A LITERATURE REVIEW: THE BENEFITS OF A PLANT-BASED DIET IN THE PREVENTION OF CANCER ONSET AND RECURRENCE

By

KARROL ANNE SHAW

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Approved by:

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Dr. Mary Marian
Department of Nutritional Sciences

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Abstract

Cancer is currently the second leading cause of death in the United States, and is expected to surpass heart disease as the leading cause in the coming years. Recent research has suggested that adhering to a whole-foods plant-based diet high in fruits, vegetables and unrefined grains, and low in red meat, processed meat, refined grains and added sugars, can assist in the prevention of cancer onset and recurrence. This analysis will explore dietary risk factors associated with the initiation, promotion, and progression of cancer, as well as certain components of a plant-based diet that can aid in the prevention of various types of cancer. An extensive body of evidence in the literature supports the finding that a plant-based diet composed of whole plant foods, in contrast to the traditional western diet high in meat, processed food, and dietary fat, can significantly reduce the risk of developing cancer. For example, a plant-based diet has been shown to positively affect survival rates in colorectal, breast, and prostate cancer. Further studies will need to be conducted in an effort to validate the findings that support the adoption of a whole-foods plant-based diet in the prevention of cancer onset and recurrence.

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INTRODUCTION

Overview of Cancer

Cancer can be defined as a disease that is characterized by the abnormal growth of cells that proliferate uncontrollably.[1] As the second leading cause of death in the United States, it has become a pervasive disease with an estimated projection of 1,688,780 new cases diagnosed in 2017.[1,2] Although the cause of many types of cancers remains unidentified, it is thought that a number of modifiable factors (i.e. dietary choices, physical activity levels, excess body weight, tobacco and alcohol use, etc.) in combination with non-modifiable factors (i.e. heritable genetic mutations, hormonal imbalances, autoimmune diseases, etc.) play a role in the onset of cancer.[2] Depending on the area of the body the cancer has affected and the degree to which it spreads to other areas that are essential to life, cancer can result in death.[1] However, cancer at an early stage is not fatal and progression of the disease can often be prevented through the modification of certain lifestyle behaviors.[1,2] The purpose of this paper is to investigate the connection between dietary choices and the risk of cancer development with a focus on specific plant-based diet modalities such as the Mediterranean diet, the vegetarian diet, the vegan diet, and a Whole-Foods Plant-Based diet.

Cancer is often classified according to "stages" that describe the extent to which cancer cells have proliferated by identifying the size and location of the primary tumor, and whether or not the abnormal cells have spread to other areas of the body.[3] Cancer staging is performed by physicians according to the *TNM classification system*, a tool created by The American Joint Committee on Cancer (AJCC) and the International Union for Cancer Control (UICC).[3] The classification system characterizes the progression of cancer according to the original or primary tumor (T), the extent to which the cancer has spread to nearby lymph nodes (N), and the extent to

which the cancer has spread to more distant areas of the body, also known as the level of metastasis (M).[3] This is a very general method of organizing and describing cancer progression. Classifications often differ for different types of cancers.

Table 1. The *TNM* Classification System[3]		
T (primary tumor)	**TX**	Tumor cannot be measured
	T0	No evidence of primary tumor (cannot be found)
	Tis	Cancer cells present in the most superficial layer of tissue (*pre-cancer*)
	T1, T2, T3, and T4	Describe tumor size and/or amount of metastasis to nearby structures
N (nearby lymph nodes)	**NX**	Nearby lymph nodes cannot be measured
	N0	No evidence of cancer in nearby lymph nodes
	N1, N2, and N3	Describe the size, location, and/or number of nearby lymph nodes with abnormal cancer cell growth
M (metastasis)	**M0**	No evidence of distant cancer metastasis
	M1	Cancer has spread to distant organs and/or tissues

Carcinogens are defined as any agent or substance capable of promoting carcinogenesis, or the transformation of normal healthy cells into cancerous ones.[4] Common causes of cancer include smoking and tobacco use, poor dietary choices, low physical activity levels, sun and other forms of radiation exposure, and infectious agents such as those that lead to human immunodeficiency virus (HIV)/acquired immunodeficiency syndrome (AIDS) and human papilloma virus (HPV).[4] The International Agency for Research on Cancer (IARC), a branch of the World Health Organization (WHO), identifies carcinogens according to their relative carcinogenicity to humans as seen in Table 2.[4]

Table 2. IARC Classifications of Carcinogens[4]

Group 1	Carcinogenic to humans
Group 2A	Probably carcinogenic to humans
Group 2B	Possibly carcinogenic to humans
Group 3	Unclassifiable as to carcinogenicity in humans
Group 4	Probably not carcinogenic to humans

Because cancer is a condition in which cells proliferate uncontrollably due to changes in gene regulation, it is considered a genetic disease.[5] Genes contain the information necessary for cells to produce proteins, some of which regulate the extent to which cells grow and divide.[5,6] Genetic causes of cancer have been extensively studied, and have concluded that cancer is the result of the dysregulation of the genetic blueprint designed to uphold natural cellular development and division.[5] This dysregulation is the result of somatic mutations in the coding sequence of genes that encode for such proteins, with only a small fraction being attributable to inheritable single-gene disorders according to Cheetham et al.[5]

Common cancer therapies include surgical intervention to remove the diseased area, chemotherapy drugs to target and destroy cancer cells at specific phases of the cell cycle, radiation therapy through the use of high-energy waves to destroy cancer cells, targeted therapy as a method of more precisely attacking cancer cells, and immunotherapy utilizing the body's own immune system through stimulation and supplying immune-enhancing components allowing the body to attack its own cancer cells.[7] The preferred choice of therapy is often dependent on the location and stage classification of the disease, as well as the patient's current clinical status.

Cancer Statistics

Due to the advances in early cancer detection and the precision of modern targeted cancer therapies, cancer survival continues to increase in the United States.[8] Incidence and mortality data tend to vary according to selected cancer types, with the variation being much larger for certain types of cancer over others.[8,1] Incidence and mortality estimate data from the American Cancer Society's most recent edition of *Cancer Facts and Figures 2017*, ranked according to the leading sites of cancer, can be found in Tables 3 and 4.[1]

Data provided by the American Cancer Society regarding the lifetime probability of developing cancer also demonstrates the widespread and invasive nature of the disease. According to the society's most recent statistics, males have a 1 in 3 risk or 39.66% of developing cancer in an invasive site throughout the course of their lifetime, and a 1 in 5 risk or 22.03% chance of dying from cancer in an invasive site.[9] Females also have a 1 in 3 risk or 37.65% of developing cancer in an invasive site throughout their lifetime, and a 1 in 5 or 18.76% risk of dying from cancer in an invasive site.[9]

Table 3. Estimated Incidence Rates for 2017 According to Selected Cancer and Gender[1]					
Male			Female		
Prostate	161,360	19%	Breast	252,710	30%
Lung and bronchus	116,990	14%	Lung and bronchus	105,510	12%
Colon and rectum	71,420	9%	Colon and rectum	64,010	8%
Urinary bladder	60,490	7%	Uterine corpus	61,380	7%
Melanoma of the skin	52,170	6%	Thyroid	42,470	5%
Kidney and renal pelvis	40,610	5%	Melanoma of the skin	34,940	4%
Non-Hodgkin lymphoma	40,080	5%	Non-Hodgkin lymphoma	32,160	4%
Leukemia	36,290	4%	Leukemia	25,840	3%
Oral cavity and pharynx	35,720	4%	Pancreas	25,700	3%
Liver and intrahepatic bile duct	29,200	3%	Kidney and renal pelvis	23,380	3%
All sites	**836,150**	**100%**	**All sites**	**852,630**	**100%**

