I. INTRODUCTION

Mushrooms have long been considered to have medicinal value. The early herbalists were more interested in the medicinal properties of mushrooms than in their basic value as a source of food. Humankind has constantly searched for new substances that can improve biological functions and thereby make people fitter and healthier. Recently, Western society has placed a great emphasis on plants, herbs, and foods as sources of these health enhancers. About 3.5 billion people worldwide, well over half of the world’s population, rely on plant-based medicines and dietary supplements for their primary health care. These products have variously been called vitamins, dietary supplements, phytochemicals, nutraceuticals, and nutriceuticals. Dietary supplements⁸¹ are ingredients extracted from foods, herbs, plants, and fungal species that are not used as a regular food but which boost the immune system or otherwise help maintain health. Phytochemical (phytonutrient) is a more recent evolution of the term that emphasizes the plant source of such protective disease-preventing compounds. Nutraceuticals, proposed by DeFelice in 1979 and quoted by Brower in 1988,³ are foods that provide medical or health benefits, including the prevention and treatment of disease. The term nutraceutical has been redefined by Zeisel⁸¹ as a diet supplement that delivers a concentrated form of a presumed bioactive agent from a food at dosage levels exceeding those that could be obtained from normal food. Nutraceuticals are present in a nonfood matrix and are used to enhance health. A mushroom nutriceutical⁸¹ is a refined and partially defined extract from either the mycelium or the fruiting body of a mushroom, which is consumed in the form of capsules or tablets as a dietary supplement (not in the form of a food) and which has potential therapeutic application. During the past decade, there has been a major expansion in the industries involved in providing these substances, especially in the United States. In 1990, U.S. dietary supplement sales were valued at U.S. $3.3 billion; in 1992, U.S. $3.7 billion; in 1994, U.S. $5.0 billion; in 1996, U.S. $6.5 billion; in 1998, U.S. $12.0 billion; and in the year 2000, it was estimated to have reached U.S. $14.0 billion.⁸¹

In 1994, worldwide sales of medicinal mushrooms, mushroom extracts and various derived products were estimated at U.S. $3.8 billion.⁵ By 1999, this figure had risen to U.S. $6.0 billion.⁷ In regional terms, Asia and Europe accounted for approximately 99% of this market with North America contributing less than 0.1% to the overall total. In 1994, the U.S. market for mushroom-based dietary supplements had an estimated value of U.S. $35 million. However, since that time, demand in North America for medicinal mushrooms and derived products has increased by between 20 to 40% annually depending on the species. The use of mushroom extracts in nutraceutical products and sports drinks constitutes the main area of expansion.

II. MEDICINAL MUSHROOMS

Of the 14,000 to 15,000 species of mushrooms in the world,²¹ around 700 have known medicinal properties. However, it has been estimated that there are about 1800 species of mushrooms that have potential medicinal attributes. Thus, mushrooms have vast prospects as sources of medicinals. These have been investigated in the last decade in in vivo and in vitro model systems. Many bioactive substances with immunomodulating effects have been isolated recently from mushrooms. These
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include polysaccharides, high-molecular-weight polysaccharides, low-molecular-weight protein-bound polysaccharides, glycoproteins (lectins), triterpenoids, and fungal immunomodulatory proteins (Fips). Many, if not all mushrooms, contain biologically active polysaccharides, which have antitumor and immunostimulating properties. As shown in Table 3.1, almost all the main taxonomic families of higher fungi have mushroom species that contain biologically active polysaccharides. The data reveal that there are 660 species from 37 taxa containing antitumor or immunostimulating polysaccharides. Fruiting bodies, submerged cultivated mycelial biomass, and liquid cultivated broth are the sources of the bioactive compounds. The majority (77.3%) of those compounds are extracted from fruiting bodies by hot water or by hot water combined with ethanol under various degrees of temperatures. The second source (20.8%) of those bioactive polysaccharides comes from cultivated mycelium, and the third origin (2.0%) is derived from liquid cultivated broth. So far, there are only two common medicinal mushrooms, *Ganoderma lucidum* and *Agaricus blazei*, which have been demonstrated to have the bioactive polysaccharides derived from these three sources — fruiting body, mycelium, and culture filtrate (Table 3.2).

