# Prevention and Treatment of Diabetes with Natural Therapeutics

— Fourth Edition —
*Published as a public service by*
National Diabetes Fund
*a program of Project Cure*
P.O. Box 96673
Washington, D.C. 20090-6673

ML226FD-REP

02/07

## Introduction:

Diabetes is a chronic disease characterized by elevated blood glucose levels and disturbances in carbohydrate, fat and protein metabolism. These metabolic abnormalities result in part from a deficiency of the blood sugar-lowering hormone insulin or from "insulin resistance" (a defect in the body's capacity to respond to insulin).

Type 1 diabetes, also known as insulin-dependent diabetes mellitus (IDDM), usually begins in childhood and is thought to be a result of autoimmune destruction of the pancreatic beta cells (the cells that produce insulin; also called islet cells). Destruction of the beta cells results in a complete or almost-complete loss of insulin production, thereby necessitating insulin injections to maintain blood sugar control.

Type 2 diabetes, also known as non-insulin-dependent diabetes mellitus (NIDDM), is usually diagnosed after 40 years of age. Type 2 diabetes is frequently associated with insulin resistance and normal or even elevated levels of insulin, although subnormal insulin levels are also seen in some type 2 diabetics.

Gestational diabetes is characterized by hyperglycemia (elevated blood sugar) during pregnancy and usually disappears after the child is delivered. However, even though gestational diabetes may be relatively short-lived, it can compromise the health of both mother and fetus.

Diabetes is associated with a number of significant medical problems. Severe hyperglycemia may result in coma or even death. Milder hyperglycemia, if present for many years, increases the risk of cardiovascular disease, which can manifest as a heart attack, congestive heart failure, stroke, gangrene of the extremities (necessitating amputation in some cases), or kidney failure.

- Atherosclerosis accounts for up to 60% of all diabetes-related deaths.[1]
- In addition, as many as 33% of all cases of kidney dialysis and 50% of all amputations in the United States and Europe are a result of complications from diabetes.[2]
- Individuals with diabetes are 2-to-20 times more likely to develop cardiovascular disease or stroke than are people who do not have this condition.
- Visual loss due to retinopathy (damage to the retina of the eye) or cataract is also common among diabetics. About 6% of all diabetics develop glaucoma, a leading cause of blindness. Diabetes is the leading cause of blindness among American adults between ages 20 and 74 years, and is responsible for as many as 40,000 new cases of blindness annually in the United States.
- Neuropathy (nerve damage) occurs in about half of all diabetics during the course of their disease.
- Diabetics also tend to suffer from poor wound healing.
- Impotence is a common complication of diabetes in men.

Despite these potential serious complications, a majority of Americans with diabetes do not believe they are at serious risk for cardiovascular disease, according to a recent survey.[3]

## Conventional Therapy

It is now well accepted that maintaining blood glucose levels as close to the normal range as possible will reduce the incidence of these complications. Conventional physicians attempt to regulate blood glucose through a combination of dietary modification, weight loss when appropriate, exercise, and blood sugar-lowering medications, including insulin and so-called "oral hypoglycemic agents." Although this approach is helpful to some extent, it has limitations. First, the conventional dietary approach often fails to emphasize high-fiber, high-complex-carbohydrate foods, or specific foods such as legumes, which have been shown to improve glycemic (blood glucose) control (see below). Consequently, the standard "diabetic diet" is frequently not as effective as it could be.

Furthermore, insulin therapy may not achieve satisfactory glycemic control in patients with insulin resistance, and oral hypoglycemic agents may lose their efficacy after five or more years of treatment. When these drugs are effective, they must be used with caution, because an excessive dose can cause medically significant hypoglycemia.

For these and other reasons, the conventional treatment of diabetes often produces less-than-adequate blood glucose control. In addition, insulin

itself is believed to be a cause of cardiovascular disease, 3,4 so safer methods of lowering blood glucose are urgently needed. Furthermore, a recent study found that using insulin injections as a means to prevent type I diabetes in persons at high risk for developing this condition failed to prevent the development of disease.[4]

Metabolic Abnormalities in Diabetics

It should be noted that the blood glucose concentration is not the only determinant of diabetic end-organ damage (i.e., neuropathy, retinopathy, nephropathy, etc.). Diabetic complications still occur (albeit with a lower frequency) in patients who carefully maintain their blood sugar near or even completely within the normal range. A number of metabolic abnormalities and pathological changes that are associated with diabetes may be at least partly independent of blood sugar levels. These include increased production of oxygen-derived free radicals, excessive platelet aggregation and protein glycosylation, and intracellular accumulation of sorbitol (see below). Although these abnormalities are not fully understood, it is possible that taking measures to correct them will help prevent some of the complications of diabetes.

## Free-Radical Damage

Oxygen-derived free radicals are normal byproducts of metabolism. However, these compounds are highly reactive and can cause significant damage (often called oxidative damage) to cell membranes and other cellular structures. Free-radical damage is believed to play a role in atherosclerosis, cataract formation, and some of the other complications of diabetes. A recent study found that men who eat a diet rich in bacon, bologna, and hot dogs are 50 percent more likely to develop type 2 diabetes than men with similar levels of risk who had low consumption levels of these foods.[5] To counteract the destructiveness of free radicals, the body possesses a complex system of antioxidant defenses that utilize various vitamins, minerals, and other naturally occurring substances. Diabetics have been reported to have significantly higher free-radical activity, as well as significantly lower concentrations of antioxidants, compared with healthy controls.[6] These changes were of greater magnitude in patients with disease complications than in those without complications. It is possible, therefore, that supplementing with foods, nutrients, and herbs that have antioxidant activity would help prevent diabetic end-organ damage.

## Glycosylation of Proteins

Another factor that contributes to the complications of diabetes is a process called glycosylation of proteins. Known to chemists as the Maillard reaction and to bakers as the browning reaction, glycosylation involves the irreversible binding of glucose or other sugars to a protein molecule. A growing body of evidence indicates that glycosylation of tissue proteins is one of the mechanisms whereby diabetics develop organ damage.[7] Although glycosylation occurs continuously in all human beings, the reaction is accelerated when blood sugar is elevated. One of the reasons that maintaining tight blood sugar control prevents complications is that the rate of tissue glycosylation is lower when the average blood sugar is lower. However, studies have shown that certain nutritional supplements also inhibit glycosylation independently of any effect they may have on blood glucose levels. Supplementation with these nutrients might therefore be expected to reduce the risk of diabetic end-organ damage.

## Sorbitol Accumulation

Another process that leads to diabetes-related organ damage is the accumulation of sorbitol in certain tissues and organs. Sorbitol is manufactured in the body from glucose. When glucose levels are elevated, sorbitol is produced inside the cells faster than it can be broken down. Since sorbitol cannot cross cell membranes, it builds up inside the cells and draws water in by the process of osmosis. This sorbitol-induced osmotic swelling is believed to be one of the main causes of tissue damage in diabetics.

Glucose is converted to sorbitol by the enzyme aldose reductase. A drug called sorbinil, which inhibits this enzyme, was shown to reverse both diabetic neuropathy and diabetic cataracts. However, because of its severe toxicity, sorbinil was rejected by the Food and Drug Administration for use as a prescription drug. Substances which can safely prevent the accumulation of intracellular sorbitol would therefore be welcomed.

