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CURRENT TOPIC

Nutrigenomics: A Budding Cross-Over

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Abstract

Nutrigenomics is a rapidly developing subject that combines genomics and nutrition to reveal the complex interactions between our genetic composition and the foods we consume. This review paper provides a thorough overview of nutrigenomics, exploring its underlying theories, methods and significant implications for customised nutrition and healthcare. The goal of nutrigenomics is to understand the molecular processes underlying the diverse ways in which people respond to different diets by examining the dynamic interplay between an individual's genetic profile and the nutrients they ingest. To provide a sophisticated knowledge of the genetic elements that contribute to the variation in human reactions to dietary components, this inquiry starts with an explanation of the fundamental concepts of genetics and genomics. The review paper continues to describe the approaches used in nutrigenomic research, with a focus on using state-of-the-art technology like bioinformatics and high-throughput sequencing. These instruments enable scientists to unravel the intricate connections between genetic variants and dietary components, leading to a more sophisticated understanding of how our genes regulate our reactions to particular foods. Nutrigenomics key component is its ability to open the door to customised nutrition. Practitioners are able to customise dietary advice for each patient based on their distinct genetic predispositions by analysing their genetic code. The one-size-fits-all strategy is superseded by this method, recognising the innate genetic variability affecting how our bodies metabolise and react to various nutrients. This review article covers current research findings, shedding light on the potential of nutrigenomics to revolutionise disease management through precision nutrition.

Key words: Biomarkers; Nutrigenomics; Nutritional sciences.

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Introduction

Nutrigenomics, a recent scientific field, reveals the genetic messages that particular diets convey. Human body is affected by eating behaviour according to genetic signals. In turn, these communications command all of the elements that make up your metabolism, the ones that instruct your body mechanism whether to accumulate or burn calories. Human body may suggestively change how food interrelates with your system, lose weight, as well as improve your health if you can understand the sign of your genes and take control of the signals and instructions they provide to your body and metabolism.[1]

Considering that nutrition is buildup of molecules which meet our system needs for both macro- as well as the micronutrients, it is a necessary aspect of life.[2] Furthermore, because some of these

chemicals directly interact through our body genome sequence and epigenome by controlling the activity of transcription factors and chromatin modifiers, they have an impact on our health. Nutrigenomics revolves around the intricate connection between our (epi)genome and nutrition.[3, 4] Regular diet-(epi)genome communication affects immune system and brain function in addition to organs related to metabolic such as adipose tissue, skeletal muscle, liver and pancreas.

The genesis of nutrigenomics

The idea that nutrition affects health is not new. In today world the nutritional manipulation has long been used to address "inborn errors of metabolism," or recognised interactions among food and inherited genes. Such interactions that are included in the field of nutrigenomics. Phenylketonuria (PKU) is one such instance; it results from a single gene mutation. Such foods containing the amino acid phenylalanine must be avoided by anyone with the condition. Another illustration in today world is intolerance towards lactose. Across the globe the majority of people worldwide are intolerant towards lactose, which means that they are unable to digest milk products since, after weaning, the gene that codes for the enzyme lactase is generally "turned off." However, a variation in a single DNA nucleotide first emerged in northern Europeans between 10,000 and 12,000 years ago. Because of this single nucleotide polymorphism (SNP), or having the SNP, the lactase gene continued to express itself into adult age. That was useful since individuals carrying this SNP may consume dairy products that are high in nutrients in areas with short growing seasons. Additionally, scientists were able to find other genes that interact with dietary components as a result of the late 20th century molecular genetics revolution.[1]

Most anthropomorphic traits, such as height or their eye colour[5] and several physiological traits, like lactase persistence[6] and the likelihood of contracting disorders like T2D,[7] are present in a particular human population in a variety of forms. Given that these characteristics are determined by the expression and function of genes, inter-individual genomic and epigenomic differences are linked to the diversity. Because of this, individuals within a group exhibit varying degrees of biological fitness, including fertility, viability and success in mating. Characteristics linked to higher levels of fitness are environmental adaptations. This is the root of Darwin's evolutionary theory of "survival of the fittest," which is frequently brought about by pressures from evolution, such as decreased access to resources like food or dangers from infections.[8]

On the other hand, personal medical and social attention to the individual characterises modern cultures. One of humanity's greatest achievements and a measure of our species' progress is the way we care for the people of our society who are less suited. Therefore, in most circumstances, the results of Darwinism now do not apply to us anymore. Nonetheless, there may be certain outliers, such as HIV-1 virus infections or the SARS-CoV-2 pandemic. Regardless, each of us carries a history of evolution inside our unique version of the genome, which plays a major role in determining our specific vulnerability to a variety of common diseases.[9]

Early January 2017, the Food and Drug Administration (FDA) in the United States (US) approved the 23andMe Genetic Health Risk Test, the first direct-to-consumer genetic test that offers information on an individual's susceptibility to certain diseases. Experts in the area generally view the accuracy and efficacy of such products with great suspicion and it is also usual to question the veracity of the promises made by the for-profit companies offering health-genomics services. While the idea sounds reasonable and there seems to be a lot of support for it, as of right now the technology does not seem to provide accurate, repeatable and reliable results.[10, 11]

On the other hand, the market is undoubtedly expanding and substantial investments are being made in the industry. Thus, the field of study known as nutrigenomics studies the relationship (nutrient–genome/epigenetic) between nutrition and the genome and accurately/precisely works on the such side which is related to, how different diets and their combinations with other food components interact with specific gene to either alter the risk of such metabolic diseases like non-insulin dependent diabetes, obesity, chronic heart disease and some types of sarcomas. These studies revile main concepts driving the nutrigenomics field forward is the creation and use of customised dietary plans based on each person's unique genetic profile, with the goal of maximising epigenetic phenomena and using genetic predisposition. Another promising application in the field of food science and technology is the creation and fundamental development of functional foods informed by nutrigenomics research.[12]

One of the main concepts driving the nutrigenomics field forward is the creation and use of customised dietary plans based on each person's unique genetic profile, with the goal of maximising epigenetic phenomena and using genetic predisposition. Moreover, another significant and potentially strong area of application in the nexus of such technology is the re-modulate and development and development of functional meals based on the findings of the study of nutrigenomics. Functional foods and dietary supplements represent a significant market, which is valued at approximately US$ 40 billion as of 2010. Projections and estimates suggest that by 2030, advancements and investments in nutrigenomics could potentially double this sector/market, reaching an estimated US$ 80 billion.[13, 14] Up to recently, research on biological structures, reactions, enzymes and signalling agents was largely focused on a narrow range of topics and simplified, which helped us understand specific molecular mechanisms but not always biological systems as a whole. On the other hand, because genomics allows for the simultaneous and integrated assessment of several biological activities at the molecular level, it may change the direction of nutrition research. These methods enable the findings of the biological structure and function of amino acids, proteins and other metabolites to be included in gene research.[15]

Nutrigenomics is a research approach that analyses both nutritional intake and genetic profile (makeup). It is based on the idea that, the many environmental factors, such as daily routine activity, contact to harmful pollutants and infections, should be taken into account and quantified as much as possible. Numerous findings showed their correlation between nutrients and genes influence gene expression, that turn to influences metabolic pathways and their activity.[16, 17] Using a genetic profile analysis under various situations, the nutrigenomics method looks for relationships between gene behaviour and the environment. As a result, study objectives are established and possible correlations are looked into, enabling hypothesis-driven numerical experimentation or research that can demonstrate their major cause and its effect.[17] Primary benefit of this strategy is its capacity to efficiently and promptly handle massive data quantities, providing a foundation for further investigation.

