LETTERS

Origin of Yellow Rain

Joseph D. Rosen (Letters, 19 Aug., p. 698) has analyzed one sample of "yellow rain," the alleged agent of toxin warfare in Southeast Asia. He reported (*1*) the detection by gas chromatography–mass spectrometry of approximately 50 parts per million of each of three trichothecene mycotoxins and 265 ppm of zearalenone, compounds produced by certain widely distributed fungi. He also noted a series of peaks suggesting the presence of polyethylene glycol (PEG). Rosen argues in his letter that this evidence for PEG, a synthetic industrial chemical, "makes irrelevant" any explanation of yellow rain as a natural phenomenon. A problem in this is that PEG could have entered the sample as a contaminant. More than 100 million pounds of PEG and its derivatives are made annually for a great many uses, including the treatment of wood and paper; the lubrication of molds for forming and rolling rubber, plastic, and metal; and as emulsifiers and detergents. Rosen's sample is reported to have been scraped from vegetation by a Hmong soldier in Laos and given to an American in a Thai refugee camp, who provided it to ABC News. ABC gave it to a private laboratory, where it was transferred to new vials and sent to Rosen. The sample could have become contaminated with PEG before, during, or after its collection. Even laboratory contamination is not excluded by the blank analysis Rosen performed after analyzing the sample. What is more, the peaks interpreted as evidence of PEG by Rosen have not been reported in mass-spectrometric analyses of samples received by the U.S. government. The origin of yellow rain is too important an issue to be allowed to hinge on an isolated finding for a single, possibly contaminated sample.

A remarkable finding in all samples of yellow rain we know to have been examined is that they contain a high proportion of pollen. This includes Rosen's sample and 15 other samples and groups of samples investigated in the United States, Australia, Canada, Great Britain, Sweden, and Thailand (*2, 3*). The pollen identified thus far is from plant families common in Southeast Asia. The families are mostly insect-pollinated, not wind-pollinated, and their pollen is gathered by bees. U.S. government investigators speculate that bee pollen is being used as a carrier for toxins in weapons (*2, 4*). However, in size, shape, color texture, and high pollen content, the spots of yellow rain closely resemble the natural excreta of bees of the genus *Apis*. Three species of *Apis*, the true honey bees, occur in Southeast Asia. Honey bees almost never defecate in their nest but instead do so in flight. Their excrement consists largely of the walls of pollen consumed from stores in the nest. The color of the fecal deposits varies but usually is pale to dark yellow or brown. Their size ranges from about 1 to 10 millimeters. The average diameter of fecal spots of *Apis cerana*, the one Asian honey bee for which we have samples (3.3 ± 0.9 mm, mean ± standard deviation; $N = 43$), does not differ from that of yellow rain spots from an alleged attack in Laos (3.2 ± 1.0 mm; $N = 25$). Honey bee feces are wet and sticky and dry to a waxy consistency. Older deposits vary from rather hard and brittle to powdery. This matches descriptions of yellow rain as well as the characteristics of aged yellow rain samples we examined (*3–5*). We also found fungal hyphae and occasional bee hairs both in yellow rain samples and in bee feces. We do not know of any characteristic of the yellow rain samples that definitely distinguishes them from honey bee feces, and the resemblance is difficult to explain for an agent of chemical warfare. We therefore conclude that the yellow rain samples may be the natural excreta of bees, a possibility not ruled out by Emery W. Sarver, chief of the Army's analytical team investigating yellow rain (*2*). If the samples of yellow rain are bee feces, reports that it is disseminated by weapons must be reevaluated.

Altogether, trichothecene mycotoxins have been reported in environmental or biomedical samples associated with 17 alleged attacks in Southeast Asia (*1, 5*). Descriptions of the mode of attack, bearing on the question of whether there was a chemical attack at all, are vague and lack consistency. Delivery of the agent is attributed to low- and high-flying aircraft (including helicopters, jets, and fixed-wing airplanes), artillery shells, mines, grenades, and simply passage through a contaminated area; no means of delivery is specified for five of the attacks. No spent or unspent chemical munitions have been recovered to confirm these or any of the more than 100 other alleged attacks, even though many accounts refer to recoverable items such as artillery shells and rockets.

The analyses for trichothecenes in environmental and biomedical samples from Southeast Asia reported by the U.S. government (*2, 5*) do not allow a distinction between artificial introduction and natural occurrence. Seven of the yellow rain samples known to contain pollen have been analyzed for trichothecenes. Four tested negative, and three (including Rosen's) tested positive, possibly because of infection of bee feces with toxigenic fungi before or after deposition. Only three other environmental samples tested positive: one of yellow powder, one of foliage, and one of water with debris. None of these was examined for pollen. No trichothecenes were found in 57 other such samples from alleged attack sites or in 16 control samples from outside the attack areas. These results give no statistically significant evidence that the toxins are more common at the sites of alleged attack than outside. Also, it is seen in retrospect that the controls were poorly matched. At least nine were not collected in the season when the toxin-containing samples were taken, and no attempt was made to include bee feces.