## Strategies for Treating Diabetes and Preventing Complications

The above evidence suggests that appropriate goals in the management of diabetes include maintaining blood glucose levels as close to the normal range as possible, minimizing the adverse effects of free radicals by enhancing antioxidant defenses, and reducing the glycosylation of proteins and the intracellular accumulation of sorbitol. A number of different interventions that are currently considered to be in the realm of "alternative medicine" have been shown to accomplish one or more of these goals. In addition, specific methods of preventing or treating diabetic complications (such as cardiovascular disease and neuropathy) have been identified. These will be discussed below.

## Dietary Factors

A considerable body of evidence indicates that a diet high in fiber and complex carbohydrates helps improve glucose regulation in diabetics. In one study, 20 insulin-treated diabetics who were not overweight consumed a standard diabetic diet (providing 43% of calories as carbohydrate) for 7 days, followed by a high-complex-carbohydrate, high fiber (HCF) diet for 16 days.[8] The HCF diet provided approximately 70% of calories as carbohydrate and was designed to maintain body weight. The daily dose of insulin was lower for each patient on the HCF diet than on the control diet and the mean insulin dose was reduced significantly from 26 to 11 units/day. On the HCF diet, insulin therapy could be discontinued in nine patients who had been receiving 15-20 units per day and in two patients who had been receiving 32 units per day. Blood glucose levels in the fasting state and three hours after meals were lower in most patients on the HCF diet, even though the insulin dose had been reduced. The mean serum cholesterol concentration also fell significantly from 206 to 147 mg/dl. This study demonstrates that a HCF diet can reduce blood sugar levels and insulin requirements in diabetics and that this effect is not dependent on weight loss. In a follow-up study, the beneficial effects of this diet were maintained for periods ranging from 26 to 86 months.8 A HCF diet has also been found to reduce insulin requirements in patients with type I diabetes.[9]

In another study, 16 diabetics consumed a conventional carbohydrate-restricted diet or a diet which excluded refined carbohydrate but allowed unrefined carbohydrate.[10] On the unrefined-carbohydrate diet, the mean postprandial (after-meal) plasma glucose concentration fell significantly by 20%. Supplementation with 78 g/day of wheat bran has also been shown to reduce the insulin requirements of insulin-dependent diabetics by 8-10%.[11]

Ingestion of legumes appears to be particularly effective at control blood sugar. Eighteen non-insulin-dependent diabetics and nine insulin-dependent diabetics received a high-complex-carbohydrate diet containing leguminous fiber, and a standard low-carbohydrate diet, each for six weeks, in random order.[12] In both groups, the mean concentrations of blood glucose (preprandial and 2-hour postprandial) and serum cholesterol, and the urinary excretion of glucose were all significantly lower on the diet containing legumes than on the standard diet. In another study, breakfasts containing lentils or whole meal bread of identical carbohydrate content were consumed by seven healthy volunteers.[13] Compared with bread, the lentils produced a significant 71% reduction in the area under the blood glucose curve and flattened the plasma insulin response. These changes are indicative of improved glucose metabolism. In addition, the lentil breakfast lowered the blood glucose response to a standard bread lunch four hours later. This study demonstrates that the beneficial effect of legumes on glucose control extends to the meal after which they are consumed.

Certain individual foods have also been shown to lower blood glucose or to improve carbohydrate tolerance in diabetics. Ingestion of 100 g/day of whole barley flour for four weeks by healthy volunteers significantly reduced the blood-glucose response to a test meal (bread).[14] In another study, addition of 600 g/day of green beans or 60 g/day of fresh onions to the diet for one week significantly lowered blood sugar levels in a group of patients with poorly controlled diabetes.[15] Ingestion of an onion extract has also been shown to reduce the rise in blood sugar in healthy volunteers during a glucose tolerance test.[16] Both garlic and onions reduced the hyperglycemic effect of glucose feeding in experimental animals.[17]

The inclusion of garlic and onions in the diet

of diabetics may be desirable for reasons other than their potential to lower blood glucose. Garlic has been reported to decrease serum cholesterol levels,[18] to prevent the oxidation of LDL cholesterol,[19] to inhibit platelet aggregation,[20] and to lower blood pressure.[21] Each of these effects would be expected to prevent the development of disease, one of the most important complications of diabetes. Onion extracts have also been shown to inhibit platelet aggregation[22] and to lower blood pressure in patients with hypertension.[23] In addition, onions contain relatively large amounts of quercetin,[24] a flavonoid compound that inhibits aldose reductase.[25] Since aldose reductase inhibition has been shown to reverse diabetic cataracts and neuropathy, inclusion of onions in the diet of diabetics seems desirable. Brewer's yeast may also be useful for diabetics, as it has been reported to contain at least two-blood sugar-lowering compounds.[26] The capacity of yeast to reduce blood glucose was reported as early as 1923, although the type of yeast used was not specified in that report.[27]

A recent study found that 90 percent of adult type 2 diabetes cases could be prevented if people ate healthier food, exercised more regularly, stopped smoking, and implemented a few other basic health behaviors.[28] A recent controlled study found that intensive dietary interventions, such as consuming less than 26% of total energy from fat, increasing fiber intake, and exercising aerobically five times per week, can increase insulin sensitivity by 23% compared to only 9% in a modest intervention group.[29]

## Vegan Diet for Diabetic Neuropathy

Twenty-one patients with diabetic neuropathy consumed a vegan diet (free of meat, chicken, fish, eggs, and dairy products) consisting of unrefined foods; these patients also participated in an exercise program. In 17 of the 21 cases, the sharp, stabbing, shooting, and/or burning pains were completely alleviated within 4-16 days. Numbness persisted, but was noticeably improved within two days. The improvement in diabetic neuropathy did not appear to be a result of better blood glucose control.[30]

## The Role of Cow's Milk

Epidemiologic studies have found an increased risk of type I diabetes among children who consumed cow's milk early in life.[31,32,33] It has been postulated that ingestion of cow's milk results in the production of antibodies that cross-react with and damage pancreatic insulin-producing cells.

However, other studies have found no association between ingestion of cow's milk and the risk of developing type I diabetes.[34] A recent study found that a diet with high levels of dairy products may decrease insulin resistance syndrome in young adults.[35] Further research is needed to resolve the conflicting data.

## Nutritional Supplements

Glucose regulation depends on a wide range of vitamins, minerals, and other micronutrients. Many of these nutrients are in short supply in the typical refined, processed American diet. In addition, some nutrients have been shown to exert effects that might be expected to reduce the risk of end-organ damage. Supplementation with appropriate vitamins and minerals may therefore be of value in the prevention and treatment of diabetes. The following is a review of specific nutrients:

## Chromium

Chromium is a component of a molecule called glucose-tolerance factor (GTF), which occurs naturally in the body and enhances the action of insulin at the cellular level.[36] Rats fed a chromium-deficient diet developed hyperglycemia and glycosuria.[37] Monkeys maintained on a low-chromium diet had abnormal glucose metabolism, which was corrected by chromium supplementation.[38] Chromium also protected guinea pigs against experimentally-induced pancreatic beta-cell destruction[39] and reduced insulin resistance in genetically obese mice.[40] A newer study found that chromium supplementation increased insulin sensitivity in diabetic rats.