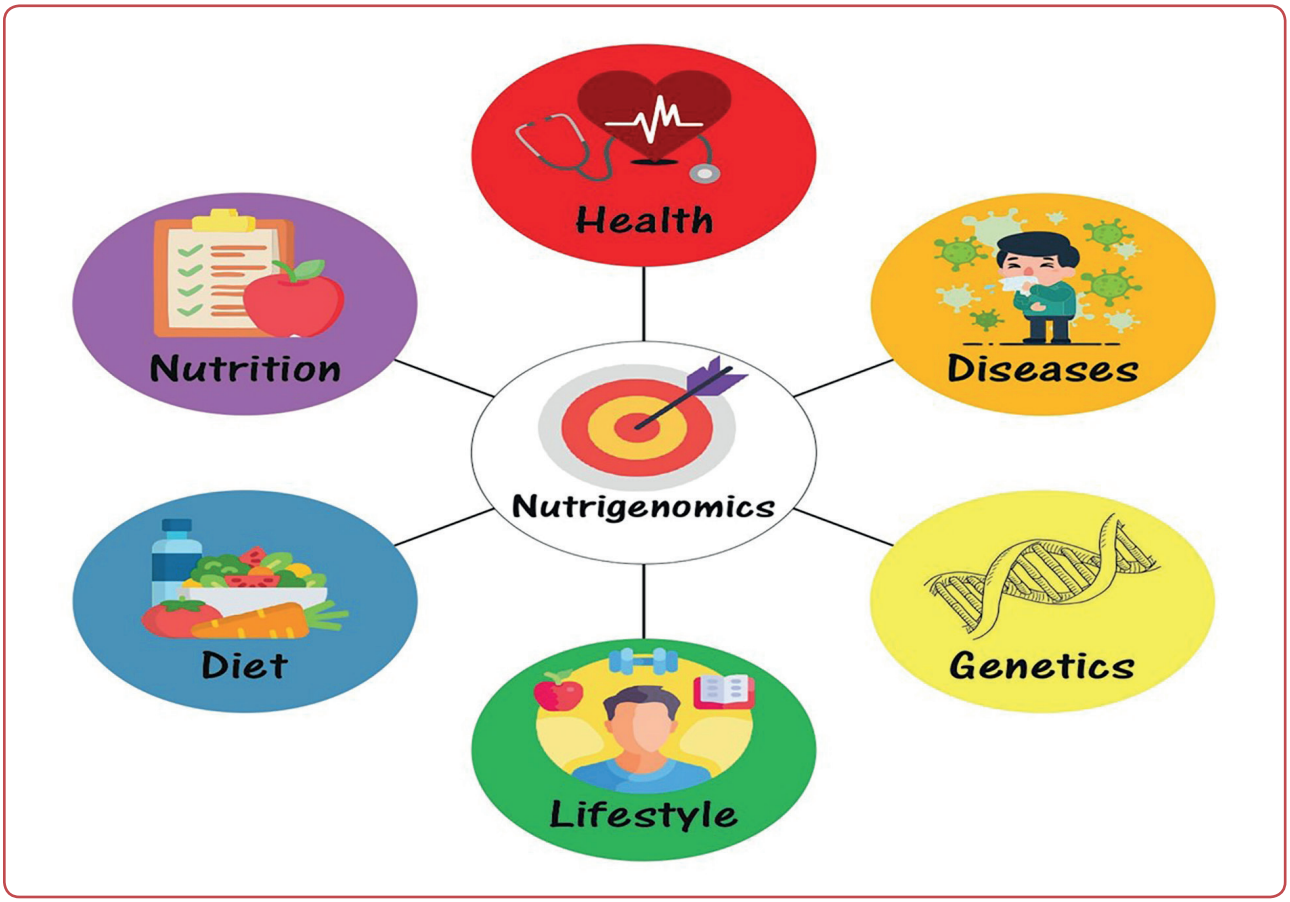

Figure 1: Nutrigenomics-oriented health optimisation

Because of its ability to process and analyse numerous biological data points from huge databases simultaneously, nutrigenomics may show to be an excellent technique for establishing the objectives regarding targeted therapy or health optimisation as depicted in Figure 1.

One of the well-established processes in prokaryotes is the expression of genes in such response as changes in nutrition values. Single-cell organisms can adapt their metabolic capacity to changes in the availability of nutrients in the culture media. For instance, the operations/regulation of the operons for lactose, histidine (amino acid) and tryptophane by their respective substrates has been well-characterised across the cytoplasm, as has the withdrawal responses of sulphur amino acids.[17] Nutrition used to just address a person's fundamental needs for survival; now, it is used to create customised meals that promote optimal health. The goal of nutritional genomics technologies is to integrate them with databases of genetic vulnerability to illness, interindividual genetic variability and genomic sequences. Clarification of impact of nutrition over hypertension, tumours, diabetes and other serious illnesses is sought using this information. Food items may potentially be modified to improve the health and wellbeing of demographic groups defined by individual genomes, but this is currently not achievable in practice. The intricacy of metabolic disorders, population-wide genetic diversity and the complication of genome-genome and genome-environment connections all provide significant barriers to the application and/or translation of nutrigenomics research.