Table 4. Estimated Mortality Rates for 2017 According to Selected Cancer and Gender[1]					
Male			Female		
Lung and bronchus	84,590	27%	Lung and bronchus	71,280	25%
Colon and rectum	27,150	9%	Breast	40,610	14%
Prostate	26,730	8%	Colon and rectum	23,110	8%
Pancreas	22,300	7%	Pancreas	20,790	7%
Liver and intrahepatic bile duct	19,610	6%	Ovary	14,080	5%
Leukemia	14,300	4%	Uterine corpus	10,920	4%
Esophagus	12,720	4%	Leukemia	10,200	4%
Urinary bladder	12,240	4%	Liver and intrahepatic bile duct	9,310	3%
Non-Hodgkin lymphoma	11,450	4%	Non-Hodgkin lymphoma	8,690	3%
Brain and other nervous system	9,620	3%	Brain and other nervous system	7,080	3%
All sites	**318,420**	**100%**	**All sites**	**282,500**	**100%**

Risk Factors Associated with Cancer

According to the *National Cancer Institute*, commonly studied and suspected risk factors associated with the onset of cancer include age, alcohol consumption, exposure to environmental carcinogens, chronic inflammation, diet, hormones, immunosuppression, exposure to infectious agents, obesity, exposure to radiation and excessive sunlight, and tobacco use.[10]

Although cancer can occur during any stage of life, age is considered to be one of the most important non-modifiable risk factors for cancer as the median age for developing cancer is 66 years.[2,10] Frequent cancers associated with advanced age include breast, colorectal, lung, and prostate cancer, while frequent cancers diagnosed among those under the age of 20 years include bone cancer, leukemias, and neuroblastomas.[10]

Alcohol consumption is associated with an increased risk of developing cancer of the upper gastrointestinal tract including the mouth, throat, esophagus, and larynx as well as the liver and breast[10], however a growing body of evidence in the literature, including a study performed by Aluyen et al., does indicate anticancer protective properties of substances present in red wine, such as resveratrol.[10,11]

Known likely environmental carcinogens whose exposure can be harmful include aflatoxins, arsenic, benzene, formaldehyde, emissions from the combustion of coal, mineral oils, radon, and soot, among others.[10] Because they are often present in the food we eat, the water we drink, and the air we breathe, they are difficult to avoid.[10]

Chronic inflammation as a result of prolonged infections, abnormal immune responses, or conditions such as obesity, ulcerative colitis, and Crohn's disease, can result in damage to the body's tissues and thus increase the risk of harmful genetic mutations.[10] Though inflammation is a normal physiological process that aids in the healing of injured tissues, it is important to note

that DNA damage resulting from chronic inflammation over time is the most common method of cancer initiation in such cases.[10,12]

Although they play an essential physiological role in both genders, female sex hormones known as estrogens are known carcinogens and may increase the risk of breast and endometrial cancer in women.[10]

Immunosuppression is often the result of the intake of immunosuppressive drugs, usually as treatment for diseases caused by infectious agents such as HIV/AIDS, Epstein-Barr Virus (EBV) and Human T-Cell Leukemia/Lymphoma Virus Type 1 (HTLV-1).[10]

Ionizing radiation as a result of exposure to high-energy radiation such as x-rays and gamma rays, ultraviolet radiation as a result of sunlight exposure, and tobacco use are also prevalent as common risk factors associated with cancer development.[10]

Finally, there are many studies that discuss the probability that specific dietary components or patterns of dietary behaviors are associated with the increase or decrease in risk of developing cancer[10,15,21-26,33,41-60,67-73], and will be the main focus of this paper.

Initiation, Promotion, and Progression of Cancer in Relation to Nutrition

Conventional stages of carcinogenesis throughout history have been divided into: cancer initiation, the result of an irreversible genetic mutation likely from a small change or deletion in the DNA molecule; promotion, or expression of the altered gene that results in increased cellular division; and progression, characterized by the instability and malignancy of the cellular division that results in a malignant tumor, as outlined in Figure 1.[13]

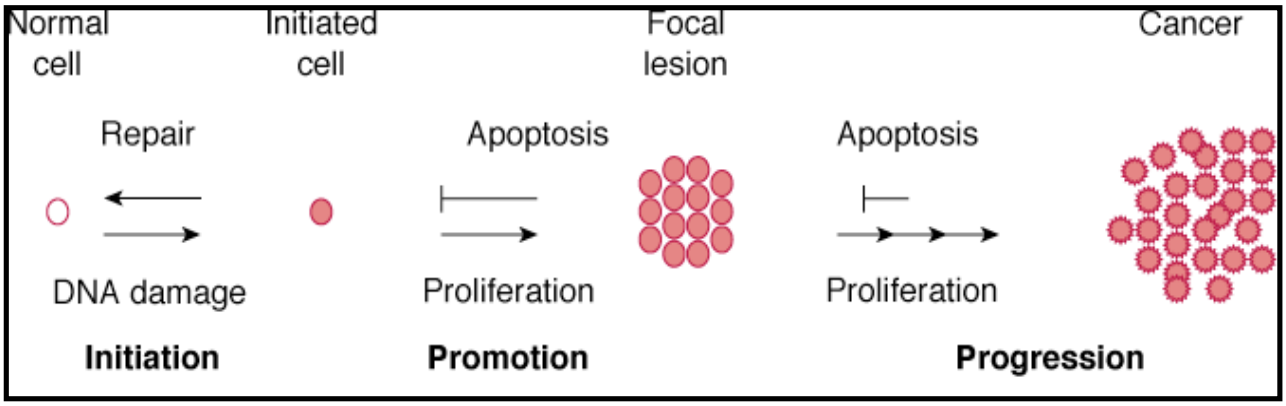

Figure 1: Stages of Carcinogenesis[13, 14]

The effect of nutrition on cancer initiation can be described as the result of a chemical carcinogen present in the food consumed and its perceived effect on the formation of a genetic mutation, leading to the enzymatic activation of the altered gene and production of a mutated cell with the ability to divide uncontrollably.[15] However, other factors can affect the initiation of cancer development by introducing environmental and biological mechanisms that affect the reactions within the cellular environment in such a way as to increase or decrease the expression of genes, a process known as epigenetics.[15,16] Ravegnini et al. describe a variety of epigenetic mechanisms including DNA methylation, histone modification, and participation of non-coding RNA sequences[17]; it is thought that modifications of such epigenetic mechanisms may indicate possible methods of reversing or reducing the risk of disease onset.[15,17]

One important characteristic of epigenetics is known as pleiotropy, defined as the phenomenon in which one gene is responsible for affecting multiple phenotypes[18], or rather multiple downstream effects as a result of one single molecular function.[15,18] This concept can further be applied to the topic of nutrition, in which the effects of a single nutrient on a gene may produce multiple phenotypes referred to as polymorphisms, or the ability of a variable to take on multiple forms, depending on the genes of the individual.[15,19] One clear example of this in the

study of nutrition is the protective effect of vitamin D on colorectal cancer through modification of the vitamin D receptor gene by the way of single nucleotide polymorphisms.[19]

However, a very broad lens is required when discussing such effects of a single nutrient, as nutrients are most often consumed through whole foods, rather than a single vitamin or mineral supplement, and thus contain a variety of nutrients and their metabolites. These all may play a role in a variety of nutrient-nutrient interactions during digestion, absorption, and other metabolic processes that take place within the body.[15] Therefore, nutrition in relation to cancer prevention must be considered and studied as a combination of many comprehensive effects.

ROLE OF A PLANT-BASED DIET IN HUMAN HEALTH AND NUTRITION

Classification of Common Plant-Based Diets and their Properties

A plant-based diet is a diet that emphasizes the consumption of plant-derived foods, including vegetables, fruits, whole grains, nuts, seeds, and legumes. There are a number of plant-based diet modalities currently being evaluated in the literature today, including the Mediterranean diet, the vegetarian diet, the vegan diet, and the Whole-Foods Plant-Based diet. All of these dietary patterns contain a high proportion of whole plant foods relative to the proportions of red and processed meat, dairy, refined sugars, and processed foods.

