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Stinking Birds and Burning Books

Want to make new discoveries in chemical ecology? Talk with a tribal hunter

by Jared Diamond

Most scientists think of the golden age of field biology, when explorers could travel to any part of the globe and count on returning with amazing discoveries and undescribed species, as a bygone era. The dwindling number of biologists who still journey to remote lands are suspected of doing it for the adventure. Other scientists would have us believe that biology's real discoveries today are being made in the laboratory, where molecular biologists are supposedly closing in on the secrets of life. Attention has also shifted to extraterrestrial space, whence some astronomers continue to await radio signals from intelligent beings on other planets.

Actually, the vast majority of this planet's species are still undescribed and unknown. In addition, remarkable new knowledge has only recently been gained about many previously described species—such as the mouse that sheds its skin, the frog that broods its young in its stomach, the naked rat that lives underground in colonies, the African monkeys that use different, gruntlike "words" to warn one another of particular species of predators, and the chimpanzees that use stone tools and wage genocidal wars.

To scientists, these are exciting discoveries. But they are not really discoveries, because much of this was already known to indigenous peoples. Technologically "primitive" peoples, who still depend heavily on hunting and gathering for their subsistence, routinely distinguish and name hundreds of species of local plants and animals and can recite the species' individual life histories. The New Guineans who guide me in the jungle, for example, often point out plants that they use as contraceptives, antimalarials, wound-healers, and abortion-inducing agents.

Much of this knowledge would be commercially valuable in the outside world. As a result, drug companies hire ethnobiologists—biologists who study the folk knowledge of natural phenomena—to collect plants and animals for testing as sources of new drugs. Tribespeople tell ethnobiologists which species to collect and what to test each species for. The scientific study of the chemicals produced by living plants and animals is called chemical ecology. A promising trend in conservation biology is for drug and chemical companies to buy "chemical prospecting licenses" in remnants of the world's beleaguered tropical rain forests.

The encyclopedic knowledge of the natural world possessed by New Guineans (*see* "This-Fellow Frog, Name Belong-him Dakwo," April 1989, and "The Ethnobiologist's Dilemma," June 1989) is on my mind now, as I have just returned from a month studying birds among the Ketengban people of Indonesian New Guinea. Showing the voluminous knowledge typical of New Guineans, my Ketengban guides described the habits of 165 local bird species. They did not, of course, use English or Latin names but names in their own language, such as toktokpáni, búlabúla, and amkeri-tololóp. Much of what my guides told me I knew to be scientifically correct; other things were new to me, but they sounded plausible. Some of them must have taken great acuity to observe.

For example, one morning my one-eyed guide, Robert Uropka, claimed that

he had just glimpsed, high above our heads in the jungle, a small bird known locally as máwe. Looking through my binoculars, I identified it as Lorentz's whistler and objected that Robert had already applied that name to another bird, which I knew as the regent whistler. Robert then gave me a short lecture (in the Indonesian language that we shared) on the distinctions. "Yes, we use the name 'máwe' for two different birds. This one lives high on the mountain, and the male and female have identical plumage. The other one lives lower on the mountain, has a different song, and the male differs in its black crown and yellow nape." I was flabbergasted, because both sexes of Lorentz's whistler are so similar to female regent whistlers that even ornithologists poring over stuffed specimens didn't recognize them as distinct species until 1939.

While Robert was demonstrably right about the whistlers, he also described to me some bird lore that sounded wildly implausible—stories of birds that stink and birds that act as living flytraps. But those stories, too, may be true; an equally wild tale, told by other New Guineans about supposedly poisonous birds, has just been confirmed by scientists. Such confirmation illustrates that major scientific discoveries, perhaps of great economic value, await teams of chemical ecologists and ethnobiologists. The stories also carry a larger message about the tragedy of shrinking human knowledge.

The recent "Case of the Poisonous Birds" has to do with three common, conspicuous, and very noisy species of jay-sized New Guinea birds called pitohuis, which have been known to scientists since 1827. Thousands of specimens are in the world's museums, and hundreds of tourists visiting New Guinea observe them in the jungle every year. I have caught hundreds of pitohuis in nets, watched and tape-recorded thousands, and published two papers on their behavior. None of us "professional" scientists suspected poison. The sole hint was a single sentence in a long book published in 1977 by the Kalam villager Ian Saem Majnep, in collaboration with New Zealand ethnobiologist Ralph Bulmer. Detailing what Kalam villagers knew about each of 137 bird species living in their valley, Majnep wrote of the hooded pitohui, "Some men say that the skin is bitter and puckers the mouth."