Key concepts and terminology

The study of nutrition and gene expression is known as "nutrigenomics," and its goal is to comprehend how a person's genetic composition impacts how their body responds to food and how food itself effects gene expression. The following are some essential terms and concepts:

- **Biostimulation:** An organism can undergo biostimulation, which is a phenomenon in which metabolic processes are altered to enable more substantial growth or yield, more efficient use of environmental resources and increased tolerance to unfavourable environmental variables. According to some descriptions, biostimulation is a universal biological phenomenon that depends on how cell molecular structures interact with outside impulses or stimuli. A series of processes, including sensing, transmission, receiving action and alteration in various gene expression, their metabolism, or cellular (and organismal) characteristics take place following the administration of a bio-stimulating substance. Physical, chemical, or biological environmental factors can induce biostimulation in living things.[18]
- **Nutrigenetics:** Focuses on how genetic variations among individuals influence their response to nutrients. By optimising food consumption, nutrigenomics offers a viable approach to cardiovascular medicine that may improve the inhibition and treatment of cardiovascular diseases (CVD). The term nutrigenomics is still refining its study methods, though and learning from both its successes and failures. Since its theoretical underpinnings have been established, we can validate it and then move forward with research focused at obtaining the higher calibre of scientific evidence required for its successful application to clinical practice. These elements are included in this review, which also provides an overview of the research on gene-diet interactions associated with intermediate and ultimate CVD symptoms.[19]
- **Nutrigenomics:** Examines how nutrients and dietary compounds affect gene expression, metabolism and overall health. It recognises that nutritional advice that is suitable for one person may not be suitable or even detrimental for another. The promise is similar to that of pharmacogenomics, its sister area that looks at personalised medication therapy. The Nutrigenomics New Zealand model offers a method for combining the different systems biology technologies at hand, with the ultimate goal of creating unique, carefully crafted meals. On the other hand, such example also offers a coherent as well as the integrated model that may be used for different research goals. A proof of principle has been used to Crohn's disease (CD), an instance of inflammatory bowel disease (IBD).[20]
- **Single nucleotide polymorphisms (SNPs):** modifications to a single nucleotide base in DNA that can impact a gene's ability to function. Finding new connections between SNPs in specific genes and a certain trait is essential towards epidemiology of genetic. A wealth of knowledge on the genetic foundation of several diseases is easily obtainable through databases like OMIM, regardless of whether the genetic basis was discovered through de-

cades of linkage and candidate gene studies or established by GWAS.[20]

- **Epigenetics:** The examination of alterations in cellular phenotype or gene expression brought about by causes other than modifications in the underlying DNA sequence. "A science dealing with the genesis, distribution and control of disease in groups of relatives and with inherited causes of disease in populations" is genetic epidemiology. This field has produced preliminary evidence supporting the theory that human genetics do affect how the body reacts to certain foods or nutrients. With differing degrees of effectiveness, several studies have linked variations in specific genes to the risk of illness. Future research, it will be crucial, should take into account more than simply one gene variation at a time.[20]
- **Bioavailability**: An important factor in the efficacy of pharmacological treatment is drug bioavailability. It establishes the extent and pace of drug-active ingredient absorption into the circulation following rectal, parenteral, oral and topical delivery. In practical terms, bioavailability refers to the quantity of a drug's supplied dose that enters the bloodstream as the active component and is subsequently used by the body system to provide a therapeutic effect. Numerous factors, including as the medication's physicochemical characteristics, the way it is administered, connections with other medications, absorption (A), distribution (D), metabolism (M) and excretion (E), all have an impact on bioavailability (ADME). The effective dosage of the active pharmacological ingredients (API) and its subsequent bloodstream entry are correlated with their bioavailability.[21]
- **Nutritional epidemiology:** The idea that a combination of environmental and dietary variables might modify multigenic characteristics is a core tenet of nutrigenomics. For the field to be effectively implemented, a precise nutritional evaluation has to be the foundation. Conventional analytical techniques include a wealth of documentation; Willett, for instance, (1995). Nevertheless, a number of the evaluation instruments used today, such as diet diaries, food frequency surveys and diet memory techniques, are infamously inaccurate.[20]
- **Nutraceuticals:** The phrase "nutraceutical" was first used in 1989 by the scientist Stephen L DeFelice, which was the founder and chairman of the Foundation for Innovation in Medicine (FIM), with the words "nutrition" and "pharmaceutical." "Any substance that is a food or a part of the food and provides medical or health benefits, including the prevention and treatment of disease," according to DeFelice, is a nutraceutical. Nutraceuticals have garnered significant interest recently because to their potential to reduce lifestyle-related illnesses such as obesity, non-insulin dependent diabetes, asthma, arthritis, CVS disease and high blood pressure. Nutraceutical ingredient may, however, have low levels of bioavailability, permeability and physical stability, which would restrict absorption from the GI tract. Research scientists are under pressure to make nutraceutical and bioactive goods more bioavailable by oral administration due to the inadequate absorption pattern of standard nutraceutical formulation.[22]
- **Dietary patterns:** One method that shows promise for comprehending the intricate connection between nutrition and health is dietary pattern analysis. Although there are numerous statistical techniques available, the majority of the research concentrates on traditional techniques such reduced rank regression, main component analysis, factor analysis, clustering analysis and dietary quality ratings. Certain new techniques have seldom, if ever, been thoroughly examined or addressed.[23]

Fundamentals of genetics and nutrition

In recent years, the researcher added a commendable finding in terms of how genes and nutrition interact. Similar to other biological domains, the initial investigations concentrated on a single or small number of genes mostly due to technological constraints during that era. With the recent removal of technical obstacles, it is now feasible to analyse several genes and occasionally the entire genome in single research. The ideas of nutrigenomics and nutrigenetics have developed within that framework. Since the International Society of Nutrigenetics/Nutrigenomics was established and the Journal of Nutrigenetics and Nutrigenomics was first published in 2008, the scientific community has been using these ideas more often. Even if there are still conceptual

problems, enough progress has been done to be able to employ both words in ways that enhance communication clarity.[24]

Overview of genetics

The term "nutrigenomics" has come to refer to the study of how nutrients affect gene expression and associated molecular and biological processes that follow. In the search to comprehend the precise impacts of nutrients at the molecular as well as at the tissue and organ levels, transcriptomics, proteomics and metabolomics will all be progressively integrated into nutrition genomics, along with more dynamic techniques introduced by fluxomic technologies. Eventually, designs that capitalise on the impacts of empirically generated gene–nutrient interactions should advance the field of nutrigenomics science. In short, nutrigenomics, itis the study of how nutrients affect body gene expression, whereas nutrigenetics is the role of variation in DNA sequence with responses to nutrition. For example, even more enlightening research on the influence of particular foods on cellular responses might be made possible by conducting tests in which people are randomly assigned based on their genotype and proven to engage in a gene-nutrient interaction phenomenon.[25, 26]

Nutrition gene expression

There is strong evidence that throughout the course of several million years of human evolution, nutrition and physical exercise have altered the genome and influenced gene expression. Environmental variables decide which vulnerable individuals will become ill, whereas genes dictate health opportunities and susceptibility to disease. Given the evolving socioeconomic landscape in developing nations, this additional stress might expose underlying genetic susceptibilities to chronic illnesses. Research has demonstrated the part of such nutrients that play a very important role in the expression of genes. For instance, scientists are currently attempting to determine why, in contrast to omega-6 fatty acids, omega-3 fatty acids suppress the micro-RNA of IL, which is increased in autoimmune diseases such as arthritis and atherosclerosis.[27] A novel approach to nutrition is provided by nutrigenomics, which also clarifies the ways in which food alters an organism's genetic code and how that alteration affects the phenotypic of the organism. Moreover, advancements in the disciplines of marketing, communication and nutrition sciences allowed for the creation of customised nutritional advising based on nutrigenomics.

