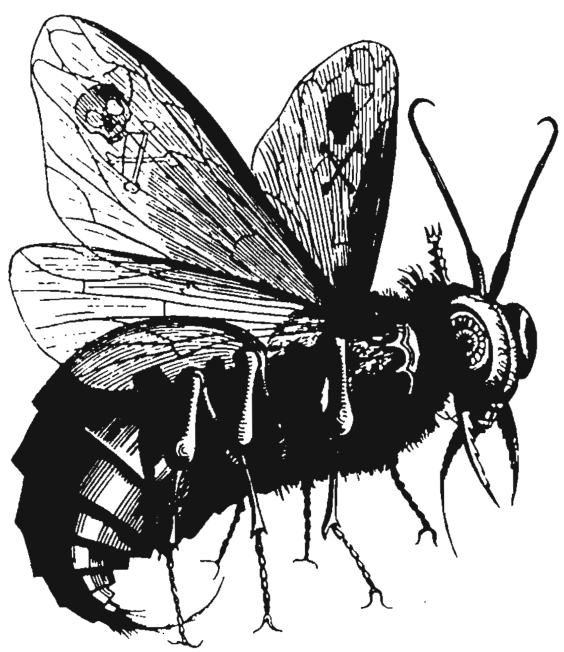
Fly Agaric, Flies, and Toads: A New Hypothesis

From the forthcoming Italian book *Animals that Take Drugs* by Giorgio Samorini

Animals take drugs. This is an undeniable fact that has been repeatedly confirmed by animal behavior studies. Some years ago, Siegel (1989) gathered together many instances of such behavior. At present, I am writing a book on the instances observed up to the present in an attempt to explain them in terms of what the biological literature refers to as the "PO factor" or "de-patterning factor."

In brief, we may note that all living species (including plant life) are endowed with a set of primary functions necessary for survival (nutrition, reproduction). However, this is not sufficient. If a species is to preserve itself over time, it must be capable of evolving by modifying and adapting itself to its incessantly changing environment. Apart from the rare cases of "living fossils," species that do not evolve will finally succumb. This is why each living species must also possesses an "evolutionary function" that is based, biologists believe, on the PO or de-patterning factor. The PO factor is probably reflected in the behavioral trait of drug-taking noted in animals and human beings. In the final analysis, drug-taking may be considered a vital evolutionary function for the preservation of the species (Samorini, *Animali che si drogano*, work in progress). Siegel comes to the same conclusion, albeit by a different route.



We already know that hundreds of natural species display this trait (including, surprisingly, lower-order species such as insects). Certain hawkmoth species—small nocturnal moths—have developed a long proboscis to draw in the nectar of a Jimson weed species. In Arizona, the *Manduca quinquemaculata* hawkmoth feeds on the nectar of *Datura meteloides* DC. ex Dunal (= *D. innoxia* Miller). By doing so it aids the pollination of the flowers. Only after repeated observation of the behavior of this species was it noticed by some researchers that this hawkmoth appeared to be intoxicated by the nectar. This was in fact anything but obvious. Firstly, observation took place by night when the plant's corolla opens. The main tasks of the botanists and entomologists who took the trouble to sit up all night beside these Jimson weeds were identifying the pollinating insects and capturing them while they were still inside the flower. However, observation of the insects that had drawn in the nectar revealed that they "appear clumsy in landing on flowers and often missed their target and fell into the leaves or onto the ground. They were slow and awkward in picking themselves up again. When they resumed flight, their movements were erratic as if they were dizzy. The hawkmoths seem to like it and come back for more" (Grant & Grant 1983: 281). It is more than likely that the nectar of this species of Jimson weed contains the psychoactive alkaloids also to be found in those parts of the plant used by man for their visionary properties. Grant & Grant advance the hypothesis that this inebriating nectar constitutes a sort of "reward" given by plants to insects for their services in pollination. For hawkmoths, however, this is a very dangerous job indeed! If they lie besotted on the ground—even very briefly—or slowly fly away, they instantly become targets for predators.

It appears that something similar also takes place with certain bees and American tropical orchid flowers. *Catasetum*, *Cynoches*, *Stanhopea* and *Gongora* flowers are not sources of nutrition. They produce a liquid perfume. Bees of the *Eulaema*, *Euplusia*, and *Euglossa* genera scratch the floriferous parts of the plants. "The liquid exudes from the scratched surface and is absorbed through the front legs of the bees.