The Mediterranean diet is traditionally followed in European countries such as Greece, Crete, southern France, and certain areas within Italy.[20] It is characterized by a high consumption of a variety of plant foods and whole grains with olive oil as the primary source of dietary fat, moderate consumption of wine, seafood, dairy products and eggs, and low consumption of red and processed meats and seeds.[20] This dietary pattern has been associated with a reduced risk of cancer, among other chronic disease states, and has been shown to serve as a protective measure

against chronic low-grade inflammation.[20,21] It is thought that the biological mechanisms associated with this diet responsible for the prevention of cancer and chronic inflammation are related to a balanced ratio of omega-3 and omega-6 essential fatty acids, as well as the high intake of plant foods that contain a considerable amount of fiber, antioxidants, phytochemicals, and polyphenols.[20] The antioxidant and anti-inflammatory processes that occur in conjunction with adherence to the Mediterranean diet are thought to act on a number of inflammatory biomarkers including adhesion molecules, cytokines, and others related to the atherosclerotic process.[21]

The vegetarian diet is characterized by the consumption of plant-based foods such as fruits, vegetables, and whole grains in addition to eggs, milk, and dairy products with the elimination of meat, poultry, and seafood from the diet.[22] It is well recognized in the literature that a vegetarian diet consisting of foods high in fiber, phytochemicals, antioxidants, and essential fatty acids is capable of reducing the risk of cancer, diabetes, cardiovascular disease, obesity, and other diseases related to chronic inflammation.[22] However, the lifestyle of the individual following a vegetarian diet may be related to its efficacy; those that consume a vegetarian diet are more likely to engage in regular physical activity and avoid a variety of harmful practices such as smoking cigarettes and frequent alcohol consumption.[22] The vegetarian diet can further be classified into lacto-ovo vegetarians, those that exclude all meat products but permit the consumption of eggs, milk, and honey; lacto-vegetarians, those that exclude all meat products and eggs but permit the consumption of dairy products; and ovo-vegetarians, those that exclude the consumption of all animal products but continue to consume eggs.[22] With relation to cancer specifically, Tantamango-Bartley et al. found that a number of prospective studies that have examined the association between the vegetarian diet in comparison to the more traditional

western diet high in meat, dairy, and processed foods, have found significant associations between following a vegetarian diet and overall protection against cancer.[23]

The vegan diet focuses on the sole consumption of plant-based foods and the elimination of all animal-based products such as meat, poultry, seafood, dairy, and eggs. While a vegan diet can consist of whole plant foods such as potatoes, corn, rice, fruits, vegetables, whole grains, beans, and legumes, it can also contain a variety of processed foods such as refined sugars and grains, refined oils, textured vegetable proteins and soy isolates.[24] In comparison to the traditional vegetarian diet that continues to permit the consumption of eggs and dairy products, those that adhere to a vegan diet tend to consume a lower amount of saturated fat and cholesterol and tend to have lower overall BMIs, lower serum cholesterol levels, and lower blood pressure.[24] However, some micronutrients of concern for those following a vegan diet include vitamin B12, vitamin D, calcium, and long-chain fatty acids.[24,25] For example, vascular studies have indicated impaired function of the arterial endothelium and increased thickness of the carotid intima-media in vitamin B12 deficient populations and may favor the supplementation of vitamin B12 in such individuals.[25]

The clear distinction between the vegan diet and the Whole-Foods Plant-Based diet is the elimination of highly processed food products such as bleached flour, refined sugar, and oil in addition to the elimination of meat, poultry, fish, dairy products, and eggs.[15] The main components of a Whole-Foods Plant-Based diet include fruits, vegetables, whole grains, legumes, nuts and seeds.[15,26] Concerns regarding adequate protein, vitamin B12, folic acid, and iron intake are often topics of debate. These concerns may be addressed with supplementation and are outweighed by the number of positive physiological effects evident in the literature associated with the consumption of a Whole-Foods Plant-Based diet, including a reduction in the

overall risk of developing chronic disease, as well as the introduction of a long-term sustainable solution for many present-day challenges identified in healthcare today.[26] A summary of the most common plant-based diets can be found in Table 5.

Table 5. Common Plant-Based Diets and their Properties[20-26]	
Mediterranean Diet	High consumption of fruits, vegetables, whole grains, and olive oil; moderate consumption of wine, seafood, dairy products, and eggs; low consumption of red and processed meat
Vegetarian Diet	Consumption of fruits, vegetables, whole grains, and other plant-based foods in addition to eggs, milk, and dairy products; elimination of meat, poultry, and seafood
Vegan Diet	Sole consumption of plant-based foods and complete elimination of all animal-based products including meat, poultry, seafood, dairy products, and eggs; permits the consumption of processed plant-based foods such as refined sugars, bleached flour, refined oils, textured vegetable proteins, and soy isolates
Whole-Foods Plant-Based diet	Sole consumption of plant-based foods and complete elimination of all animal-based products including meat, poultry, seafood, dairy products, and eggs; does not permit the consumption of highly processed plant-based foods such as refined sugars, bleached flour, refined oils, textured vegetable proteins, and soy isolates

Effects of Dietary Carcinogens

The human diet includes a wide variety of cancer-promoting agents known as carcinogens, or mutagens, as well as cancer-protecting agents such as antioxidants and phytonutrients. The majority of carcinogens present in the diet induce DNA damage and

mutation through the generation of reactive oxygen species that promote the development and progression of tumor growth.[27,28] Reactive oxygen species are chemically reactive molecules that are formed as a natural byproduct of oxygen metabolism, and they function in numerous roles related to cell signaling and the body's ability to maintain a state of homeostasis.[27,28] These oxygen radicals likely act as initiators in the degenerative process of many diseases such as cancer, cardiovascular disease, and aging.[27] When significant damage to cellular components occurs, the result is a state of oxidative stress in which there is an imbalance between the relative amount of reactive oxygen species in a system and the system's ability to rid itself of the reactive intermediates whose presence can result in oxidative damage.[27,28,29]

Dietary carcinogens can be divided into two categories relevant to the onset of carcinogenesis, the first being microcomponents such as oxidative agents that induce genetic mutations and the second being macrocomponents related to total calorie intake and cancer.[30,31] Reactive species can be generated in a number of ways through the activation of certain chemicals, namely heterocyclic amines (HCAs), which have been given primary focus in recent nutritional research; HCAs are formed during high-temperature cooking of meats in which amino acids (building blocks of protein) and creatine (a compound that resides in muscles) react and can induce oxidation of various cellular components such as lipids, proteins, and DNA molecules.[30] In a study assessing the relationship between high HCA intake and oxidative stress, Carvalho et al. found that there was a positive association between HCA intake and malondialdehyde (MDA) concentration in the plasma, a marker of oxidative stress.[30] Other common dietary carcinogens in the microcomponent subset are mycotoxins, toxic substances produced by fungi, the most common of which is known as aflatoxin and is produced by the *Aspergillus flavus* species of mold[31]; nitrites and nitrates that are commonly found in food

additives for the purpose of long-term preservation or as a food coloring[31]; and dioxins, a highly toxic compound formed as a byproduct of manufacturing operations such as the production of herbicides and paper bleaching, that accumulate in the fatty tissue of animals that humans consume as a food source.[31]

