Influences of the Nutrition Transition on Chronic Disease

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D. Noland et al. (eds.), *Integrative and Functional Medical Nutrition Therapy*,
https://doi.org/10.1007/978-3-030-30730-1_2

2.1 Nutrition Transition: A Model of Changing Dietary Patterns

Nutrition transition (NT) is a complex conceptual framework. It is rooted in the historic processes of demographic and epidemiological transition theories that describe trajectories in fertility, mortality, disease patterns, and causes of morbidity and mortality, respectively [1]. Nutrition transition is described by Barry Popkin as evolutionary stages or patterns (Fig. 2.1) that occur globally in a nonlinear fashion over time and space. Stage 1 is referred to as the "hunter-gatherer"; Stages 2 and 3 are termed "famine" and "receding famine"; Stages 4 and 5 are termed as "degenerative disease" and "behavioral change," respectively [please refer to Table 2.1] [2]. A majority of the writings on the subject draw attention to Stages 4 and 5, where dramatic shifts in diets, activity patterns, and health outcomes have been observed in different parts of the world over the last three centuries [3, 4]. Each stage is viewed as a pattern of food use and corresponding nutrition-related disease that affects individuals in the short term and populations in the long term [3]. In this view, each stage is a roadmap that highlights historical developments that occur in global societies during different time periods. Each stage is marked by specific patterns of food acquisition, food use, and physical activity with the ensuing stature, body composition, and nutrition-related health outcomes that affect individuals and, consequently, populations [5]. Transitory changes in food acquisition exist along a continuum, beginning with subsistence agriculture, progressing through industrialized agriculture to a globalized food system. Concomitant changes related to nutritional status lie along a spectrum of malnutrition ranging from undernutrition and nutritional deficiency to overnutrition

Table 2.1 Nutrition transition stages

Stage	Description
Stage 1	Hunter-gatherer
Stage 2	Famine
Stage 3	Receding famine
Stage 4	Degenerative disease
Stage 5	Behavioral change