A randomized study in cats found that glucose concentrations ad glucose half-life were significantly lower in cats who received chromium supplementation than in a control group that did not receive the supplement.[41]

Chromium deficiency is known to occur in man. Individuals maintained on parenteral nutrition developed a complex metabolic disorder including impaired glucose tolerance, which was reversed by chromium supplementation.[42,43] Less severe forms of chromium deficiency may be common in the United States. Because of farming

techniques that fail to replenish trace minerals in the soil, the chromium content of food is probably lower than it was at the turn of the century. Tissue chromium levels were found to decline with age in Americans,[44] but not in individuals living in other countries.[45] One dietary survey revealed that 90% of American diets contained less than the minimum suggested daily intake for chromium.[46]

In a double-blind trial, daily administration of 200 mcg of chromium produced a significant reduction in 2-hour post-prandial glucose levels in elderly women with borderline glucose tolerance.[47]

In another study of elderly patients, chromium supplementation significantly reduced plasma glucose concentrations during a glucose tolerance test and significantly improved glucose utilization.[48] Treatment with 150 mcg/day of chromium for four months normalized glucose tolerance in four of ten elderly individuals with abnormal glucose tolerance.[49] Administration of 150 to 1,000 mcg/day of chromium improved glucose tolerance in three of six diabetics. The estimated safe level of daily chromium consumption has been set at between 50 and 200 mcg/day, so ingestion at higher levels could be risky.[50,51] A variety of studies have shown that suboptimal ingestion of chromium is associated with an increased risk of various factors linked with diabetes and cardiovascular diseases. Chromium supplementation has been found to reverse glucose intolerance and severe neuropathy in individual patients.[52] Newer research has found some of the underlying factors that account for the ability of chromium to promote the action of insulin and lower blood glucose levels in diabetic patients.[53] An additional study involving human subjects found that chromium supplementation reduces oxidative stress, a key factor in the progression of diabetes.[54]

Other studies have produced negative results. In two double-blind studies, supplementation with 150 or 200 mcg/day of chromium failed to improve glucose tolerance in diabetic patients.[55,56] These conflicting results may be due to several factors.

First, in all of the studies described above, chromium chloride was used. Because absorption of this form of chromium is only about 0.5%, the dosage may have been inadequate. Second, in order to exert an effect on glucose metabolism, inorganic chromium must be converted to GTF. Biosynthesis of GTF requires, among other things, an adequate supply of niacin, a nutrient which may be in short supply in many individuals (see below).

Ingestion of foods containing GTF may therefore be a preferred way of obtaining biologically active chromium. GTF occurs naturally in brewer's yeast and to a lesser extent in other foods, including beef, chicken, bananas, lobster, shrimp, mushrooms, and cheese.[57] GTF chromium is also promoted as a nutritional supplement.

However, according to Mertz, who originally discovered GTF, analysis of one of the so-called "GTF chromium" products revealed no GTF activity.[58] The exact molecular structure of GTF is still unknown, and no one has been able to synthesize it. Therefore, claims that "GTF chromium" supplements are superior to other well-absorbed forms of chromium (such as chromium aspartate, chromium picolinate, or chromium polynicotinate) are questionable. A new study has found that dietary supplementation with chromium can moderate glucose intolerance and control blood sugar in diabetic patients.[59] Another study found strong antioxidative effects on the oxidative stress that leads to complications in type 2 diabetic subjects.[60] An additional study found that chromium supplementation stabilized the effects of insulin and improved blood sugar control in a group of type 2 diabetic patients.[61] A newer study found that the use of chromium early in the course of therapy in diabetics reduced the degree of insulin resistance.[62]

A different study found that chromium-enriched yeast supplementation in type 2 diabetics reduced oxidative stress and improved blood glucose variables.[63] A study of patients with type 2 diabetes mellitus found that a combination of chromium picolinate and biotin improved glycemic control when added to a typical diabetes care program with hypoglycemic drugs.[64] The researchers also concluded that these improvements could add to reduced costs in diabetes management over time.

Newer studies in animals have found that chromium supplementation decreases the symptoms of hyperglycemia and improves kidney function in diabetic mice.[65] Another study in human with type 2 diabetics found that chromium supplementation significantly reduced oxidative stress, which is a key indicator in the progression of the disease.[66]

## Niacin and Niacinamide

As a component of GTF, niacin (nicotinic acid) plays an important role in carbohydrate

metabolism. Many refined foods consumed by Americans are depleted of niacin. Grains and other foods that are "enriched" usually contain added niacinamide, which is capable of performing most of the functions of Vitamin B3, but which cannot apparently be converted by the human body into niacin. In addition, most vitamin supplements contain niacinamide rather than niacin. A small amount of niacin may therefore be necessary for some individuals to enable the production of adequate amounts of GTF. Researchers have found that nicotinamide can protect vital pancreatic cells from diabetes-inducing factors.[67]

In one study, 16 healthy elderly individuals received either 200 mcg of chromium, 100 mg of niacin, or both, daily for 28 days.[68] Fasting plasma glucose levels and glucose tolerance were not affected by either chromium or niacin individually.

However, the combination of chromium plus niacin produced a significant 14.8% decrease in the area under the glucose curve during a glucose tolerance test and a significant 6.8% reduction in fasting glucose. This study suggests that a relatively low dose of supplemental niacin, when combined with chromium, improves glucose metabolism and may therefore be useful for preventing and treating diabetes.

Larger doses of niacin (such as 1-3 g/day) can effectively lower serum cholesterol levels and reduce the risk of cardiovascular disease. Although this treatment is often prescribed by conventional physicians, many doctors are reluctant to recommend high-dose niacin for hypercholesterolemic diabetics because it will occasionally increase blood glucose levels in diabetics.[69] However, the effect of high-dose niacin is variable and this vitamin has been also been reported to reduce insulin requirements in some type I diabetics.[70] Consequently, high-dose niacin is not contraindicated in diabetics; however, blood glucose levels should be monitored closely. Both niacin and niacinamide may also help prevent the onset or progression of diabetes by protecting the insulin-producing pancreatic beta cells from being damaged. In animal studies, niacinamide protected against streptozotocin-induced diabetes[71,72] and inhibited the development of experimental autoimmune diabetes.[73] Niacin administration also prevented the diabetes-inducing effect of alloxan in rabbits and rats.[74] There is evidence that both experimental diabetes and type I diabetes in humans are related to a depletion of nicotinamide adenine dinucleotide (NAD) within pancreatic beta cells, resulting in failure of oxidative metabolism and subsequent cell death. As precursors to NAD, niacin and niacinamide are apparently capable of preventing the depletion of NAD in pancreatic beta cells.[75]