Pitohuis in general, and that sentence in particular, were far from the mind of American graduate student Jack Dumbacher in 1989, when he set up nets in the New Guinea jungle to trap birds of paradise. Hooded pitohuis got caught in the nets and had to be removed. In the process, the birds scratched Dumbacher's hands with their claws and bills, and he noticed that the birds had a strong, sour smell. When he licked off his wounds, his lips and mouth began to tingle and burn and then went numb for several hours. His New Guinea field assistants later told him that the hooded pitohui was "good for nothing, a rubbish bird" and was not to be eaten unless carefully skinned.

The explanation began to emerge when Dumbacher sent dead specimens of hooded pitohuis to National Institutes of Health scientists for chemical testing. Injection of pitohui skin or feather extracts into mice caused the mice to develop hind-leg prostration and paralysis, leading to convulsions and death in as little as fifteen minutes. Dumbacher's belated discovery came as a real surprise. Although many other animals, such as monarch butterflies, were known to accumulate or synthesize poisons to make themselves unappetizing to predators, this was the first well-documented example among birds. Presumably such would-be predators as snakes and possums would be driven off after one bitter, mouth-puckering lick of the pitohui's feathers, and the bird's sour smell and bold, orange-and-black coloration would help them remember the experience.

Another surprise emerged when the hooded pitohui's poison was extracted, purified, and chemically identified. It proved to be the nerve and muscle poison homobatrachotoxin—a substance otherwise known only from a different continent and different vertebrate class—in South and Central American poison-dart frogs, so called because Indians use the animals' skins to poison blowgun darts. Homobatrachotoxin is one of the most poisonous substances known, hundreds of times more powerful than strychnine. One hooded pitohui contains enough of the poison to kill more than 500 mice. How the pitohui's nerves and muscles resist its own poison is not known.

The appearance of the same toxin in frogs and birds exemplifies, astonishingly, the phenomenon of convergent evolution at the molecular level. Just as birds, bats, and pterodactyls independently evolved wings, pitohuis and poison-dart frogs have converged on each other by evolving homobatrachotoxin. The poison itself has no odor, so pitohuis seem also to have evolved some as-yet-unidentified, sour-smelling chemical to warn off predators before they can take a bite.

Dumbacher and his colleagues identified homobatrachotoxin not only in hooded pitohuis but also (albeit at lower concentrations) in two related species, the variable pitohui and the rusty pitohui. As its name implies, the variable pitohui shows far greater geographic variation in plumage than any other New Guinea bird species. Until now, no ornithologist had the faintest idea why two populations of variable pitohui, from opposite ends of New Guinea, are orange and black like hooded pitohuis; why some are uniformly

New Guinea's rusty pitohui: common, noisy—and poisonous.
Brian J. Coates; Bruce Coleman, Inc.


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rusty, like rusty pitohuis; and why some have color patterns that differ from those of the first two.

Now we have a clue: "Müllerian mimicry," the phenomenon, well known in tropical butterflies, whereby several poisonous species share the same bold pattern. As a result of this mutual mimicry, each species benefits by the other's poison, because a predator that tastes and spits out one species thereby learns to avoid the other species as well. In the two parts of New Guinea where I collected pitohuis, however, not only did I smell and taste nothing after handling the birds myself, but the local New Guinea tribesmen working with me also stuffed and ate them with no ill effect and volunteered no stories about their being "rubbish birds." Perhaps the presence of poison varies geographically in New Guinea pitohuis, and the variable pitohuis resemble the hooded pitohui, rusty pitohui, or neither, depending on which species is locally poisonous.

But the pitohui story has still bigger implications. All three pitohui species are leaders of wandering flocks, composed of several dozen different species belonging to at least seven different families. All members of the flocks are various shades and combinations of rust and black. And several flock members also mimic other member species' calls. Why?

When I published an article on the flocks six years ago, I advanced the usual two explanations that ornithologists have invoked to explain convergence in other flocks of unrelated species: the mimicry may make it hard for a would-be predator to concentrate on following any single potential victim and easy for each flock member to stay with the group. Now, as a result of the discoveries by Dumbacher and his colleagues, I have to wonder whether the flock members are also simultaneously signaling or pretending to be poisonous.