Genetic variation

With the sequencing of many eukaryotic genomes, our knowledge of human illness has advanced at a faster pace. Out of the 1000 genes linked to human disease to far, 97 % cause monogenic disorders, meaning that a single defective gene causes the illness. Certain monogenic disorders like phenylketonuria and galactosemia can be prevented by altering the consumption of specific dietary components. An uncommon recessive defect in galactose-1-phosphate uridyltransferase (GALT) causes galactosemia, which raises the risk of mental retardation by causing a buildup of galactose in the blood.[27] For instance, a recent meta-analysis of almost 2000 microarray data covering 22 distinct tumour forms by researchers[28] showed that similar functional modules exist between diverse cancer types rather than a solitary common gene mutation causing the development of these cancers. Therefore, preventing the beginning of these illnesses by food is an ambitious and difficult objective that necessitates understanding not only how a single nutrient may impact a biological system but also how a complex mixture of nutrients (ie, diet) will interact to control its biological activities.

As a result, gene variations, or SNPs, may contribute in minor or significant ways to the complex characteristic. The particular trait or illness is the consequence of the combined effects of causal alleles in many QTLs.[29] The majority of phenotypic characteristics, such as potential height and weight, blood glucose levels while fasting, susceptibility to illness, etc, are quantitative characteristics. Examining what is now known about the chromosomal regions might help demonstrate the idea that numerous genes and various environmental effects contribute to a complex characteristic.

Basics of nutrition

Nutrients as well as diet are thought to be the most powerful environmental influences. Although nutrition has ancient origins, current science has advanced to the point where we understand that nutrients are not only vital for good health but also that the right amount of each nutrient is needed. Our knowledge of nutrition and how it affects health has improved with the advent of molecular methods and nutrition-

al studies. Multigenic mechanisms control the body's response to food. Different people react differently to different nutrients. It is due to genetic differences. The field of nutrigenetics elucidates the degree to which genetic diversity and its molecular underpinnings impact characteristics and illnesses related to diet. In the "hypothesis-driven approach," the researcher looks for sequence variation in the candidate genes after testing them for a characteristic or condition and then conducts an association or linkage analysis. Another "holistic" method uses a whole genome scan to identify the genes linked to a certain characteristic or disorder's likelihood of contracting a particular disease.

The 20th century has contributed to a fundamental comprehension of macro and micronutrients. The Food Guide Pyramid and My Plate were two examples of one-size-fits-all programs that were highly effective in lowering nutritionally deficient illnesses and malnutrition. several genetic variations have been linked to certain nutrition-related features by the genome-wide association study (GWAS) and these variants are also accountable for the creation of several diet-related gene interactions and a wide range of human disorders. Numerous dietary factors and the effects of varying genotypes influence how various nutrients are metabolised, which can lead to detrimental diet-gene interactions.[30]

Macronutrients and micronutrients

Components regarding the healthy diet having these two major factors: macronutrients and micronutrients. All of the system nutritional needs are satisfied when protein, carbs and fats are properly balanced with vitamins and minerals. Individual differences exist in the specific daily requirements due to a variety of characteristics, such as age, gender, weight, degree of exercise and overall health. Proteins and carbs have the same number of calories per gram, whereas fat and alcohol have more.

Human body system uses proteins for a variety of purposes, including production of energy, tissue development and repair and cell signalling. Although their main function is to supply energy, carbohydrates also play various other functions, such as controlling satiety. The micronutrients that the body needs are minerals and vitamins. They do a variety of tasks and frequently cooperate.[31]

Minerals were widely employed by ancient cultures as amulets, talismans and sickness cures. The late 1800s marked the beginning of vitamin discovery. Despite consuming varied meals, people's health was found to be comparable around the world, leading experts to conclude that food's constituents had an impact on health. To ensure that the diet has all the micronutrients needed, a range of foods including meat, fish, grains, fruits and vegetables must be consumed. Provitamins (including β-carotene) and all the vitamins were identified as vitamin study proceeded and their respective roles were ascertained. Determining the structures and being able to synthesise every vitamin required fifty years. All things considered, advances in pharmacology, anatomy, physiology and biology have led to better medication regimens and illness therapies.[32] The essential component of a healthy human metabolism is the sense of nutrition cues through cellular receptors and chemicals. Metabolic disorders can arise from any disruption in the recognition and transmission of nutrients. The lack of resources has caused the majority of cellular functions to develop. The finding of both external and intracellular metabolites, including the lipids, sugars, amino acids, etc, depends heavily on hormone signalling. The long-range signals that help an organism coordinate its response are called hormones. Sensing various nutrients in mammalian cells involves a multitude of distinct processes.[33]

Nutrient absorption and metabolism

The notion that one's diet has an impact on their health is not new. Moreover, it is widely acknowledged that individuals possess varying dietary needs. Numerous studies have revealed that the two main determinants of health and illness are an individual's environment and food, both in terms of quality and quantity. Numerous food ingredients have bioactive properties that can straight or indirectly change the expression of the genome, transcriptome and proteome, controlling biological processes and providing substrates for the production of energy.[33]

To define nutrition, bioinformatics should be utilised in combination with a high-throughput studies involved in genomics investigations, such as single-nucleotide polymorphisms (SNPs), quantitative transcriptomics, metabolite alterations and proteomics. The term "nutrigenomics" describes the application of technology to nutrition, including nutrigenetics (study of DNA, including SNPs), transcriptomics (mRNA), pro-

teomics (protein complement) and metabolomics (metabolite complement). By encouraging people to change their eating habits, a tailored diet based on nutrigenomics may enhance public health. Meals and nutrients often have a beneficial effect on genes; nevertheless, there are rare instances when this interaction might become lethal, which calls for further research.[31] Human health is influenced by both environmental and genetic factors and maintaining normal health status requires consideration of both. The study of nutrition science focuses on how nutrients maintain homeostasis in the body at the cellular, tissue and organ levels. The mechanism of nutrient-dependent interactions at the genetic, molecular, protein production and metabolic profile levels must be understood by this research. Consequently, the field of nutrition study has advanced to include molecular biology, genetics and nutritional genomics in addition to epidemiological and physiological aspects. Innovative food products that provide health advantages need to be seen as a wise decision in order to succeed. Novel meals with eye-catching appearances and health advantages that consumers want to know about have the best chance of succeeding. There is only one way to make sure that customers are involved in product design evaluations. Nutrition research and the food processing sector suffer when new food products are marketed without a clear benefit to consumers.[32, 33]

The interaction between genes and diet

Since its state that neither nature nor nurture can fully account for the molecular mechanisms behind human health or illness, an increasing number of scientists are supporting and creating integrative methods to the study of chronic illness and, in fact, biology. One such integrated science is nutrigenomics, often known as nutritional genomics. By changing the genes expression and/or structure of an individual's genetic composition, common food chemicals, or nutrients, can impact the balance between health and sickness. A century ago, research in the fields of genetics, biochemistry and molecular biology revealed about a thousand different mutations that lead to human illnesses. Monogenic mutations account for 97 % of these disorders; that is, a mutation in a single gene is sufficient to produce the illness. This is the working definition of nutrigenomics, which aims to give a genetic and molecular knowledge of this process.

