlagen</td>
</tr>
<tr>
<td>ADRB2</td>
<td>β-2 adrenergic receptor</td>
<td>rs1042713 (A); rs1042714 (G)</td>
<td>Obesity,&lt;sup&gt;9&lt;/sup&gt; type 2 diabetes, and asthma</td>
<td>ARUP Lab.; 23ANDME; INHERENT HEALTH; CGC; EUGENOMIC; EGGP</td>
</tr>
<tr>
<td>ADRB3</td>
<td>β-3 adrenergic receptor</td>
<td>rs4994 (C)</td>
<td>Susceptibility to obesity&lt;sup&gt;10&lt;/sup&gt;</td>
<td>23ANDME; INHERENT HEALTH; EUGENOMIC; GENYSALUD; EGGP</td>
</tr>
<tr>
<td>APOA5</td>
<td>Apolipoprotein A V</td>
<td>rs662799 (G); rs2266788 (C); rs651821 (C); rs3135506 (C); rs2075291 (T); rs619054 (T)</td>
<td>Lipid metabolism&lt;sup&gt;11&lt;/sup&gt; (elevated triglycerides)</td>
<td>23ANDME; CINFA; CGC; CAGT; GENYCA; SECUGEN</td>
</tr>
<tr>
<td>APOB</td>
<td>Apolipoprotein B</td>
<td>rs5742904 (A)</td>
<td>Lipid metabolism&lt;sup&gt;11&lt;/sup&gt; (elevated low-density lipoprotein cholesterol)</td>
<td>Athena Diagnostics; Johns Hopkins Medicine; 23ANDME; CINFA; EUGENOMIC; GENETAQ; GENYSALUD; LABGENETIC</td>
</tr>
<tr>
<td>FTO</td>
<td>Body fat mass and obesity</td>
<td>rs9939609 (A); rs3751812 (T)</td>
<td>High body mass index and common obesity&lt;sup&gt;12,13&lt;/sup&gt;</td>
<td>EUGENOMIC; CAGT; CINFA; 23ANDME; DECODEME</td>
</tr>
<tr>
<td>GCK</td>
<td>Glucokinase</td>
<td>rs4607517 (A)</td>
<td>Diabetes&lt;sup&gt;14&lt;/sup&gt;</td>
<td>CINFA; GENETAQ; INNOVAGENOMIC; LABGENETIC; SISTGENOMICOS; Athena Diagnostics; Correlagen; DECODEME</td>
</tr>
<tr>
<td>HNF1A/</td>
<td>HNF1 homeobox A; Transcription factor 1</td>
<td>NA</td>
<td>Diabetes&lt;sup&gt;15&lt;/sup&gt;</td>
<td>GENETAQ; INNOVAGENOMIC; LABGENETIC; SISTGENOMICOS; Athena Diagnostics; Correlagen</td>
</tr>
<tr>
<td>TCF1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HNF1B/</td>
<td>HNF1 homeobox B; Hepatonuclear 1</td>
<td>rs4430796 (A)</td>
<td>Diabetes&lt;sup&gt;15&lt;/sup&gt;</td>
<td>GENETAQ; Athena Diagnostics; Correlagen; DECODEME</td>
</tr>
<tr>
<td>TCF2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HNF4</td>
<td>Hepatocyte nuclear factor 4</td>
<td>NA</td>
<td>Diabetes&lt;sup&gt;15&lt;/sup&gt;</td>
<td>GENETAQ; INNOVAGENOMIC; LABGENETIC; SISTGENOMICOS; Athena Diagnostics; Correlagen</td>
</tr>
<tr>
<td>IPF1</td>
<td>Insulin promoter factor</td>
<td>NA</td>
<td>Diabetes&lt;sup&gt;15&lt;/sup&gt;</td>
<td>GENETAQ; Athena Diagnostics; Correlagen</td>
</tr>
<tr>
<td>IRS1</td>
<td>Insulin receptor substrate 1</td>
<td>rs1801278 (a lower risk); rs2943641 (C)</td>
<td>Insulin resistance, type 2 diabetes&lt;sup&gt;16&lt;/sup&gt;</td>
<td>DECODEME; EUGENOMIC</td>
</tr>
</tbody>
</table>

Figure 1. Genes and single-nucleotide polymorphisms analyzed by at least two laboratories from Spain and the United States and related metabolic function or disease.

