

# Nutrigenomics: Let Your Genes Know Your Nutrients – A Review

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## Abstract

Nutrigenomics is an upcoming interdisciplinary subject that explores the relationship between nutrition, genomics, and human health. At the same time it is exciting to know that there is an increasing concept that targeted modifications in food and dietary patterns can support health and minimize the hazard of diet-related diseases. It investigates how nutrients and diet based ingredients influence the expression of genes and how the variation in individual genes influence metabolism of nutrients, dietary requirements, and susceptibility to diet-related diseases. By integrating molecular biology, genetics, bioinformatics, and nutritional sciences, nutrigenomics aims to develop personalized nutrition strategies that optimize health outcomes and prevent chronic conditions such as obesity, diabetes, cardiovascular diseases, and certain cancers. Advances in high-throughput genomic technologies and computational analysis have accelerated the identification of gene-nutrient interactions and biomarkers for dietary response. Ultimately, nutrigenomics adds to the growth of precision nutrition, enabling tailored dietary interventions based on an individual's genetic profile. This personalized approach has the potential to transform public health by shifting the focus from generalized dietary recommendations to targeted strategies that promote longevity and well-being. The current review highlights the concept, multiple definitions, role of elements involved and its application. It illustrates that, how the diet and its nutrients can influence actions of our genes and how these genes can manipulate nutrient utilization. It is an effort to enhance the understanding of diet-health relationship and to ensure that people get benefitted from this ongoing revolution-genomic revolution with respect to diet and health.

**Keywords:** Nutrigenomics, health, nutrition, personalized nutrition, precision nutrition

## Introduction

Study of nutrients and its effect on the body is not a new concept and many sciences have their evolution from this concept. Scientists and nutritionists all over the world are working day and night towards elaborating the effect of numerous macro and micro nutrients on the health of human beings. Still the human force is facing newer kinds of diseases and diagnosis every new day. Nutrigenomics is one such field of study where effect of nutrients on gene activity is studied. It is now more evident that some of the diseases are gene based and these genes get affected by the nutrients the individual consumes. For every individual, the genetic make-up is unique and each individual's body responds to the food it consumes in a very different way. Thus nutrigenomics combines the study of genetics and nutrition with the aim to reveal the response of nutrients on human genetic sequence and ultimately on its health.

Nutrition-gene interaction is a two way process where the nutrients we consume affects the phenomenon of gene expression and secondly genes hold the potential to affect the response of our body towards these nutrients. The results are also of benefit to the society in two ways, firstly by making individual healthier by providing selective gene based choicest nutrients and secondly it could reveal some of the beneficial results to cure deadly diseases and disorders like obesity, cancer, cardio vascular diseases etc,. This can be achieved through personalized nutrition based on tailored nutrient diets which compliments a person's unique genetic profile. Because of its potential toward the prevention and mitigation of chronic diseases and certain types of concerns through small but specific dietary changes, the concept has been widely accepted and it has now been taken up seriously in researches. As there is specific medicine for a specific disease, nutrigenomics promises to provide specific nutrient i.e., personalized nutrient as medicine based upon the understanding of individual's genotypes, its nutritional and health status as well as nutritional requirements. It is based on the belief that many types of cancers and other chronic diseases that are sometimes initiated and triggered by a specific biochemical combination or a nutrient compound supplied through our diets can easily be delayed or prevented by providing sensible balanced nutrient based diets. This branch of research may specifically can be successful in addressing large population based nutritional problems and even malnutrition of specific type by providing tailored diets and maintained nutrition.

As per Gale Encyclopedia of diets [1] the basic thought behind nutritional genomics can best be understood in light of the following concepts:

1. For a number of diseases, diet can be a serious risk factor especially in some sensitive individuals or in some individuals during certain circumstances
2. The chemicals in diet or the 'dietary chemicals' as we know them as nutrients can either directly or indirectly may act on human genome to alter either structure or expression of gene
3. Individual genetic make-up is capable of influencing the balance between healthy and diseased states.
4. Some diet regulated genes and their normal as well as common variants play an important role in the onset incidence, progression and/or severity of chronic diseases.
5. Personalized nutrition or the genotype in association with dietary interventions based on status of individuals can be conveniently used to prevent, mitigate or cure and chronic disease.

### **The Concept**

Nature Vs Nurture debate is not new and at the same time we understand that it is not only either nature or nurture which could individually influence the health and growth of human body. It is not only the nutrient that will influence the growth and at the same time it is not the gene or genetic mutation that will take place and cause disease. Both these factors alongwith various environmental and behavioral factors are responsible for both disease and health. So far, individually we are convinced that the food we eat or the diet we consume directly affects our state of health both physical and mental i.e., the variability between individuals with respect to the food they consume is the basis of nutrition research and practice [2]. The nutrient content of food consumed by individuals affect their weight, height, blood pressure, blood cholesterol, blood sugar, energy levels, fat content and many more aspects [3]. Also, the physiological state of individuals, life style and other activities they undertake also influence the response of the nutrients consumed. Today many individuals are undertaking personalized nutrition, knowingly or unknowingly, with respect to their genetic response to that diet. Their reason could be fitness, individual's health condition, liking or disliking for a particular food or food group, regional and social influences and others.