The outcomes and insights gained from these diverse research domains will impact the framework, tactics and methods of nutritional genomic investigation, particularly concerning the identification of such diet-regulated genes implicated in terms of susceptibility, onset, incidence, progression and/or severity of chronic illnesses.[34]

Genetic influence on nutrient processing

Nutrigenetics is another topic of research within nutrigenomics. In the latter, the relationship between a genotype—that is, the existence of SNPs or other genetic variations—and certain eating habits is studied. In fact, every individual may react to nutrients in a different way and genetic differences across various human ethnicities result from adaptive evolution toward certain dietary patterns. DNA sequences that share common SNPs are the main source of genetic variation. They are the result of DNA mutation followed by population selection. This evolutionary process is hampered by the nutritional environment, which causes the participants' DNA mutations to spread more quickly.[35]

Owing to the intricate nature of gene-diet interactions, advancements in nutritional studies have been made recently. Within the field of both the anabolism and catabolism disorders, genetically engineered *in vitro* study via suitable models, including cell lines, co-cultures, and three-dimensional (3D) cultures, as well as the use of mice models (knock-out, knock-in) carrying the desired mutations, make it possible to research study about the impact of genetic variations on dietary intake. As per these research, genetic background may have an impact on the deleterious consequences of fatty acid excess or obesogenic/steatogenic diets, respectively and these effects may be reversible with the addition of appropriate micro- and macronutrient supplements.[36] Since it can evaluate the effects of nutrients including (macro- and micro) on the transcriptome as a whole, the DNA microarray methodology has been the most widely used instrument for transcriptomic data processing in recent years. It is also a potential approach for nutrigenomic investigations. Investigating the role of these

transcripts—that is, determining which proteins they code for—begins after it is evident which transcripts are controlled by nutrition. The study of protein expression profiles, which represent cellular activity, is known as proteomics. Numerous antibody-based methods, including blotting, enzyme-linked immunosorbent assay (ELISA) and electrophoretic separations, are utilised in proteomics investigations. Mass spectrometry (MS), on the other hand, is a more inventive and sophisticated approach to proteome research as it can concurrently identify every protein that is synthesised.[35]

Furthermore, it might be deceptive to assume that the final molecular product of metabolism is insensitive to a variety of environmental stimuli, not only nutrition. Nuclear magnetic resonance (NMR) spectroscopy is a crucial technique in metabolomics that allows for the chemical structure as well as the measurement of metabolites. On the other hand, NMR may occasionally accurately identify metabolites at high doses. The analysis of metabolites from bodily fluids and tissue samples is possible using both NMR and MS.[35, 37]

Epigenetics and nutrigenetics

The already established epigenetic relationships between DNA and environment are described by nutrigenomics, specifically with regard to nutrition. Nutrient–DNA interactions involve several actors and understanding their combined contributions is essential to understanding how dietary ingredients, diet and lifestyle might impact the course of an individual's health. One phenotype of the baby that ultimately regulates the risk of such disorders in adulthood is the nutrition of the mother during pregnancy, which is a strong example of crucial ecological component regulated as a diet-inherent and also the habituation expression of the genome.

Currently, nutrigenomics can help explain some of the cellular and molecular processes behind clinical pathological disorders which can be improved, avoided, or improved controlled with diet thanks to the quantitatively large amount of specialised literature. In this respect, a large portion of the literature mentions; it has been characterised more specifically in recent years and less exactly in previous years, when a general epigenetic theory linking food to illness was published.

A common premise of such nutrigenetic studies that are acknowledged by the researcher community and published in the primary literature is that a single gene (or single pathway) product(s) contributes to a particular metabolism, as indicated by a particular metabolic parameter and a range of penetrance that equally reveal the manifestation object of the study.

The scientific fields of genetics, biochemistry and physiology are at least three areas where nutritionetics is connected. Thanks to the advancements in mass sequencing technology, we can now characterise the particular allele contributions in the Mediterranean basin that are associated with the health of autochthonous populations.[38]

DNA methylation and histone modification

The genetics of food metabolism took on the dignity of a distinct science a few years ago, nutrigenetics, similar to the shift from pharmacology to pharmacogenetics. This was further supported by the establishment of the International Society of Nutrigenetics/Nutrigenomics in 2005 and the organisation Further the addition of methyl group "2018 American College of Nutrition Meeting".[39] The importance of inherent changeability, which is not at all insignificant nowadays, has finally been acknowledged aimed at both sciences; for far too long, this basic idea was ignored even in scientific settings that were far more likely to rely on gene multiplicity showed in each unique individual or her unique genome than on the normal individual, who does not exist. It is crucial to emphasise that establishing a clear link between genotype and phenotype in nutrigenetics is more challenging than in traditional genetics. As an illustration, consider the particular phenotype of "food wellness," which is itself a nebulous yet helpful trait. Hundreds of genes and genotypes can influence how this phenotype manifests itself. Additionally, we run the danger of being in the dark with every data report in population research if we additionally consider the phenomena of penetrance.[39]

At the carbon 5' position, the addition of methyl group of the cytosine within the cytosine-guanine (CpG) dinucleotide is recognised as DNA methylation (DNAm) and it is a characteristic of many eukaryotic genomes. This complex reaction likely involves flipping the cytosine base out of the intact double helix. DNAm usually occurs in areas rich in CpG di-nucleotides (also known as CpG Island). The primary mechanism underlying the conservation of genomic integrity and the epigenetic regulation of gene expression is

DNAm. Therefore, the study of cell growth control, tissue-specific differentiation, carcinogenesis and aging requires an assessment of DNAm state. Histone acetylation and methylation are the two main types of histone modification. Caloric restriction alters the expression of important genes such as Foxo, p53, Ku70, p16INK4a and PGC-1a and activates the deacetylation-affected SIRT1 and HDAC1 genes. Histone modification is also crucial in the regulation of essential genes, such as hTERT and p16INK4a. Thus, epigenetic control actively corrects aberrant gene expression during caloric restriction (CR), for example, contributing to the delayed aging and longer lifespan associated with CR.[40]