Macrocomponents related to carcinogenesis often include the relationship between total calorie intake, total fat intake, and daily salt intake as mechanisms of cancer onset.[31] The majority of evidence in the literature supports the finding that excess calorie intake and excess body fat have been associated with an increased risk of tumor development; this is likely due to the fact that the excess nutrients that must be digested, absorbed and metabolized produce more reactive oxygen species with the ability to induce DNA damage.[31] Additionally, a high fat intake from saturated animal fat sources have been associated with an increase in cancer incidence rates; however, some controversy remains regarding the anticancer effects of plant-derived fat sources such as corn, safflower, and sunflower seed oil that are high in polyunsaturated fatty acids (PUFAs).[31] Though PUFAs may act to inhibit certain pathways that lead to carcinogenesis, excessive fat and calorie intake that leads to accumulation of fat in the adipose tissue is still demonstrated in studies measuring the extent of cancer development with regards to dietary fat consumption.[31]

A correlation has also been found between incidence rates of gastric cancer and dietary salt intake; the high osmotic pressure generated by damage to epithelial cells due to high salt consumption has been shown to be a precursor to lesions consistent with various gastric cancers.[31]

Nutrition and Chronic Inflammation in Relation to Cancer

Inflammation can be defined as the body's physiological response to an injury or infection of the tissue, and is an indication that the body is attempting to remove harmful stimuli and promote healing.[32] As one of the body's defense mechanisms, acute inflammation is a normal biological response and can often manifest as pain or redness to the area, swelling, immobility, and warmth to the touch.[32] Inflammation can become chronic as a result of a prolonged disease states such as cancer, rheumatoid arthritis, systemic lupus erythematosus, chronic obstructive pulmonary disease, and various irritable bowel disorders including Crohn's disease and ulcerative colitis.[32] It is widely accepted that the state of chronic inflammation can be a key player in the underlying molecular mechanisms responsible for tumorigenesis. Cancers with an etiology related to inflammation have cytokines, growth factors, and reactive oxygen species, all of which are examples of inflammatory mediators, present in the tumor microenvironment.[32]

Human serum C-Reactive Protein (CRP) and Interleukin-6 (IL-6) are two very common and widely tested inflammatory markers that are elevated during the presence of chronic disease states.[33] Comparisons can be made between the concentrations of CRP and IL-6 and nutritional status.[33] A study by Smidowicz et al. assessed these variables and found a relationship between specific dietary patterns and reduced inflammation in humans.[33] According to Smidowicz et al., diet models responsible for a reduction in the chronic inflammatory response, as indicated by decreased CRP and IL-6 levels, include the Mediterranean diet, vegetarian and vegan diets, and the Dietary Approaches to Stop Hypertension (DASH) diet.[33]

Levels of inflammation in the body can also be characterized according to Dietary Inflammatory Index (DII) scores, an evidence-based dietary index that assesses the inflammatory

potential of an individual's diet ranging from a maximal pro-inflammatory diet score to a maximal anti-inflammatory diet score.[36] In one randomized controlled trial by Turner-McGrievy et al., the researchers hypothesized that overweight and obese individuals (BMI 25.0-49.9 kg/m^2) adhering to a vegan diet would have lower DII scores overall and improvements in fiber, carbohydrate, saturated fat, and cholesterol intake.[34] They found that individuals adhering to a vegan diet, vegetarian, and pesco-vegetarian diet had significantly greater improvements in the aforementioned macronutrient profile as well as improvements in DII scores at the 2 month interval.[34] They also found that nutrients that are commonly of concern for individuals following a vegan diet, such as vitamin B12, iron, zinc, and protein, were not significantly different than the other diet groups assessed.[34] Results of DII analysis of this study can be found in Table 6.

Table 6. Dietary Inflammatory Index Analysis in Overweight/Obese Individuals for Turner-McGrievy et al. Study[34]

	Vegan	Vegetarian	Pesco-Vegetarian	Semi-Vegetarian	Omni	*P* value for difference among groups
DII						
Baseline	0.3 +/ 0.6	0.4 +/ 0.6	0.9 +/ 0.6	0.9 +/ 0.6	-0.1 +/ 0.6	*P* = .75
2 months	-1.2 +/ 0.5	-1.0 +/ 0.5	-0.7 +/ 0.5	1.3 +/ 0.6	0.2 +/ 0.7	*P* = .04
6 months	0.1 +/ 0.6	-0.2 +/ 0.7	-0.2 +/ 0.6	0.2 +/ 0.7	-0.5 +/ 0.8	*P* = .97

DII scores were compared with the other groups at baseline and intervals of 2 months and 6 months.[34] At 2 months, individuals adhering to vegan diets as well as vegetarian and pesco-vegetarian had significantly lower DII scores, as evidenced by a *P* value < .05, compared to individuals adhering to a semi-vegetarian or omnivorous diet.[34]

As evidence in the literature supports the finding that specific dietary patterns can influence the levels of inflammation in individuals, as well as the finding that inflammatory mediators contribute to the onset of carcinogenesis, it can be expected that specific diets that influence the level of inflammation in the body may also play a role in carcinogenesis. According to the results of the Turner-McGrievy et al. study, it can be hypothesized that a correlation may exist between vegan and vegetarian diets and lower cancer incidence rates, because they result in lower DII scores and promote less inflammation in the body.[34]

Nutrition and Obesity in Relation to Cancer

In addition to the association between inflammation and cancer, there is also evidence supporting a relationship between obesity and cancer. Recent studies indicate that a state of high body fat increases the risk for obesity-associated cancers.[35-39] Among these are breast, renal, esophageal, gastrointestinal, and reproductive cancers, prevalent in both men and women.[35] Current mechanisms by which it is hypothesized that obesity contributes to cancer progression include altered levels of adipocytokines such as leptin and adiponectin, chronic low-level inflammation that promotes a state of oxidative stress, and increased blood levels of insulin and insulin-like growth factor-1 (IGF-1).[35,36] In addition to their success in lowering inflammation in overweight and obese individuals, there is also evidence to support the success of plant-based diets in the prevention of overweight and obesity status, thereby reducing the risk of cancer onset.[35]

It is believed that obesity creates a microenvironment within the adipose tissues that produces alterations in favor of tumor initiation and progression.[35] Two such alterations are the concentrations of adiponectin, a protein hormone with antioxidant capacity involved in fatty acid catabolism and regulation of blood glucose levels, and leptin, a hormone produced

predominantly by adipose cells that inhibit hunger as a method of regulating energy balance in the body.[35] Adiponectin has been shown to exert anticancer properties by inhibiting tumor growth and metastasis in *in vivo* experiments, and leptin has been shown to activate pathways responsible for cancer cell proliferation.[35] However, in obese individuals, adiponectin levels tend to decrease and leptin levels tend to increase; therefore, the role of adiponectin in tumor suppression is significantly reduced and the effect of leptin on cancer progression is enhanced in states of obesity.[35]

In addition to metabolic alterations that favor tumor initiation and progression, obesity has also been associated with a state of chronic low-level inflammation that can contribute to an increased risk of cancer in obese individuals.[36] The state of chronic inflammation in obese individuals can be characterized by the presence of pro-inflammatory cytokines including IL-1, IL-6, and IL-8, plasminogen activator inhibitor (PAI), various reactive oxygen and nitrogen species (ROS and RNOS respectively), as well as tumor necrosis factor-α (TNF-α).[37] The secretion of these molecules by macrophages, large phagocytic cells present in high concentrations at sites of inflammation, are considered to be major contributors in the transition from acute to chronic inflammation.[37] IL-6, in addition to the other interleukins, has a pro-inflammatory effect that stimulates the proliferation of cancer cells and metastasis; excess body fat increases secretion of PAI that is believed to have carcinogenic properties in the gastrointestinal tract; ROS and RNOS, as previously discussed in this paper, play a role in DNA damage through the oxidation of various cellular components; and TNF-α is a pro-inflammatory adipokine produced by macrophages, neutrophils, and natural killer (NK) cells with the effect of enhancing all stages of cancer development.[37] In addition to macrophages, other inflammatory cells known as neutrophils infiltrate the adipose tissue and strengthen the inflammatory signals

expressed by the macrophages.[37] Figure 2 illustrates the various players involved in the promotion of chronic inflammation in obese individuals and the subsequent effects on adipokine imbalance, oxidative stress, and carcinogenesis.