Although bioactive polysaccharides are widespread among mushrooms, different species can produce polysaccharides with different types of polysaccharides having different properties. For example, the protein-bound polysaccharide PSK (trade name, Krestin) was developed in Japan from the cultured mycelium of *Coriolus versicolor* CM-101 strain. It is composed of 62% polysaccharides and 38% protein. The mean molecular weight is 94 kDa. The main component of the carbohydrate moiety is glucose, with galactose, mannose, xylose, and fucose as minor components, whereas polysaccharide-peptide (PSP) in China was developed in submerged mycelium of the strain Cov-1 of the same species. It possesses a molecular weight of approximately 100 kDa and is composed of 90% polysaccharides and 10% peptides. The carbohydrate moiety of PSP is mannose, xylose, galactose, arabinose, and rhamnose; however, PSK contains no arabinose or rhamnose, but contains fucose. The protein moiety both of PSK and PSP is rich in acidic amino acids (such as aspartic acid, glutamic acid, etc.). Moreover, different origins (fruiting body, mycelium, liquid growth) of polysaccharides isolated from the same strain can have quite different chemical structures and functions. For example, the structures of polysaccharides isolated from *Agaricus blazei* are mainly β-glucan protein in the fruiting body, glucomannan protein in the mycelium, and mannan protein in the filtrate.

Yang et al. demonstrated that the exopolymer obtained from a liquid culture broth of *Ganoderma lucidum* enhanced the swimming endurance capacity of mice, but neither the material extracted from the fruiting body nor the endopolymer produced from cultured mycelium of the same species showed any positive response in this regard. The results also indicated the potential of *G. lucidum* exopolymer in exhibiting hypoglycemic, hypolipidemic, endurance enhancing, and immunomodulating activities in the experimental animals. Yang et al. reported that the administration of the exopolymer (200 mg/kg body weight) obtained from submerged broth of *Lentinula edodes* reduced the plasma glucose level by as much as 21.5% and increased plasma insulin by 22.1%, as compared to the control group. It also lowered the plasma total cholesterol and triglyceride levels by 25.1 and 44.5%, respectively. As mentioned in the above section, more than 77% of all medicinal mushroom products are derived from the fruiting bodies, which have been either commercially farmed or collected from the wild. Only about 20% of all products are based on extracts from cultivated mycelia, and about 2% are from submerged broth used for growing mycelia. Mycelia formed by growing pure cultures in submerged conditions are of constant composition, and the submerged culture is the best technique for obtaining consistent and safe mushroom products. In addition, increased quality control of the mushroom products and year-round production under controlled conditions make mycelial-based products, including exopolymers from culture broth, the wave of the future.

Most of the knowledge about the medicinal properties of mushrooms comes from literature from the Far East, where such mushrooms as *G. lucidum* (Curt.: Fr.) P. Karst., *L. edodes* (Berk.) Sing., *Coriolus versicolor* (L.: Fr.) Quel., and *Tremella fuciformis* Berk. have been collected,
### TABLE 3.1

<table>
<thead>
<tr>
<th>Taxa</th>
<th>No. of Species</th>
<th>Fruiting Body</th>
<th>Mycelial Biomass</th>
<th>Liquid Broth</th>
<th>Remarks</th>
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<td>Percentage (%)</td>
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<td>77.2</td>
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Mushrooms: Cultivation, Nutritional Value, Medicinal Effect, and Environmental Impact

