the cat-chaneller were lacking was clearly not intelligence. Yet at the same time, a vast sinkhole of stupidity had become lodged in their brains. The rational, critical faculty that could analyze DNA transcription or restriction enzymes had somehow become wholly separated from the emotional, uncritical aspect that was saving canned goods against the day when Ramtha will eradicate unbelievers.

Thus, my editor friend's comments struck a deeper chord than they might otherwise have done. As I made my way back into the Boston snow, it occurred to me that having learned the secrets of holistic touch, she would continue editing those same books meant to inoculate the next generation against such irrational thinking. While the science she read all day long found a home in her consciousness, the scientific world-view evidently did not. No part of her thinking was equipped to ask what waving your hands over someone else's body has to do with a mathematical theory of hadrons, how the "therapist" came by the knowledge he claimed to have, or why a supposed connection between string theory and therapeutic touch has never been suggested in credible scientific literature.

Among the various emotions this realization caused was a generalized guilt, a quiet feeling of having abandoned a generation that is looking to us for guidance. These are children, after all, who are growing up among a host of adults who do not want them to be fully rational; who are lobbying to insert their religious views into laws, to elect government officials based on metaphysical affiliation, and to bracket and sticker responsible science textbooks and replace them with creationist bunk.

My more immediate response, however, was anger. Anger not at my friend but at the snake-oil salesman who suckered her into hokum by calling it quantum. Anger at the cult that offered a potentially fine biologist in Ohio a way out of reality that proved too tempting for her emotional vulnerabilities, taking her sharply tuned brain and clotting it with gibberish. Anger at whatever group teaches the next great thinker to distrust his own senses, at whatever clan tells the next great philosopher to discredit her own mind, and at the guru who tells any one of us, in any profession, to forfeit our birthright as rational, clear-headed beings.

There was a moment in my conversation with Dr. Susskind when we considered the possibility, as string theory and inflationary theory both suggest, that we may actually be living in a multiverse—a vast conglomeration of universes in which the entirety of what we see, billions of light-years in any direction, is only a single grain in an infinite shining beach. This is the kind of reality contemporary physics actually hints at. These are the heights, vastly greater than Olympia, that our scientific imagination is capable of scaling. It's a view to make the most jaded mystic tremble. □

FOLLOW-UP

Zombies and Tetrodotoxin

TERENCE HINES

In the July/August 2007 issue of SKEPTICAL INQUIRER, Costas J. Efthimiou and Sohang Gandhi (2007a) argued that Haitian voodoo witch doctors create real zombies by using preparations containing the poison tetrodotoxin (TTX). I will address several problems with the Efthimiou and Gandhi paper and then discuss the wider issue of whether TTX is a valid explanation for Haitian zombies, an argument first made in 1983 by Wade Davis, an ethnobotonist with a PhD from Harvard.

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Efthimiou and Gandhi describe a zombified patient who had been studied by a Haitian doctor. This patient came to their attention through a 2002 television documentary. The original article contained several errors in the description of the brain scan that was illustrated on page 33. The authors corrected these errors in their reply to letters to the editor regarding the article (Efthimiou and Gandhi 2007b). There are, however, a few more problems in the original paper that need clarification. On page 33, the authors claim that patients suffering from TTX poisoning are sometimes certified as dead but wake up just before burial. This is surely an extraordinary claim, but the authors do

not provide a single reference to any such case.

Also on page 33, they state that the body of someone suffering from TTX poisoning will "show signs of rigor mortis and even produce the odor of rot." Here they confuse paralysis with rigor. As will be described in detail later, the effect of TTX is to block nerve impulses. These impulses are necessary to enable muscles to contract. In the absence of these impulses, patients are unable to move their muscles. But their muscles are *not* rigid; they are instead limp or flaccid. There are conditions that result in rigid muscles, but these are caused by too many, rather than too few, nerve impulses.