The bees return repeatedly to the floral source of the liquid, and exhibit clumsy movements on the flowers which are interpreted as a result of intoxication" (DODSON 1962 and VAN DER PIJL & DODSON 1966 in GRANT & GRANT 1983: 283). This particular type of commerce between insects and flowers, whereby pollinated plants reward insects for their services (with the drug as a partial or entire reward), is probably much more widespread than is recognized at present.

The behavior exhibited by hawkmoths in the presence of Jimson weed led me to reconsider the behavior of the common fly (*Musca domestica*) in the presence of fly-agaric (*Amanita muscaria*). The name of this mushroom "muscaria" is derived from the Latin for fly, "musca," because it is known that flies are attracted by the caps of fly-agaric and that they are "killed" as a result of contact. In the past, indeed right up to our own century, fly-agaric caps have been placed on windowsills as insecticides. Often, the cap was (or is) crushed and mixed with sugar or milk to attract large quantities of flies. In this manner, the flies would actually consume greater quantities of the inebriant. The flies then die, probably due to overdose. I have often noted apparently dead flies around the caps of the fly-agaric that I have prepared on various occasions (preparation consists of stripping the cap of its gills to prevent rot and laying out the caps in a well-aired place for drying). Unless one wishes to dry the caps with a warm air flow in an open oven, the natural length of time for drying the mushrooms can range from a few to many days according to the temperature and humidity of the surroundings. At times, I have counted dozens of flies that had "died" during the drying period. The number depended not so much on the number of caps laid out, or days necessary for complete drying, as on the number of flies in the vicinity. The "victims" of contact with the caps—lying on their backs with their legs up in the typical position of a dead fly—only *appear* to have died. If you leave them alone and come back after an hour or so, or the next day, you will find that they have flown away! Normally, one might remove these "dead" flies, but perhaps others have taken the place of the first ones you saw, and have also been intoxicated by the caps. Seeing as one would find it hard to distinguish between individual flies, it is hardly surprising that this turnover goes unnoticed. This is the reason for the folk belief that fly-agaric kills flies by poisoning them. However, a number of 19th century mycologists noticed that flies were not so much poisoned as drugged into a state of "lethargy," and it was recommended to those who used the mushroom against flies that they sweep up the immobilized flies and throw them into the fire (see, for example, PAULET 1793 and CORDIER 1870: 94).

On careful observation, we see that the flies land on the cuticles of the fly-agaric cap and lick the surface. After a while (5–20 minutes), some show signs of inebriation. They fly erratically or not at all; they become sluggish; a tremor appears in the legs or there is a trembling of the wings. Eventually, the flies will roll over onto their backs legs in the air, perfectly still. If you touch them with a pencil tip, some will exhibit no response, while others will move their legs. Under a magnifying glass, one may observe a peristaltic movement, which proves that these flies are not dead. Over a period ranging from 30 minutes to 50 hours, the flies wake up and soon move about in a normal manner. BOWDEN *et al.* (1965) showed that flies, on awakening, move their legs first, then their wings. They then fly off as though nothing had happened at all. Some flies do not exhibit inebriation on coming into contact with the surface of fly-agaric. This may depend on the time of exposure to the inebriant. There are probably various degrees of inebriation, the signs of which range from markedly frenetic behavior during flight, to complete catalepsy.

During the late 1960s, a number of the collaborators of the great French mycologist ROGER HEIM—one of the founding fathers of modern ethnomycology and a pioneer in visionary mushroom research—at the NATURAL HISTORY MUSEUM in Paris (of which HEIM was director), carried out specific experimental research into the relationship between the common fly and fly-agaric (BAZANTÉ 1965, 1966; LOCQUIN-LINARD 1965–67). The researchers wished to establish the degree of inebriation that this mushroom induced in the fly. However, their work tells us little about the relationship between the two species in a natural setting. They placed flies in PETRI dishes together with the mushroom or a liquid extract of the same. Many of the insects therefore died either due to overdose induced by the experimental conditions or—a point recognized by the researchers themselves—specifically, due to the carbon dioxide produced by the mushroom itself, leading to asphyxia. These experiments established that the active principles of the mushroom acts upon the nervous system as opposed to the muscular system. In addition, it was found that flies were also inebriated by the spores of fly-agaric, and by *Amanita pantherina*, a mushroom species similar to fly-agaric containing the same active principles and endowed with the same psychoactive properties (for humans).

The most active portion of the mushroom is located immediately under the red cuticles of the cap. It is yellowish and is the region in which we find the highest concentrations of isoxazolic alkaloids (ibotenic acid and muscimol). It was once thought that muscarine was the inebriating chemical for flies, as well as for human beings. However, attempts at feeding insects with pure muscarine had no effect at all. It was shown, instead, that flies are inebriated by the same alkaloids that are now known to produce effects human beings.