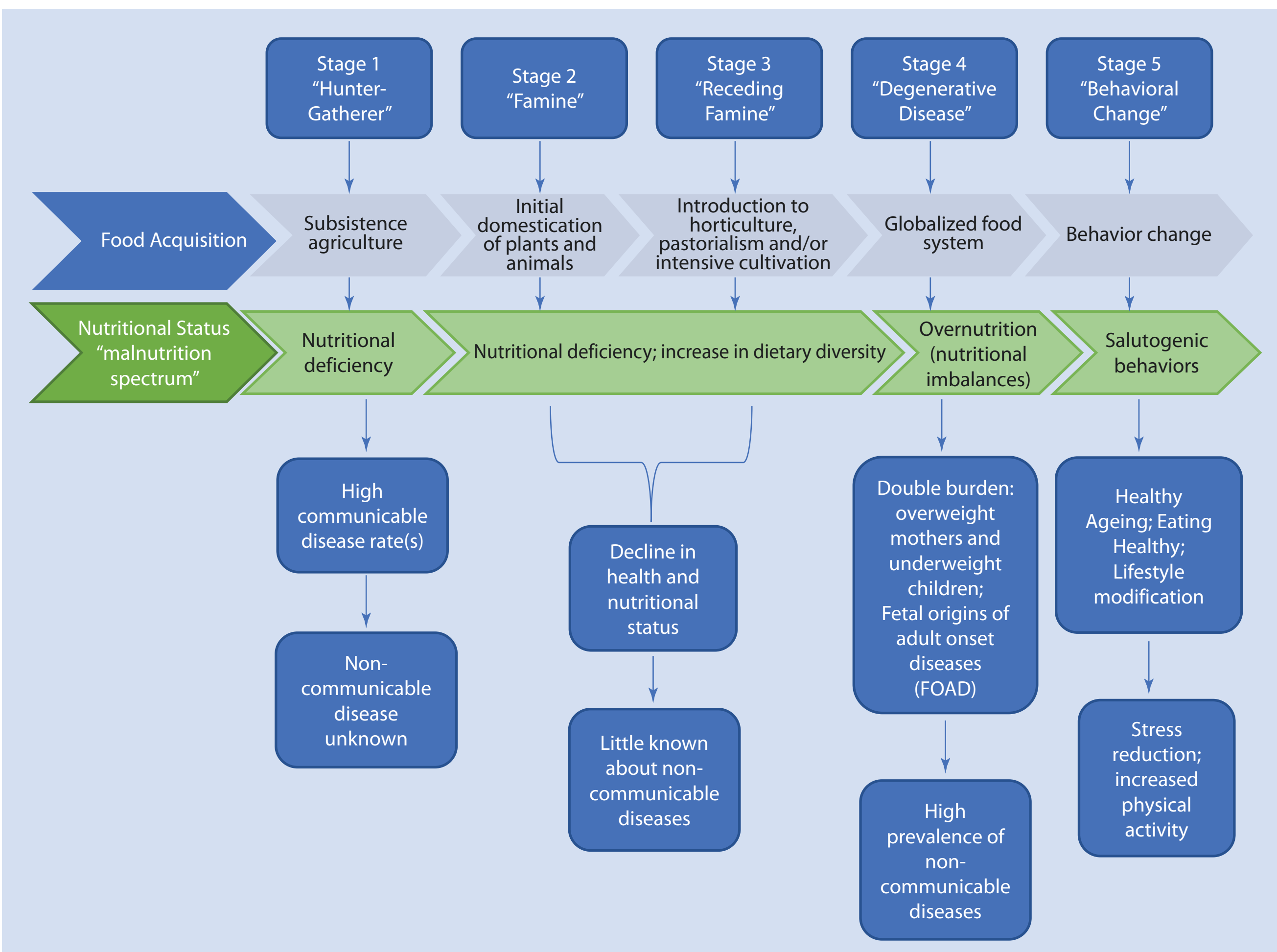

Fig. 2.1 Stages of nutrition transition

and non-communicable diseases. The timing and degree to which these changes occur depends on the degree of development experienced by various global societies. Sociocultural and political factors, environmental conditions, degree of urbanization, industrialization, population demographics, migration dynamics, physical activity patterns, dietary acculturation, and the ability of the individual country's healthcare infrastructure to simultaneously handle infectious and chronic disease prevalence and incidence mediate these transitions and their health outcomes [6, 7].

2.2 The Changing Face of Food Over Time and Space

Stage 1 Stage 1 describes the myriad ways in which early global societies or "hunter-gatherers" engaged in food procurement and consumption practices. *Stages 2* and *3* mark the transition from a "hunting-gathering" society to a "food-producing" milieu. The latter was created with the advent of agriculture and the industrial revolution, along with the climatic and production fluctuations associated with these respective milestones. Regardless of location, dietary choices in *Stage 1* were limited to wild plant and animal foods indigenous to the geographic areas of inhabitance. For example, high-latitude populations such as the *Inuits* relied on seafood with almost no plant foods, while populations in the lower latitudes depended on fruits, nuts, roots, berries, and hunted or scavenged animal foods [8]. Stage 1 was noted for its (1) high degree of ecological availability, nutrient density, and need for dietary flexibility and (2) energy-intense food procurement activities. In general, humans experienced a shorter lifespan and non-communicable diseases were unknown [9]. However, at that time, there was a high probability of mortality from communicable diseases, inhospitable environmental conditions, and dangerous encounters [8].

Stage 2 The transition to *Stage 2* occurred with the initial domestication of plants and animals around 11,000 BCE, followed by the introduction of horticulture, pastoralism, and/or intensive cultivation.

Stage 3 In *Stage 3*, the domestication of plants and animals and the cultivation of one or more plant foods such as rice, wheat, or maize intensified. This shift is believed to have occurred in various locations around the globe at different times [8]. These activities provided populations with a plethora of locally harvested traditional or indigenous foods. Foods produced were native to the geographic area and not necessarily uniform across the globe; however, they were adequate in quantity and quality to meet the nutritional needs of the local population. For example, the *Inuits*' seafood-dominated diets were high in saturated fats with few carbohydrates, while the Balinese rice farmers [10], the Nigerian *Kofyars* [11], and the Papua New Guinea *Tsembaga* [12] relied on diets that were high in carbohydrates, including fiber, but low in fat, particularly saturated fats. Stability and abundance was ensured with the establishment and specialization of agriculture for the expanding populations. Cereals, legumes, and starchy foods became predominant dietary staples. Food was polysemic and served roles beyond sustenance. For instance, cultural anthropologists note that the first domesticated animals and plants were primarily bred and cultivated to be used as foods during feasts and for trading; they were symbols of power and status in addition to serving a hunger need [13]. Although the agriculture-oriented food system at that time ensured food security, it was limited in its resiliency to withstand shocks and vulnerabilities, such as droughts or floods that led to production swings and unpredictable availability [14]. *Stages 2 and 3* were marked by gradual decreases in diet diversity compared to *Stage 1*. Populations were subject to cycles of plenty and scarcity caused by migrations, political conflicts, overuse and degradation of natural resources, including soil fertility, arability, and unpredictable climatic conditions [8]. History is replete with instances of geographical regions subjected to such vulnerabilities resulting in famines, increased nutritional deficiencies, and a generalized weakened food supply with a growing dependence on foods from elsewhere [14]. Concomitantly, demographic changes marked by expanding populations and sociocultural and economic factors led to stratification by gender and social status, inequities, and unequal access to food and other basic necessities [15]. Historical records note the overall decline in health and nutritional status, citing maladies such as dental caries, anemia, and enamel defects, reduced stature and cortical bone thickness in various geographical locations [16, 17], yet through this period, little was known about the incidence and prevalence of non-communicable diseases.

2.3 The Globalization of Food

By the turn of the twentieth century, food procurement no longer remained an isolated activity that fostered self-reliance and kinship. Instead, the era's prevailing political, socioeconomic, and technological environments influenced food-related activities. For instance, the industrial revolution, rise of mechanization, new seed varieties, and the introduction of synthetic fertilizers caused massive shifts in the production, processing, distribution, and consumption of foods. The Green Revolution in South Asia in the 1960s and 1970s was credited as a success for its increased global yields; however, the following decades witnessed its consequences in the form of greater socioeconomic divides, poverty, catastrophic environmental degradation, and farmer suicides [18]. Parallel advancements in medicine; immunizations; antibiotics; sanitation and access to safe, good-quality water; the discovery of micronutrients; and, more recently, the expansion of healthcare technologies, e.g., telemedicine [19, 20], have since facilitated gradual improvements in the public's health.

