This review provides an overview of the botany and classification of seeds, summarizes recent research examining the health benefits of seeds, and discusses barriers to incorporating seeds into Western diets. Strategies to help practitioners support their patients in incorporating more seed foods into the diet are suggested. Seed foods, including cereals and pseudocereals (whole grains), legumes, and nuts and oilseeds, are used as staple crops in traditional diets and still comprise nearly 50% of the world’s food supply. The health benefits of seeds are supported by both epidemiological evidence and intervention trials. The variety of specific health benefits attributable to at least 1 of the 3 categories of seeds includes lower rates of obesity; improved body composition; improved intermediate cardiometabolic risk factors such as blood triglycerides, post-prandial insulin, and HbA1c; reduced inflammation; lower risk of metabolic syndrome; and lower risk of cardiovascular disease. Measurable health benefits can be achieved by incorporating seeds into the diet in modest amounts, either by adding them to an existing diet or using them to replace other foods. Barriers to incorporating seeds into diets include personal taste preferences, lack of knowledge or preparation skills, convenience, environmental defaults, allergies (ie, nuts), and issues of economic access. Practitioners can best support greater consumption of seeds by implementing SMART Goals (specific, measurable, actionable, relevant, time limited) and by providing education or referring patients for skills training. Nutr Today. 2016;51(1):50–59

THE BOTANY AND CATEGORIES OF SEEDS

Seeds have been both a staple food and a delicacy throughout the history of agriculture and cooking, and they continue to encompass a variety of roles in current nutritional practices, health promotion, and cuisine. Most consumers typically define “seeds” as the dry part of a plant that can be stored and used to grow more plants, yet consumers are often unaware that many commonly consumed foods are seeds and that seeds deliver a multitude of health benefits. From a botanist’s perspective, seed plants are those whose embryo (the germ) is enclosed by a protective covering (the hull) made by the parent plant. The germ has an energy-rich food supply (the endosperm) that powers embryo development, supports dormancy, and can fuel germination during the underground stages of growth. Of the 5 groups of seed plants that exist today, conifers (gymnosperms) and flowering plants (angiosperms) are the most widespread. Seeds from flowering plants are, by far, the seeds most frequently consumed by humans. As an example, major crops such as wheat, rice, and soybeans come from flowering plants, whereas the relatively minor...
commodity of pine nuts comes from conifers. Intact whole seeds (comprised of germ, endosperm, and hull) provide the full complement of nutrients required by plants to germinate. When seeds are processed for human consumption, often by milling away the outer layers, this rich nutrient content is diminished.

Seeds can be classified into 3 major food categories: true cereals from grasses and seeds similar to cereals (pseudocereals), edible nuts and oilseeds, and legumes. As described in the following list, each classification of seeds offers a rich array of nutrients and delivers a variety of health benefits.

(1) Cereals and Pseudocereals

The fruits of grasses (Poaceae) contain only 1 seed and are dry, not fleshy, at maturity. Their single seed is wrapped in a dry ovary wall, and they are called cereals. Practically, cereals are the seeds of grasses consumed as food; technically, they are the edible fruits of grasses. Unprocessed cereals are what most people consider intact “whole grains,” although the dry outer hull, which is indigestible, is typically removed. The digestible components of whole grains include lipid- and protein-rich bran (aleurone, the outermost endosperm layer), digestible starch (endosperm), and the lipid-rich embryo (germ). Refined cereals, processed and milled to remove the aleurone and embryo, typically contain only the white starchy endosperm. During the milling process, the digestible proteins, lipids, and vitamins found within the aleurone and embryo are removed, and as a consequence, there is substantial loss of nutrients. A cup of unenriched, refined wheat flour, for example, provides 19% less protein and 60% less total fat (the majority of which was unsaturated), as well as reductions of more than 50% for calcium, iron, magnesium, phosphorus, potassium, zinc, niacin, and B6, compared with an equivalent serving of whole-wheat flour.

In addition, the fiber content of 1 cup of refined wheat flour is only 3.4 g compared with 12.8 g in an equivalent serving of whole-grain flour—a resulting loss of 73%. Examples of whole-grain cereals include wheat, brown rice, maize or corn, oats, rye, millet, and sorghum. In addition, pseudocereals are small, dry seeds released individually from plants other than grasses. Pseudocereals reemerging in modern cooking include amaranth, buckwheat, and quinoa. Whole-grain products, such as breads, pasta, or crackers, are derived from cereals after undergoing some processing.