Impact on gene expression

There is now more attention in the relationship among diet and periodontal disease due to advances in our knowledge of the process behind the deterioration of periodontal tissue, the possible defensive effect of such nutrients and the development of current genomic assessment methods. The majority of big databased cross-sectional studies and minor double-blind randomised study trials that have provided evidence of a direct correlation between nutrition and periodontal disease to date have found that there is less significant correlation across the nutrient under investigation and markers of periodontal disease status. Given the strong likelihood that food and genotype interactions influence the risk of the majority of multifaceted illnesses, it is quite plausible that these interactions will also influence the risk of periodontal disease. The importance of comprehending these interactions is emphasised by a number of nutritive genetic trails whose outcome measures have been markers of disease risk, most notably cancer and cardiovascular disease. These studies also demonstrate where such these kinds of observational studies may have missed the effect of dietary modification on the progression of periodontal disease.[41] Lipids' oxidative stability is also influenced by their chemical structure, which results in the production of secondary metabolites that have a variety of effects on molecular reactions. Studies conducted on animal models demonstrate how the kind, quantity and duration of exposure to a diet high in fat may alter cellular reactions mediated by controlling gene expression, greatly advancing our understanding of the nutrigenomic function of dietary fats. However, as research on humans' advances, the situation gets more complicated due to the role played by both the richness of the gut microbiota and individual genetic variability. The gene-dietary fat connection suggests that SNPs contribute to complex biological responses that may not match results from *in vitro* or preclinical research.[42]

Role of microbiome in nutrient interaction

The microbial community that is most abundant in the digestive system is supported by fermentable substrate, which is provided by food consumption. Dietary trends include paleolithic and ketogenic diets, as well as Western, Mediterranean and vegetarian diets, influence the gut flora. The microbiota is affected when the proportions of fat, protein and carbohydrates are changed, especially when these are consumed in extremes. Rich diets in fermentable carbohydrates contribute to the relative abundance of bacteria that can break down sugars, polysaccharides and oligosaccharides, such as *Bifidobacterium, Prevotella, Ruminococcus, Dorea* and *Roseburia*. Quite high diet in terms of fats, on the other hand, promote the growth of bile-resistant bacteria like *Bacteroides* and *Bilophila*.

Published research on the connection between food, microbiota and health dates back more than a century, demonstrating the longevity of this idea. Research conducted before the development of modern molecular methods for classifying intestinal microbes has shown that the make-up of the food affects intestinal gas production, which in turn affects bacterial metabolism and the generation of proteolytic metabolites such phenols. What constitutes a healthy microbiota profile is still unknown, despite the fact that the size and significant interindividual variety of the microbes present in gut—suggested by the collective genomes of such microorganisms isolated from faecal samples—have lately come to light. When ingested at high concentrations, phenolic metabolites—byproducts of tyrosine catabolism—have detrimental systemic effects on epithelial cells of intestine and gut integrity. The several other metabolites that arise from the fermentation of amino acids and the catabolism of microbial fat, each with their own set of local and systemic impacts, have been discussed elsewhere. Apart from the end products of macronutrient fermentation, there are probably countless microbially produced metabolites that arise from the bioconversion of minor food constituents, or dietary-sourced substrates, that can affect human health.[43]

More clinical research using multiomics methodologies is needed to identify the bacterial species involved, assess their real contribution to the micronutrients balance and, ultimately, establish their importance in preventing and/or mitigating any deficiencies. By elucidating the processes behind the link between our microbial counterparts and micronutrient bioavailability, postbiotic techniques may be able to generate a broader spectrum of precision customised therapies addressing micronutrient shortages and associated illnesses.[44]

Applications of nutrigenomics

Nutrigenomics, or nutritional genomics, is the study of the interface between cellular or genetic processes and the nutritional environment. It aims to comprehend how a person's food affects their genes and overall health. By modifying the expression or structure of a person's genetic composition, nutrigenomics aims on mechanism of human genetic makeup and common dietary substances affecting the delicate balance between health and sickness. It is the science of how people react to substances found in food by utilising post-genomic technologies.[45] Following are applications of this field.

Personalised nutrition

One of very important applications of nutrigenomics is ability to provide personalised nutrition. The promise of personalised treatment has been brought about human genome sequence analysis to find out diversity in human genes. This study connects variations in genes and biomarker for disease which can be of phenotypic nature.[46] In a similar vein, nutritional genomics and genetics, or the study of relationships between genes and nutrients provides information and expertise to help each person create a diet that is ideal for maintaining health and preventing disease.[47] The complex nature of food and the fluctuating mechanisms producing different physiology in health condition presenting a variety of challenges for research and applications based on human genetic heterogeneity, despite the enormous advantages related to individualised healthcare and economic issues for individual's population. Enhanced study designs and methodologies can effectively tackle these obstacles. Nevertheless, there is still a major obstacle to overcome. The proportional reduction in average disease risk over a specified time interval that would be achieved by eliminating the exposure of interest from the population," is derived from population studies that support genome wide association study which may be based on genetic data or nutritional status.[48] All other factors remain unchanged. A person's supplement and food choices can have a significant impact on their level of physical performance. Individual nutrition therapy focusses on recommended personal diet on the basis of genetic data in order to maximise performance health and composition of human body and exercise performance in athletic populations. Suit ability of different athletics like team of sport dietitians and nutritionists have long been trained in order to apply extra scrutiny for nutritional standards termed as "one-size-fits-all general population". Generic "one-size-fits-all" advice is still in place, though. Absorption and excretion of nutrients from food affected the genetic variations which further influences a variety of metabolic processes. Personal choices of food can impact their level of physical performance in a significant manner. Individualised nutrition therapy can be designed for targeting of dietary recommendations according to genetic profile of any person in order to maximise exercise performance in athletic populations. Suitable athletic populations of different kind of sport dietitians and nutritionists are trained for application of extra scrutiny to nutritional standard "one size fits all" for general population. Variations at gene level can influence pattern of nutrients absorption out of bioactive food, its metabolism and excretion leading to modifications in a variety of metabolic processes.[49]

Tailoring diets based on genetic profiles

Each and every human has a unique genetic blueprint for nourishment. The expression of these genes is influenced by nutrition and bioactive dietary ingredients. The study of gene-nutrient interactions, or "nutrigenomics," can result in the creation of individualised dietary guidelines for preserving good health and warding off disease. The bioavailability of nutrients and their metabolism may be impacted by the genetic variability among different ethnic groups. The scientific disciplines of genomics along with nutrition, bioinformatics and molecular biology along with epidemiology are all combined in the field of nutrition genomics.[25] Tests for particular genetic polymorphisms may therefore prove to be a helpful tool in managing weight loss and completely

understanding the connections between genes and nutrients. Genes control the absorption and metabolism of various bioactive nutrients, which can further influence genetic expression in positive or negative way.[50]

Nutrigenomic testing

The idea that obesity and CVD together account for a sizable share of adult global morbidity and mortality is supported by epidemiological data. Dietary and environmental factors, including genetics, interact intricately to cause obesity and cardiovascular disease. As an environmental component, nutrition has a major and well-known role in managing health as well as preventing obesity and diseases linked to it, such as CVD. Nonetheless, people with the same food pattern but obese exhibit a notable difference in CVD. This diversity can be justified by the many genetic polymorphisms, giving rise to the idea of nutrigenetics. The field of nutritional genomics, also known as nutrigenetics, examines and describes gene variants linked to varying responses to particular nutrients and links these variations to a variety of disorders, including obesity-related CVD.[51]