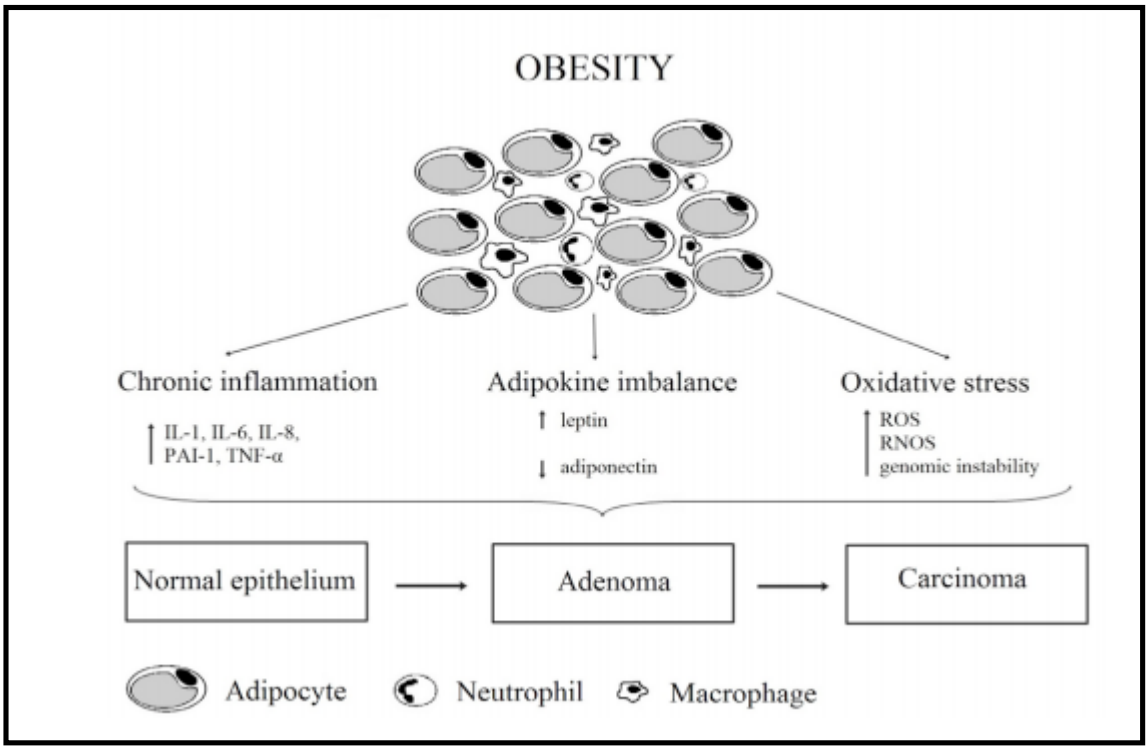

Figure 2. Relationship between Obesity and Chronic Inflammation in Cancer Progression as depicted in Pietrzyk et al. Study [37]

Increased blood levels of insulin and IGF-1 are also associated with cancer progression.[35,36] Hyperinsulinemia and elevated IGF-1 levels are indicative of an increased risk for cancer development.[37] Insulin is produced and secreted by β-cells in the pancreas, and is traditionally responsible for regulating blood glucose levels.[35,36] IGF-1 is produced in the liver when stimulated by growth hormone (GH) and is primarily responsible for stimulating systemic growth and DNA synthesis in most cells of the body.[35,36] However, insulin and IGF-1 can activate pathways that inhibit cellular apoptosis, and thus contribute to cancer progression by

preventing programmed cell death of carcinogenic cells.[35] Additionally, cell growth and proliferation are stimulated by IGF-1 signaling, thereby encouraging a cascade of cellular pathways that stimulate carcinogenic processes.[35]

Studies consistently support the finding that those who adhere to a vegetarian or vegan diet tend to have lower Body Mass Indexes (BMIs) in comparison to their omnivorous counterparts, as well as significantly lower rates of common comorbidities associated with obesity such as cardiovascular disease, type 2 diabetes, and cancer.[38,39] There is also evidence to support the role of vegetarian and vegan diets in weight management strategies.[39] Additionally, the evidence supports that a well-planned and balanced vegetarian and vegan diet can supply all essential nutrients including those that are often cause for concern such as vitamin B12, vitamin D, calcium, and some essential fatty acids.[39] Obesity prevalence is currently estimated at 36.5% of the adults in the United states.[38,39] The success of plant-based diets in the prevention of obesity and other comorbidities, that induce a state of chronic inflammation, may support the adoption of a plant-based diet in an effort to reduce the risk of cancer onset and progression.

ANTICARCINOGENIC ASPECTS OF A PLANT-BASED DIET

Plant-based diets focus on foods of plant origin that are minimally processed, and contain a number of specific dietary components that contain anticarcinogenic properties. Some of these properties include the variety of phytonutrients and antioxidants that protect against disease, promotion of a healthy microbiome, effectiveness as immunity mediators, and a high fiber content. In addition to dietary components, there are also environmental factors associated with a plant-based diet that can reduce the risk of cancer development.

Dietary Factors: Phytonutrients as Bioactive Foods

Phytonutrients can be defined as any biologically active non-nutritive compound in a plant[40], and have been noted in the literature for their possible health effects. Phytonutrients are categorized into a number of groups, some of which are organosulfurs, carotenoids, alkaloids, polyphenols, and nitrogen-containing compounds.[40] These phytonutrients take part in a wide range of activities related to cancer prevention, namely protecting against oxidative damage by eliminating free radicals and inhibiting proliferation of cancer cells.[40,41] Some phytonutrients have the ability to interact with the bacteria in the microbiome and undergo bacterial modification, thereby producing metabolites that are more potent than the original compound.[40] Specific phytonutrients that have been associated with decreased cancer risk include dietary plant sterols, dietary phytoestrogens, carotenoids, isothiocyanates, and resveratrol.[40-45]

Plant sterols are well known for their ability to significantly lower blood cholesterol levels.[42] Recent research indicates they have a role in breast cancer risk reduction through anticancer mechanisms that overlap with their cholesterol-lowering activities.[42] Plant sterols are found as components of plant cell membranes, and common examples found in abundance include campesterol, stigmasterol, and β-sitosterol.[42] It is estimated that global consumption of plant sterols is between 200 and 400 mg daily, with doses between 1 and 2 g effectively lowering LDL-cholesterol levels.[42] With regards to cancer, β-sitosterol intake has been associated with a greater likelihood of estrogen receptor positive (ER+) tumors, which respond much better to treatment than those of the estrogen receptor negative (ER-) phenotype.[42] Plant sterols have also been shown to regulate secretion of cytokines IL-2 and IFN-γ, thereby exerting a protective effect on cancer metastasis.[42]

Similar to plant sterols, phytoestrogens are phenolic compounds derived from plants that exhibit a variety of chemopreventive mechanisms.[43] The four main classifications of phytoestrogens include isoflavones, stilbenes, coumestans, and lignans.[43] Resveratrol is also considered a phytoestrogen found in the skin of red grapes and red wine, and is known for its antioxidant properties.[43] Mechanisms of cancer prevention displayed by phytoestrogens include epigenetic modifications, inhibition of topoisomerase, induction of apoptosis in carcinogenic cells, and antioxidant properties.[43] Interestingly, Asian populations are known to consume significantly higher amounts of phytoestrogens than their western counterparts, which is consistent with their lower incidence rates of breast and prostate cancer.[43]