(2) Legumes

Food legumes, or pulses, are members of the bean family (Fabaceae) and include beans, peas, lentils, peanuts, and soybeans. Their seeds grow along the spine of a pod that opens on 1 side like a book. Both seed and pod (fleshy ovary wall) may be eaten fresh, such as with sugar snap peas or green beans, or the seed alone may be eaten fresh or dried, such as with black beans, lentils, navy beans, pinto beans, or black-eyed peas. Peanuts, also called ground nuts, are often labeled a nut because of their high lipid content (50% compared with 20% in soybeans). However, peanuts are, in fact, legumes; their dried pods open to reveal 2 or 3 seeds in a row.

(3) Tree Nuts and Oilseeds

Edible nuts and oilseeds can be grouped together because of their high lipid content. The term “tree nuts” includes hazelnut, chestnut (Castanea sativa), almond, walnut, pistachio, pecan, Brazil nut, cashew, pine nut, and macadamia nut. Tree nuts are large, dry, 1-seeded fruits whose ovary wall has dried into a hard stony shell around the edible embryo. In the popular sense, a “nut” is a fruit with a hard or brittle shell surrounding an edible, firm, and oily kernel within. Unlike cereal grains, nuts cannot be refined because their stony shell is inedible. The botanical definition of nuts is based on developmental fate of the ovary wall. What consumers typically think of as “nuts” (such as almonds, Brazil nuts, pecans, walnuts, and pistachios) are not true nuts because part of their ovary wall remains fleshy (eg, the green fleshy husk of unpicked almonds, coconuts, and walnuts). From a culinary perspective, however, these seeds are viewed as “nuts” because their edible cores are covered by a hard shell. Oilseeds are frequently what people think of when they hear the word “seeds.” These include sunflower seeds, flaxseeds, sesame seeds, chia seeds, and others. Oilseeds are often processed to extract oil by removing the outer husk, separating the seeds from the chaff (the nonseed material), then running the seeds through a press or expeller to squeeze out the oil.

GLOBAL SEED INTAKES

Traditional diets relied heavily on seed foods as staple crops, with cereal grains and legumes comprising a majority of the staple crop consumption globally. While staple crops do not provide all essential nutrients, they do provide a significant source of energy. Cereal grains, legumes, nuts, and oilseeds, even in the presence of a global trend toward increasing animal product consumption, still account for nearly 50% of the world’s total food supply. The wide variety of cereals, pseudocereals, and legumes historically consumed as staple and supplemental crops varies considerably across the globe as summarized in Table 1, Supplemental Digital Content 1, http://links.lww.com/NT/A6. Aside from direct consumption, seeds are typically used as ingredients in spices/seasoning, coffee and chocolate, soybeans and soy products, and for the purposes of extracting oil (ie, palm oil, canola oil, peanut oil). Based on the Food and Agriculture Organization of the United Nations Food Tables data, on average, total cereals are among the top 5 food categories contributing to energy in the US food supply (798 kcal/capita per day), with wheat
and wheat-based products being the primary source of energy (590 kcal/capita per day), followed by maize and maize-based products (93 kcal/capita per day), rice (77 kcal/capita per day), and oats (21 kcal/capita per day). It is important to note that the major contributors of calories from cereals are derived from refined cereal grains. Groundnuts (52 kcal/capita per day) and total tree nuts (8 kcal/capita per day) are also important, as are total pulses (30 kcal/capita per day). However, many of these seed foods fall beneath a variety of other foods with respect to their contribution to total energy in the US food supply, including alcoholic beverages (158 kcal/capita per day), sugar plus sweeteners (569 kcal/capita per day), and total meat (432 kcal/capital per day). Other top sources of calories include poultry, extracted oils, milk, and starchy vegetables. Total consumption of cereals from all countries in Africa ranks wheat, maize, and rice among the top 4 individual food products. On average, rice is the no. 1 individual food in Asia, with wheat following and both of these consumed more frequently than total animal products.9

**NUTRIENT COMPOSITION OF SEEDS**

The health benefits of cereals, legumes, and nuts and seeds are potentially extensive, in part, because of the high amounts of nutrients and phytochemicals (plant chemicals present in typically small amounts that are generally thought to have health-promoting properties). Health benefits across the seed family are highly variable because of their potential synergistic effect. The nutrient content of each of the 3 seed categories are summarized in Tables 2, 3, and 4, Supplemental Digital Content 2, http://links.lww.com/NT/A7, Supplemental Digital Content 3, http://links.lww.com/NT/A8, and Supplemental Digital Content 4, http://links.lww.com/NT/A9. Given the great breadth and variation of nutrient composition, emphasizing the need to consume a variety of seeds is important. Seed foods provide certain nutrients to the US diet currently considered as “shortfall nutrients” by the 2015 Dietary Guidelines for American Committee Report,10 meaning they are consumed at low levels compared with the Estimated Average Requirement or Adequate Intake levels set by the Institute of Medicine.11 Some of the nutrient gaps, which can be improved by increasing seed foods consumption, include vitamin E, magnesium, calcium, potassium, and dietary fiber. Seeds, particularly certain nuts, are also good sources of polyunsaturated fat, and all seeds are low in saturated fat, a nutrient of concern due to overconsumption compared with recommended intakes.10