Nutrigenomics is evaluation of nutrients affecting gene function and expressions as well as response of an individual towards the nutrients consumed. The study begins from the minute segment of the DNA, called the 'gene', which is not only physical but functional unit that carries heredity traits from parents to their young ones. These segments are capable of tailoring specific protein. Thus any alteration in DNA segment will ultimately result in different kind of protein as well [4].

Gene expression is not an individual mechanism taking place in physiological system. It is an interactive process which involves macronutrients, micronutrients, bioactive or also taken as bioreactive compounds; interact collectively in an environment in their own ways. At the physiological level many protenecious compounds including enzymes, hormones, receptors, ion exchangers and pathways, transporters influence the basic functions of body viz., ingestion, digestion, absorption, metabolism, transport, deposition and excretion. Thus the coding and encoding of these proteins will directly affect these physiological activities and ultimately the reflection will be seen in the health status of the individual. These reflections could be responsible for better health or for diseased condition of the individuals. Also it is a kind of 'Personalized nutrition', occasionally referred to as 'precision health care', represents an emerging approach to customized nutritional therapy. This concept aims not only to prevent and manage various diseases but also to promote and sustain overall health and well-being [5].

### **History**

The roots of nutrigenomics can be credited to the discovery of DNA back in the history of Scienc & Technology. A Switzerland based physician Friedrich Miescher was the first to isolate DNA while investigating proteins leukocytes (1869). While investigating various biochemical compounds, he identified a substance, non-protenecious in nature, having strong identical biochemical properties. Working with various biochemical compounds, later in 1944, a group of scientists including Avery, Mcleo and McCarty were successful in proving DNA, an elementary biochemical compound as hereditary material. The invention was pivotal and gave various scientists a new direction of work and during this course of time, scientists' duo, Watson and Crick (1953) discovered a compound with double helix structure and it was the discovery of double helix structure of DNA. This discovery accelerated the research in the field of molecular biology especially in 1980's, advances in molecular biology had led to the commercialization of DNA technologies. In the year 1990, revolutionary launch of Human Genome Project accelerated the gene based studies including gene mapping and its further sequencing. The field of nutrigenomics formally began to take shape in 1997 with the establishment of the first company dedicated to its application. In 1999, Nancy-Fogg-Johnson and Alex Merolli coined the term, nutrigenomics', redefining nutritional genomics as a powerful approach for identifying genetic factors involved in disease susceptibility. The launch of the human genome, further accelerated progress in the field and laid the foundation for the broader 'omics' revolution [6]. The human genome project is a breakthrough in

the conception of nutrigenomics, which aimed at keeping the human population healthy in different dietary conditions [7].

**Table: Major milestones in the development of nutrigenomics [6]**

S.No.	Milestone	Scientist/ worker	Year
1	Discovery of DNA	Friedrich Meisher	1869
2	DNA as hereditary material	Avery, Mc Leo and Mc Carty	1944
3	Double helix DNA	Watson & Crick	1953
4	Human Gnome Project	NIH with Other laboratories & institutions	1990
5	Commercialization of DNA technologies	FDA & others	1997
6	Coined the term 'nutrigenomics'	Nancy-Fogg-Johnson & Alex Merolli	1999
7	Completion of human genome project	National Human Genome Research Institute	2003

### Definition(s)

Continuous development in science and technology has modified many aspects of human studies of which nutrition or health issues are always the priority. Initially, nutrigenomics started with the concept 'to study the effect of nutrients on the expression of an individual's genetic makeup'. The study area has now broadened and the definition now encompasses the 'nutrition based factors that are responsible for protection of genome from damage'. The impact of dietary components on the genome, proteins (proteomes) and metabolites (metabolomes) is now defined as nutrigenomics [8]. This interrelationship of 'nutrient & gene' and 'gene & nutrient' is called nutrigenomics or the nutritional genomics. The effect of nutrients on the gene function and the effect of genetic make on the nutritional status is the study named 'nutrigenomics'.

The global scientific organization, IUFOST (2012)[9] describes nutrigenomics as the scientific approach that includes both nutritional sciences and genomics with the technological inputs from other related fields viz., transcriptomics, proteomics and metabolomics.

Nutrigenomics is a new science that teaches us the messages the food carries for our body. 'What specific foods tell your genes' [10]. What we eat carries genetic messages for the body, which ultimately controls the molecules responsible for metabolic activities.