In Japan, mushrooms that attract flies have also been used for a long time as insecticides. The most well-known example is *Tricholoma muscarium* KAWAMURA, known as *haetori-shimeji* (fly-killing mushroom). This produces another isoxazolic alkaloid, tricholomic acid (= dihydroibotenic acid) which, apparently, is not psychoactive in man (TAKEMOTO & NAKAJIMA 1964). JONATHAN OTT (1993: 356) noted this compound in the common *Pleurotus ostreatus* (JACQUIN ex FIES) KUMMER, an edible mushroom cultivated and marketed in great quantities in Europe and America. We should note that this mushroom is a carnivore. In its natural state, it releases a neurotoxin into the soil that immobilizes nematodes, which are then trapped by the hyphae of this mushroom and ingested (THORN & BARRON 1984). OTT is convinced that the neurotoxin is tricholomic acid (*i.e.* the compound that attracts flies).

It may therefore be the case that isoxazolic alkaloids are produced by mushrooms both as a means of protection against certain predators and as a trap for underground worms, and that 'by chance' these substances also attract and inebriate flies (which are clearly *not* a source of nutrition for these particular mushrooms; carnivorous behavior has not been observed in *Amanita muscaria* and *A. pantherina*). But the question remains: why should the maximum concentration of ibotenic acid in these Amanitas be just below the cuticle in the cap (well away from the ground), instead of in the stem?

HEINRICH (1991) notes that flies lay eggs in mushroom stems. The grubs then move toward the gill area to feed. We may therefore imagine that isoxazolic alkaloids might act as an insecticide to prevent the flies from laying there. If this is the case, we do not know why the maximum alkaloid concentration is in the cap just under the cuticle and not in the stem, the preferred site for egg-laying. See, for example, the recent analyses by GENNARO *et al.* (1997) on fresh samples of *Amanita muscaria* collected in Piedmont (northern Italy). The muscimol concentration in the cap is 0.38 g/kg and 0.08 g/kg in the stem (ibotenic acid: 0.99 g/kg and 0.23 g/kg, respectively). Furthermore, it is not clear that the grubs of these eggs adversely affect the sporogenic activity of these mushrooms (the grubs would actually help spread the spores). Lastly, the relation between fly-agaric and flies is one of attraction, not repulsion.

This strange behavior on the part of flies is not just a chance occurrence. Nor is it by mere chance that flies are attracted by fly-agaric, or that the flies' inebriation rarely leads to death. Philosophically speaking, "chance" (or what we consider chance), is generally the measure of our ignorance. Faced with chance occurrences, we tend to consider such circumstances in this manner and look no further.

I would therefore like to advance a new hypothesis concerning the natural relationship between fly-agaric and flies, and also with respect to the findings on hawkmoth inebriation from Jimson weed. Such behavior patterns are not just recklessness on the part of flies attracted by fly-agaric (accidental inebriation mysteriously brought about by a monkey wrench in the evolutionary 'works'). Flies deliberately seek the state of inebriation, as do hawkmoths with Jimson weed. Flies, like the Siberian reindeer, take fly-agaric as a drug.

In nature, the relationship between flies and their drug is non-obligatory. The flies exposed to this mushroom are not all "killed" (*i.e.* undergo the paroxysmic effects of the active principle). The physical and mental effects of *Cannabis* smoking in humans are gradual. They range from the so-called "high" (a mental and partly physical state of excitation) to a visionary or ecstatic state accompanied by sedation, which can immobilize the consumer for hours on end. The range of effects may depend on quantity, but other factors also come into play. Individual reactions to *Cannabis* vary and also depend on one's own personal relationship with the substance and how this has developed over time. If we consider flies, it may well be that—up to the present—our observations of their relationship with fly-agaric are just the tip of an iceberg, and that other less evident aspects have been neglected. Perhaps flies that are not "killed" by the mushroom are inebriated to a certain extent. MORGAN has observed the effects of fly-agaric in a fruit fly (*Drosophila*):

> It made an attempt to fly off, and spiraled onto the table upon which the mushrooms lay. It remained motionless for at least a minute, and then recovered and flew off (MORGAN 1995: 102).

Fly-agaric may be quite the opposite of an "artificial" paradise for any number of insects (especially of the woodland undergrowth), and not just the common fly.