Carotenoids are a diverse group of natural pigments, often yellow, orange, or red, found in plants capable of conducting photosynthesis, and are essential to photosynthetic organelles of many plant varieties.[44] They are precursors of vitamin A (retinol) and are very efficient scavengers of reactive oxygen species, thereby decreasing oxidative stress and exhibiting protective effects against cancer initiation.[44] Similarly, isothiocyanates, commonly found in cruciferous vegetables such as broccoli, also exhibit protective effects against cancer through detoxification of chemical carcinogens and antioxidant activity.[45]

There are several mechanisms by which the human body has evolved to counteract the hazardous effects of oxidative stress brought on by the presence of dietary carcinogens, and they occur through the production of antioxidants.[28,29,40-45] Antioxidants consumed through the diet can play a substantial role in the prevention and repair of damage induced by a state of oxidative stress.[28,29] Through the diet, humans ingest an array of natural antioxidants and bioactive compounds that play a role in the prevention of DNA damage and therefore, the prevention of cancer onset.[28,29] Dietary antioxidants have the ability to restrict the chain reactions that lead to

DNA damage caused by free radical intermediates, as well as oxidizing themselves in order to inhibit the detrimental effects of certain oxidation reactions.[28,29,40-45] Dietary antioxidants mentioned above are found in highest concentration in fruits, vegetables, and other foods of plant origin, and are often not synthesized by humans and animals.[40-45] This evidence supports the notion that the consumption of plant-based foods, high in such dietary antioxidants, can be a defense strategy in minimizing the likelihood of developing cancer throughout the lifetime.

Dietary Factors: The Microbiome

Recent research has led to advances in our understanding of the gut microbiome and its role in human disease development. The microbiome is defined as the community of microorganisms inhabiting the human body, and can include bacteria, fungi, and viruses that are collectively referred to as microbes.[46] Diet plays a large role in the bacterial species that make up the microbiome.[46,47] Furthermore, the microbes living within our body have the ability to alter the way in which we metabolize the food we consume, medications, hormones, and other substances that are foreign to the body.[46] As such, they have the ability to counteract some of the harmful effects introduced by the compounds we ingest, as well as further exacerbate them.[46,47]

Present-day findings have indicated that the balance of microbes that make up the human microbiome can influence one's susceptibility to developing a chronic disease.[46,47] The microbes within our gastrointestinal tract can form one of two relationships with the human host: a microbial symbiotic relationship in which both the microbe and host mutually benefit, and a microbial dysbiotic relationship in which an imbalance in gut microbes leads to inflammation in the host and various related diseases.[46,47] These imbalances in the bacterial strains present in the microbiome are a result of certain dietary and lifestyle tendencies, and can influence a number of health determinants most often reflected in markers of oxidative stress, glucose metabolism,

inflammation profile, and adiposity.[46] Some of the eating pattern and lifestyle habits consistent with the western diet, characterized by a high intake of meat, fat, and processed foods, can alter the microbiome in such a way to aggravate these health determinants.[46,47] Similarly, a plant-based diet consistent with high intake of fruits, vegetables, whole grains, legumes, nuts, and seeds can alter the microbiome in such a way to improve these health determinants.[46,48] These microbial alterations can provide an insight into our understanding of how chronic disease develops and how this development can be delayed.

A study by Glick-Bauer et al. explored the connection between a plant-based vegan diet and the health of the gut microflora in comparison to the gut microflora of those following an Omnivorous diet.[48] The gut profile of those following a vegan diet were shown to have significantly reduced levels of inflammation as exhibited by lower levels of plasma C-reactive protein, indicating a greater abundance of protective microbial species relative to pathogenic or disease-causing microbial species.[48] Some of these protective species include *Faecalibacterium. prausnitzii*, a gram-positive bacteria that represents more than 5% of bacteria inhabiting the human gastrointestinal tract.[49] Low levels of *F. prausnitzii*, a common occurrence in the Omnivorous diet, have been associated with the onset of obesity, asthma, Crohn's disease, and major depressive disorder.[49-52] Although more evidence is warranted in the study of long-term diet adherence to assess the practicality of a vegan diet in the promotion of healthy gut flora, there appears to be a strong relationship between a healthy intestinal microbial profile and plant-based dietary patterns.[49]

In addition to the relationship between a plant-based diet and healthy gut flora, there is also a relationship between pathogenic bacteria, as a result of poor dietary habits, and carcinogenesis in humans.[47] Pathogenic microbial species can include *Enterobacteriaceae*, a

large family of gram-negative bacteria that includes *Salmonella enterica* and *Escherichia coli*, that can produce endotoxins resulting in a systemic inflammatory and vasodilatory response when released into the body's bloodstream.[49,53] A study by Sheflin et al. explored the cancer-promoting effects of microbial dysbiosis, a state in which there is an imbalance in the microbiota of the gastrointestinal tract.[47] Microbial dysbiosis can contribute to the etiology of a number of chronic disease states, including carcinomas of the colon, stomach, esophagus, pancreas, breast, and gallbladder.[47] This etiology is tied to the level of inflammation of the host, increasing their vulnerability to pathogenic bacteria.[47] However, diet is only one representation of how the dynamics of the gut microbiome can be altered to promote health and prevent chronic disease. Other therapies include consumption or supplementation of probiotics and fecal transplants.[47]

Dietary Factors: Plants as Immunity Mediators

The immune system is composed of a complex system of specialized cells that work to prevent and eliminate infection and disease. There is a growing awareness in the scientific community of a discipline known as "immunonutrition", or the study of the effects of specific nutrients and their metabolites on inflammation and disease resistance.[54] Plants are comprised of a variety of phytonutrients that engage in both anti-inflammatory activities, as well as elimination of free radicals, thus enhancing the immune system in such a way that it may protect against the onset of cancer.[54] Some of the most common plants with immunonutritive properties include garlic, green tea, ginger, and echinacea.[54]

Garlic contains compounds known as organosulfurs, which include diallyl sulfide (DAS), diallyl disulfide (DADS), δ-glutamyl-S-allyl-L-cysteine, S-allylmercaptocysteine (SAMC), among others, all of which have the ability to produce a number of biological effects in the body.[54] According to Sultan et al., immunomodulatory properties of garlic include lymphocyte

proliferation, macrophage phagocytosis, and stimulation of IL-2, tumor necrosis factor-α (TNF-α), and interferon-γ (IFN-γ) release.[54] Garlic intake has also been associated with the upregulation of genes related to cancer immunity; Charron et al. found increases in mRNA transcripts of genes related to apoptosis of carcinogenic cells and stimulation of cytokines that can inhibit tumor cell proliferation after consumption of raw, crushed garlic.[54,55] These anticancer activities have been reported to decrease the risk of skin, colon, prostate, breast, lung, and gastric cancer.[54]

Green tea, a beverage becoming more popular worldwide, has been endorsed for its anti-inflammatory, anticancer, and antioxidant properties.[54] The principal antioxidant in green tea is epigallocatechin-3-gallate (EGCG), which contributes 30% of the total antioxidant capacity of green tea.[54] EGCG has been shown to regulate cytokine production, inhibit tumor cell growth, lower inflammatory response, and reduce formation of nitric oxide radicals.[54] In addition to mitigating carcinogenic pathways in the body, EGCG has also been shown to enhance humoral and cell-mediated immunity and reduce overall oxidative stress.[54,56]