Agriculture in the 1980s became a "global phenomenon" as its focus shifted from one of "traditional or indigenous foods" to a "cash crop" economy. Sugarcane, palm oil, wheat, soy, and animal source foods became agricultural trading commodities moving to the forefront to meet processing demands [21]. At present, the scope of the food system has broadened from one of ensuring adequate food supplies to that of a financial enterprise governed by consolidation, economies of scale, money, and markets [22–24]. Selective breeding techniques, biotechnology, genetic engineering, fortification, enrichment strategies, expansion of the functional foods and nutraceutical categories, novel food processing and packaging technologies, and the introduction of information and communication technologies (ICTs) have facilitated increased yields of agricultural commodities, product innovation, diversification, and volume production of value-added processed and ultra-processed foods [25]. Precision agriculture or site-specific farming that combines global positioning systems (GPS) and geographic information systems (GIS) to monitor climatic conditions and provide farmers site-specific information is one such innovation in the agriculture realm [26, 27]. Farmers use this information to efficiently utilize and monitor their agricultural environments for crop planning, soil sampling, pest control, application, and yield mapping, mitigating several climatic fluctuations of previous centuries.

Advances in retailing, marketing, advertising, and the introduction of formalized markets provide a platform to inform and sell consumers the cornucopia of processed foods with different qualitative and nutritional attributes. Improved transportation, the development of domestic and international markets fueled by the expansion of global trade, and the introduction of high speed connectivity ensure better global food systems management while guaranteeing food access to large populations worldwide [27]. Continued urbanization, expanding populations consequent to global migration, and natural increases provide the necessary consumer base that sustains demand for these products. Further, the liberalization of trade policies is a key facet of the twenty-first-century globalization phenomenon facilitating trade across national borders. Low- and middle-income countries (LMICs), such as China, India, and Brazil, recognize the incentives and economic advantages of market-oriented agricultural policies [22] and have gradually liberalized their agricultural markets both domestically and internationally. Imports, exports, consolidation and merger activity in the food system, foreign direct investments (FDI), and the establishment of transnational food and beverage companies [28] have boosted economic developments in their food sectors [22]. Transnational entities such as Coca-Cola, PepsiCo, Nestle, Kraft, Carrefour, Danone, and Walmart have consequently expanded their markets and gained a significant foothold in emerging economies such as China, India, Brazil, and Mexico, thereby changing the scope and nature of these countries' food systems [29, 30].

2.3.1 Changing Trajectory of Populations' Lifestyles

The evolution of the globalized food system has proven to be a double-edged sword. Depending on the degree, pace of industrialization and globalization, different parts of the globe have experienced a mixed bag of positive and negative consequences and health outcomes [31, 32]. On the one hand, enormous economic developments and benefits to health and nutritional status have accrued in industrialized societies and the LMICs transitioning to *Stage 4* of the NT process [3]. Incomes have risen for many, poverty has declined, standards of living have improved, healthcare is more accessible, and these societies have seen a wider variety of processed foods, energy-saving devices, and technologies. Easy access to a globalized food system has fostered increased and varied consumption patterns worldwide, changing the trajectory of cultural foodways, value systems, human behaviors, and lifestyles of global populations [33, 34].

On the other hand, myriad challenges signaled by nutritional imbalances consequent to dietary pattern shifts, occupation-related stress, sharp divides in socioeconomic status, inequities in healthcare access, and chronic disease trajectories have risen for selected population segments such as the poor, women, and children [35]. A major consequence is the increased reliance on and dietary convergence of food components such as fats and oils, sugars, animal products, and processed and prepared products, all at the expense of traditional, indigenous foods [36]. High-, middle-, and low-income countries experience concomitant dietary pattern changes, such as increased portion sizes, eating out, and snacking frequency at varying rates [37, 38]. These patterns, coupled with a high degree of dietary convergence, are collectively referred to as the "Westernized diet or dietary patterns" [21, 36]. For instance, in the United States between 1977 and 2006, the overall energy intake from sweetened beverages increased by 135% while that from milk decreased by 38% [39, 40]. Sugar-sweetened beverages contributed a substantial amount of energy to the diet of Australian children, with mean intakes ranging from 4% in children 2–3 years of age to 7.5% in adolescents [41]. Mexico had the largest per capita (163 liters) intake of soft drinks in 2011 [42]. A market data analysis between 2000 and 2013 for ultra-processed food consumption by Euromonitor International for four lower-middle-income, three upper-middle-income, and five high-income Asian countries raised concerns about the growth in the carbonated soft drinks sector in the LMICs while their sales were declining or stagnating in high-income countries such as the United States [34]. Specifically, soft drink sales and volume were reported to be high in Thailand and in the Philippines, while sales of oils and fats were high in Malaysia.

