Ray Peat's Newsletter

Ideas won't keep; something must be done about them. --Alfred North Whitehead

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Mushrooms--observations and interpretations

Indigenous people in all the forested parts of the world have eaten mushrooms. England and Spain and their colonies have been notable for their aversion to mushrooms (Norway, Finland, and much of Africa are other mycophobic areas). This has probably affected the way mushrooms have been treated scientifically. Until recently, most mushroom research published in English had focussed on their toxicity, but now there is a rapid increase of publications recognizing their nutritional, medical, and ecological importance.

In the 1970s and '80s many studies showed that even occasional mushroom eating could produce a high incidence of cancers of the stomach, intestine, liver, and other organs in experimental animals. Bela Toth's research showing liver toxins even in the most popular mushroom varieties led me to stop eating them. (Toth was educated in Hungary, a country in which mushrooms had been used in a love potion.) More recently, some studies have shown an impressive freedom from cancer in people who eat them regularly (cooking destroys the toxins in most species). For example, in China patients with breast cancer were much more likely not to have eaten mushrooms than women who ate at least 10 grams of mushrooms daily. Women who had a high intake of mushrooms and also drank green tea were only 11% as likely to have breast cancer as those who ate neither mushrooms nor green tea (Zhang, et al., 2009).

When the incidence of cancer and other diseases in different countries is compared, differences in diet are often thought to explain the difference, but the role of mushrooms is seldom considered. If eating mushrooms is in fact extremely beneficial, it's important to understand how they work, and what the implications of increasing their use might be.

Particular foods usually exist within an ideology, a context of morality, esthetics, economics, effects on health and ecology, etc. Local communities used to have their own food cultures that regulated the ways foods were produced and used, but colonialism and industrialization have imposed a new ideology of "rationalizing" the production and use of food, arguing for economy of scale, scientific dietetics, and a "free market." The Green Revolution, based on seed monopoly, sale of fertilizer, insecticides and herbicides, and control of water, was imposed by governments and corporations acting together, supported by schools, universities, and mass publicity. Simultaneously, nutritional thinking has been "rationalized" in terms of "essential nutritional requirements," genetically defined.

That ideology has formed the background for alternatives such as T.C. Campbell's *China Study*, arguing that animal proteins cause cancer, and the "small planet" idea that combining rice and beans to make a complete protein could reduce starvation and environmental degradation. Alternative thoughts about food systems are needed, but I think they should incorporate the best knowledge available, rather than just arguing for a particular vegetarian ideology of agriculture or more efficient ways to meet our need for essential nutrients.

Traditionally, especially with influences from ancient Hinduism and Jainism, morality has been the basis for vegetarianism, an empathetic dislike for killing and eating sentient or conscious beings. Recently, a psychologist, Diana Fleischman, published a detailed argument that vegans can include oysters or mussels in their diet, because the bivalves' nervous system isn't organized the way other animals' are. She mentions the issue of self-awareness, but cites the opinion of many psychologists that dogs and cats aren't self aware, because they don't recognize themselves in a mirror. (That is a reflection on the mentality of those psychologists.) She argues that oysters lack the ability to suffer, and so can be ethically used for food.

Since oysters have eyes, and react to movements in their environment, it can be argued that they are aware of being in the world, distinct from their surroundings, and that their defensive behaviors correspond to a preference for not being eaten. Plants also have holistic defensive reactions to injury or threat, so the arguments of vegetarians sometimes rest on particular doctrines regarding the nature of consciousness. Meat eaters sometimes use the awareness of self or its absence to explain why they will eat most types of animal, while frowning on cannibalism. The dietary customs of a society probably guide that society's beliefs about the awareness of organisms, as much as those beliefs guide its food customs.

A good ecological view of nutrition should accommodate some of the existing cultural themes (economic efficiency, avoidance of environmental degradation and cruelty, optimizing health), while taking into account the fact that our human culture and biology are changing, along with changes in the whole planet and its ecosystems.

Although plants produce all the amino acids needed by animals, the limited present knowledge and technology aren't sufficient to make a vegan diet both economical and nutritionally adequate--the children of vegan women are often affected by an insufficient supply of protein in particular.

Mushrooms have very high quality protein that is easily assimilated, in association with a good balance of other nutrients. Mushrooms and other fungi are, like people, completely dependent on plants nutritionally; plants can make sugar from air, water, and sunlight, and that is the source of the energy that sustains fungi and animals. The cellulose and lignin of dead plants provide the energy for mushroom growth. The not-so-green revolution of industrial agriculture has substituted petroleum for this constantly renewed energy.