Ginger is a traditional herb that holds great therapeutic significance in the healthcare community. α-zingiberene, α-farnesene, α-curcumene, β-bisabolene, [6]-gingerol, etc., are all bioactive molecules in ginger associated with colorectal, ovarian, skin, liver, and gastric cancer reduction.[54] Ginger also has the capacity to induce apoptosis and produce lymphocytes with the ability to infiltrate tumor cells.[54] Mechanisms for anti-inflammatory activities include up-regulation of genes responsible for histone acetylation and suppression of histone deacetylation, as well as down-regulation of genes responsible for nitric oxide synthase and cyclooxygenase 2 (COX-2), molecules capable of inducing inflammation.[54]

Echinacea is another plant known for containing a vast number of phytochemicals responsible for improved immune functioning in the body.[54] Betaine, sesquiterpenes, caryophyllene, polyacetylene, echinacoside, alkyl amides, and arabinogalactan-proteins are a few of the phytochemicals present in echinacea. Echinacea has been reported to stimulate immunity through neutrophil phagocytosis, upregulation of granulocyte and lysozyme concentrations, and modulating hematinic agents that increase hemoglobin levels, quality of blood, and oxygen transport.[54]

Dietary Factors: The Role of Dietary Fiber

Dietary fiber is a component of plant foods that is known for fighting cancer, specifically in protecting against colorectal cancer.[57] Fiber is a type of carbohydrate that is indigestible by humans and can contribute to slower digestion, protection of the colorectal lining, as well as increased satiety.[57] The two forms of fiber are: *soluble*, capable of dissolving in water, and *insoluble*, incapable of dissolving in water.[57] Table 7 lists examples of both soluble and insoluble fiber.

Table 7. Examples of Soluble and Insoluble Fiber[53]

Soluble	*Insoluble*
● Oats, oat bran ● Soy ● Beans ● Lentils ● Barley ● Nuts and seeds	● Whole-wheat, wheat bran ● Dark leafy greens ● Legumes ● Cabbage ● Lettuce ● Onions

The evidence is very strong regarding fiber intake and a decreased risk of colorectal cancer. This protective effect is likely related to fiber's ability to add bulk to the digestive system, decreasing the length of time waste must travel through the colon.[58] According to a

meta-analysis by Bradbury et al., cancers of the upper gastrointestinal tract were inversely associated with fruit consumption, and colorectal cancer was inversely associated with both fruit and vegetable consumption; a significant trend was found between combined fruit and vegetable intake and decreased colorectal cancer incidence.[58]

Dietary fiber has also been associated with a reduction in breast cancer risk, as evidenced by an inverse association between dietary fiber intake and risk of breast cancer onset in a meta-analysis by Aune et al.[59] It is hypothesized that the reduction in breast cancer risk in relation to dietary fiber intake is due to increased fecal estrogens and decreased blood concentrations of estrogen in women adhering to a vegetarian or vegan diet, in comparison to women adhering to an Omnivorous diet.[59] Additionally, Aune et al. found that soluble fiber specifically, and not insoluble fiber, was inversely associated with breast cancer risk, though results from prospective studies within the meta-analysis may have been selectively biased.[59]

Furthermore, fiber intake has also been inversely associated with the risk of prostate cancer as displayed in the Deschasaux et al. study performed by a nutritional epidemiology research team.[60] Experimental data obtained in the study suggested that dietary fiber intake was inversely associated with prostate cancer risk, specifically through consumption of total fiber, insoluble fiber, and fiber from legumes[60]; results were not significant for consumption of fiber in the form of cereals, fruits, and vegetables.[60]

A variety of experimental data exists regarding the mechanism through which dietary fiber from plants reduces the risk of cancer. Properties of dietary fiber that are well-established in the literature include anti-inflammatory effects, improved sensitivity to insulin, reduction in IGF-1 bioactivity by increasing concentrations of insulin-like growth factor binding protein (IGFBP),

and decreasing estrogens and androgens in circulation thereby influencing overall steroid hormone concentrations.[60]

Environmental Factors: Global Cancer Patterns

Cancer is not only prevalent in the United States, but remains a global concern among countries of all incomes and demographics.[61] Regulatory measures on exposure to environmental carcinogenic agents should be of primary concern in reducing the globalization of cancer. Current factory farm methods of raising animals for human consumption are creating a number of health hazards that are contributing to an increased risk of environmental carcinogen exposure.[61,62] These methods lead to the contamination of food products by persistent environmental pollutants such as arsenic, cadmium, mercury, lead, dioxins, and pesticides associated with cancer promotion.[61,62]

Environmental Factors: Environmental Carcinogens

Environmental carcinogens of highest concern in the meat-based food system today are dioxins, a group of persistent environmental pollutants that accumulate in the food chain in the fatty tissue of animals raised for human consumption.[63] Dioxins are classified by the International Agency for Research on Cancer (IARC) as a known carcinogen, and are often recognized by the name of their structurally and chemically related family of *(a)* polychlorinated dibenzo para dioxins (PCDDs), *(b)* polychlorinated dibenzofurans (PCDFs), and *(c)* dioxin-like polychlorinated biphenyls (PCBs).[63] Greater than 90% of human exposure to dioxins occurs through meat, dairy, fish, and shellfish consumption.[63] Dioxin contamination is a result of industrial and manufacturing processes, namely smelting, chlorine bleaching, and herbicide and/or pesticide production.[63] Exposure to dioxins has been associated with an increase in all cancer mortality, however it is especially significant for non-Hodgkin's lymphoma.[63,64] In

addition to their carcinogenic properties, dioxins are also known to cause damage to the immune, reproductive, and developmental systems of the body.[63,64]

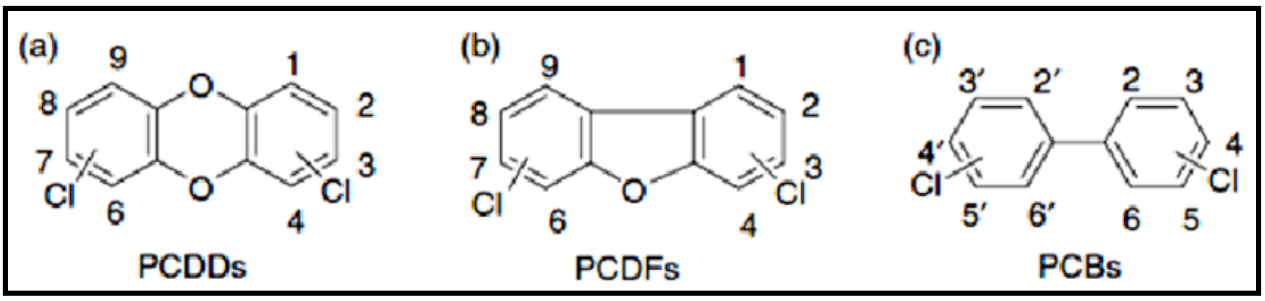

Figure 3. Basic Chemical Structures of Dioxin Compounds[63,65]

Environmental Factors: Sustainability of Plant-Based Diets

Additionally, diets high in animal-based products deplete a substantial amount of natural resources and thus are more taxing on the environment.[62,66] The current food production system in the United States requires 50% of the country's total land area, 80% of its fresh water supply, and 17% of fossil energy used in the country, with the vast majority of energy, land, and water resources being required by the meat-based food system.[66] For example, it takes 1,800 gallons of water to produce a pound of beef in comparison to 147 gallons of water to produce a pound of corn.[66] Therefore, the sustainability of plant-based diets is under consideration as a more favorable alternative to animal-based diets in optimizing the world's food supply.[62,66]

IMPACT OF A PLANT-BASED DIET IN REDUCING THE RISK OF CANCER RECURRENCE

It has already been established that certain dietary factors increase the risk of developing cancer. However, research indicates that diet and other lifestyle factors may also influence patient outcomes and recurrence rates.[67] It is important to note that patients previously diagnosed

with cancer are often highly motivated to seek out dietary and lifestyle interventions to protect against recurrence, and thus may be a factor in the success of certain dietary interventions.[68] Nonetheless, adherence to a plant-based diet may be effective in reducing the risk of colorectal, breast, and prostate cancer recurrence.[68-73]