cultivated, and used for thousands of years. In the past two decades, several pharmacologically active substances have been identified. Biologically active polysaccharides are the best-known mushroom-derived substances, which are particularly effective in retarding the progress of various cancers and other diseases through immune stimulation rather than direct cytocidal effects, and in alleviating the side effects of chemotherapy and radiation treatment through cell-level regenerative effects. Mizuno et al.\textsuperscript{44} and Hobbs\textsuperscript{22} have summarized these studies. The first three biologically active compounds developed from medicinal mushrooms were polysaccharides, and all of them are $\beta$-glucans. These are krestin (PSK) from \textit{C. versicolor} mycelia containing $(1\rightarrow4)$, $(1\rightarrow3)$ or $(1\rightarrow6)$-$\beta$-$D$-glucan.\textsuperscript{66} lentinan,\textsuperscript{9,32} a high-molecular-weight $(1\rightarrow3)$-$\beta$-$D$-glucan from \textit{L. edodes} fruiting bodies; and schizophyllan,\textsuperscript{28,31} a high-molecular-weight $(1\rightarrow3)$, $(1\rightarrow6)$-$\beta$-$D$-glucan prepared from \textit{Schizophyllum commune} culture filtrates. Another popular edible mushroom, \textit{Flammulina velutipes} (Curt.:Fr.) P. Karst., also has high antitumor activity. Polysaccharides and a low-molecular-weight protein-bound polysaccharide (EA6) were isolated from this mushroom.\textsuperscript{23} It was demonstrated that EA6 was active against tumors when administered orally, but was not so effective by intraperitoneal injection. These polysaccharides are of different chemical composition and the biochemical mechanisms for mediating their biological activity are still not clearly demonstrated. However, numerous studies have shown that regular consumption of certain mushroom species as either a regular food or as extracted compounds (nutriceuticals) is effective in both preventing and treating specific diseases, mainly through immunopotentiation and antioxidant activity. Thus, the intake of mushrooms and their extractable bioactive compounds appears to be effective in cancer prevention and growth inhibition. Another important fact is the certainty that mushroom extracts, compared with other drugs, show a very low toxicity when regularly consumed, even in high dosages. While the historical and traditional usage of the medicinal mushrooms, especially in the Far East, is extremely extensive,\textsuperscript{22} attention is given in the following sections to a few of the modern approaches that have been verified in the last three decades by accurate scientific and medicinal studies.

III. EFFECTS OF MEDICINAL MUSHROOMS

A. HEMATOLOGICAL EFFECTS

Lectins are proteins or glycoproteins with specific binding sites for sugars. They are not antibodies or enzymes\textsuperscript{16} but have a specific affinity toward glycosylated materials, and they have become
useful reagents in studies of cell surface structures. Some lectins have been shown to have antitumor and immunomodulatory activities. Furthermore, lectin–carbohydrate interactions represent a common and important feature of molecular events underlying the immune response. The term lectin is used interchangeably with such terms as agglutinins, hemagglutinins, and phytohemagglutinins. The interaction between the fungal lectin and the surface glycoproteins of red blood cells is an example of the hematological activities of edible mushrooms, and some fungal lectins have been characterized and purified as described below.

The lectin isolated from Agaricus campestris is a tetramer with an estimated molecular weight of 64,000. Its hemagglutination reaction is not inhibited by sugar but is inhibited by a sonic suspension of red cell ghosts. The lectin purified from Flammulina velutipes was estimated to have a molecular weight of 20,000 and to be mitogenic with respect to mouse spleen lymphocytes in addition to its hemagglutination activities. This lectin does not contain carbohydrate, half-cystine, methionine, or histidine.

Volvatoxin A is a lectin isolated from Volvariella volvacea and has been shown to reduce hemolytic activity toward Group O red blood cells. This lectin is composed of two subunits with molecular weight of 50,000 and 24,000, with the hemolytic activity associated with the smaller subunit only. Another lectin was also isolated from V. volvacea. It has a molecular weight of 26,000 and has shown moderate hemagglutination toward Group O red blood cells. This lectin is composed of two identical subunits and does not contain half-cystine, methionine, or histidine.

Pleurotolysin is a lectin from Pleurotus ostreatus and is a hemolytic agent for mammalian red blood cells in vitro. It is a dimer with a molecular weight of 24,100 and an isoelectric point at pH 6.4.