Below, we highlight some of the unique contributions of seeds to the composition of the diet. Examples include:

- In general, seed foods are high in dietary fiber, but fiber types vary across seeds. For instance, whole-grain wheat and rye provide insoluble fiber, whereas oats and barley provide soluble fiber, in particular β-glucan.12 Increasing soluble fiber intake slows nutrient absorption, improves glycemic control, lowers cholesterol, and affects the gut hormone response,13 whereas insoluble fiber acts to increase stool bulk and prevent constipation, speeding up total transit time.14

- Most whole grains, legumes, and nuts are rich sources of the minerals magnesium and potassium. Magnesium is involved in hundreds of enzyme systems that regulate a variety of biochemical reactions related to energy metabolism, protein synthesis, muscle function, and glucose regulation, whereas potassium acts to regulate water and sodium balance.

- Legumes and nuts can contribute toward calcium intake as part of a nutrient-dense diet. Sesame seeds and chia seeds are particularly good sources of calcium, with a 1-oz serving providing ~277 mg per approximately 180-g serving, respectively.

- Nuts, which are high in fat, provide substantial amounts of polyunsaturated fat acids (PUFAs) compared with saturated fat acids (SFAs).15 A higher ratio of PUFA to SFA is associated with lower risk of cardiovascular disease (CVD).16 In particular, walnuts, sunflower seeds, flaxseeds, pine nuts, and chia seeds have some of the highest ratios of PUFA/SFA (>5-fold difference).3

- Flax and chia seeds provide a rich, nonmarine, food source of the omega-3 fat α-linolenic acid, the precursor used by humans to synthesize eicosapentaenoic acid and docosahexaenoic acid,17 2 of the essential fats that are thought to confer a variety of health benefits.

- Almonds and sunflower seeds are rich sources of vitamin E, with a 1-oz serving of almonds providing roughly half of the recommended dietary allowance for vitamin E (7.2 mg of 15 mg/d for adults) and a 1-oz serving of sunflower seeds providing more than half (9.9 mg).

**HEALTH BENEFITS OF SEED CONSUMPTION**

In this review, we do not present the totality of evidence examining the impact of seed consumption on intermediate biomarkers of disease risk or disease end points. Instead, we highlight the findings of recent meta-analyses of randomized controlled trials (RCTs)18-27 and cohort studies28-34 published in the past 5 years (2010–2015), which have systematically reviewed the evidence of seed foods and cardiometabolic health (see Tables 5, 6, and 7, Supplemental Digital Content 5, http://links.lww.com/NT/A10, Supplemental Digital Content 6, http://links.lww.com/NT/A11, and Supplemental Digital Content 7, http://links.lww.com/NT/A12). As is the case with all meta-analyses, results need to be considered in light of the fact that there is often considerable heterogeneity across individual studies in terms of duration, exposure, methods, and comparator groups. With respect to whole-grain research, for example, inconsistencies exist between studies in the definition and quantification (servings vs grams) of whole-grain food products, and misclassification of whole-grain exposure in observational studies may exist because of the inclusion of added bran in products.35 In addition, for the most part, the meta-analyses grouped all nuts together or all legumes together for the analysis; however, individual studies may have examined a mixture of nuts or legumes or focused on 1 particular type of nut or legume, which do vary considerably.
in their nutrient profiles and as such may have a different effect on the outcome.