Dietary Patterns on Colorectal Cancer Recurrence and Survival Rates

One prospective observational study by Meyerhardt et al. followed 1,009 patients previously diagnosed with stage III colon cancer.[68] Two dietary patterns were noted among the individuals; the first dietary pattern, consistent with the standard western diet, was characterized by high intakes of meat, saturated fat, refined grains, and sugar.[68] The second dietary pattern was characterized by high intakes of fruits, vegetables, and other plant-based food sources.[68] Subject follow-up after 5 years produced the following results: 233 patients died after recurrence of colon cancer, 324 patients had colon cancer recurrence, and 28 patients died with no documentation of cancer recurrence.[68] A higher intake of the dietary pattern of red and processed meat, saturated fat, refined grains, and sugar had a significantly higher risk of colon cancer recurrence or death in comparison to those consuming the dietary pattern high in plant-based foods.[68]

Another cohort study by Zhu et al. explored the relationship between dietary patterns and colorectal recurrence and survival.[69] This study followed 529 newly diagnosed cases of colorectal cancer with follow-up approximately 10 years after recruitment.[69] Dietary intake was reported through the use of food frequency questionnaires and dietary patterns were categorized into two groups: a high processed meat dietary pattern characterized as the 'western' diet and a plant-based diet higher in fruits and vegetables characterized as the 'prudent' diet.[69] The researchers found that the processed meat dietary pattern or 'western' diet was associated with a

significantly higher risk of tumor recurrence, tumor metastasis, and death related to colorectal cancer in comparison to those consuming the 'prudent' diet.[69]

Dietary Patterns on Breast Cancer Recurrence and Survival Rates

A meta-analysis of two randomized controlled trials and one large prospective cohort study by Xing et al. explored the effects of a low-fat diet high in fruits, vegetables, and fiber on breast cancer survival rates.[70] Data from 9,966 breast cancer patients was extracted using standardized data collection form and analyzed using the RevMan 5.1 analysis software.[70] Results of the meta-analysis indicated that after diagnosis of breast cancer, adherence to a low-fat diet high in foods of plant origin reduced the risk of breast cancer recurrence by 23% and all cause mortality of breast cancer by 17%, supporting the adherence to a low-fat plant-based diet to reduce the overall risk of breast cancer recurrence.[70]

Another prospective study by Vrieling et al. explored the relationship between two major dietary patterns in German postmenopausal breast cancer survivors.[71] This study followed 2,522 postmenopausal women previously diagnosed with breast cancer and assessed their dietary patterns through food frequency questionnaires.[71] The two dietary patterns identified were categorized into a 'healthy' group characterized by high intakes of fruits, vegetables, vegetable oils, sauces, condiments, soups and bouillons, and an 'unhealthy' group characterized by high intakes of red meat, processed meat, and deep-frying fat.[71] Increased consumption of the 'unhealthy' dietary pattern was associated with an increased risk of overall mortality, and the 'healthy' dietary pattern was inversely associated with both breast cancer recurrence and overall mortality.[71] It was concluded that consumption of foods consistent with the 'unhealthy' dietary pattern can increase the risk of mortality after breast cancer diagnosis, while consumption of

foods consistent with the 'healthy' dietary pattern high in plant foods may reduce the risk of both recurrence and overall mortality.[71]

Dietary Patterns on Prostate Cancer Recurrence and Survival Rates

A pilot clinical trial by Nguyen et al. on the adoption of a plant-based diet by patients with recurrent prostate cancer explored the relationship between a 6-month dietary change, in combination with a stress reduction intervention, and prostate cancer recurrence rates.[72] The purpose of the study was to determine if a specific plant-based dietary intervention could influence the promotion and progression of prostate cancer recurrence.[72] Fourteen eligible participants were recruited and provided intensive instruction on increased intake of fruits, vegetables, whole grains, and legumes and decreased intake of meat, dairy, and refined carbohydrates.[72] After 6 months, the researchers found that changes in the rate of rise in prostate-specific antigen (PSA), a substance produced by the prostate gland that indicates disease progression, was inversely related to the increased intake of plant-based foods.[72] It was concluded that the adoption of a fully plant-based diet, in conjunction with the stress reduction techniques, may have therapeutic potential in recurrent prostate cancer management.[72]

A meta-analysis by Berkow et al. explored dietary patterns and survival following diagnosis of prostate cancer.[73] This study analyzed data from 8 observational studies and 17 interventional laboratory trials on the effects of a plant-based diet on progression and clinical outcome of prostate cancer.[73] This literature review used the MEDLINE database to search for studies addressing the relationship between specific dietary patterns and prostate cancer survival rates.[73] After statistical analysis of the data, it was concluded that patients who adopted a plant-based diet after prostate cancer diagnosis and unsuccessful treatment had a lower rate of cancer progression than those adhering to a different dietary pattern.[73] The study concluded that a

predominantly plant-based diet high in fiber and low in saturated fat favorably influenced clinical outcomes and recurrence rates in patients with prostate cancer diagnoses.[73]

Practical Clinical Interventions for Cancer Survivors

Although treatment of cancer through conventional therapies such as chemotherapy and radiation are still key interventional components, the importance of expanding treatment to include the promotion of healthy dietary and lifestyle choices can be both practical and transformative in the patient's overall health and wellness. If the patient is in an overweight or obese BMI range, recommendations can be made regarding the limitation of high-calorie, high-fat foods along with increases in physical activity levels.[74] Patients should be encouraged to engage in regular physical activity with a goal of at least 150 minutes per week with 2 additional days of strength training each week.[74] With regards to dietary patterns, cancer patients should aim to achieve a diet that includes at least 2 to 3 servings of fruits and 2 to 3 servings of vegetables per day, be counseled on the benefits of opting for whole versus refined grains, as well as the benefits of avoiding processed meats and limiting the consumption of red meat to 18 oz. or less per week.[74] Evidence in this literature review also supports the incorporation of a plant-based dietary pattern with significant limitations in meat, dairy, and processed food consumption as a method of reducing risk of cancer development and as a therapeutic agent in cancer recurrence. Weight management, engagement in physical activity, and evidence-based dietary practices can all promote favorable improvements in cancer survivors.[75]

CONCLUSION

Cancer is a rising global epidemic in our world today with incidence rates rising each year. Its detrimental impact on social and economic advances create a large burden on the

developing world. Common plant-based diets discussed were the Mediterranean diet, the vegetarian diet, the vegan diet, and the Whole Foods Plant Based diet, all of which contain a higher proportion of plant-based foods as a major source of calories and nutrients in comparison to the standard western diet high in meat and processed foods. Diets high in foods of plant origins were also shown to reduce the risk of chronic inflammation and promote weight management strategies in order to prevent a state of obesity. Dietary factors discussed that contributed to the anticarcinogenic aspects of plant-based diets included beneficial alterations in microbial gut flora, enhanced immunity, increased dietary fiber consumption, and presence of phytochemicals with a variety of anticancer and antioxidant effects. Environmental factors discussed include global cancer patterns, environmental carcinogens such as dioxins, and the long-term sustainability of adopting a plant-based dietary pattern. In addition, analysis of cancer recurrence in colorectal, breast, and prostate cancer indicated that plant-based diets may play a significant role in reducing the risk of recurrence and mortality following a cancer diagnosis.

In conclusion, adherence to a poor dietary pattern, often one high in meat, dairy, saturated fat, and processed foods, can lead to an increased risk of cancer development, cancer recurrence, and mortality. Conversely, a diet high in plant-based foods such as fruits, vegetables, whole grains, legumes, nuts, and seeds may provide protection against the onset and recurrence of cancer through both dietary and environmental influences.

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