Since the mid-1950s, developed countries have used specialized technologies such as oilseed breeding and oil extraction techniques to increase seed oil content, contributing to the widespread availability of cheap vegetable oils such as soybean, palm, and canola oils in LMICs of Asia and Latin America [43]. Between 1985 and 2010, vegetable oil consumption increased three- to sixfold in LMICs such as India and China. In India, the consumption of edible vegetable oils in urban and rural areas rose from 24 g/day to 36 g/day and 36 g/day to 48 g/day, respectively [44]. Data from China indicate that between 1994 and 2004, edible oil production increased nearly twofold in China, and 83% of the population had cooking oil intakes over 28 g/day by 2010 [45]. Shifts in easy accessibility to vegetable oil [46], increasing market concentration in other food sectors, e.g., the beverage industry, coupled with growing fast food sales [21] have and continue to contribute to increased dietary fat intakes and global obesity rates.

2.3.2 Is the Nutrition Transition Experience Different Between the Developed and Developing World?

Despite varied and limited global epidemiological data on diet and physical activity, certain key differences exist between developed and developing countries. Developed countries, like the United States, carry a large burden of heart disease, cancer, diabetes, chronic pulmonary, and mental disease with a lower proportion of infectious diseases [47].

Stage 4 Since the 1980s, these countries have experienced *Stage 4* of the transition phenomenon with massive shifts in dietary and physical activity patterns resulting in body composition changes [32]. Adiposity, marked by a high BMI with the associated chronic inflammation and oxidative stress, is one of the well-documented risk factors at the nexus of the NCD concerns in this part of the world. Considerable scientific evidence reports that the high glycemic load, undesirable dietary fatty acid composition, altered macro- and micronutrient status, disturbed acid-base balance, unbalanced sodium and potassium ratios, and decreased dietary fiber content exacerbate the morbidities associated with NCDs [36].

Increasing dietary convergence to a more processed, westernized diet, a decline in traditional, indigenous food consumption, sedentary lifestyles, changes in average stature and body composition, and NCD morbidity and mortality are reflective of the LMICs transition phenomenon [21]. The complexity of these transitory changes and their contextual occurrence are noted by Corinna Hawkes as particularly pertinent to the nutrition-related non-communicable diseases or *Stage 4* in the nutrition transition spectrum. In a recent ecological analysis using multiple regression and cluster analysis on a sample of 98 countries across the globe, Oggioni et al. studied the association of obesity and diabetes with the agricultural, transitional, and Westernized dietary patterns. The Westernized dietary pattern had a direct dose-response association with diabetes prevalence, while the agricultural diet had the lowest prevalence of obesity and diabetes association [48]. Yet the NT experience of the LMICs is different and unique for several reasons.

First, the NT and disease pattern shifts in the LMICs of Asia, Africa, the Middle East, Latin America, and Oceania are occurring at an accelerated pace. Compared to the nearly five decades of transitory changes in the industrialized world, the LMIC transition has occurred over the last two decades. Further, the simultaneous population expansion consequent to a demographic transition from a high fertility and mortality pattern to one of low fertility and mortality has exacerbated the situation [49].

Second, according to Popkin [31, 32], there is considerable intra- and inter-country heterogeneity in transition patterns and health outcomes within and between different population segments. Ecological, internationalization, political, technological, and socioeconomic climates that prevail in the individual countries and/or regions during the transition phases are responsible for this heterogeneity. For instance, within Asia, China experienced great shifts in dietary and physical activity patterns between 1985 and 2000, while India's transition is still in the early stages and gaining momentum in urban areas [50, 51]. While the Chinese experience a high burden of hypertension followed by diabetes and cardiovascular disease, diabetes rates and susceptibility to cardiovascular disease in the South Asian region have skyrocketed in the last decade. India ranks highest in the world for diabetes incidence; Bangladesh accounts for 40% of all diabetes among the least developed countries and 10% of Pakistanis suffer from diabetes [52–54].

Third, obesity rates in many LMICs are two to five times greater than those of the industrialized countries with stark changes in specific subsets of the population – the poor, women, and children [55]. The UNICEF–World Bank–WHO group reports that the overweight prevalence in children is on the rise; between 1990 and 2014, the numbers have risen from 31 million to 41 million [56]. Since 2000, obesity rates for children under 5 years of age have risen by more than 50% in Africa and 40% in Asia [57]. Myriad reasons are fueling the obesity pandemic across the lifespan, increasing vulnerability and impacting health outcomes. These include unhealthy food choices, energy imbalances caused by sedentarism, chronic stress, and genetic and ethnic body composition predispositions that favors adiposity [58, 59]. Further exposure to environmental toxins, inequities in income and healthcare, healthcare systems that are unable to simultaneously handle chronic diseases caused by under- and overnutrition, and epigenetic fetal programming changes only make the situation worse [59].

2.3.3 A Growing Double Burden of Disease

The rising prevalence of obesity promotes a misconception that communicable and nutritional deficiency diseases are eradicated and supplanted by obesity and NCDs. However, this is far from reality [60]. Instead, global epidemiological data reflect the concurrent existence of undernutrition and overnutrition referred to as *the double burden of disease*. Compared to the developed world, the LMICs experience disproportionately large problems given the rapid globalization, economic growth, and population expansion these countries face [61, 62]. LMICs have always experienced a high incidence and prevalence of undernutrition, infectious and deficiency diseases driven by socioeconomic challenges, poverty, food insecurity, famine, and poor healthcare quality, access, and utilization. However, with nutrition and epidemiological transitions, LMICs face the additional challenge of a rapid increase in obesity and overweight status. Accompanied by pathophysiological metabolic risk mediators such as hs-CRP, IL-6, obesity increases vulnerability to NCDs across the lifespan [63]. According to the annual WHO report, nearly 40 million people succumb to NCDs, accounting for 70% of all global deaths. Approximately 17 million die before age 70 and 87% of these premature deaths occurred in LMICs [64]. The metabolic syndrome, in which abdominal obesity and insulin resistance play a central role, is associated with a doubling of cardiovascular disease risk [65].