B. Antiviral Effects

Cochran was the first to report that antiviral substances were present in mushrooms. This encouraged the screening of aqueous extracts of some Japanese mushrooms. As a result of this program, it was found that an aqueous extract of the donko mushroom (Lentinula edodes) fruiting body, as well as the spores, contained antiviral activity against influenza A/SW15 virus infection in mice. The antiviral influenza activity was mediated by the induction of interferon on the host. A phenol fraction of the mushroom extract was capable of conferring the antiviral activity. These results suggested that perhaps the RNA fraction of the mushroom extract was inducing interferon since double-stranded RNA (ds-RNA) has been documented as capable of inducing interferon. Suzuki et al. confirmed that the interferon-inducing activity is due to the ds-RNA from the spore extract of L. edodes. The origin of this ds-RNA was ascertained to be derived from the mycophages attached to the spore and the fruiting body. It was further discovered that viruslike particles were present in several mushrooms — not only in L. edodes.

Human immunodeficiency virus (HIV) was isolated as the etiological agent of acquired immunodeficiency disease syndrome (AIDS). Anti-HIV activity, an inhibitory effect on HIV replication in vitro, was reported from an extract of the culture medium of L. edodes mycelia. Lentinan, a polysaccharide isolated from the fruiting body of this mushroom, has no ability to block HIV infection. However, sulfated lentinian completely prevented HIV-induced cytopathic effect. PSK from Coriolus versicolor has also been reported to possess antiviral activities against ectromelia virus and cytomegalovirus infections. Anti-HIV activities were reported in a water-soluble extract of Ganoderma lucidum. Most recently, el-Mekkawy et al. isolated the anti-HIV compounds and reported them as ganoderiol F and ganodermanondiol. Min et al. also isolated anti-HIV components as ganoderic acid B, ganodermanondiol, ganoderanotriol, and ganolucidic acid A, and lucidumol B. Zhuang and Mizuno reported that sulfated Grifola frondosa extract was able to prevent as much as 97% HIV-infected T-helper lymphocytes from being destroyed in vitro. This is important because measuring the T-helper cell count is one way to trace the progression of HIV to full-blown AIDS.
C. Antitumor Effects

The viruslike particles from *Lentinula edodes* are even able to suppress the Ehrlich ascites carcinoma in mice. Antitumor activity is not unique to *L. edodes*, as it is also present in other mushrooms. However, since the late 1970s, most research effort has focused on studies of *L. edodes*. Much literature has accumulated about the antitumor activity of *L. edodes*, with most information concerned with the identification and purification of the responsible ingredients, but not with the mechanism of action.

Chihara et al. reported that a water-soluble polysaccharide fraction from a fruiting body of *L. edodes* could inhibit the growth of mouse Sarcoma 180 in mice, and even complete regression was observed in Swiss albino mice. The dosages for bioassay ranged from 1 to 10 mg/kg body weight and were given intraperitoneally.

Fujii et al. isolated and characterized a new antitumor polysaccharide, KS-2, which was excreted from the cultured mycelia of *L. edodes*. KS-2 suppressed Sarcoma 180 as well as Ehrlich ascites carcinoma in mice when given orally or intraperitoneally; moreover, it could induce interferon production in mice.

Sugano et al. even detected the anticarcinogenic actions of water-soluble and alcohol-insoluble fractions from the culture medium of *L. edodes* mycelia. The alcohol-insoluble fraction was composed of a xylose-containing polysaccharide and protein. Ehrlich ascites carcinoma in mice was used as a bioassay system in this study.

Antitumor polysaccharides from mushrooms have been extensively studied during the last 15 years. These polysaccharides are found in the fruiting bodies, cultured mycelia, and culture broth of mushrooms as described in Table 3.1 and Table 3.2. They vary in chemical composition, structure, and antitumor activity as shown in Table 3.3. Many mushroom polysaccharides are present mainly as glucans with different types of glycosidic linkages such as (1→3), (1→6)-β-glucans, and (1→3)-α-glucans, but some are true heteroglycans. The others mostly bind to protein residues as PSK and PSP. The main sources for antitumor polysaccharides are from mushroom cell walls that consist of chitin and cellulose. However, mushroom chitin does not have any antitumor activity.