Living in decaying organic matter, the mushroom mycelium is exposed to a great variety of bacteria and other fungi. Animals have to deal with a similar microbial situation in their intestines. Even though our internal exposure to microbes and their products isn't very massive, it can have fatal consequences, as explained by Metchnikoff. The success of mushrooms in dealing with their microbe-rich environment can help us to understand our own problems of "immunity," the processes involved in maintaining the integrity of our organism.

The theory that our immune system consists of mechanisms for distinguishing "self" from "other," and destroying the "other," is being replaced by the "danger theory" of Polly Matzinger and the "damage" or "morphostasis" theory of Jamie Cunliffe. Cunliffe argues that it is the disturbance of our organismic integrity that activates the immune process, not an abstract "otherness." Fungi effectively maintain their integrity without the cellular complexities involved in our multilayered immune system.

Much of the thinking about the medicinal use of mushrooms has focussed on the identification of factors that stimulate our immune system, for example by activating cytokines that increase our production of killer cells. The polysaccharides, betaglucans have had the most attention, as activators of the immune system and for use in cancer chemotherapy, for their direct toxicity to cancer cells. Unfortunately, activation of the immune system involves inflammation, and inflammation generally contributes to the loss of organismic integrity.

Rather than looking for "drugs" in mushrooms, I think we should be trying to understand the nature of their resistance to potential pathogens, and thinking analogically--can their effects such as preventing cancer result from biological features that we have in common with them?

Cell water behaves differently when cells are functionally stable or unstable, being more mobile in cells that are unstable. Substances that act on cell water can modify the stability of the cell. Estrogen, histamine, and nitric oxide increase the "structural temperature" of water, destabilizing the cell, and progesterone, cholesterol, oxygen and carbon dioxide have opposing effects. Several substances in mushrooms probably function as stabilizers, protecting them from destabilizing factors produced by potentially pathogenic bacteria. There is evidence that some of those factors are similarly effective in animal cells, which could explain the wide range of their protective effects.

In the 1960s, S.J. Webb found that inositol (a six carbon ring, $C_6H_{12}O_6$, with a more rigid form than glucose) protected cells from the destabilizing effects of dehydration and irradiation. Trehalose, a disaccharide like sucrose, but chemically more stable, is one of the main sugars of mushrooms, and it has similar stabilizing effects on cell water. (In the blood and other extracellular fluids, it reduces glycation and lipid peroxidaton.)

The stable cell substance is more lipophilic than ordinary water, making fats less likely to separate into droplets inside the cell, and regulating the interactions of proteins, including prevention of their clumping. In degenerative diseases, the clumping of proteins (for example, prion, tau, amyloid, lens crystallin, synuclein, polyglutamine) is an important aspect of cell failure. This impairment of the cell's solvent properties results from an energy source that doesn't fully compensate for stress (a process that leads to excitotoxicity), but simply adding a stabilizing substance such as trehalose can maintain the proper solvation of proteins.

Trehalose also increases autophagy (Sarkar and Rubinsztein, 2008, Casarejos, et al., 2011, Emanuele, 2014), a process in which aggregated insoluble proteins are eliminated, which has implications for all the degenerative diseases. In mice it can reverse a nervous disorder, ataxia (Chen, et al., 2015). The way it reduces inflammation, lowering nitric oxide and NF-kB (He, et al., 2014, Noh, et al., 2014, Yurkiv, et al., 2015), is probably a result of its stabilization of cell structure.

Although our intestines contain enzymes for turning trehalose into glucose, these are mostly in the lower part of the intestine, allowing some of the trehalose to be absorbed into the blood and into the tissues. When a stressor acts on a cell, the cell takes up water and begins producing nitric oxide, leading to a "phase change" in the cell's physical properties and functions, but this process can be blocked when the stabilizing factors are available.

Estrogen, ionizing radiation, hypoxia, carbon monoxide, and endotoxin all increase cell water content and nitric oxide. The activity of nitric oxide synthase is regulated by the state of the cells' structural proteins (Zharikov, et al., 2001), especially the actin filaments, and by causing a shift away from oxidative energy production, the cell persists in that state until functions are restored by the organism's adaptive mechanisms, including the increased delivery of glucose and oxygen to the affected tissues. The steroids progesterone and cholesterol are among the organism's adaptive resources. Excitatory stress causes the aging brain to lose cholesterol (Sodero, et al., 2010). The ester form of cholesterol is increased by excitatory stress (Kim, et al., 2011).