Although chemical attacks in Southeast Asia were alleged to have occurred in all seasons, 23 of 26 samples reported to have trichothecenes were collected at the end of the dry season, between mid-February and mid-April in 1981, 1982, and 1983 (*1, 5*). This includes all six environmental samples and biomedical samples from 17 out of 20 individuals. Trichothecenes are reported in the blood, urine, and tissues of 18 alleged victims and are tentatively identified in two others. The total number of alleged victims testing negative has not been made public. Nine unexposed individuals selected as controls tested negative. The controls were not matched for diet, and they were not reported to have been ill. In contrast, at least 10 of the 20 alleged victims who tested positive for trichothecenes had symptoms of illness at or shortly before the time of sampling. Two were sampled postmortem. The use of apparently healthy controls risks excluding trichothecene positives from the control group, as toxins in the body are likely to be associated with illness. Indeed, there are indications that the trichothecenes reported in biomedical samples are of natural origin. Most of the blood samples that tested positive for intact T2 toxin were drawn between 1 and 10 weeks after the alleged attacks. Available animal studies (*6*) suggest a half-life of T2 in the blood of only a few hours. Thus the toxin found in refugees could have originated from exposure long after the alleged attacks. In an autopsy conducted 5 weeks after an alleged attack, T2 was reported at much higher concentrations in the stomach and intestines than in other organs; aflatoxin B1 was also present at high levels in the digestive organs, suggesting the inges-

tion of moldy food within the previous day or two. That T2 can contaminate food in the Asian tropics is indicated by reports from India of high levels in corn, sorghum, and safflower seed (*7*).

Although a more systematic investigation is needed, the available evidence strongly suggests that the yellow rain samples and the trichothecenes result from natural phenomena. Similar phenomena may have been responsible for the complaints brought by Cambodia before the United Nations Security Council 19 years ago alleging that U.S. and South Vietnamese planes were spraying lethal yellow powder over Cambodian villages (*8*). If the yellow rain is a natural phenomenon, there could nevertheless remain serious and possibly widespread human illness caused by trichothecenes.

PETER S. ASHTON
Arnold Arboretum, Harvard University, Jamaica Plain, Massachusetts 02130
MATTHEW MESELSON
Department of Biochemistry and Molecular Biology, Harvard University, Cambridge, Massachusetts 02138
J. P. PERRY ROBINSON
Science Policy Research Unit, University of Sussex, Brighton, BN1 9RF England
THOMAS D. SEELEY
Department of Biology, Yale University, New Haven, Connecticut 06520

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Adjectives, Nouns, and Hyphens

Reading Milton Hildebrand's recommendation against the "adjective noun use tendency" in the writing of biologists (Letters, 19 Aug., p. 698), I remembered the copybook injunction against the use of nouns as adjectives. But I also remembered a day in Santo Domingo when, waiting for my host's car to be allowed past an accident scene, I spent a moment translating a movie marquee and discovered that the Dominicans could see "The Fever of the Night of Saturday." I decided then that my copybook injunction might well be discarded formally, as it had already been functionally, and I found myself glad that English allowed me the advantage of using nouns as adjectives.

I have considered Hildebrand's examples and find that I prefer "heart chamber pressure change" to "change in the pressure of the chamber of the heart," "sea snake diet data" to "data on the diet of the snake of the sea," "hair cell orientation pattern" to "pattern of orientation of the cells of hair," and "ankle joint angle measurement" to "measurement of the angle of the joint of the ankle." I prefer even more "heart-chamber pressure change," "sea-snake diet data," "hair-cell orientation pattern," and "ankle-joint angle measurement." True, "lizard ovary winter lipid level change" is poor writing, but again, "change in the level of the lipids of the ovaries of the lizard in winter" is not lucid either. But use of a hyphen and three noun adjectives yields "winter changes in lizard-ovary lipid levels," which seems clear, efficient, and unobtrusive.

In summary, noun adjectives are not the problem, logical juncturing is; and logical juncturing can in fact be facilitated by noun adjectives, especially when they are aided by hyphens. We used to have a rule about hyphens (which I have exemplified in this letter); it is not currently in vogue among style-rule-book writers. Hildebrand's problem would dissolve if science editors would ignore the current fashion in rules and attend instead to clarity, efficiency, and unobtrusiveness in science writing.

DONALD M. BAER
Department of Human Development and Family Life, University of Kansas, Lawrence 66045

Erratum: In R. Jeffrey Smith's News and Comment article "Antisatellite weapon sets dangerous course" (14 Oct., p. 140), a remark on page 141 (column 3) by Richard Garwin about the usefulness of rockets, balloons, and aircraft to supplant U.S. photoreconnaissance and meterological satellites was inadvertently attributed to Robert Buchheim. And a characterization on page 141 (column 2) of the Soviet antisatellite weapon, or ASAT, was actually made by General Lewis Allen, the former Air Force chief of staff, not by General David Jones, the former chairman of the Joint Chiefs of Staff. Finally, a footnote on page 142 should have identified the Patriot as an air-to-air missile, not an air-to-ground missile.