### Principle(s)

A field of science that studies the application and effect of various 'omics' (including transcriptomics, proteomics and metabolomics) based studies to investigate the integrated effect of nutritional sciences and genomics on health is referred to as 'Nutrigenomics' [11]. Various reports suggest the interaction of gene and diet on the variability of individuals and have proved these genetic alterations [12]. Dietary interventions influence variability amongst individuals is the basic principle of food and nutrition science. As, high blood pressure, diabetes, high cholesterol and maintaining an ideal body weight, all are influenced by dietary intake of individuals and can be influenced either way.

Nutrigenomics is a scientific and evidence based discipline that explores the interaction between an individual's genetic make-up and their nutritional environment. It integrates insights from genomics to understand how specific nutrients and dietary patterns influence, gene expression, metabolic pathways and overall health outcome. In addition to genomics, nutrigenomics draws upon data from various applicable 'omics' fields (viz, proteomics, metabolomics and transcriptomics) to provide a more comprehensive understanding of how food components affect biological systems at a molecular level. This approach aims to develop personalized nutritional strategies that can optimize health, prevent disease and improve therapeutic outcomes. The genetic makeup of almost all the human beings is the same and the sequencing of gene matches to an extent of 99.9 per cent. However, the requirement of food for each individual is influenced by polymorphisms, common at cellular levels. This variation in phenotype is guided by the sequential variation which is as minute as 0.1 per cent in the above sequence [13]. This minute variation is responsible for characteristic responses of individuals towards the food they consume. In a normal DNA with nucleotides sequence of Adenine (A), Thymine (T), Cytosine (C), Guanine (G) gets varied with the replacement of a single nucleotide in a species or in a paired chromosome is called Single Nucleotide Polymorphism (SNP). It is the most common type of polymorphism identified [14]. In an individual approximately 3million SNP's are identified. Even a change in the single base,

as in SNP, is responsible for 90 per cent of variations. These varied SNP's may result in various types of unique individual responses amongst the individuals consuming the same food or following the same diet [15, 16]. Besides this SNP's, other variations in chromosome including inversion, deletion, insertion, duplicity or copying; causing major structural differences, rarely affect the metabolic pathways [17, 16, 18].

### Essential Elements

The whole concept of nutrigenomics depends on the basics of DNA and its fraction. The first and foremost element of the study is 'Gene' which is responsible for transferring the hereditary characteristics from one generation to another. It is the chief physical and functional segment of DNA. DNA has segments with specific information to produce specific protein type. Any variation in DNA is responsible for variation in structure as well as function of the concerned protein. SNP (Single Nucleotide Polymorphisms) are one of these variations, where a single nucleotide varies. Any variation in the location of gene in a chromosome is called as 'Alleles'. The combinations of these alleles from the maternal and paternal counterpart are responsible for the identity (genotype) of an individual. These genotypes, however do not display their characteristics apparently and thus completely differ from the 'phenotypes'. Phenotypes on the other hand display their traits in the form of occurrence of some diseases (gene based), colour of hair and eyes, concentration of sugar in blood and similar. Genotypes of same set may vary in their phenotypes, i.e., genotype of some individuals could be same but their phenotype may differ from one another as they dwell in diverse environments. Polymorphisms or a cluster of gene based polymorphisms are generally inherited collectively and they form the 'haplotype' which is a bunch of alleles passed together from one generation to another. In addition, character and gene expression may or may not require biochemicals like, resveretrol and genestein. These are mainly important ligands that directly affect gene expression and carryout transcription process. Another important biochemical compound namely 'choline' is responsible for altering the signal transduction pathways and thus may influence the expression of genes indirectly.

### Applications

Nutrigenomics is a study that involves diet, disease and gene. There are two important factors needs to be considered in nutrigenomics; firstly to consider diet as an important reason or risk factor that may be responsible for some disease in some individuals. Secondly, any nutrient ordinarily present in the diet is capable of changing the gene expression directly or indirectly by acting on a genome [18, 19, 20]. The main aim of nutrigenomics is to improve the lifestyle of human beings with healthy dietary intervention strategies at individual levels, so that some disease can be cured thereby enhancing the quality of life. Nutrigenomics focuses on tailored diets to fight diseases and improve health, lifestyle and limit the occurrence of diseases by prescribing a healthy lifestyle. The main aim of nutrition and genetic sciences collectively is to restrict occurrence of diseases through effective diet based interventions, thereby elevating the living standards. These technologies collectively can be helpful by limiting disease and improving human health by precision diets, lifestyle improvement recommendations that can promote controlling diseases [21, 22].

### Conclusion

Nutrigenomics is the field of science that studies the interrelationship of diet, its nutrients and their effect on genes and their activity. The discipline helps to identify the occurrence of any disease that too prior to the visibility of its symptoms. SNP (Single Nucleotide Polymorphism) is one of such discoveries which help to identify the cause of disease before the symptoms reveal it. This further facilitates nutritionists and dieticians to live a healthy life with précised/ personalized diet. Nutrigenomics is a novel discipline which brings food scientists, technologists, dieticians and related health professionals, policymakers and others together under one roof with the aim of making everyone's life healthy with personalized diets and lifestyle advice.

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