In a recent pooled analysis of 1698 population-based studies consisting of over 19 million male and female participants in over 180 countries, the prevalence of overweight and underweight using body mass indexes (BMIs) was studied over the 1975–2014 period. BMIs increased from 21.3 (1975) to 24.2 (2014) in men and from 21.7 to 24.6 in women, respectively [66], with some regions experiencing more accelerated rates than others. For instance, regional BMIs were highest for men (21.4–29.2) and (21.8–32.8) women in South Asia and the Polynesian islands, respectively. The prevalence of being underweight globally decreased from 13.8% to 8.8% in men and 14.6% to 9.7% in women; however, South Asia had the highest prevalence of underweight individuals at 23.4% and 24% in men and women, respectively. In 2014, of the 667 million children under five in the world, 159 million were stunted and 50 million were wasted [56].

Short-term consequences of the double burden of disease include malnutrition-related stunting and premature child deaths and compromised immunity, physical development, and cognitive abilities; long-term consequences include obesity, NCD-associated morbidities, and mortality. Ultimately this results in a lower productivity and quality of life in adulthood and higher healthcare costs [67]. The impact of these changes is variable between urban and rural populations, escalating with increased migration and changing food environments. The healthcare systems in LMICs lack the capacity and governance to address the double burden efficiently and adequately and the costs of treating NCDs are rising, consuming larger proportions of health budgets in LMICs. Initiatives such as the Millennium Development Goals, which were originally designed to combat undernutrition, are underway and need to keep pace with the NCD trajectory [68].

2.3.4 The Overlap Between Undernutrition and Overnutrition

The causes and consequences of both undernutrition and overnutrition as distinct health status entities are well described [48]; however, recent WHO reports and research from Africa, Mexico, the Middle East, and South Asia [69] highlight overlap of these two conditions, sometimes within the same household or individual. While the poor and uneducated are disproportionately affected, of particular concern are the long-term consequences in women at the population level [70–72]. At the individual level, the common manifestation of the double burden is the dual occurrence of energy imbalance and micronutrient deficiency. For example, between 1990 and 2005, obesity rates in West Africa increased by 114%, with more women affected than men [73]. In urban Burkina Faso, 73 out of 310 apparently healthy adults had one marker of overnutrition concurrently with at least one nutritional deficiency [61]. Studies using nationally representative data from three developing countries, Mexico, Peru, and Egypt, showed that overweight women were deficient in iron and other micronutrients such as vitamin A [74]. Reports from Sub-Saharan Africa note that while obesity is more prevalent among the affluent, more than 20% of women have BMIs of less than 18.5, 57.1% are anemic, and 18.5% are deficient in vitamin A [75, 76]. At the household level, the most common occurrence is a stunted child coexisting with an overweight mother [77]. The WHO classifies a country as experiencing a double burden of disease when at least 30% of children under 5 years old are stunted with an age-adjusted overweight rate for females above 25% [69].

Researchers interested in the fetal origins of adult-onset disease view undernutrition and overnutrition as being linked at the level of developmental programming and metabolic adaptation in the fetus, with important health consequences as individuals age and their environments change [78, 79]. In this regard, the double burden of disease in LMICs poses a threat both as a metabolic programming consequence of maternal undernutrition and a cause for NCDs in adult life. Epidemiologists attribute the NCD incidence in LMICs to perinatal and postnatal influences and reduced birth weight [80–82]. While public health focus continues to center on the mitigation of undernutrition [83], there is consensus that undernutrition, obesity, and NCDs are linked through the processes of developmental programming and metabolic adaptation that require immediate attention and action [84].

2.3.5 Metabolic Programming and NCDs

Developmental programming and metabolic adaptation are the major principles underlying the fetal origins of adult-onset diseases (FOAD) hypothesis, also known as the developmental origins of adult disease proposed by Barker in 1986 [85]. According to Barker, "adverse influences early in development and particularly during intrauterine life can result in permanent changes in physiology and metabolism, leading to an increased disease risk in adulthood" [86]. Prenatal insults include acute and chronic nutritional deficiencies, environmental influences such as smoking, exposure to endocrine disruptors, limitations in maternal physical stature, exposure to steroid hormone excesses, and maternal physiological and psychosomatic stress marked by elevated glucocorticoid hormones. These adverse influences pose several constraints during critical periods of fetal development, consequently altering tissue and organ development, structure and function which are also referred to as developmental programming [75, 87]. For instance, lowered intra-uterine protein availability can modify pancreatic islet cell proliferation, causing future alterations in glucose homeostasis [88]. Undesirable fetal developmental programming in a compromised nutritional environment results in dysfunctional metabolic capacity and physiological function as future consequences. For instance, in utero stresses alter mitochondrial activity that influence the function of oxidative phosphorylation linked to skeletal muscle insulin resistance in type 2 diabetics [89]. The ensuing metabolic maladaptations in early life owing to inadequate maternal nutrition reflect the development of a thrifty phenotype with an altered metabolism that is beneficial to the survival of the fetus and anticipatory of a similar future postnatal environment. However, a mismatch occurs when there is a discrepancy in this expectation upon exposure to a food and a nutrient-rich environment, resulting in a greater susceptibility eventually culminating in obesity and metabolic disease [90]. While epidemiological and animal studies have garnered a large body of evidence, the mechanisms are yet to be elucidated. Suggested mechanisms include permanent alterations in cell numbers affecting structure and function of organs, inheritable epigenetic changes that affect DNA methylation patterns consequent to an altered maternal nutrient supply. These alterations potentially mediate the metabolic priming process very subtly through gene expression modulations [87, 91].