Although the vast majority of epidemiological evidence suggests a positive health benefit of increasing the consumption of seed foods, the recognized caveat of these studies is that observed associations may arise because of residual confounding from other lifestyle factors associated with the consumption of seed foods, such as physical activity, overall dietary quality, socioeconomic status (SES), or others. Although the observed health benefits have been directly associated with seeds themselves, the individual attributes of seeds\(^6\) such as the high fiber, micronutrient, and phytochemical composition, along with the low fat content and overall composition, may act synergistically with other aspects of diet and lifestyle.\(^37,38\)

Because an observational design precludes the establishment of causality, considering evidence from RCTs, designed to reduce bias and establish a causal relationship, is needed. In contrast to the evidence from observational studies supportive of a health benefit of seeds, the results from RCTs linking seeds to potential health benefits have been inconsistent, with the vast majority of studies reporting a null finding. Inconsistent and null findings may be because (1) the incorporation of individual “seed” foods is insufficient to cause a clinically meaningful change in risk factors, or (2) to achieve a measurable effect, a larger dose of seeds or a combination of different seeds is required. The following 3 sections provide a summary of the overall findings of meta-analyses on whole grains, legumes, nuts, and seeds and a variety of cardiometabolic outcomes; however, we encourage readers interested in seeds to review the original studies as dose, duration, and sample characteristics are important in the interpretation of results.

WHOLE GRAINS

A recent meta-analysis of 14 observational studies (11 prospective and 3 case-control) suggests that compared with individuals who rarely consumed whole grains, those with the highest whole-grain intake have a lower risk of coronary heart disease, with an overall risk reduction of 21% (95% confidence interval [CI], 0.743–0.833).\(^28\)

Of note, a significant association was found only in cohort studies, not in case-control studies, which may reflect a potential limitation in recalling grain exposure in case-control studies. With respect to diabetes, a meta-analysis of 10 prospective studies concluded that the relative risk of type 2 diabetes (T2D) was 22% lower (95% CI, 0.58–0.81) among consumers of at least 3 servings of whole grains per day.\(^29\) The findings are consistent with a similar meta-analysis of RCTs conducted by Ye and colleagues,\(^30\) who, in addition to T2D, CVD, and weight gain in observational studies, investigated changes in CVD intermediate risk factors, including fasting glucose, insulin, total and low-density lipoprotein (LDL) cholesterol, blood pressure, and weight gain in 11 to 16 RCTs. From this meta-analysis, weighted mean differences in postintervention concentrations of fasting glucose (differences in fasting glucose, –0.93 mmol/L [95% CI, –1.65 to –0.21 mmol/L], total cholesterol (–0.83 mmol/L [95% CI, –1.24 to –0.42 mmol/L], and LDL cholesterol (–0.72 mmol/L [95% CI, –1.34 to –0.11 mmol/L]) were significantly lower after the whole-grain interventions compared with controls.\(^30\) Pol and colleagues\(^38\) conducted a meta-analysis of 26 interventions aimed at increasing whole-grain intake, and while their analysis did not find a significant effect of whole grains on body weight, it did find a small but significant effect on body fat (weighted difference, –0.48% [95% CI, –0.95% to –0.01%]).

LEGUMES

A meta-analysis of 6 prospective cohort studies found that adults who consume 4 or more servings (based on 100 g per serving) of legumes per week have a 14% lower risk (95% CI, 0.78–0.94) of fatal ischemic heart disease (IHD) compared with those consuming less.\(^35\) In the same meta-analysis, no significant reduction in risk of diabetes or stroke was observed. A recent meta-analysis of 10 RCTs examining the effect of legume consumption (other than soybeans) on lipids reported significant mean net reductions in total cholesterol and LDL cholesterol, of 11.8 mg/dL and 8.0 mg/dL, respectively, after treatment with a legume intervention, although heterogeneity between studies existed in terms of the type of legume, treatment dose (ranging from 120 to 440 g/d), and fiber content of the intervention.\(^27\)

Another meta-analysis of 8 RCTs on the effect of isocaloric substitution of legumes for other foods found that legume consumption significantly lowered both systolic blood pressure (SBP), with a mean change of 2.25 mm Hg, and mean arterial blood pressure with a mean change of 0.75 mm Hg.\(^21\) These modest reductions were achieved by isocalorically substituting doses of a variety of legumes (chickpeas, lentils, green beans, and others) of only 81 g/d up to 275 g/d into the usual diet or a comparator diet, which is comparable to approximately half a cup to 1½ cups. A larger meta-analysis of 26 studies on the effect of increased legume consumption on blood lipids also observed a significant reduction in LDL following the legume interventions (mean difference, –0.17 mmol/L; 95% CI, –0.25 to –0.09 mmol/L) but no change in apolipoprotein B or HDL.\(^20\)

NUTS

With respect to the incorporation of nuts in the diets of adults, consumption of at least 1 serving per day was associated with a 39% risk reduction in CVD mortality in a meta-analysis of 9 prospective cohort studies.\(^31\) A comparable finding was reported in a meta-analysis of 18 prospective cohort studies, whereby consuming at least 4 servings...
of nuts weekly was associated with a risk reduction of 24% (95% CI, 0.69–0.84) of fatal IHD. Significant associations with higher nut consumption were also found for IHD, CVD, and all-cause mortality. In a smaller meta-analysis of 9 prospective studies, consumption of tree nuts or peanuts more than twice per week was associated with an 8% (95% CI, 0.87–0.97) lower risk of hypertension in an analysis of 7 studies; however, no association was found with T2D.