The claim that TTX produces the "odor of rot" is one I have not come across before. It might be the result of the anal sphincter losing tone and thus causing the patient to defecate involuntarily. However, I have enough experience in the autopsy room to know the difference between the smell of feces and a decomposing corpse. Presumably, Efthimiou and Gandhi have not had these happy experiences.

Efthimiou and Gandhi argue, as did Davis earlier (Davis 1985), that zombification could "easily be caused deliberately by the voodoo sorcerer, say, who could slip the dose into someone's food or drink." This claim is implausible. The amount of TTX in puffer fish flesh varies as a function of fish sex, species, and time of year, as well as the anatomical location of the flesh (Kaku and Meier 1995). Further, the effect of any drug on an individual varies as a function of the individual's age, sex, state of health, body weight, experience with related drugs, and numerous other variables. Even experienced physicians find it difficult to prescribe the correct dosage of drugs to patients who vary on these characteristics as all human beings do. And these are drugs produced to exacting specifications so the physician knows the exact dose the patient will receive. This is a bit different from a bunch of ground up, dead fish and who knows what else produced on the spur of the moment by the local witch doctor. Witch doctors simply could not produce such fine-tuned effects with such poor quality material to work with, even if at some hypothetical "right dose" TTX had such effects. The basic problem is that at *any* dose, TTX would not have any such effects.

Wade Davis and the Zombies of Haiti

Davis' claim that TTX in zombie powder is the root cause of zombification first came to the attention of the general public when his book *The Serpent and the Rainbow* was published in 1985, although he published a paper in the scientific literature earlier making this claim (Davis 1983). There are two separate aspects of Davis' claim. First, he claims that the zombie powder he obtained in Haiti contained significant amounts of TTX. Second, he said that these levels of TTX would produce the traditional zombies known to Haitian mythology.

In his 1985 book, Davis described his trips to Haiti, his introduction to Haitian culture, and his attempts to acquire the powder used to produce zombies. The book is an excellent example of a credulous foreigner taken advantage of by local tricksters and is full of scientific absurdities. On page 26, for example, he informs the reader that the "muscles of the iris continue to contract for hours after death." This is simply wrong. On page 50, he describes going to a voodoo ceremony specifically produced for tourists (admission was $10) at which a woman took a glowing hot coal in her mouth without suffering any burns. He marvels that she does this every night without harm. His explanation? She had "clearly entered some kind of spirit realm." Davis obviously never even considered that this perhaps was just a standard sideshow stunt to fool the tourists. No such skeptical thoughts ever seem to have entered Davis' head. One is reminded of Margaret Mead being conned by clever Samoan children during her studies (see "The Fateful Hoaxing of Margaret Mead," SI November/December 1998).

Davis reports that the zombie state can be made to last for long periods of time. Allegedly, one zombie was kept for years so he could work as a slave on a plantation. "Together with many other zombies, he had toiled as a field hand from sunrise to sunset," claimed Davis (1985, 80). The obvious suggestion here is that witch doctors not only make zombies but keep them in the zombie state for years. This would be quite the pharmacological accomplishment, as will be seen below. Davis later seemed to back off this claim, admitting that the case in point was difficult to verify (Booth 1988).

Ultimately, Davis secured samples of zombie powder. Since one of the powder's ingredients is bits of dead human tissue, Davis commissioned a grave robbery to obtain the decomposed flesh of a recently buried child (Davis 1985, 92–95). Pictures of the process, including using a stick to remove bits of decomposed brain, are found in his books (Davis 1988, p. 115–116). As might be expected, Davis was heavily criticized for this ethical breach (Anderson 1988; Booth 1988).

In the end, several samples of zombie powder were analyzed for TTX levels by Kao and Yasumoto (1986). They found only "insignificant traces of tetrodotoxin in the samples of 'zombie potions' which were supplied for analysis by Davis." Furthermore, they stated: "it can be concluded that the widely circulated claim in the lay press to the effect that tetrodotoxin is the causal agent in the initial zombification process is without factual foundation" (p. 748).