Because of its capacity to protect pancreatic beta-cell function, niacinamide has been studied as a possible treatment for newly diagnosed type I diabetes, which is characterized by progressive destruction of beta cells.[76] In a double-blind study, 16 type I diabetics received either niacinamide (3 g/day) or a placebo, beginning one week after the start of insulin therapy. Insulin was successfully discontinued in 85.7% of the patients taking niacinamide, compared to 55.6% of those taking placebo ($p<0.05$). Three patients treated with niacinamide for 18 months remained in remission for more than two years. Remissions of such long duration are extremely rare in type I diabetes. In another study, 14 children who were at high risk of developing diabetes (as determined by high levels of antibodies against pancreatic islet cells) received either niacinamide (150-300 mg per year of age per day, maximum dose = 3.0 g), while eight children at similar risk served as controls.[77] All eight of the untreated children developed diabetes, compared with only one of the 14 children who received niacinamide ($p<0.001$). A recent meta-analysis of 10 randomized controlled trials concluded that niacinamide effectively preserves residual pancreatic beta-cell function in children with type I diabetes, when treatment is begun at the time of initial diagnosis. A new study found that nicotinamide helps prevents complications, especially infections, in type 2 diabetic patients.[78] A study of nicotinamide found that supplementation with this compound had effects in the body that are similar to insulin in its ability to control blood sugar.[79] A randomized, clinical study of children with type 1 diabetes mellitus found that the use of nicotinamide alone or in combination with vitamin E improved metabolic control in these patients.[80]

## Biotin

The B-vitamin biotin plays a role in the intracellular metabolism of glucose. Biotin deficiency resulted in impaired glucose tolerance in

rats.[81] In another study, administration of biotin (2-4 mg/kg of body weight/day) to genetically diabetic mice improved glucose tolerance and lowered insulin resistance.[82]

Biotin has also shown promise in the treatment of diabetes in humans. Seven insulin-dependent diabetics were removed from insulin therapy and treated with biotin (16 mg/day) or a placebo for one week. Fasting blood glucose levels rose significantly in patients given placebo, but decreased significantly in those treated with biotin.[83] In another study, serum biotin levels were significantly lower in 43 patients with non-insulin dependent diabetes than in healthy controls.

Eighteen diabetic patients were given 9 mg/day of biotin for one month, while 10 other patients received a placebo. The mean blood glucose concentration fell by 45% ($p<0.05$) in patients receiving biotin, but did not change in those given placebo.[84]

Biotin has also been used to treat diabetic neuropathy. Three patients with severe diabetic peripheral neuropathy received 10 mg/day of biotin intramuscularly (IM) for six weeks, followed by 10 mg IM three times a week for six weeks, then 5 mg/day orally.[85] The treatment duration ranged from 64 to 130 weeks. Within 4-8 weeks of the start of treatment, painful muscle cramps, paresthesias, and ability to walk improved markedly and restless legs syndrome disappeared.

Biotin has been found to have beneficial effects on glucokinase (GK), a key factor in the proper regulation of glucose metabolism. A recent clinical study in Japan found that 3 mg of biotin administered three times daily led to significantly lower fasting glucose levels in patients with type II diabetes without any substantial side effects.[86]

## Vitamin B6

Serum vitamin B6 levels were below normal in 25% of a series of 518 mostly adult diabetics[87] and in 24% of 63 childhood diabetics.[88] Pyridoxine (vitamin B6) supplementation of diabetic patients improved glucose tolerance in some studies[89,90] but was without effect in others.[91] Fourteen women with gestational diabetes were treated with 100 mg/day of pyridoxine for 2 weeks. At the end of the treatment period, 12 of the 14 women no longer had gestational diabetes.[92] The same dosage of vitamin B6 also produced a significant improvement in glucose tolerance in 13 women with late-pregnancy gestational diabetes.[93] A controlled study found that patients with diabetic polyneuropathy had a significant improvement in nerve conduction velocity after a combination regimen of vitamins B1, B6, and B12.[94,95] Other studies have failed to confirm the beneficial effect of vitamin B6 on gestational diabetes.[96] However, in that study, the women were hospitalized and confined to a sedentary existence. It is possible that a beneficial effect of vitamin B6 on glucose tolerance was counterbalanced in that study by a lack of activity.

In another study, pyridoxine at a dosage of 50 mg three times per day had no effect on blood glucose but reduced the concentration of glycosylated hemoglobin (HbA1c) by about 6% after six weeks.[97] This finding suggests that vitamin B6 inhibits the glycosylation of proteins and might therefore help prevent diabetic complications. Indeed, a study in diabetic rats found that pyridoxine inhibited the progression of kidney disease.[98]

Vitamin B6 has been used to treat patients with diabetic neuropathy. Eighteen such patients received 50 mg of pyridoxine three times per day or a placebo for four months. Six (67%) of nine of pyridoxine-treated patients reported significant relief from neuropathic symptoms, compared with 4 (44%) of nine placebo-treated patients. This preliminary report warrants further study.[99] A study in children with type 1 diabetes found that a combination of folate and vitamin B6 significantly improved the health of the endothelium of the patients, which is a measure of disease progression.[100]

## Vitamin E

Several decades ago, Wilfrid Shute, M.D., a pioneer in vitamin E therapy, reported that vitamin E supplementation reduced blood sugar levels in some diabetics.[101] This observation was confirmed in one study,[102] but others failed to find a beneficial effect of vitamin E.[103,104] More recently, in a double-blind, placebo-controlled study, administration of 900 mg/day of vitamin E for four months to non-insulin-independent diabetics significantly improved glucose tolerance.[105] Vitamin E also inhibited glycosylation of proteins when administered at doses of 600 or 1200 IU/day; the

higher dose was slightly more effective than the lower dose.[106]

Newer research has also suggested positive effects on diabetes from vitamin E supplementation. A study found that vitamin E supplementation significantly reduced oxidative stress to tissues in a study of 30 patients with non-insulin-dependent diabetes mellitus. A different study found that vitamin E supplementation increased blood flow to tissues in diabetics. An additional study added further weight to this evidence by suggesting 1,000 IU daily supplementation of vitamin E led to improved circulation to tissues in diabetic patients after three months.[107] A significant body of evidence indicates that vitamin E may help prevent heart disease, one of the main complications of diabetes.[108,109] A recent study found that vitamin E supplementation decreased several markers of thrombosis in patients with type 2 diabetes.[110]

A different study found that patients with type 2 diabetes given 600 mg per day of vitamin E had improvements in the health of nerves that control the functioning of the heart.[111] A study found that 500 IU of vitamin E per day given to patients with type 2 diabetes reduced the levels of factors that increase the risk of developing vascular complications.[112] An additional study found that 800 IU per day of vitamin E improved beta-cell function, increased plasma insulin, and may have decreased insulin resistance in 40 patients with type 2 disease who took the supplement for a month.[113]

New evidence further gives weight to the idea that vitamin E protects against the oxidative stress effects associated with arteriosclerosis.[114] A new study of women with type 2 diabetes found that a combination therapy of vitamin E (1800 IU daily), vitamin C, and the amino acid L-arginine significantly improved the condition of the cardiovascular system in these women.[115] A new study of a large population in Singapore found that low vitamin E is a risk factor for the development of vitamin E.[116] A newer study found that high levels of vitamin E (alpha-tocopherol) in the blood are associated with a decreased risk of type 1 diabetes mellitus in the siblings of children with the disease.[117] A new study has found that the combined use of vitamin C, vitamin E, and N-acetylcysteine reduced some of the oxidative stress produced from a medium-fat meal in patients with type 2 diabetes mellitus.[118]

## Magnesium

Serum magnesium concentrations were significantly lower in a group of 56 diabetics than in healthy controls.[119] Hypomagnesemia was more pronounced in individuals with diabetic retinopathy[120] or cardiac complications[121] than in diabetics without such complications. Poor control of diabetes was often associated with low serum magnesium.[122] HbA1c levels correlated significantly with Mg concentrations in plasma, muscle, and mononuclear cells.[123] Magnesium deficiency has also been found to be common in children with type I diabetes.[124]