In a meta-analysis of 26 reports of 21 RCTs, higher nut consumption was found to lead to a significant reduction in SBP among nondiabetic adults only (n = 26 studies; mean difference, 21.29 mm Hg; 95% CI, 22.35–20.22 mm Hg). In a 25-study meta-analysis of RCTs, nut consumption of at least 67 g/d (slightly >1 handful) was found to significantly reduce blood lipid levels, including total cholesterol (10.9 mg/dL) and LDL cholesterol (10.2 mg/dL) and triglycerides (20.6 mg/dL). A meta-analysis of 33 clinical trials in which diets were enriched with nuts, however, found a nonsignificant pooled effect on body weight, body mass index, and waist circumference. There was considerable heterogeneity across the various studies in terms of isocaloric substitution versus diet enrichment with nuts. It is important to note that the majority of these interventions required isocaloric substitution; thus, nuts were added as replacements for other calorically dense foods rather than in addition to the baseline diet, which could potentially lead to weight gain. The practice of substitution when adding more calorically dense foods such as nuts into the diet is important to highlight in public health communications and messaging, as many consumers may add nuts to their diet without proportionately substituting out other foods.

**DIETARY PATTERNS WITH EMPHASIS ON SEED CONSUMPTION**

Many diets used to improve health emphasize foods rich in whole grains, legumes, and nuts and seeds. For instance, 2 popular diets for CVD prevention that incorporate a variety of seed foods as part of a nutrient-dense diet are the Mediterranean diet and the Dietary Approaches to Stop Hypertension (DASH) diet. For the Mediterranean diet, the potential of coronary heart disease prevention has been observed in the Lyon Heart Study, which found a 50% to 70% reduction in risk of recurrent heart disease among intervention subjects (n = 423 at follow-up) after 46 months of follow-up. The DASH diet has been explored in many studies, and in a meta-analysis of 20 RCTs, it significantly lowered SBP and diastolic blood pressure, as well as total and LDL cholesterol levels.

A very low-fat plant-based/vegan diet, rich in a variety of seed foods, has been used in adults to significantly improve T2D management as compared with a diet based on the American Diabetes Association guidelines and has led to reductions in medication use in diabetic adults (n = 99) over 74 weeks through improvements in glycemia, body weight, and blood lipids. In comparison to an American Heart Association diet, a plant-based diet was found to lead to greater improvements in blood lipids, C-reactive protein, body pressure, and body mass index z score over a 4-week intervention in a small sample (n = 30) of overweight and obese children.

The overall findings of intervention studies that incorporate a variety of seeds as part of a healthy diet may serve to empower patients to take charge of their own health by making dietary changes, in some instances, even before relying on medications for the management of chronic disease conditions.

**HEALTH BARRIERS TO INCORPORATING SEEDS INTO WESTERN DIETS**

A variety of health barriers that exist to hinder consumers from adopting more seed foods into their diets are described below.

**Tree Nut and Peanut Food Allergies**

Amid the myriad of health benefits associated with seeds, the prevalence of certain food allergies is a potential concern, especially for parents of young children. Food allergy is considered an adverse immune reaction arising from exposure to a specific food that occurs predictably. It is estimated in a systematic review of top individual food allergies in Europe that wheat, soy, peanut, and tree nut allergies number in the top 8 allergies, at 3.0%, 0.4%, 1.3%, and 2.2% of the general population, respectively, for all ages combined. In the United States, the presence of overall food allergy has been rising over the past few decades among all ages, with 6.5% of children and 9.7% of adults self-reporting some type of food allergy, according to the 2007–2010 National Health and Nutrition Examination Survey. However, based on these data, estimates of the prevalence of specific seed allergies among all ages combined for peanuts, tree nuts, wheat, soy, and corn were 1.16%, 0.52%, 0.29%, 0.25%, and 0.28% respectively (in the United States, other allergies such as milk and shellfish comprise a larger portion of total allergies). In addition, a meta-analysis of the food allergy prevalence showed heterogeneity across different categories of allergies, making exact prevalence rates difficult to distinguish.