The great ethnomycologist, R. GORDON WASSON, dedicated an entire chapter of his monumental work *Mushrooms, Russia and History* (1957A, I: 190–214) to the relationship between flies and fly-agaric, not to mention the notes in his essay on *Soma* (1968; 198–202). He was rather sceptical about the idea that flies are attracted and inebriated by fly-agaric. This is because he concentrated on the purely semantic relationship between these two species. Although he was unable to deny the existence of an ecological relation, after the research carried out by BAZANTÉ and others (see above), he nevertheless attempted to make little of it. He commented that the folk belief that fly-agaric kills flies reflected "that curious fund of 'facts' that people keep repeating to each other and believing, without verification or analysis" (WASSON 1968: 198). My own opinion is that this folk belief—as with so many such beliefs—contains a grain of truth that is verifiable by anyone who, like myself, has come into intimate contact with fly-agaric (collecting, handling, drying). WASSON, apparently, had no such contact. One cannot deny the fact that flies, in the laboratory or elsewhere, "die" when coming into contact with fly-agaric. I've often observed this, and there's convincing evidence that this folk belief is more than just hearsay.

In his attempt to down-play the ecological side of this "folk belief," WASSON stresses that the relation in question is not present throughout the world—that it is only to be found in certain specific, albeit extensive, regions of the world. He notes the absence of this belief in Italy and the Iberian peninsula, but hastens to add that his research with regard to these geographic areas is not exhaustive (*ibid.*: 198). However, fly-agaric is actually known to be a "fly killer" in Italy (*e.g.* Liguria; cf. CALZOLARI 1998: 29) and in the Catalonia region (FERICGLA 1994; 138). CLARK HEINRICH, who has plenty of experience with samples of *Amanita muscaria*, also mentions that he has frequently noticed the "narcotic" effects of this mushroom on flies (HEINRICH 1999).

The semantic/symbolic association between flies and fly-agaric observed by WASSON, which he concentrated on to the exclusion of other aspects, is interesting and partly true. All flying insects have a universally demoniac valence. During the Middle Ages, delirium—the state of drunkenness and mental illness—was ascribed to insects reaching the brain of the victim; for a number of cultures, "having a bee in one's bonnet" indicated madness. However, this folk belief in no way justifies the opinion that fly-agaric "kills" flies. It is more likely that the following semantic association came about: mental illness is to the presence of flies in the head is, the inebriant effect of fly-agaric is to the presence of flies on the cap (head) of fly-agaric.

This semantic/symbolic relationship developed from observation of the ecological factor associating flies and fly-agaric. Moreover, if we consider the facts in the light of our new hypothesis, *i.e.* that flies get "high" on fly-agaric, we can also partly explain the relationship (established over thousands of years) between fly-agaric and toads in the absence of any recognized ecological relation between fly-agaric and toads. Wasson is categorical on this: "Toads do not sit on wild fungi, not under nor around them; neither do they eat them. Indeed toads and frogs have no direct physical or biological link with toadstools. Our word [toadstool], with roots deep in our folkways, is not, in any way, obvious to us, a distillate of man's observation of nature" (Wasson & Wasson 1957a, I: 65). Wasson was sometimes too categorical in his conclusions, as we find when he denies all mycological interpretations of the "mushroom-tree" fresco of the Plaincourault Romanesque church (cf. Samorini 1997). Morgan (1995: 2) points out that, in nature, fly-agaric and toads are rarely seen together. Most ethnomycologists believe this semantic association originated in the poison of the one and the venom of the other. Ramsbottom recalls a folk belief that mushrooms "are formed from the harmful substances of the earth and the venom of toads and that fungi always grow in places where toads abound, and give shelter to them when they take the air" (Ramsbottom 1953: 3). We still know rather little about the intimate relations between the various species of living things in nature. The recent discovery of the relationship between the hawkmoth and Jimson weed flowers is a case in point. During my own encounters with fly-agaric in the Alpine woodlands of Italy I came across toads (*Bufo bufo*) in the vicinity only twice. However, I should also point out that I have never looked for toads in the undergrowth where fly-agaric abounds nor have I ever remained for any considerable length of time near a fructification (which may include more than one hundred carpophores over an area occupied by a few dozen trees). Toads eat slow-moving insect and larvae. They would find it hard to catch fast-moving flies, if the flies were not injured or inebriated and therefore less agile.

It is absolutely not my intention to erect categorical barriers. I would, however, advance the following hypothesis: since flies are attracted by fly-agaric and since inebriation can lead to slower movements, toads may have learned that they can find easy prey around these fungi. It is possible that this hypothetical ecological relationship between fly-agaric, flies and toads may indeed be insufficient as an explanation for the relationship between these three life forms established by folk culture. However, the ecological relationship I refer to above does not clash with Wasson's semantic/symbolic associations, the demonstrations of which remain valid. ✧

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