Thus, tailored nutrition advice based on an individual's genetic background may improve the outcomes of a given dietary intervention and constitute a novel dietary approach to improving health by lowering obesity and CVD. With these suppositions, it seems sense to assume that the understanding of food and gene interactions will provide more targeted and efficacious dietary treatments in the prevention of CVD and obesity through nutrigenetics-based personalised nutrition. Various kind of genes are linked to obesity and cardiovascular disease and are responsible for the relationship between nutrition and gene expression and the key nutrition-related genes are involved in both conditions. Advancement in recombinant DNA technology at molecular level resulted in specific genetic study and a far more specific awareness, via sequencing of genetic matter, depicting individual uniqueness and extent of genetic diversity. Pharmacologists have extensively researched and exploited the implications of genetic diversity in medication creation, drug metabolism evaluation and adverse drug responses. Over the last two decades, researchers have explored mechanism of occurrence of genetic variation and interactions between genetic matter and nutrients further impacted chronic diseases like diabetes, disease of cardiovascular system, high blood pressure, different types of cancer and obesity depicting the role of nutrients in gene expression. A new age is dawning, possibly termed as 'nutrigenomics'. This branch of science possess implications for nutrition research for the management of chronic diseases. As the family members share similar genes and similar environment (nutrition), similarities can arise from either. Much research has been conducted to determine each's role and effect in personal development of the individual. Awareness about genetic predisposition related to disease will aid in the identification of persons with a higher risk for occurrence of disease and its responsiveness to nutrition. Specific kind of nutritional treatment for individuals projected obtaining most therapeutic advantages has clear substantial clinical and economical type of effects, specifically for diseases with high prevalence like coronary artery disease, hypertension, osteoporosis etc. Emerging revolution in genetic technology, continued investment for research provides unparalleled opportunity to better understanding of disease mechanism, elimination of internal issue and environment concerns, developing novel techniques to improve global life quality. Along with this, understanding genetic vulnerability for a particular disease help to aid in identifying those at higher risk and their response to nutrition. As a result, there will be a need to design novel diets aimed at individuals, families and population segments. Being emerging technology, field of pharmacogenetics is the prime focus of nutrition scientists to widen interaction between field of genetics and nutrition leading to development of nutrigenomics subject in twenty-first century.[52]

Disease prevention and management

Some of chronic disease, particularly obesity, act as the leading cause of morbidity and mortality throughout globe. Obesity and its related comorbidities continue to have a significant negative influence on health due to absence of prevention and treatment approaches. Precision nutrition, a new treatment method that considers personal genetic and information, as well as age, gender, or specific physiopathological status. Advanced studies of gens are helping to improve our understanding of the significance of genetic variations, epigenetic markers, along with pattern of genetic expression for development of many severe illnesses, as well as its mechanism of disease progression influencing therapeutic activity.[53]

This understanding prompted the hunt of indicators related to genetics and are capable of prediction related to likelihood of acquiring severe type of diseases and personalise the management of diseases. Along with this, novel interventions of nutrition or bioactive food chemicals causing modification in epigenetic markers and gene expression can be implemented. These kinds of novel scientific insights leading to development of novel treatments for control of severe chronic diseases associated with disorder like obesity.

Population which are more susceptible to diet-related illnesses and malignancies because of lifestyle and eating habits modifications. Furthermore, it is proven that dietary changes greatly lower the chance of contracting illnesses. Although the field of nutrigenomics is relatively new, it has great potential for managing and preventing specific illnesses and carcinomas.

Research is being done on the potential of nutrigenomics in preventing diet- and lifestyle-related illnesses such as cancer. It defines metabolic response and gene expression, which affects people's health and susceptibility to disease. The onset and pathophysiology of illness is significantly influenced by change in gene function. The two most prevalent are chromatin remodelling and DNA methylation. Certain bioactive food chemicals have been shown to have a demonstrated effect in prevention of cancer through changes in gene function that are heritable and that do not entail a change in DNA sequence, although omega 3 fatty acids are the best example related to interaction of nutrition and gene without DNA methylation. Dietary polyphenols are very crucial in the prevention of mouth, breast, skin, oesophagus, colon, prostate, pancreas and lungs malignancies.[54]

Nutrigenomics in chronic diseases

The study of nutrigenomics examines how foods affect the genome and how each person's genetic composition reacts to food. Nutrigenetics, on the other hand, focuses on how a single gene is affected by nutrients. While certain SNPs determine an individual's dietary needs, others may be the cause of sickness. While individual nutrition is the main focus of nutrigenetics, system biology approach is mostly employed in nutrigenomics. Two main elements that influences development of chronic diseases like cancer, cardiovascular disease, diabetes, hypertension, obesity, are diet-related active molecules and human genetics. Sufficient and appropriate nutritional intake keeps us from being chronically ill.[55]

A subspecialty of medicine called human nutrition studies the biochemical reactions that food has with the human body. A change in gene expression and/or protein status can explain the phenotypic shift from health to illness state. This concept led to development of new field known as "-omic science." The function of "-omics sciences" (nutrigenetics, nutrigenomics, proteomics and metabolomics) in relation to health status and as a potential therapeutic intervention in chronic degenerative illnesses was examined in this study. Specifically, we examined the function of nutrigenetics and the connection between eating patterns, genetic sequence variations and the development of nutrition-related disorders as shown in Table 1. The impact of nutrition on gene expression and nutrigenomics was also looked.[56, 57]

Table 1: Nutrition-related disorders

Nutrient	Mechanism of action	Health impact	Example condition
Folic acid	Regulates DNA methylation	Prevents neural tube defects	Spina bifida
Fatty acids	Bind to transcription factors	Reduces inflammation	Cardiovascular disease
Vitamin D	Enhances mRNA stability	Supports immune function	Autoimmune diseases
Vitamin E	Acts as an antioxidant, reducing oxidative stress	Protects against chronic diseases	Cancer, heart disease
Theaflavins	Inhibits mRNA synthesis	May reduce cancer risk	Various cancers
Flavones	Induce DNA fragmentation	Potentially reduces cancer risk	Cancer
Niacin	Impairs DNA repair mechanisms	Associated with neurological issues	Memory loss, Alzheimer disease
Vitamin B6	Aids in amino acid metabolism	Reduces homocysteine levels	Cardiovascular health
Omega-3 fatty acids	Modulate gene expression related to inflammation	Supports heart health	Heart disease
Polyphenols	Influence gene expression related to metabolism	May lower risk of chronic diseases	Obesity, diabetes