There is currently mixed evidence around the question of whether pregnant women should avoid consumption of nuts to reduce the potential for allergies in children. For example, maternal consumption of peanuts during pregnancy has been linked to both higher and lower rates of peanut allergies in offspring. Among 10 907 mothers (offspring of women in the Nurses Health Study) without peanut or tree nut allergies, nut consumption 5 or more times per month during the peripregnancy period compared with less than once per month was associated with a
significant 69% reduction in the odds of peanut allergy in offspring.48 Certain allergies also may resolve on their own49 among young children, as 1 prospective study (n = 5276) found that 22% of peanut allergies diagnosed in children at age 1 year had resolved by age 4 years.50 Research on food allergies, however, remains an emerging area of investigation, and it is currently recommended that individuals avoid known food allergens.

GLUTEN ALLERGIES
Celiac disease, an autoimmune disorder caused by a total intolerance to gluten, the main protein in wheat and related grains, has been increasing on a worldwide scale.51 Consumption of even small amounts of gluten can trigger an immune response that causes damage to the villi of the small intestine, creating problems with nutrient absorption as well as discomfort and symptoms of poor digestion. The only treatment is strict adherence to a gluten-free diet, and if untreated, the disorder may lead to the development of other autoimmune disorders, neurological damage, or intestinal cancers. Even adherence to a gluten-free diet may be associated with certain nutrient deficiencies including fiber, B vitamins, iron, and certain trace minerals among patients who are not carefully consuming a nutrient-dense diet or who are not relying enough on the pseudocereals (eg, quinoa or buckwheat) in place of wheat.52 The condition is associated with some reduced quality of life because of the inconvenience of finding acceptable gluten-free foods53 and presents difficulties in procuring whole-grain foods because wheat is the most commonly consumed and widely available grain in the United States. Many consumers, although not formally diagnosed with celiac disease, believe themselves to have some level of gluten or other intolerance54 attached to a variety of symptoms, and this perception may influence their ability to find whole-grain foods they are willing to eat.

FLATULENCE
Increased flatulence has long been associated with greater consumption of fiber,55 as the oligosaccharide components of fiber are broken down in the colon, and flatulence-causing gas is produced through fermentation in the gut by intestinal bacteria.56,57 However, the fear of increased flatulence, though common,58 is not always consistently experienced with increased fiber intake,59 although it has been observed in interventions of shorter duration60 (a few weeks as opposed to a permanent change). A greater number of complaints of flatulence are observed during the first week of an intervention as opposed to later on.51 Unfortunately, this can be another reason that people are hesitant to increase fiber intake, particularly by eating legumes, which are very high in fiber. An analysis of 3 different clinical interventions that provided a daily serving of beans and measured perceptions of increased flatulence62 found that perceptions of flatulence increased only initially during an 8-week trial, and levels dropped substantially after several weeks on the test diets that contained either a half cup of pinto beans, black-eyed peas, or vegetarian baked beans. Certain legume intervention studies have tended to be of shorter duration, sometimes only 2 to 3 weeks55 perhaps not allowing sufficient time for flatulence to diminish. Thus, consumers may need encouragement to wait out the transition or incrementally increase intake of fiber-rich foods into their diets or to introduce fiber-rich foods into their diet more gradually. In addition, sprouting legumes or soaking them or discarding the soaking water are 2 strategies that may be used to decrease flatulence.63

BEHAVIORAL BARRIERS TO INCORPORATING SEEDS INTO WESTERN DIETS
While health barriers can prevent individuals from incorporating seeds into the diet, other barriers relating to knowledge, skills, and preferences can present equally significant barriers (see Table 8, Supplemental Digital Content 8, http://links.lww.com/NT/A13). Personal taste preferences: Taste preferences, although influenced by experiences in early childhood,64 are largely conditioned responses based on more recent past experiences with an element of addiction65 in the case of high-sugar, high-fat, high-salt foods.66 Many consumers do not realize the degree to which taste preferences are learned and hence have beliefs that they do not like a particular food. They are largely unaware that their taste preferences could be altered with sufficient repeated exposures to newer, healthier foods such as seeds.67 Knowledge/familiarity with the foods: A lack of knowledge and accompanying motivation to consume whole grains, legumes, and nuts is a baseline characteristic of the modern Western food environment. Because seeds are plants, a more plant-based diet will automatically contain greater quantities of seed foods; however, an overall plant-based diet also poses challenges in adoption. A random-household survey in Australia identified the following barriers to adopting a plant-based diet (defined as a diet centered largely around plant foods but that may still contain meat or dairy): lack of knowledge, reluctance to change habits, lack of support from family, lack of access, not enough choice, lack of willpower, cost concerns, flatulence concerns,68 and questions about the nutritional adequacy.67 Lack of preparation skills: It has been established that eating out is associated with a decline in diet quality,68 yet home meal preparation in the United States has declined because of lack of cooking skills and knowledge about food ingredients such as whole grains and legumes.69
Increased patterns of eating out affect seed consumption, as consumption of unprocessed seed foods is more likely to occur when meals are prepared at home.