(continued on next page)
<table>
<thead>
<tr>
<th>Gene</th>
<th>Name</th>
<th>Present SNPs with scientific evidence (risk allele)</th>
<th>Related metabolic function or disease</th>
<th>Laboratories/company</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDLR</td>
<td>Low-density lipoprotein receptor</td>
<td>rs688 (T); rs5925 (C)</td>
<td>Hypercholesterolemia&lt;sup&gt;17&lt;/sup&gt;</td>
<td>Athena Diagnostics; 23ANDME; EUGENOMIC; GENETAQ</td>
</tr>
<tr>
<td>LEP</td>
<td>Leptin</td>
<td>NA</td>
<td>Regulation of body weight by inhibiting food intake and stimulating energy expenditure&lt;sup&gt;18&lt;/sup&gt;</td>
<td>CAGT; GENYCA; GENYSALUD; SISTGENOMICOS; 23ANDME; BCM</td>
</tr>
<tr>
<td>LEPR</td>
<td>Leptin receptor</td>
<td>rs1137101 (G)</td>
<td>Appetite control; early-onset obesity&lt;sup&gt;19&lt;/sup&gt;</td>
<td>Athena Diagnostics; Correlagen; 23ANDME; BCM; GENYSALUD</td>
</tr>
<tr>
<td>MC4R</td>
<td>Melanocortin 4 receptor</td>
<td>rs17782313 (C); rs10871777 (G); rs2229616 (A);</td>
<td>Food intake and body-weight balance&lt;sup&gt;13,20&lt;/sup&gt;</td>
<td>CAGT; CINFA; CIRCAGEN; GENYCA; LABGENETICS; SISTGENOMICOS; Athena Diagnostics; Johns Hopkins Medicine; Correlagen; 23ANDME; DECODEME; CGC</td>
</tr>
<tr>
<td>MTHFR</td>
<td>5,10-methylenetetrahydrofolate reductase</td>
<td>rs1801133 (T)</td>
<td>Hypertension&lt;sup&gt;21&lt;/sup&gt;</td>
<td>Johns Hopkins Medicine; ARUP Lab.; BCM; CINFA; GENYSALUD; SECUGEN; EGGP</td>
</tr>
<tr>
<td>NPY</td>
<td>Neuropeptide Y</td>
<td>rs16139 (G)</td>
<td>Energy homeostasis, appetite control&lt;sup&gt;22&lt;/sup&gt;</td>
<td>EUGENOMIC; EGGP; GENYSALUD</td>
</tr>
<tr>
<td>POMC</td>
<td>Proopiomelanocortin</td>
<td>rs6713532 (C)</td>
<td>Energy balance and food intake regulation&lt;sup&gt;23&lt;/sup&gt;</td>
<td>CAGT; GENYCA; 23ANDME; BCM</td>
</tr>
<tr>
<td>PPARγ</td>
<td>Peroxisome proliferator-activated receptor-γ</td>
<td>rs1801282 (G)</td>
<td>Metabolic syndrome, type 2 diabetes&lt;sup&gt;13&lt;/sup&gt;</td>
<td>EUGENOMIC; CAGT; CINFA; GENYCA; GENYSALUD; 23ANDME; DECODEME; INHERENT HEALTH</td>
</tr>
<tr>
<td>SH2B</td>
<td>Sh2b adaptor protein</td>
<td>rs7498665 (G)</td>
<td>Obesity and type 2 diabetes&lt;sup&gt;24&lt;/sup&gt;</td>
<td>EUGENOMIC; DECODEME</td>
</tr>
<tr>
<td>UCP2</td>
<td>Uncoupling protein 2</td>
<td>rs659366 (T)</td>
<td>Energy efficiency&lt;sup&gt;25&lt;/sup&gt;</td>
<td>GENYSALUD; 23ANDME</td>
</tr>
</tbody>
</table>

<sup>a</sup>SNP=single-nucleotide polymorphism.  
<sup>b</sup>ATP=adenosine triphosphate.  
<sup>c</sup>NA=not available/not applicable.