This was not the end of the matter, however. Benedek and Rivier (1989) reported that they found significant amounts of TTX in one out of six samples of zombie powder. Kao and Yasumoto (1990) strongly criticized the Benedek and Rivier report on various technical grounds, including the fact that the analysis these authors used was

not specific for TTX.

The refutation of Benedek and Rivier by Kao and Yasumoto is powerful and conclusive but raises another question. If biochemical analyses of the zombie powder supplied by Davis *had* shown the presence of TTX in significant quantities, would this have strengthened Davis' claim of the creation of zombies using such a concoction? To answer this question, we need to closely examine the pharmacological effects of TTX.

The fundamental unit of information processing in the nervous system is the action potential, an electrical signal that travels along nerves. It is produced by flows of ions (charged particles) that cross nerve cell membranes through specific channels, one channel for each species of ion. One of the most important channels is the sodium channel, which allows positively charged sodium ions to pass into the neuron, or nerve cell. In fact, it is the passage of sodium ions into the neuron through sodium channels that allows the action potential to proceed along the neuron. If something blocked these sodium channels, no action potentials would be produced. Dire results, including death, are possible if enough sodium channels are blocked. TTX does exactly that; it selectively blocks sodium channels on the neural membrane. TTX prevents sodium ions from entering the neuron and thus prevents the generation of action potentials. It should be noted that the major effect of TTX is on nerves in the peripheral nervous system that control motor output and relay sensory information to the brain. Little if any TTX actually enters the brain, which is protected by a barrier that prevents certain types of molecules, such as TTX, from crossing the blood stream into the brain.

TTX occurs naturally in a number of animals, the best-known example being several species of puffer fish found in both Asiatic and Caribbean waters. Interestingly, these fish do not themselves produce TTX but obtain it from TTX-producing bacteria (Mebs 2002). Newts and toads in the Pacific Northwest produce TTX, but its biological origin is not clear. TTX is best known as the cause of fugu poisoning. Fugu, raw Japanese puffer fish, is a delicacy in Japan prepared by specially trained chefs who remove the poisonous tissues of the fish while leaving uncontaminated portions for consumption.

TTX poisoning is a real and serious medical problem in areas where puffer fish are considered food. The first mention of puffer-fish poisoning, at least by a Western writer, is found in 1774 in the journal of Captain Cook's second voyage (Isbister et al. 2002). Since the toxin affects motor and sensory nerves, both motor and sensory symptoms are encountered, especially at higher levels of poisoning. The severity of poisoning is classified by four levels, or grades (Isbister 2004). At grade one, there are only mild sensory symptoms, such as numbness around the mouth, but nausea may also be present. At grade two, numbness becomes more widespread and there is some motor difficulty, including slurred speech. At grade three, symptoms become more severe, including a "generalized flaccid paralysis, respiratory failure, aphonia and fixed/dilated pupils; patient remains conscious" (Isbester 2002, 1635). Finally, in the most severe grade-four cases, one finds more serious respiratory problems, hypotension, and cardiac difficulties. The patient may lose consciousness. If enough toxin is ingested, death will occur. If death does not occur, patients generally recover with supportive care within a week.

Note that these symptoms are very different than the usual images of the zombie, either those seen in horror films or put forth by Davis. In both, the frightening zombie, devoid of any but the most minimal level of consciousness, lurches around with stiff arms and legs. But real victims of puffer-fish poisoning aren't going to be doing much moving around at all. They will suffer from *flaccid* paralysis, meaning that there will be little or no muscle tone. There will be breathing problems and, in serious cases, the blood will not carry sufficient oxygen to the brain. They will also feel nauseated. As noted above, Davis argues that zombies can be created for use as laborers on plantations in Haiti. It seems to me that a bunch of nauseated, paralyzed guys would not make very productive field workers!

The total lack of similarity between the real symptoms of TTX poisoning and the mythological zombies of Hollywood should be enough to sink the claim that zombies are caused by TTX poisoning. This fact led the scientific community to dismiss Davis' claims as absurd back in the 1980s. Unfortunately, this debunking never found its way into the mainstream press, as is so often the case.

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