The reduced concentrations of magnesium seen in diabetics appears to result in part from increased urinary magnesium excretions.[125] In addition, the American diet tends to be low in magnesium. Dietary surveys have shown that 80-85% of American women consume less than the Recommended Dietary Allowance (RDA) for this mineral.[126] Daily magnesium intake in two other studies was only about two-thirds of the RDA.[127,128]

In a double-blind study of 12 nondiabetic elderly individuals, magnesium supplementation was found to improve the secretion and action of insulin.[129] In addition, a considerable body of evidence indicates that magnesium can prevent cardiovascular disease, for which diabetics are at increased risk.[130]

Magnesium supplementation has been found to improve insulin sensitivity and insulin secretion in patients with Type II diabetes.[131] Magnesium deficiency has been associated with insulin resistance and overall poor diabetic control in elderly individuals who are borderline diabetic.[132] A newer study has found that a group of persons with type 1 diabetes had insufficient levels of magnesium dietary intake.[133] This study also found that magnesium supplementation in these same patients led to reduced insulin-stimulated glucose uptake. Low serum levels of magnesium have also been found to be associated with complications of type 2 diabetes, such as the development of foot ulcers.[134] A new study has found significant evidence that magnesium intake is significantly associated with a reduced risk of developing diabetes.[135] A new study of overweight women found that magnesium supplementation significantly reduced the risk of developing diabetes.[136] A study of patients with diabetes and

those without the disease found that the diabetic patients had lower levels of magnesium in the blood and that magnesium supplementation stabilized blood sugar levels in those with disease.[137] Thus, magnesium supplementation may be an important component of the overall treatment of many diabetics.

## Ascorbic Acid (Vitamin C)

The importance of vitamin C for blood sugar regulation has been demonstrated in both humans and animals. Guinea pigs fed a vitamin C-deficient diet developed diabetic glucose tolerance curves, glycosuria, and decreased pancreatic insulin content.[138]

A study of diabetic rats found that vitamin C supplementation leads to protection against oxidative processes.[139]

A newer study found that vitamin C supplementation decreases insulin resistance and improves glucose regulation in diabetic mice.[140] Diabetic blood sugar curves were also seen in humans with vitamin C deficiency; these values returned to normal after supplementation with vitamin C.[141] A study of 56 outpatients with non-insulin-dependent diabetics found that 2 grams per day of vitamin C led to improved glycemic control and fasting blood glucose levels in addition to having a favorable effect on cholesterol and triglycerides.[142]

Diabetics are at increased risk of developing vitamin C deficiency. For example, the vitamin C concentrations in plasma,platelets,[143] and white blood cells[144] were significantly lower in diabetics than in healthy controls. Vitamin C deficiency in diabetics may be more pronounced within the cells than in plasma or other body fluids. That is because vitamin C is structurally similar to glucose, and may therefore compete with glucose for transport into cells. In the presence of elevated blood sugar, the uptake of vitamin C into cells appears to be impaired.[145] This reduced entry of vitamin C into certain tissues may result in a kind of "localized scurvy." It is noteworthy that the vascular changes resulting from scurvy resemble those seen in diabetics.

In addition to maintaining the integrity of blood vessels, vitamin C has been shown to inhibit three different biochemical processes that are associated with end-organ damage in diabetics. First, vitamin C functions as an antioxidant. Second, this vitamin inhibits the intracellular accumulation of sorbitol.

In one study, supplementation with 2,000 mg/day of vitamin C reduced erythrocyte sorbitol accumulation by 56.1% and 44.5% in healthy individuals and diabetics, respectively.[146] Third, vitamin C significantly reduced the glycosylation of proteins, when given to healthy volunteers at a dose of 1 g/day.[147] A study of 20 diabetic patients found that 500 mg of ascorbic acid given twice daily led to significantly increased levels of ascorbic acid in the blood and decreased the albumin excretion rate, a key measure of disease progression in diabetics.[148]

A different study of vitamin C supplementation in rats found that vitamin C inhibits the action of interferon alpha, a substance that inhibits the release of insulin.[149] A randomized, double-blind study of 30 patients with type 2 diabetes found that supplementation with 1250 mg of vitamin C per day slowed the progression of kidney disease that developed as a complication of diabetes.[150]

A new study has found that vitamin C decreases oxidative stress and improves blood vessel function in diabetic patients.[151] A randomized, double-blind study of 30 patients with type 2 diabetes mellitus found that improved the function of arteries, an important finding in the prevention of complications in this condition.[152] An additional study found evidence that vitamin C reduces oxidative stress and improves blood vessel function in diabetics.[153] These studies suggest that long-term supplementation with vitamin C may help prevent many of the complications of diabetes.

## Vitamin B12

Injections of vitamin B12 have been used to treat retinopathy in patients with type I diabetes. In one study, 15 patients added 100 mcg of vitamin B12 to their daily insulin injection. After one year, all signs of retinopathy had disappeared in seven cases.[154] Similar results were reported by others.[155] Vitamin B12 has also been used to treat diabetic neuropathy. In one study, 12 patients received 15-30 mcg/day of vitamin B12 by injection for the first 7-14 days, followed by 15-30 mcg, 1-2 times a week.[156] Seven patients had complete or almost complete remission of the neuropathy and three had partial improvement. The response appeared to depend more on the frequency of the injections than on the amount of each individual dose. Other

investigators have also found vitamin B12 to be helpful in the treatment of diabetic neuropathy.[157]

## Copper

Copper deficiency in experimental animals resulted in impaired glucose tolerance[158] and increased concentrations of glycosylated hemoglobin (indicative of chronic hyperglycemia).[159] Because the typical American diet contains only about half of the Recommended Dietary Allowance (2 mg/day) for copper,[160] a deficiency of this mineral may be common. Two male volunteers who consumed a controlled intake of 0.7-0.8 mg of copper per day for 5-6 months had increased [161]glucose levels during a glucose tolerance test. These levels returned toward normal after adequate amounts of copper were restored to the diet.[162] In two other volunteers, administration of 6 mg/day of copper improved glucose tolerance, suggesting that their usual diet was deficient in copper.[163] A study in patients with type 2 diabetes found that those with progressive kidney disease excreted higher levels of copper in urine and had lower levels in plasma than patients with less serious disease.[164]

## Potassium

Potassium deficiency in rats resulted in elevated blood glucose levels and a reduced insulin response to a glucose load.[165] Obese patients undergoing a protein-sparing modified fast without potassium supplementation had a striking reduction in peripheral glucose utilization and insulin levels.

These changes were reversed by potassium supplementation.[166] Administration of potassium to children with protein-energy malnutrition resulted in rapid improvement in the insulin response to an intravenous glucose load.[167] Potassium supplementation also prevented the impairment of glucose tolerance that sometimes results from treatment with thiazide diuretics.[168] These studies indicate that potassium plays an important role in glucose metabolism. The beneficial effect of a high-fiber diet on glucose metabolism may be due in part to the relatively large amount of potassium present in fruits, vegetables, and other high-fiber foods.