**Figure 1.** (continued) Genes and single-nucleotide polymorphisms analyzed by at least two laboratories from Spain and the United States and related metabolic function or disease.
CURRENT SITUATION

The genes analyzed by at least two companies or laboratories in Spain and the United States with solid scientific evidence are reported (Figure 1). Some of these SNPs have been associated with a higher risk of developing a disease in genome-wide association studies (GWAS). A common variant in the FTO (body fat mass and obesity) gene (rs9939609) has been associated with metabolic syndrome and obesity traits in a number of GWAS in populations of different ethnic origins.12 Something similar occurs with several variants (rs17782313 and rs12970134) near the melanocortin 4 receptor gene.20 For cardiovascular risk, some SNPs have been repeatedly identified in GWAS studies, such as several variants in the APOE (apolipoprotein A V) gene (rs651821 and rs662799).26 However, other variants usually analyzed in commercial test panels have never been found in GWAS or meta-analysis studies. This is the case with rs5925 or rs5742904 for cardiovascular risk, rs1801278 and those of the ADRB2 (β-2 adrenergic receptor) for diabetes, and rs16139, rs659366, rs6713532, rs2229616, rs45994, and those of ADRB2 (β-2 adrenergic receptor) for obesity. At this moment, real value as biomarkers of disease risk must be questioned and additional studies must be conducted to provide more scientific basis for their predictive value.27 In addition, databases do not offer prevalence data about many of the questionable SNPs that are often included in the nutrigenetic tests.

The commercialized test panels are very heterogeneous in relation to the number of genes and the price, and many of them omit data about the technical and key aspects and the number and names of the SNPs. Undoubtedly, the name of the analyzed SNPs is the most important information when choosing a nutrigenetic service, but many laboratories try to hide this information from the public (to avoid competitors using and profiting from these innovations), which is contradictory to Clinical Laboratory Improvement Amendments (CLIA) regulations.

On the other hand, although some SNPs could influence the response to specific nutrients, most of the gene–nutrient interaction studies have been performed in very small samples of individuals, and these data must be validated in larger populations. A good example is the two genetic variations at the LPL (lipoprotein lipase) gene (rs328 and rs1059611) that have been described as interacting with the consumption of polyunsaturated fatty acid to modulate plasma lipids in 2,206 individuals of the LipGene study.28

Selection of SNPs and Genetic Scores

The selection of the SNPs included in genetic tests should have its origin in large, multi-ethnic studies based on GWAS, meta-analyses, or linkage studies, but this is not often the case. A good example of the accuracy of this type of study is the meta-analysis reported by Asselbergs and colleagues, which included 32 studies in 66,240 individuals of European ancestry and was replicated in a cohort comprising an additional 24,736 individuals.29 From the odds ratios, this type of study can provide information needed to calculate the predisposition for disease development (ie, disease risk score). Although this approach will never be as accurate as the prediction of strongly genetically determined monogenic diseases,30 the design and application of genetic scores computing the carried alleles are gaining importance.31 The knowledge of the complex interactions between genes (or genes and environmental factors) could potentially lead to more focused advice for complex disorders. In any case, the results of genetic testing for disease risk should never supersede a clinical decision based on phenotypical traits and family history, but should be complementary.32

APPLICATION OF PERSONALIZED NUTRITION AND CONSUMER ATTITUDE

Applications of Personalized Nutrition in Primary Care and Need for Health Professionals

The rash of discoveries has raised expectations and hopes due to the proliferation of genetic risk tests that, based on disease susceptibility variants, could predict early in life those individuals at risk to develop metabolically associated disorders. These outcomes could also be used for more effective preventive and therapeutic interventions, but attention should be paid to non–peer-reviewed information that is often available at Internet sites.33,34

Genetic variability is dependent on, among other factors, sex and racial/ethnic background. In fact, most of the studies have been carried out in white populations and could not be extrapolated to other ethnic groups. In this sense, some projects, such as the Genographic Project 2.0 Beta, studied ancient human migrations to create a global database with donated samples to study the similarities between different ethnic groups.35 This approach could be useful if, in the future and with millions of DNA samples, these data are used for screening disease susceptibility among individuals of different ethnic background. Health professions must consider these factors in order to adapt existing programs and services to culturally diverse individuals and communities in an individualized manner.36