2.4 Pathophysiological Consequences of NT

Just as the germ theory provided a monocausal focus for infectious and communicable diseases [92], modern lifestyles are proposed as a major contributor to the NCD pandemic. Egger and Dixon [93], in a recent review on chronic disease determinants, describe the role of “anthropogens” in the etiology of meta-inflammation [94]. Anthropogens are man-made environments, their by-products and/or lifestyles encouraged by these, some of which may be detrimental to health [93]. Meta-inflammation is a low-grade, chronic systemic inflammation linked to a dysfunctional immune response. It differs from the classic, acute inflammatory response to infection and injury initiated by the body’s innate immune system [95] in the following ways: first, chronic inflammation is low grade with systemic effects causing small rises in immune system markers such as proinflammatory cytokines, e.g., TNF alpha, hs-CRP, and interleukin 6; second, it is persistent, resulting in a chronic activation of the immune and neuroendocrine systems in an effort to bring about homeostasis; and third, it perpetuates a chronic, dysmetabolic state induced by anthropogens [93]. Although obesity is thought of as a prerequisite [96, 97], several behaviors linked to post-industrial, globalized lifestyles, e.g., poor diets, inactivity, stress, inadequate sleep, occupation, prescription and non-prescription drugs, smoking, toxic exposures, dysfunctional relationships, the social factors that encourage such lifestyle patterns over time, and the obesogenic environments in which they occur, e.g., technology, environment, occupation, air pollution [98], and endocrine-disrupting chemicals [99] are also pro-inflammatory. Viewed in the broader social, economic, and environmental contexts, anthropogens are extremely detrimental to human health. Anthropogens foster a chronic stress milieu, promoting a low-level, sustained chronic inflammation response. The innate immune system and the central stress axes are constantly activated without opportunity for the resolution and termination of the natural inflammatory response as seen in the acute stress response [95]. The proinflammatory cytokines either cause or are caused by dysmetabolic responses, leading to core imbalances in one or more of the body’s physiological systems [100]. For example, unhealthy, calorie-dense, highly processed diets increase NCD risk, while feasting, cultural foodways, and changing food habits can act as moderators to enhance or decrease risk; chronic stress determined by an individual’s coping capacity leads to elevated adrenocortical hormones and activation of the hypothalamic–pituitary–adrenal axis resulting in a host of vascular, metabolic, and inflammatory processes; obesogenic endocrine-disrupting chemicals (EDCs) and persistent organic pollutants (POPs) are documented to cause significant physiological and behavioral changes, e.g., increased appetite, ultimately contributing to obesity. Individual responses to the anthropogens are not uniform and dictated by genetic and epigenetic predispositions, as well as fetal programming [93, 101].

2.5 Anthropogens and Chronic Inflammation

Inflammation is the body’s natural response to damage after injury or pathogen invasion. It is a self-limiting process consisting of an initiation, a resolution, and a termination phase. Its action is controlled by the synergistic roles of the innate immune system, the sympathetic nervous system, and the hypothalamus pituitary adrenal axis [95, 102]. The stress axes are involved in the response primarily through the action of norepinephrine and cortisol by modulating insulin and cortisol sensitivity. The efficiency of the response depends on the capability of the glucocorticoid and catecholamine receptors of the innate immune system. The inflammatory response is initiated by polymorphonuclear neutrophils that generate proinflammatory cytokines like leukotriene B4 and prostaglandins from arachidonic acid with the help of lipoxygenase 5 and cyclooxygenase 2 enzymes. While the leukotrienes exert their strong chemo-toxic response to the invading pathogen or stimulus, the prostaglandins regulate the switch to the second or resolution phase when their concentration equals that of the leukotrienes primarily by limiting the lipoxygenase enzyme activity. This phase is marked by high anti-inflammatory activity as seen in the production of specialized pro-resolving mediators (SPMs) such as *lipoxins*, *resolvins*, *protectins*, *and maresins* from eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) [103, 104]. SPMs are described recently to be involved in myriad mechanisms that promote the resolution and termination of the inflammatory response, such as switching off the stress axes, enhancing microbial clearance through generation of non-cytotoxic macrophages. Both omega-6 and omega-3 fatty acids play critical roles in their biosynthesis and are expected to be of potential therapeutic value in microbial defense, pain, organ protection and tissue regeneration, wound healing, cancer, reproduction, and cognition [105–107].