An additional study found that potassium levels in the body are critical to the stability of potassium ion channels, which are vital to the health of blood vessels.[169] Sufficient potassium intake may help reduce vascular complications from diabetes.

## Zinc

Plasma zinc concentrations were reduced and urinary zinc excretion was elevated in diabetic patients.[170,171] Zinc plays a role in the synthesis of insulin by pancreatic beta cells[172] and in the action of insulin at the cellular level.[173,174] Patients with zinc deficiency resulting from gastrointestinal diseases had significantly higher glucose levels and significantly lower insulin levels than did similar patients without zinc deficiency.[175] Zinc supplementation increased plasma insulin levels in these patients. Healthy male volunteers consuming a low-zinc diet had a significant increase in fasting blood glucose levels.[176] Impaired glucose tolerance also developed in rats fed a zinc deficient diet.[177]

Diabetics often have impaired immune function (manifesting as increased susceptibility to infection), which may be due in part to zinc deficiency. In one study, administration of zinc to diabetic patients increased the T lymphocyte response to phytohemagglutinin (a measure of immune-system function).[178] Zinc also plays a crucial role in wound healing, which is abnormal in many diabetics.

The typical American diet is low in zinc. In one dietary survey, 68% of adults consumed less than two-thirds of the RDA for zinc.[179]
Newer research in animals continues to demonstrate the important relationship between zinc ingestion and glucose stability. Mice with type 2 diabetes mellitus had normalization of previously high blood glucose levels after administration of a zinc complex.[180] A study in diabetic rats found that zinc along with 2 other compounds derived from prostate tissue has the ability to reduce blood glucose.[181] A controlled study of 50 humans with diabetes mellitus found that zinc levels in the blood were significantly lower than in normal individuals.

A group of 15 diabetic neuropathy patients that were given 660 mg of zinc sulfate daily for six weeks had significant improvement in fasting blood sugar levels, blood sugar levels after eating, and in nerve conduction velocity tests.[182]

A newer study found that supplementation with 30 mg daily of zinc for six months, either alone or combined with chromium supplementation, led to improvement in at least one measure of

disease progression.[183] A new study has shown that zinc can lower blood glucose and reduce toxic effects throughout the system in diabetic subjects.[184] An additional study found that oral zinc supplementation reduces blood sugar in diabetics with high blood sugar and stimulates more efficient glucose metabolism, especially in muscle tissue .[185] A new study of diabetic patients in Tunisia found zinc supplementation prevents some of the negative effects of oxidative stress that occur in these patients.[186] These data suggest that zinc supplementation may be especially important for diabetics.

## Selenium

Selenium-deficient rats had decreased insulin secretory reserve. When combined with vitamin E deficiency, selenium deficiency resulted in glucose intolerance.[187] Dietary selenium protected against early stage retinopathy in rats.[188] In a group of insulin-dependent diabetic pregnant women, there was an inverse association between serum selenium concentration and the degree of visual impairment.[189] Newer research indicates selenium mimics the action of insulin.[190] A new study found that selenium reduces resistance in the body to the effects of insulin, thus making insulin more effective in reducing blood sugar.[191] An additional study found that selenium has powerful antioxidant effects against oxidative stress in diabetic patients.[192] Yet another study found that selenium supplementation improved blood sugar and fat metabolism in patients with type 2 diabetes mellitus.[193] A different study found evidence that patients with type 2 diabetes mellitus have lower levels of selenium in the blood.[194] Selenium may activate key proteins that are also activated by insulin.

## Thiamine

When animals were fed a thiamine-deficient diet, there was a significant increase in blood sugar.[195] Blood thiamine concentrations were significantly lower in insulin-dependent diabetics than in healthy controls, but the levels in non-insulin-dependent diabetics were normal.[196] Administration of 10 mg/day of thiamine for four weeks reduced blood glucose levels and urinary excretion of glucose in six (54.6%) of eleven diabetics.[196]

Thiamine, in combination with other B-vitamins has been recently tested as a treatment for diabetic neuropathy. Twenty-four patients received daily either a placebo or 320 mg of allithiamine (a lipid-soluble derivative of thiamine found in garlic), plus 720 mg of pyridoxine and 2.0 mg of vitamin B12.[197] After two weeks, the dosages of the vitamins were reduced by about two-thirds.

After 12 weeks of treatment, there was a significant improvement in nerve-conduction velocity in the vitamin-treated group compared with the placebo group. No significant side effects were seen. Thiamine has been found to play a large role in the proper regulation of glucose metabolism and pancreatic beta-cell function. A more recent study of 10 children with type 1 diabetes found that a form of thiamine administered for three months led to improved metabolic control in the children.[198]

A new study of a mixture compound consisting of thiamine, arginine, caffeine, and citric acid found evidence that this formulation reduced body weight, improved fat metabolism, and improved blood sugar levels in diabetic subjects.[199]

## Vanadium

Vanadate, an oxidized form of the trace mineral vanadium, appears to have an insulin-like action.[200] A study found that administration of vanadyl sulfate (another form of vanadium) at a dose of 50 mg twice daily for four weeks to patients with non-insulin dependent diabetes reduced the mean blood glucose concentration significantly by about 20%.[201] Other research has found beneficial effects from vanadium in both non-insulin-dependent and insulin-dependent diabetics.[202] Animal studies have demonstrated short-term use of vanadium sulfate can improve insulin-resistant diabetes.[203] A newer study in rats found that a compound that included vanadium improved the ability of insulin to control blood glucose in diabetic animals.[204] An additional study in diabetic rats found that a form of vanadium reversed some of the chemical changes caused by the disease.[205] A study involving diabetic mice found that treatment with vanadium in drinking water led to significant improvement in the animals in many areas and did not produce any obvious toxicity.[206] A different study found that a variety of compounds that include vanadium enhance insulin activity and stabilize blood glucose.[207]

Vanadium is currently being promoted in

the popular press and by some physicians as an effective treatment for diabetes. However, it should be noted that the dose of vanadium used in the study mentioned above was several thousand times as much as that found in a typical diet. There is no precedent for using such large amounts of a trace mineral, and there are concerns about the potential toxicity of such large doses. Vanadium accumulates in the body with long-term use, and toxic effects of this trace mineral have been reported in animal studies.[208] A new study of diabetic subject has found that a formulation of vanadium and molybdenum, and some other metal complexes has strong blood sugar lowering-properties.[209] Until long-term safety studies are done with humans, high-dose vanadium cannot be recommended as a treatment for diabetes.

## Alpha-lipoic Acid

A study of lipoic acid administered to diabetic patients has found that this compound has many similar properties and effects to those of insulin.[210] A new study of an oral time-released formulation of alpha-lipoic acid in diabetic subjects found that blood sugar levels were significantly lowered over a six-week period.[211] Other studies have found that alpha-lipoic acid can reduce and prevent oxidative stress damage in diabetic subjects.[212] A different study found that alpha-lipoic acid improves the sensitivity of insulin action in the body.[213]

## Treatment of Diabetic Neuropathy

In addition to biotin, vitamin B6, vitamin B12, and a vegan diet (discussed previously) several other treatments have been used for diabetic neuropathy. In one study, intravenous administration of lipoic acid (a B-vitamin: 600 mg/day for 3 weeks) reduced the symptoms of diabetic peripheral neuropathy, without causing significant adverse reactions.[214] A different study found that 10 patients with diabetic neuropathy who received 600 mg/day of lipoic acid for 70 days significantly reduced lipid peroxidation, a key factor in the diabetic disease process.[215] A controlled study of 12 patients with Type 2 diabetes found that daily administration of 600 mg of alpha-lipoic acid led to improvement in a variety of neuropathic symptoms such as numbness, pain, and burning.[216] More than one recent experimental and clinical trial has shown that alpha-lipoic acid can improve glucose regulation in patients with type 2 diabetes.[217] These studies also found that lipoic acid significantly decreased a variety of diabetic pathologies, such as polyneuropathy, vascular damage, and cataract formation.