**Convenience:** The link between food availability, food-purchasing behavior, and food consumption is an emerging field of study, and a consistent association between eating patterns and convenience exists across socioeconomic groups. The choice of shopping venue is associated with purchasing, as adults who shop at farmer’s markets and specialty grocery stores, as compared with supermarkets, are more likely to purchase greater amounts of fruits and vegetables. In a population of adults living in a food desert, wanting quick foods that were easy to prepare played a role in steering consumption away from foods that would require more preparation from scratch, such as green beans.

**Environmental defaults:** The effect of food-purchasing patterns on seed consumption is not so much a matter of specifically choosing to avoid seeds, but rather of behavior directed toward purchasing processed foods. Such behavior is driven by the purchasing environment. In addition, it may be more difficult to incorporate seeds into a family diet, as other foods are perceived to be more acceptable to young children, and marketing to children is not generally geared to promote the consumption of seed foods. The convenience of food is largely determined by the modern food environment, which offers many options for prepared and processed food, but these foods rarely contain whole grains, legumes, or nuts. Research has demonstrated that when the food environment offers healthier choices intended as “optimal defaults,” individuals are more likely to choose the healthier option. However, the current food environment, in both restaurants and supermarkets, pushes foods made with refined grains, solid fat and added sugar, and excessive animal products.

**Issues of economic access, including food insecurity, living in food deserts, and lack of mobility/transportation:** In addition to the barriers listed previously, those with low SES experience further difficulties. In urban areas, habitual personal tastes and the lack of knowledge surrounding the health benefits and consumption of seeds are further crippled by food access issues. Corner and convenience stores often serve as the primary food source for economically disadvantaged populations, and these venues typically stock a high proportion of high-fat, highly processed foods with few seeds, such as whole grains, legumes, or nuts. Food availability, in the context of food deserts, is severely limited by proximity and access to personal transportation, limiting access to healthier, fresher foods such as seeds. For economically disadvantaged populations, cost is another big consideration, with many heads of household making shopping choices based on which foods are on sale in stores. This type of shopping pattern often results in processed and unhealthy items such as French fries, fries, and so on, making up the majority of the diet. There is also a reluctance to branch out from a short list of foods perceived to be acceptable to their children, with French fries (chips) being at the top of this list.

**Strategies and Resources for Physicians and Dietitians**

Clinicians, such as physicians and registered dietitian nutritionists, should be prepared to address a variety of barriers and concerns from their patients. Challenges surrounding the incorporation of seed foods are common across socioeconomic and demographic groups, but economically disadvantaged populations living in urban areas face additional problems of access and poor resources. For physicians, incorporating the delivery of nutrition education into medical practice can be challenging because of the limited amount of time available with a patient, as well as insurance payer policies regarding services covered. Physicians may wish to consider offering group appointments, as well as collaborating with a registered dietitian to deliver nutritional education to patients. The American Association of Family Practice provides a white paper on reimbursement codes for group appointments, and several codes may be relevant for nutrition education from both physicians and dietitians. The best practice is always for the clinicians to check the Current Procedural Terminology manual and then check with their individual payers about which services are reimbursable.

In light of both epidemiological evidence and clinical interventions, the take-home message for practitioners is that even small changes in the diet, such as substituting 1 serving of refined grains for whole grains or replacing 1 meal’s worth of animal-based protein with legumes, can have a positive health benefit. While certain problems, such as food access due to low SES, mobility issues due to lack of public or private transportation, or default foods encouraged by commodity food subsidies, require legislative and institutional support to change, practitioners have a unique window of opportunity to address multiple barriers to change on an individual level.