2.5.1 Behavior Change for Positive Vitality

Stage 5 A growing awareness of the negative consequences of NCDs and/or the diagnosis of a chronic disorder such as diabetes prompts motivated individuals and communities to try and adopt a healthy lifestyle through behavior modification strategies. Stage 5, referred to as the behavior change stage, encompasses the various initiatives at the individual and population level that prevent or delay degenerative diseases and prolong life through healthy aging. It includes the practice of salutogenic behaviors that promote robust lifestyles, such as eating healthy foods, stress reduction, and increased physical activity. Healthy aging is "the condition of being alive, while having a highly preserved functioning of the metabolic, hormonal and neuroendocrine control systems at the organ, tissue and molecular levels" [108, 109]. Maintaining functional organ reserves and biological resiliency or the ability to adapt and/or withstand environmental stressors are at the core of the healthy aging concept. Furthermore, it is well recognized that healthy aging can be successful, provided a holistic multidimensional approach that addresses environmental, physiological, and psychological factors and healthy lifestyles is taken. For instance, a multifactorial behavior modification approach that includes programmed exercise activities, stress-reduction techniques like yoga and meditation, eating healthy foods like fruits and vegetables, and purchasing organic foods due to environmental concerns [110] can independently and synergistically contribute toward building and sustaining biological resiliency over the course of a lifetime. Personalized lifestyle medicine is one such approach that builds on the healthy aging concept using a combination of functional medicine principles [111] and innovative emerging *omic* technologies such as genomics, epigenetics, and diagnostic assessment tools [100]. Identifying the root cause of the disease rather than a symptom resolution approach, assessing for antecedents, triggers, and mediators, and keeping the biological uniqueness of the individual in perspective are major principles of functional medicine [112, 113]. Specialized assessment techniques such as nutrition-focused physical assessments and other functional diagnostic assessments, such as organic acid testing for assessing mitochondrial health and stool tests for gut permeability, are then employed to analyze an individual's NCD health metrics. Genomic analysis and testing [114, 115], molecular diagnostics, and tailored biomarkers are examples of specialized functional diagnostic techniques that provide personalized assessments and advice so that treatments can be individualized. They have the potential to improve health outcomes by developing sustainable lifestyle medicine-oriented strategies, empowering individuals so that they can be in control of their health [116–118] as well as facilitate the identification of clinical imbalances at an earlier stage before they become pathological.

2.5.2 Initiatives Addressing the Nutrition Transition

Nutrition transition underscores the need for all nations to build healthcare capacity and infrastructure, regardless of their economic status, to address the dual burden of malnutrition. This requires immediate action which necessitates healthcare and nutrition policies in developing countries to offer a more comprehensive integrated approach to address both undernutrition and overnutrition simultaneously. In a recent review of nutrition policies of 36 low-income, 48 low- and middle-income, and 55 upper-middle-income countries, only 39.6% had nutrition policies that addressed the dual burden of disease, while a majority of the countries' nutrition policies continue to focus on the mitigation of undernutrition [119]. The study further pointed out that having a nutrition policy in place did not necessarily translate into positive health outcomes. This highlights two important issues.

The first is the importance of a strong governance to facilitate the translation of the nation's policies into sustainable action and initiatives that are context-specific to individual countries [119]. Strong governance entails (1) stewardship; (2) development of surveillance systems that facilitate early detection of NCDs; (3) collaborative partnerships between stakeholders such as government, industry, health sector, consumers, and policymakers; (4) learning from previous experiences in other countries; and (5) strengthening the evidence base to enhance and support the design and implementation of health-promoting interventions [120–123].

The second is the need to focus policies that take on a life course approach to a healthy diet and physical activity lifestyle using culturally appropriate methods and messages initiated early in life [124]. This is the focus of the World Cancer Research Fund International's ongoing NOURISHING framework [125] for obesity prevention in 11 high-, middle-, and low-income countries (Fig. 2.2). The policy recommendations span across three critical factors that impact healthy eating and physical activity: food environment, food system, behavior change, and communication. This framework informs governments in these countries regarding appropriate interventions, such as restricting marketing of unhealthy foods to children, salt reduction strategies, using existing policies designed for combating micronutrient deficiency to simultaneously address the obesity problem by promoting local fruits and vegetables via local farm networks. Another major initiative is the Global Strategy on Diet, Physical activity, and Health action plan aimed at prevention and control of NCDs between 2013 and 2020. The action plan resulted from a multi-stakeholder consultation process consisting of the WHO member states, relevant UN agencies, funds and programs, international financial institutions,