Studies in rats have suggested the administration of d-alpha-tocopherol (vitamin E) protected diabetic animals from developing albuminuria, an important complication of the disease.[218] A more recent study found that diabetic rats fed a diet supplemented with vitamins C and E had significant inhibition of diabetic retinopathy compared to a control group.[219]

In another study, 111 patients with mild diabetic neuropathy were randomly assigned to receive 12 capsules per day of evening primrose oil or placebo for 1 year in double-blind fashion.[220] Evening primrose oil was significantly more effective than placebo, as determined by various objective measurements of nerve function.

## Herbal Treatment of Diabetes

Herbal medicine has been used for many years by different cultures around the world, both for the prevention and treatment of diabetes. It has only been recently that some of these herbal treatments have been studied scientifically.

## Trigonella foenum graecum (Fenugreek)

Fenugreek seed (Trigonella foenumgraecum) is an annual plant of the leguminous family. Fenugreek seeds are commonly used as a condiment in India. Yemenite Jews have traditionally used fenugreek to treat type II diabetes. A study in rats found that fenugreek administered in the ratio of 2 to 8 grams per kilogram of body weight in diabetic rats led to significant reductions in blood glucose levels. In a newer study involving diabetic rats, researchers found that the oral administration of a diet containing 5% fenugreek led to normalization of fasting blood glucose levels after 21 days.[221] In a study involving humans, 10 insulin-dependent diabetics consumed isocaloric diets with or without 100 g/day of debittered, defatted fenugreek-seed powder, each for 10 days in random order.[222] The powder was divided into two equal doses and incorporated into bread. Compared with the control diet, the mean fasting plasma glucose concentration was significantly lower by 28% and glucose

tolerance was significantly better during fenugreek treatment. Serum total-and LDL-cholesterol levels were also significantly reduced by fenugreek. Similar results were achieved with a lower dose of fenugreek seeds.[223] A newer double-blind, placebo-controlled study involving 25 patients diagnosed with type 2 diabetes found that 1 gram per day of fenugreek led to improved blood glucose control and decreased insulin resistance.[222] A new study has found further evidence that fenugreek can improve cardiovascular factors in diabetic subjects.[224] A new double-blind study of fenugreek in diabetic subjects found that this compound improves blood sugar control and reduces resistance to insulin in the body.[225] The researchers found that the group receiving fenugreek had a significant improvement in these areas compared to a control group that only received the typical regimen of dietary control and exercise.

### Aloes

The dried sap of the aloe plant is used as a traditional remedy for diabetes in the Arabian peninsula. A study in diabetic mice found that the administration of 500 mg of aloe for every kilogram of body weight in the animal led to significant reductions in blood glucose after five days.[226] Aloe vera treatment has been found to improve wound healing in diabetic animals.[227] Administration of one-half teaspoon daily for 4-14 weeks to five patients with non-insulin-dependent diabetes resulted in a mean reduction in serum glucose from 273 to 151 mg/dl ($p<0.05$).[228]

### Arctium lappa (Burdock Root)

Burdock root has been used traditionally in cases of skin eruptions, gout, and rheumatism. It is commonly used in Japanese cooking. In an uncontrolled study, administration of burdock root in doses of 54-81 g/day reduced insulin requirements in several diabetics. This effect disappeared when the treatment was discontinued; resumption of Burdock root again reduced insulin requirements.[229]

### Momordica charantia (Bitter Gourd)

The fruit of Momordica charantia (Bitter Gourd) has been used in traditional herbal medicine for the treatment of rheumatism, gout, dysmenorrhea, jaundice, and disorders of the liver and spleen. Administration of an extract of momordica to mice with alloxan-induced diabetes significantly lowered blood sugar and delayed the onset of retinopathy, nephropathy[230] and cataract.[231] Administration of 230 g/day of momordica for 8-11 weeks to a group of nine diabetic patients, significantly improved the results of oral glucose tolerance tests.[232] New studies suggest bitter gourd has the ability to regenerate dormant pancreatic beta cells that stimulate insulin in the body.

### Panax Ginseng (Korean ginseng)

Panax Ginseng, commonly known as Korean ginseng, has a long history of use in Asian countries as a tonic. It is used in China to treat diabetes. At least five constituents of this herb have been shown to exert hypoglycemic effects. A recent study found that diabetic mice that received daily injections of Panax ginseng berry extract for 12 days had significant improvement in blood sugar regulation.[233]In one study, 36 non-insulin-dependent diabetics were randomly assigned to receive ginseng (100 or 200 mg per day) or a placebo for eight weeks (the type of ginseng was not specified). Compared with placebo, treatment with ginseng lowered blood sugar levels and improved mood and psychological performance. The 200-mg dose of ginseng was more effective than the lower dose.

A study of 9 subjects with type 2 diabetes mellitus found that 3 grams of American ginseng administered 40 minutes before an oral glucose challenge significantly reduced blood glucose levels compared with control subjects. A different study 10 men and women with type 2 diabetes found that 3 grams of American ginseng led to blood glucose reductions after eating and was effective in lower these levels as 6- and 9-gram doses. A new randomized crossover study in healthy subjects found that American ginseng reduced blood sugar levels following eating in a dose-independent manner.[232] The researchers found that 1,2, and 3 grams were equally effective in controlling blood sugar release. The ginseng was effective only when given 40 minutes before eating. A different study found that 3,6, and 9 grams of American ginseng led to significant improvements in blood sugar regulation following eating in a group of 10 patients with type 2 diabetes. In this study, timing of the ginseng ingestion was not as significant as in the other study. Patients who took ginseng before

or with the meal had equal blood sugar regulation benefits. A double-blind, placebo-controlled study of 36 patients with type 1 diabetes found that 100 and 200 mg supplementation with ginseng led to significant improvements in body weight, mood, and fasting blood glucose levels.[234] A new study in diabetic mice found that an extract from the ginseng berry, and not the root, improved insulin sensitivity, reduced body weight, and normalized blood glucose levels in the treated animals.[235]

## Allium cepa (Onion)

An active ingredient in onions has been found to have anti-diabetic properties. The callus part of the onion was found to have the most anti-diabetic activity in a study involving diabetic rats.[236] A different study found that diabetic rats fed a diet of 3% freeze-dried onion powder had significant improvement in a variety of diabetic measures.[237] These rats did considerable better than a group that received a diet containing 15% capsaicin powder. A compound called SMCS, isolated from onions, produced similar effects as insulin in a group of diabetic rats.[238] These diabetic rats received a daily oral dose of 200 mg/kg body weight for 45 days.