In general, high-molecular-weight glucans appear to be more effective than those with low molecular weight. However, obvious variations of antitumor polysaccharides are also noted. Antitumor polysaccharides may have other chemical structures, such as hetero-β-glucan, heteroglycan, and so on.

### Table 3.3

<table>
<thead>
<tr>
<th>Species</th>
<th>Tumor or Cancer Treated</th>
<th>Polysaccharide Origin</th>
<th>Polysaccharide Structure</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Coriolus versicolor</em></td>
<td>Cancer of digestive organ, lung and breast</td>
<td>CM</td>
<td>(1→4), (1→3) or (1→4), (1→6)-β-glucan</td>
<td>25, 66</td>
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<tr>
<td><em>Lentinula edodes</em></td>
<td>Cancer of stomach</td>
<td>FB</td>
<td>(1→3)-β-glucan</td>
<td>10, 32</td>
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<tr>
<td><em>Schizophyllum commune</em></td>
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<td>CB</td>
<td>(1→3), (1→6)-β-glucan</td>
<td>31</td>
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<td>(1→6)-β-glucan</td>
<td>44, 47</td>
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<td><em>Agaricus blazei</em></td>
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<td>FB, CM</td>
<td>(1→3)-β-glucan</td>
<td>44</td>
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<tr>
<td></td>
<td>Antitumor</td>
<td>CM</td>
<td>(1→3), (1→6)-β-glucan</td>
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</tr>
</tbody>
</table>

*CM, culture mycelium; FB, fruiting body; CB, culture broth.

<p>| | | | |</p>
<table>
<thead>
<tr>
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</tr>
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<tbody>
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<td></td>
</tr>
<tr>
<td>b</td>
<td></td>
<td></td>
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</tbody>
</table>
Medicinal Value

β-glucan-protein, and heteroglycan-protein complexes. In conclusion, the antitumor components of mushrooms vary in their chemical nature and include polysaccharides, proteins, glycoproteins, and triterpenoids. It does appear that the inclusion of cultivated mushrooms, particularly *L. edodes*, *Grifola frondosa*, *Agaricus blazei*, and *Pleurotus* spp., in the diet is likely to provide some protection against some diseases, particularly some tumors.

D. Antioxidant Activity

As noted previously, recent years have seen a steady expansion of the mushroom industry as it relates to the medicinal properties of mushrooms. The ability of mushroom-derived preparations (MDPs) to prevent oxidative damage to cellular DNA has been evaluated using the single-cell gel electrophoresis (“Comet”) assay. MDPs were obtained from fruiting bodies of nine common mushrooms. These showed wide variation in their ability to protect against oxidative DNA damage with the highest protection afforded by an MDP obtained by cold water extraction of *Agaricus bisporus* fruiting bodies (Ab-cold) and with the next highest protection obtained by hot water (100°C) extract of *Ganoderma lucidum* (Gl-hot). Jones and Janardhanan reported also that the methanol and aqueous extracts of *G. lucidum* showed a marked free radical scavenging activity.

These findings indicate that some edible mushrooms consist of a valuable source of biologically active compounds with potential for protecting cellular DNA from oxidative damage. Such protective compounds have possible commercial value as dietary supplements for offsetting adverse biological effects associated with coronary heart disease, cancer, and age-related neurodegenerative diseases. They might also facilitate the development of treatments for the repair of indiscriminate cellular DNA damage that occurs during certain forms of chemotherapy and radiotherapy.

E. Cardiovascular and Renal Effects

Volvatoxin A is a cardiotoxic protein from *Volvariella volvacea*. In isolated toad hearts the toxic protein caused ventricular systolic arrest at a dose of 0.1 mg/ml; in cats an intravenous injection of the protein produced changes in the electrocardiogram (ECG) at a dose of 0.7 mg/kg body weight. It depressed the ST segment and inverted the T wave, but no significant changes in blood pressure were noted.