The steroids of animals and fungi are produced from the precursor, lanosterol; plant steroids are produced from cycloartenol, a molecule with a slightly different shape. This suggests that fungal steroids might be more compatible with our cells than those in plants. A few people have been concerned about the incorporation of foreign DNA into our cells, but there has been little interest in the cumulative effects of the alien plant steroids. The fact that some plant sterols can block the absorption of cholesterol has led to their use in some dietary supplements. Some plant sterols can interfere with the enzyme that removes fatty acid from cholesterol esters, and there is some evidence that a diet lacking plant sterols can be protective (Wilson, et al., 2013).

Cholesterol is our basic stability-promoting lipid, which is needed for maintaining the organization of the cell structures, including those involved in cell division. It associates with hydrophobic areas of proteins ("the interaction between cholesterol and peptides is inversely correlated with the extent of the peptide-peptide interactions," Zhao, et al., 2011), and that makes it likely to be a factor in preventing the clumping of proteins in aging and degeneration. In Alzheimer's disease and other dementing conditions, the concentration of cholesterol in crucial brain areas is decreased, (Ledesma and Dotti, 2012, Roher, et al., 2002, Wallin, et al., 1989, Vakulenko, 1980). while the concentration of cholesterol esters increases.

The fungal sterol, lanosterol, which is very similar in structure to cholesterol, can reverse protein aggregation in cataracts (Zhao, et al., 2015), and a mushroom extract (containing a variety of related sterols) can prevent the formation of cataracts in vitro (Ganeshpurkar, et al., 2011), preventing the proteins from becoming insoluble, and in living animals the extract reduced cataract formation by 75% (Isai, et al., 2009). Mushrooms have been found to improve learning in animals, and to decrease symptoms of dementia in people (Wang, et al., 2012, Seo, 2010, Mori, et al., 2009).

In the 1960s, I heard about the temporary complete recovery of a demented patient at a geriatric hospital in Santee, California. The day-long episode of mental clarity began after she had been outside on the hospital grounds, and later they found a half-eaten mushroom in her apron pocket. The doctors believed it was a toxic amanita variety. One of the chemicals later identified in the Amanita muscaria species was named muscimol, a GABA analog, which protects against excitoxicity, but that species also contains many other substances that affect nerves.

Estrogen has excitatory, anti-GABA effects in the brain (Smith, et al., 2000, Gu and Moss, 1996), and some of the mushrooms' protective effects result from inhibiting aromatase, the enzyme that synthesizes estrogen (Chen, 2002, Chen, et al., 2006), and also from blocking estrogen receptors (Jang, et al., 2015, Jiang, et al., 2006). Enzyme studies show that a variety of molecules in the common white button mushroom contribute to these anti-estrogen effects, and inhibit cancer cell growth (Grube, et al., 2001). Studies in mice showed that an extract of these mushrooms inhibited growth and increased apoptosis in human prostate cancer cells (Adams, et al., 2008). The effects of mushrooms on cancer are parallel to those of progesterone, inhibiting a wide variety of cancer promoting mechanisms. One of the major mushroom sterols, ergosterol, has been identified as an anticancer agent (Li, et al., 2015).

Besides the cell-stabilizing trehalose and steroids, mushrooms contain a variety of flavonoids, including some that are found in citrus fruits, such as rutin, luteolin, and apigenin. A high vitamin E content (Vamanu, 2014) might contribute to their anti-inflammatory effects.

In England, about 70% of the people still don't eat any mushrooms, and the *per capita* intake is only about 120 grams per year (Roman, et al., 2006). It seems likely that the development of mycophobia in the English and Spanish empires was a result of the suppression of witchcraft (the use of psychoactive mushrooms for divination and love potions, etc.), combined with the cultural dominance of cities, where mushrooms were scarce

In the absence of a traditional mushroom culture, failure to recognize toxic varieties will increase the risk of poisoning. Currently, silibinin, from milk thistle, is the most commonly used antidote for Amanita phalloides poisoning, but other anti-inflammatory and anti-estrogenic inhibitors of prostaglandin and nitric oxide synthesis might be safer.

The hydrazine-containing toxins that Toth and others wrote about are destroyed by heat. Since extracts made by boiling the mushrooms for three hours were very active, I think it's good to boil them from one to three hours.

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