The early involvement of health professionals in the development of gene-based nutrition advice is needed to allow the integration of their practical, social, and ethical considerations in the technical and scientific agendas. This tool should be in the hands of a specialist (eg, nutritionist, registered dietitian, geneticist, etc) with specific knowledge that must be able to translate the genetic results into common language. There is also the need for monitoring the treatment or implementation of dietary advice and avoiding the risk of self-administration of dietary treatments based on genetic analyses without sufficient knowledge. However, some important views toward gene-based nutrition advice exist.37 It is critical to explore and create initiatives for health professionals to exchange their perspectives, identify different sorts of barriers, and participate in the innovative process.38

Consumer Attitudes toward Genetic-Based Personalized Nutrition

Some studies have surveyed the attitudes of consumers toward participating in genetic risk profiling, whether they are interested in personalized nutrition advice, and whether they require functional food products adapted to their individual nutrigenetic profile. Consumers showed a positive attitude toward the testing of their genetic profile to be used for nutrient advice. Nearly half of the study sample agreed to such a test and would like to obtain personalized advice on nutrition.39 A new project launched and funded by the
European Union, called Food4Me, was designed to analyze the European population’s awareness of personalized nutrition based on genetic advice and the limitations to apply to it.40

Consumers can also be harmed by other aspects of genetic diagnosis. First, the genetic information provided by private companies might be inaccurate and could induce consumers to make poor decisions. Concerns about misinformation have also led a number of professional and advisory bodies, such as the National Institutes of Health and United Kingdom or Australian Boards, to issue statements warning consumers to be skeptical of genetic advice industries because many companies provide test results without any counseling. In February 2012, the National Institutes of Health initiated a database making information on kits/chips available.41 This position needs to be considered in light of the vagueness that attends many screening and diagnostic tests. Lack of, or uncertain, information can generate needless worry, which can lead to anxiety and/or depression for those who do not know, estimate, or understand the probability of developing a disease.42 This concern would generate a worse ethical problem in the case of false positives. In addition to this, some consumers have also expressed hesitation related to genetic privacy.43

On the other hand, this outcome can make the genetic diagnosis a motivational tool because regardless of whether the risk is described as genetic or nongenetic, it increases motivation to eat more healthfully.43 In another study, the criteria for assessing motivation included the anticipation that genetic test results would more concretely define the risk and help maintain the level of motivation and make changes in diet to delay disease onset. In several cases, the genetic testing “opened their eyes” to the risks they faced. Some participants thought that the genetic risk information could also be valuable to other family members as well.44

However, many individuals may become overconfident if the genetic results indicate no increased risk of disease development, which could lead to an undesirable “lack of care” about the basic health guidelines. Furthermore, the sensibility and specificity of some of these genetic tests might generate uncomfortable situations for the patient and for health professionals.

THE FUTURE OF NUTRIGENETIC SERVICES

Emerging Technologies and Scientific Evidence

Emerging technologies, such as omics platforms, are promising global approaches that will lead to refining the current nutrition recommendations and implementing the potential of individualized nutrition. Therefore, it seems likely that in the near future it will be possible to offer personalized

Figure 2. Some examples of gene–nutrient interactions included in nutrigenetic tests. SNP=single-nucleotide polymorphism. HDL=high-density lipoprotein.
recommendations to more subgroups. In order to provide scientific evidence about the relationship between genetic variants and nutritional imbalances, there is a perceived need for more studies and more variety in examined populations. With more people being analyzed, including additional ethnic groups and mixed-race people, better prevention and treatment of hidden malnutrition, obesity, and other metabolic diseases could result. This strategy would allow the adjustment of recommendations according to the inheritance background and ethnic and social characteristics of the patients.

The knowledge of genetic variants in larger populations can clarify the importance of genetics in complex diseases and the interactions that occur with environmental factors. This approach will demand additional bioinformatics applications and analytical support to correctly interpret the substantial information supplied by the omics technologies. In some cases, this can be overcome by devising genetic scores.

The nutrigenetics field should be flexible and dynamic. It must not only collect enough scientific evidence related to all the genetic factors affecting disease development, but also continuously update new findings that emerge in the field of gene–nutrient interactions, some of which are shown in Figure 2. Research must be focused on finding new, less-common SNPs, particularly for genes related to regulation of appetite, oxidative stress, inflammation, and metabolic pathways, and new environmental factors affecting those SNPs already described. For this purpose, when the cost of the technology decreases, sequencing will be a promising tool that could complement microarrays when applied to large populations.