Practitioners can support patients in consuming diets high in whole grains, legumes, and moderate amounts of nuts by providing education about the health benefits of seed consumption and potential cost savings, providing or making referrals for training in practical food preparation skills, and teaching strategies for navigating family dynamics to support greater seed consumption, including offering demonstrations, taste samples, and group cooking classes to familiarize patients with easy-to-eat seed foods. Encouraging individuals to enroll family and friends in supporting the patient’s dietary program, as well as self-monitoring, may also support behavior change. Clinicians should be mindful and check with patients about known food allergies.
Practitioners may also wish to emphasize the health and/or cost-savings benefits of seeds, as appropriate, to motivate individuals to incorporate seeds into their diet. Dry beans, nuts, and seeds are the most cost-effective way to add fiber in the diet, and dry beans are among the lowest-cost sources of iron, with an overall favorable nutrient-to-price ratio. These health benefits may be more meaningful to older adults, whereas the cost savings may be more relevant to younger people, especially young parents. Legumes are an excellent choice for low-cost, dietary protein, and the nutritional effect of substituting legumes for meat is a net benefit in dietary quality. In terms of communication, short, consistent, positive messages that are practical and flexible are best. In addition, practitioners may wish to use the SMART Goals model (specific, measurable, actionable, relevant, time limited) in helping individuals to make commitments and set goals for their behavior change. For example,

**Less effective:**
The fewer whole grains and legumes you eat, the more at risk you are of becoming obese, which is associated with a wide range of health problems, including hypertension, metabolic syndrome, cardiovascular disease... it's really important that you keep on top of your diet. We need to get you eating more whole grains and legumes—what do you think you can do?

**More effective:**
If you can replace some of the white bread and meat you eat each week with whole grains and legumes, you can make a real difference in your health, possibly improving your blood lipids and your blood pressure. Let’s talk about what you think you’re up for doing as far as the quantities, what you can substitute, and what kind of time limit you’ll give yourself.

Practitioners may wish to explore with patients possible strategies for shifting their personal environment to be more supportive of a “default inclusion” of seed foods. Some helpful strategies include spending time examining the patient’s personal environment, including what they stock in their kitchen, opportunities to eat prepared food on their typical commute, the schedule they keep, and the snacks they keep on hand in the car and at work. Another possibility is examining the patient’s schedule or availability to make more time for food preparation and examining their budgets to identify the true cost of eating out compared with home cooking.

If the patient faces barriers related to mobility, economic access, or geographic access to a supermarket, discussing these barriers and the extra effort required to surmount them (shifting the schedule to accommodate public transportation, seeking a shopping buddy with a car, planning shopping lists to substitute seed foods for prepared foods) will not negate the implications of a nonsupportive environment, but individuals may be empowered to shift the consequences of that environment in small increments. Practitioners can help to motivate dietary changes by stressing the fact that dietary choices do matter and have measurable positive effects on health.

**CONCLUSION**
Current intakes of seeds are low in the United States based on recent estimates from the National Health and Nutrition Examination Survey, which reported that whole-grain intake, was 1 serving or less per day, with less than 6% of adults consuming 3 or more servings per day. Based on the aggregate data for nuts, seeds, and beans, average intake was also less than 1 serving per day on average among adults. Approximately 30% of whites, 25% of blacks, and 40% of Mexican Americans met guidelines of 4 or more servings per week. The incorporation of whole grains and legumes into the diet is promoted by the American Heart Association, the American Diabetes Association, and the American Cancer Society, as well as the US Department of Agriculture 2010 Dietary Guidelines (see Table 9, Supplemental Digital Content 9, http://links.lww.com/NT/A14). The recent 2015 Dietary Guidelines for American Committee Report modeled 3 healthy dietary patterns designed to achieve consumption levels of the nutrients associated with health benefits—a Healthy US-Style dietary pattern, a Healthy Mediterranean dietary pattern, and a Healthy Vegetarian Dietary pattern. These 3 examples suggest a minimum consumption of whole grains (3 oz equivalents, or servings, per day), legumes (between 1.5 and 3 cups per week), and nuts (4-7 oz equivalents, or servings, per week). Similarly, the DASH diet emphasizes incorporation of nuts, seeds, and legumes into the diet, with servings varying from 3 to 4 times per week to 4 to 5 times per week, depending on the energy requirements of the individuals. Serving sizes can be considered as approximately one-third cup of nuts (1.5 oz), 2 tablespoons of seed or nut butter, or a half cup cooked legumes. Whole-grain servings can be considered 1 oz, or ounce equivalent.

Consumption of these portions can be achieved by preparing grain-based main dishes or grain-based salads, choosing whole-grain breads, adding legumes to soups or salads, as well as using them pureed in baking as replacements for eggs or butter, and using nuts as condiments for other dishes. Overall acceptance and consumption of seed foods as the basis of the diet are within reach of most Americans, provided they can access appropriate instruction and support.

**REFERENCES**