Chronic ingestion of *Lentinula edodes* was reported to reduce the serum cholesterol level in human subjects (hypertension is attributable to a high serum cholesterol level). An antiplatelet substance was isolated from the aqueous extract of *Auricularia polytricha*. This antiplatelet substance could inhibit platelet aggregation. This substance was later identified to be adenosine, and was suggested to be responsible for the low incidence of arteriosclerosis among Asians who consumed *A. polytricha* regularly.

An aqueous extract from *Pleurotus sajor-caju* was associated with a hypotensive action that could reduce the glomerular filtration rate (GFR) in rats. The hypotensive action was mediated by interfering with the renin–angiotensin system like a converting enzyme inhibitor. The clinical implication of a GFR-reducing effect is to reduce the rate of nephron deterioration and thus extend the life span of patients with chronic renal failure, but the mechanism of action is unknown. Bailey et al. reported that *Coprinus comatus* can lower blood glucose in mice. Normal mice were fed a diet containing powdered dried fruiting bodies of *C. comatus* (33.3% w/w). Plasma glucose concentrations were reduced after 11 days, and intraperitoneal glucose tolerance was improved.

Furthermore, the aqueous extract of *V. volvacea* has been reported to produce a hypotensive effect in normotensive rats. Feeding powdered maitake (*Grifola frondosa*) mushrooms to spontaneous hypertensive rats resulted in a lowering of the blood pressure. It has also been reported that when the dried powder of two other edible mushrooms, *A. auricula* and *Tremella fuciformis*, was fed to the rats, they effectively lowered both the serum total cholesterol and the low-density lipoprotein (LDL) cholesterol levels. Because the mushroom did not affect the concentration of
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serum high-density lipoprotein (HDL) “good” cholesterol, the reduction of serum total cholesterol by the mushroom diets is attributable to the fall in the LDL “bad” cholesterol.

F. Carcinogenicity of Mushrooms

The chronic toxicity of mycotoxin is closely related to hepatocarcinogenicity — e.g., aflatoxin b from Aspergillus flavus. Chronic toxicity is rare in edible mushrooms but not non-existent, and Agaricus bisporus is included in this group. This commonly eaten cultivated mushroom of commerce in the Western hemisphere contains a chemical that has a nitrogen–nitrogen bond-containing-chemical called agaritine. The breakdown product of agaritine, 4-(hydroxymethyl) benzenediazonium tetrafluoroborate, is gastric tumorigenic in Swiss albino mice when given orally at a dose of 400 μg/g of body weight.

G. Allergic Reaction to Spores

Allergic reactions to spores from Pleurotus ostreatus and other species of Pleurotus were reported in the early 1970s, both in West Germany and in Great Britain. Several years later Pleurotus spores as allergens were further studied. Recently, the incidence of Pleurotus growers developing respiratory problems was documented in Canada. Severe symptoms reoccurred within 30 minutes to 1 hour on each of three subsequent exposures to spores of P. ostreatus, but not to mushroom compost or other mushroom species. The symptoms generally included fatigue, mild headaches or sinus pressure, coughing, mild difficulty in breathing, pain in the limbs and joints, and a generalized malaise or ill feeling. These influenza-like symptoms included a fever of 39 to 40°C, which lasted from 1 to 2 days up to 1 week, but then disappeared without treatment. Similar symptoms associated with a Pleurotus spore allergy were also reported in China.

By use of the radio-allergo-sorbent test (RAST) to determine the level of antibody present in the blood of allergic persons, Halmepuro et al. suggested that P. ostreatus spore allergens share antigenic determinants with those present in P. ostreatus cap or mycelia. More details of the role of basidiospores in the allergic reactions have recently been reported.