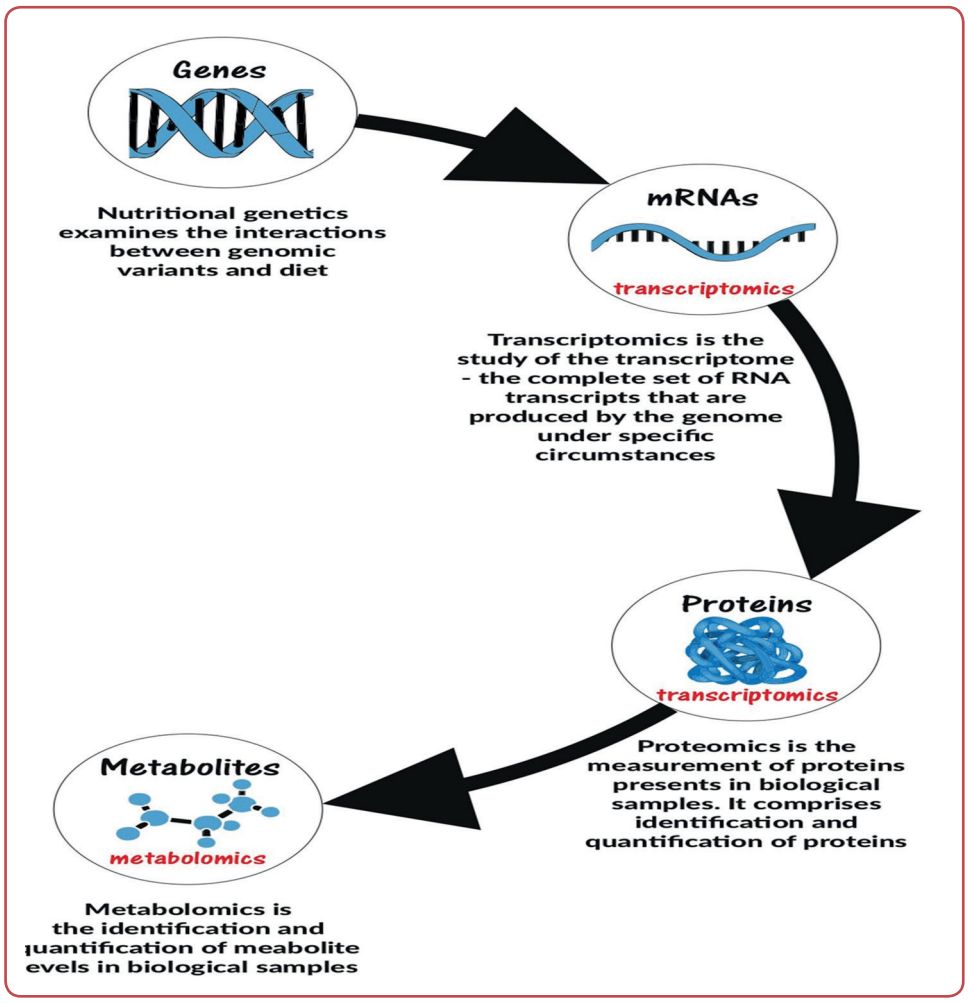

Figure 2: Personalised nutrition approach

Potential for precision medicine

Advances in genomics gave rise to the idea that a greater understanding of individual traits, such as genetic pattern help in more effective therapy of pharmaceutical and nutritional oriented. Advancement in proteomics field and metabolomics field, as well as wearable technology to track factors like nutritional intake, physical activity, heart rate, along with blood glucose level, have fuelled the concept. Along with these advancements, significant increasing number of direct-to-consumer microbiome genetic testing as well as personalised nutrition approach as depicted in Figure 2.

Key scientific problems covering divergent datasets accuracy of present forecasts are and how they might be improved in the future. A lot of lessons can be learned from systems biology seeking data integration from several levels of organisation which may be genomic, proteomic or metabolomic nature while also predicting behaviours of organisms and its biological systems. The current research examines the history and recent developments of 'big data' and systems methods in medicine and nutrition.

Ethical and social implications

This article provides an outline of the ethical considerations surrounding nutrigenomics research and personalised nutrition. The concepts of research ethics, including autonomy, beneficence, non-malfeasance and justice, are being challenged by fast-expanding cross-border research operations that use existing and new biobanks to study the relationship between genes and nutrition on the risk of common diseases. We highlight some of the outstanding ethical difficulties in worldwide collaboration initiatives that researchers should be aware of. Personalised nutrition (tailoring diet based on genotype) is one potential use of nutrigenomics research. However, unless the scientific evidence for diet-gene interactions is significantly stronger, providing tailored dietary advice based on specific genotypes remains problematic. From an ethical and

social standpoint, nutrigenomics offers great opportunity to enhance public health by increasing understanding of the mechanisms via which nutrition can be used to minimise the risk of prevalent polygenic disorders.[58]

Conclusion

The combination of numerous technologies has provided mechanistic insights and influenced the progress of precision medicine and personalised nutrition. Relevant ethical considerations include who has access to new technologies and how commercial companies store, use and/or mine customer data. Questions of efficacy (both long-term behavioural change and health outcomes), cost-benefit and effects on health inequities have yet to be completely addressed.

The link between nutrition and genes has long been suggested and in certain cases, it has been directly linked to specific disorders. After many years of research and coincidental findings, it is now recognised that this link, known as "Nutrigenomics" is a significant factor in a variety of illnesses. In this review essay, nutrigenomics, beginning with fundamental definitions and enzymatic functions and concluding with its palpable relationship with cancer was examined. Now, diet refers to what we eat on a daily basis. Everything that enters our digestive tract is broken down into little molecules and amino acids. These chemicals interact with our microbiome and genome in discrete fashion. For example, it was shown how optimal probiotic intake promotes good bacteria, which may treat IBS and prevent colorectal cancer in the long run. It was also demonstrated how a folic acid-rich diet is required for methylenetetrahydrofolate reductase (MTHFR) function, lowering the risk of colorectal cancer. It was explored how specific diets have been linked to the development of particular cancers. For example, red and processed meat are strongly linked to colorectal and prostate cancer, salty diets to stomach cancer and obesity to breast cancer. The change of these diets greatly reduced the risk and improved the prognosis for these tumours, among others. It was also looked at how micronutrients could help prevent cancer, as vitamins A and C act as antioxidants. In addition, it was demonstrated how folic acid prevents DNA mutations by improving protein methylation processes. Finally, after conducting a thorough analysis of several literature on the aetiology and prevention of cancer, we believe that diet should be an important component of cancer prevention and treatment programs. Healthy diets and micronutrients may eventually be able to gradually alter the susceptibility to cancer-causing genetic alterations. It will also help boost treatment and improve the prognosis of diagnosed tumours.

Ethics

This study was a secondary analysis based on the currently existing data and did not directly involve with human participants or experimental animals. Therefore, the ethics approval was not required in this paper.

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Conflicts of interest

The authors declare that there is no conflict of interest.

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Data access

The data that support the findings of this study are available from the corresponding author upon reasonable individual request.

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