Most importantly, a randomized comparative study performed in 260 diabetic humans found that 60 grams of fresh onion added to the diet every day led to significant decreases in blood sugar levels in a group of patients.[239] All of the patients in the study ate a well-controlled diet, but some of the patients received a diet supplemented with green beans rather than onions. Those receiving green beans showed no significant improvements in blood sugar regulation.

A newer study found additional evidence that onion has powerful antioxidant properties that help prevent and treat arteriosclerosis.[240] Another study found that onion has antidiabetic effects on the most basic levels of tissue function.[241]

## Garlic

Some garlic compounds are chemical cousins to many of the compounds found in onions. Garlic is widely known to have beneficial effects on the cardiovascular system. A new study has found that garlic has beneficial effects on the cardiovascular system in diabetic subjects.[242] A different study found that garlic oil can prevent or delay the most severe complications associated with diabetes.[243]

## Mulberry

Mulberry leaves have been shown to have some anti-diabetic properties. A study of diabetic mice found that hot water extracts of mulberry leaves administered in a single dose of 200 mg/kg led to significant improvements in blood sugar levels in treated animals.[244] A study of 24 humans with type 2 diabetes found that patients who received a compound derived from mulberry leaves had significant improvement in blood sugar control compared to a group that received glibenclamide, a commonly-used drug in the treatment of type 2 diabetes. In addition, the researchers discovered that a variety of blood lipid factors, such as total cholesterol, triglycerides, and plasma free fatty acids, were improved in the mulberry group. This is an important consideration in diabetics because of their increased vulnerability to cardiovascular disease.

## Grifola frondosa (Maitake Mushroom)

Animal studies have shown that one or more components of maitake mushrooms have blood glucose-regulating properties. A group of diabetic rats had significant improvement in a variety of diabetes measures after receiving maitake for 100 days.[245] A different study involving diabetic mice found that the administration of 1 gram per day of maitake led to significant reductions in blood glucose. An additional study involving diabetic mice found that a single administration of 140 mg FXM, a component of maitake, improved glucose/insulin metabolism in the treated animals. Increased insulin sensitivity accounted for most of this improvement.

## Traditional Chinese Medicine

In Traditional Chinese Medicine (TCM), there are three main causes of diabetes: improper food intake (fat, alcohol, and sweets), emotional impairment (stress and anxiety) or sexual stress. Any of these may result in one of the following three distinct syndromes (italicized terms refer to the TCM diagnosis, which frequently differs from the Western use of the term):

1) The "Upper Jiao" type of diabetes is related to a lung deficiency. In TCM the function of the lung is to control breathing and to dominate qi (energy, pronounced "chi"). This lung deficiency results in a fluid

deficiency, and the prevalent symptom is great thirst.

2) The "Middle Jiao" type of diabetes, is related to the spleen. The spleen in TCM is synonymous with both the adrenal gland and pancreas of Western medicine. This deficiency leads to symptoms of great hunger.
3) The "Lower Jail" type of diabetes relates to the kidney. The function of the kidney in TCM is to dominate water metabolism. The kidney in TCM relates both to the kidney and the reproductive organs in Western medicine. Kidney deficiency leads to symptoms of great urination.

## Chinese Herbal Formulas

Long-established systems of traditional medicine have evolved from recordings of human experience. Although not based on concepts of modern science, they are founded on a body of organized knowledge and have provided useful treatments for thousands of years. Chinese herbal formulas usually consist of a combination of individual herbs that are believed to have synergistic effects.

- A number of formulas have been studied in diabetic rats.
  Administration of the formula Xuetangping (at a dose of 1.5g/k/day) lowered serum glucose to near-normal levels after 14 days.
- Dai-saiko-to decreased blood-glucose levels at 30, 60, and 120 minutes during a glucose tolerance test.[246]
- Administration of Tang-Niao-Tung to diabetic rats significantly decreased blood-glucose levels after 2,4, and 6 hours.[247]
- Paweiwan decreased the baseline glucose concentration, and ameliorated the blood-glucose response to a glucose challenge.
- Xiaoke tea, a traditional Chinese treatment for diabetes mellitus, lowered blood glucose concentrations in diabetic mice.
- In human studies, Jin Pi Jang Tang Pain was administered to 40 diabetics patients. After two months of treatment, fasting and postprandial blood glucose con- centrations were both significantly decreased. Jiang Tang San has also been found to reduce glucose and lipid levels, as well as blood pressure, in 30 patients with non-insulin-dependent diabetes.
- Sixty-eight patients diagnosed with kidney deficiency and blood statis were given Bushenhuoxue. This treatment lowered serum levels of lipid peroxides, decreased blood sugar, and increased HDL cholesterol levels.
- Twenty-three patients with diabetic retinopathy who were diagnosed with kidney and yin deficiency and blood statis responded to a Chinese herbal formula with a marked increase in visual acuity.
- An extract of Buddlejae Flos was found to inhibit the activity of aldose reductase in rat lens tissue in vitro. This effect was attributed to the flavonoid luteolin, which is found in high concentrations in this plant.[248] A similar effect has been reported with Glycyrrhiza uralensis fisch (a species of licorice). Oral administration of this herb significantly reduced the concentration of sorbitol in erythrocytes of diabetic rats, without affecting blood-glucose levels.[249] These herbs may therefore have value for the prevention and treatment of diabetic complications, although human studies have not yet been performed.
- Gosha-jinkl-gan, which consists of ten herbs, has been widely used to treat neuropathy and other complications of diabetes. This formula has been shown to improve nerve conduction velocity in diabetic rats.[250,251]
- Administration of Rheum officinale to diabetic rats significantly reduced the severity of nephropathy.[252]
- A new study has found that Wen Dan Tang is effective for the treatment of diabetic microvascular complications.[253]

## Acupuncture

Traditional Chinese acupuncture treatments have been shown to relieve the pain associated with diabetic neuropathy.[254]

A study of 55 patients with insulin-dependent-diabetes mellitus found that 10 sessions of acupuncture treatment led to improved circulation in the lower extremities of 78.2% of cases.[255] A study in diabetic rats found that electroacupuncture can induce a sustained reduction in blood sugar levels.[256] A study of 46 patients with painful,

chronic neuropathy in the limbs underwent six courses of traditional Chinese Medicine acupuncture points over a period of 10 weeks.[257] During a one-year follow-up period, 77% had significant improvements in symptoms.

## New Approaches

- Capsaicin, the component in peppers that makes them hot, lowers blood sugar in diabetic dogs, according to a recent study.
- Another study demonstrated that high doses of aspirin can counteract some of the negative effects of insulin resistance. The researchers warn that such high doses have detrimental effects, but these new findings may help develop safer therapies in the future.
- A different study recently found that a synthetic antioxidant, a molecule that protects body tissues and cells from the harmful effects of oxygen, may slow or reverse autoimmune diseases, such as diabetes. In this particular study, the investigators found that this antioxidant compound protected cells in diabetic mice that are required for the production of insulin.
- A study in a May issue of the Journal of the American Medical Association found that a couple of alcoholic drinks per day may prevent diabetes in older women. The women in the study were at high risk for developing diabetes and received a controlled diet. The women were compared to a similar group of women who consumed orange juice with no alcohol. The researchers cautioned that additional research is needed before alcohol can be recommended in persons at risk for developing diabetes.

**(Endnotes)**


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