IV. GENERAL CONSIDERATIONS

There is no doubt that mushroom-based products can serve as superior dietary supplements, particularly, the Ganoderma products, which have been used as a dietary supplement or medicinal food in China for more than 2000 years. Recently, the products of medicinal mushrooms have been demonstrated to enhance the immune system and promote the natural defense system. They are also good for patients who have received treatment with radiotherapy or chemotherapy, as they may help to reduce the side effects from such therapies. These include (1) increasing the number of leucocytes in the blood, and enhancing the immune functions (it has been known that chemotherapy treatment can markedly deplete the number of platelets in the blood and put patients at risk of excessive bruising, internal bleeding, brain hemorrhage, and sometimes death); (2) increasing and improving appetite; (3) reducing pain; (4) anti-emetic properties; (5) stopping hair loss; (6) inducing tumor regression; (7) potential antioxidant and genoprotective properties, and (8) general health-improving effects. Exactly how these products work is still a matter of conjecture, but numerous trials (both laboratory and human) have shown, again and again, that they are effective in complementing conventional medicines in fighting diseases. People unfamiliar with the field may ask, “If those mushrooms have such beneficial effects, can chemists isolate the active component so that it can be marketed as a drug?” If the answer is “yes,” the main focus is on a single active component of the mushroom, e.g., lentinan, which is close to drug standard, and on certain diseases, e.g., cancers or heart diseases only. The products are prescription drugs. If the answer is
“no,” then the main focus is on a group of compounds, and on people’s quality of life. The products are dietary supplements and are not single active components. Instead, there are many of them. They all contribute to the beneficial effects of the mushroom. For example, the protection against cancer afforded by *Ganoderma* products could be attributed to several compounds present in *Ganoderma*: the tetro-glucans, lectins, terpenoids, steroids, nucleic acids, and immunomodulatory proteins, such as Ling Zhi-8. It seems that these compounds, and possibly other compounds yet to be identified in *Ganoderma*, contribute in concert to the anticancer, antitumor, antiviral, antibacterial, and immunomodulating properties of *Ganoderma*. This means that the synergistic effects of several components in an extract are responsible for the therapeutic or prophylactic properties rather than a single active chemical ingredient. It could be tentatively concluded that mushroom products (mushroom nutriceuticals) are of multifunctional value.

At the end of 1999, the number of children orphaned by AIDS in Sub-Saharan Africa, stood at 12.1 million, compared to 1.1 million children orphaned by AIDS in the rest of the world. In several countries in the SADC region (e.g., Botswana, Lesotho, Namibia, South Africa, and Zimbabwe), some 20 to 30% of 15- to 25-year-olds are living with HIV/AIDS. With the well-established fact that *Ganoderma* and other medicinal mushrooms (e.g., *Lentinula edodes* and *Grifola frondosa*) can be farmed on available natural substrates and are known to be very effective in promoting the body’s immune systems, including them as a dietary supplement to HIV-positive individuals and AIDS victims is a reasonable approach. The financial challenge involved in cultivation and preparation of the products is manageable, as the world market for these mushrooms is very lucrative.

The current intense industrial interest worldwide in medicinal mushroom materials has resulted in a huge increase in the number of products reaching the retail market in recent years. The medicinal effect and health benefits of qualified mushroom products should not be doubted. However, a major problem associated with mushroom-based dietary supplements is their wide variability and the current lack of standard production and testing protocols necessary to guarantee product quality.\(^6\)\(^,\)\(^40\) Unfortunately, less reputable manufacturing companies have exploited the fact that quality control regulations are virtually nonexistent in order to market poorly defined products of questionable efficacy. However, it is generally recognized that the situation is changing and that companies, in particular those marketing their products in the major growth areas of North America and Western Europe, will shortly be required to (1) back up efficacy claims with hard scientific data and (2) provide clear evidence of product quality control. Therefore, there is serious need for improvement in both quality and regulatory controls in the area.\(^9\)\(^6\) Both are essential to increase and maintain consumer confidence, protect public health, and to meet current and future quality and safety criteria set by the regulatory authorities.

The research achievements in medicinal mushrooms during the last two decades give the impression, and the confidence, that medicinal mushrooms have much to offer to the health-care system for humans in the 21st century. In cases where modern medicines may not provide a complete remedy, complementation by mushroom nutriceuticals may augment the success of the treatment. Prevention of diseases is beneficial to everyone and deserves the same attention that is given to the curing of diseases. Efforts directed to disease prevention can have positive financial and social impact and, on the individual basis, can maintain or even improve quality of life and human dignity.

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