Recent discoveries suggest an epigenetic modulation of the metabolic disorders, such as obesity and type 2 diabetes, and environmental factors and nutrient intake, especially in the perinatal period, can be involved in the developmental origin of health and disease. In this sense, methylation variable positions are common epigenetic markers whose methylation patterns, when identified by epigenome-wide association studies, can be used to characterize subgroups of individuals.

**ETHICAL AND LEGAL ISSUES**

Some of the direct-to-consumer genetic tests have minimal or no clinical value. This raises new ethical, legal, and social issues of urgent importance. The National Institutes of Health launched a centralized registry for genetic testing linked to the US National Library of Medicine in 2012, the Genetic Testing Registry, which unveils that there are genetic tests for >2,500 diseases and will help generate trust in this therapeutic strategy.

On the legislative front, CLIA has helped ensure the validity of analytical diagnostic laboratories by validating different genetic tests. CLIA is also responsible for the management of quality control, staff qualifications, and aptitude tests in specific areas.

The commercialization process of genetic tests in the United States is considerable. The tests should pass validation by an independent laboratory certified by the Centers for Medicare and Medicaid Services and CLIA. However, the basic standards established by CLIA can vary depending on the laws of each state. New York, for example, has some of the most stringent regulations. After validation, the US Food and Drug Administration must approve the test.

In Europe, each country has its own “nutrigenetic” legislation, as recently reviewed by Borry and colleagues. In the case of France, Germany, Portugal, and Switzerland, policies are more restrictive than in other countries, such as Spain, the United Kingdom, and Belgium. This field is trying to be harmonized by the European Commission through the issuance of certain documents, such as the “Additional Protocol to the Convention on Human Rights and Biomedicine, Concerning Genetic Testing for Health Purposes.” This protocol states that genetic tests with important implications for health must be performed under medical care, meet generally accepted criteria of scientific validity, and be of appropriate quality.

In this sense, the European project “EuroGentest” is trying to harmonize the genetic testing process across Europe, from sampling to advice. It also tries to ensure that all aspects of genetic testing are high quality, and that they provide accurate and reliable results for the benefit of patients. At the same time, other scientific initiatives, such as Nutrigenomics Organisation and the International Society of Nutrigenetics/Nutrigenomics, are being developed to respond to these ethical concerns.

**CONCLUSIONS**

Nutrigenetics, founded on the higher or lower predisposition of patients to develop obesity or other nutrition-related diseases, is proposed as a potential instrument that can complement dietary advice in primary care and prevention. It could be a useful tool for reducing public health costs based on the ability to provide tailor-made management of disease by dietary advice.

However, there are some limitations concerning nutrigenetic applications in nutritional prevention and treatment. There is a lack of evidence of some of the SNPs usually analyzed in these tests, and more studies with large populations are needed. Furthermore, as most of the SNPs differ in importance depending on ethnic background, more research is required in relation to the different ethnic subgroups and in mixed populations. The cost of the genetic analyses and the personalized advice must be lowered in order to extend the use of nutrigenetic methods to public health and clinical practices. Finally, accuracy provided by sensibility and specificity is something else to be discussed in the next several years.

RDs and other specialists must be familiar with the genetic information of these tests and be able to translate the genetic results into common language. The tests should be able to incorporate other factors that modulate gene expression, especially environmental (nutrition and physical activity interactions) and epigenetic factors. This scenario of developments would increase the confidence of health professionals about genetic diagnosis. The objective of nutrigenetic tests is to transmit personalized advice to consumers and achieve an increase in demand for these tests to sustain optimal health status. In this regard, the companies offering the genetic tests play an important role. In order to help select the most appropriate criteria for each individual, the information available to health professionals should be
increased, especially the SNP5s analyzed accompanied by ad hoc references. Finally, there is a need for harmonizing legislation and for early detection of direct-to-consumer genetic tests with insufficient scientific accuracy and that lack nutritional monitoring and advice.

References


Does the causal pathway from gene to obesity matter? 


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