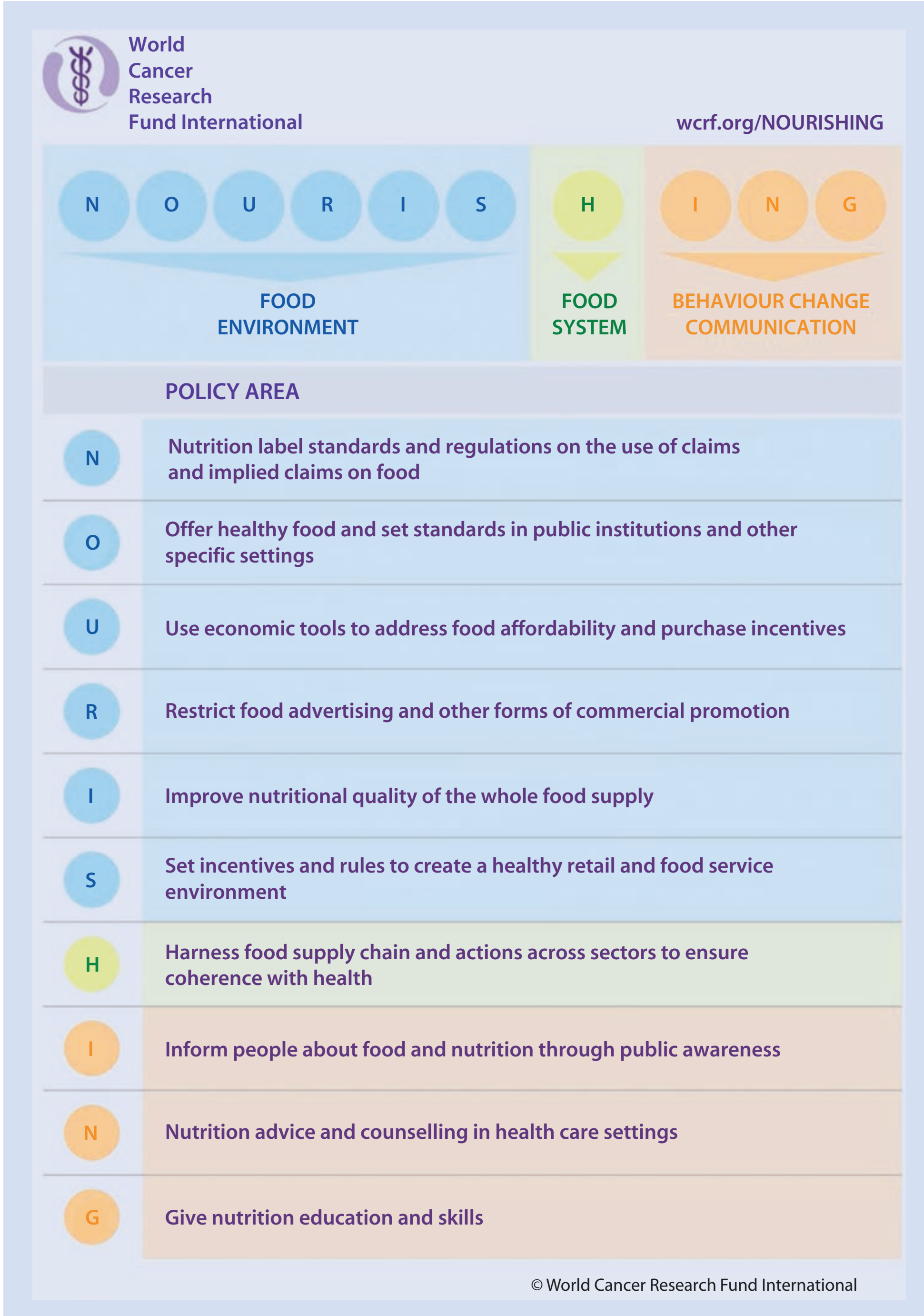

Fig. 2.2 Nourishing framework. (Used with permission from World Cancer Research Fund International. Wcrforg. 2017. Available at: ► http://www.wcrf.org/int/policy/nourishing-framework)

banks, NGOs, professionals, academicians, the civil society, and the private sector [126]. It operationalizes the tasks articulated in the Political Declaration of the General Assembly's initiative on the prevention and control of NCDs. The action plan focuses on four major chronic diseases, namely, cardiovascular disease, cancer, chronic obstructive pulmonary disease, and diabetes; several chronic conditions, e.g., mental illness; disabilities; and four shared behavioral risk factors – tobacco use, unhealthy diet, physical inactivity, and harmful use of alcohol [126–128]. While the WHO leads and coordinates the plan through engagement, international cooperation, and collaboration, the individual governments are responsible for action and monitoring. The overarching principles are as follows:

1. Highest quality and standard of health is a fundamental human right.
2. Social determinants of health should be addressed to create equitable, productive healthy societies.
3. Member governments and international agencies should create alliances and foster high-level multi-sectoral engagement.
4. A life course approach starting at preconception moving through healthy aging in later life will lead to sustainable health outcomes.

5. Communities should be engaged at all stages of planning, implementing, evaluating, and monitoring to ensure empowerment and motivation for sustained success.
6. Evidence-based and/or experiential-based best practices that are cost-effective, affordable, and culturally congruent should be implemented.
7. All segments of the society should have access to safe, affordable, effective, and quality-based promotive, preventive, curative, and rehabilitative services.

2.6 Conclusion

It is apparent that NCDs are the most pressing challenge at the present time. They pose a threat to healthy aging for global communities, irrespective of their stage of socioeconomic development. At the same time, it is important to not lose sight of the communicable and nutritional deficiency diseases that persist across large segments of the globe. It is important to recognize that malnutrition at either end of the spectrum is distinctive in etiology and physiological manifestations yet, in fact two sides of the same coin. Undernutrition and overnutrition share certain common risk factors and are multifactorial in their etiology, and the need for their control and prevention cannot be underscored.

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