And yet another big question arises. In the rusty-and-black flocks are individuals (mostly females) of at least fifteen species of New Guinea's most famous birds, the birds of paradise. Male birds of paradise have attracted much scientific attention because they evolved through sexual selection to have the world's most bizarre plumage. Females have drawn much less interest, their rusty-and-black plumage being much more conservative. But note a comment of feather collector A. E. Pratt, reduced by starvation nearly a century ago to eating a bird of paradise. He wrote of his dinner: "The most shocking flesh I have ever eaten...as bitter as gall...it was truly abominable, and after the first spoonful we got no further." While ornithologists have been concentrating on the gaudy bird of paradise males and ignoring the females, could they have been missing another story of poison and Müllerian mimicry on a grand scale?

Thus, behind one sentence in the ethnobiological literature lurked a cascade of major discoveries and questions: the first proven examples of poisonous birds; a case of convergent evolution at the molecular level; a case of Müllerian mimicry; a possible explanation for geographic variation in plumage; a force behind mixed-species flocking; and a major selective force on birds of paradise. In retrospect, one might ask why none of the biologists who had read Majnep's and Bulmer's book beat Dumbacher to his discovery of poisonous birds. Undoubtedly, the main reason is that Majnep's clue was no more than a single, qualified sentence in a long book. Dumbacher discovered the bitter skin for himself and came across Majnep's sentence afterward. But there is also another reason: chemists aren't yet accustomed to asking New Guinea villagers for suggestions about promising research projects. Here's one hint to chemists who may now be starting to regret their past oversight: also buried in Majnep's book is a paragraph about the bitter, mouth-puckering taste of the blue-capped ifrita, a New Guinea bird quite unlike pitohuis.

In the case of the pitohuis, we now know that local folk knowledge was scientifically valid. Next, let's consider the "Case of the Stinking Birds."

The case began one morning in July 1967, when a group of New Guineans and I were sitting in a tent in the jungle, skinning some bird specimens that we had just caught. A Foré tribesman named Esa was working on a mound builder, a large bird famous for incubating its eggs with the heat of scraped-together mounds of rotting vegetation. Esa complained of feeling sick from the carcass's stink; then he abruptly vomited. This surprised me because the bird had been shot only that morning, it had had little time to rot, and the temperature was cool. None of my field assistants had vomited over a carcass before, and, in fact, they had struck me as notably unfastidious in their willingness to eat birds that had been killed the day before.

Another New Guinean present, who was more familiar with mound builders than Esa or I, explained that they were distinctive in stinking much sooner after death than other bird species. When I later traveled to the Solomon Islands, where mound builders are abundant, I was given the same information. My Solomon Island friend Alisasa Bisili told me the following traditional story of how his people hunt mound builders (called e-yo in Alisasa's Roviana language):

> If you want to eat an e-yo, here's what you have to do to cook it before it can start stinking. During the day, go into the jungle and look for a low branch with a white stain on it. That stain is the e-yo's droppings. The stain tells you that that's the branch on which an e-yo roosts at night. Then go back there after sunset with a pot of water and a bow and arrow. When you spot the e-yo sleeping on the branch, light a small fire on the ground directly under it, and set the pot on the fire. When the water reaches boiling, shoot the e-yo with your bow and arrow, so that it falls straight into the pot of boiling water. That's the only way that we can kill an e-yo and cook it soon enough that it won't start to stink!

Mound builders aren't the only stinking New Guinea bird, as I learned in 1966 when I took the Tudáwe tribesman Omwai to Utai village in the Sepik Basin. An Utai villager named Uténo had earned Omwai's dislike by threatening to poison him and by nevertheless coming to our hut every morning to cadge bird carcasses and tobacco. On this particular occasion, I saw Omwai give Uténo the skinned carcass of a giant cuckoo known as Menbek's coucal, and named píni in Omwai's Tudáwhe language. I asked Omwai with surprise why he had given so much meat to a man whom he despised. Omwai explained—and I confirmed with my own nose the next time we shot a píni—that the píni is the only other bird that starts to stink as quickly as does a mound builder. The gift of the píni was Omwai's revenge against Uténo.

We all know that dead animals smell bad, but we rarely pause to reflect on the smell's possible function. Think of any dead body as a potential battleground between hyenas, beetles, other animal scavengers, and many species of microbes, all seeking to digest the carcass for themselves. If a hyena swallows the carcass, it thereby becomes unavailable to bacteria. Biologically synthesized poisons, bad-tasting substances, and evil-smelling gases are weapons of chemical warfare by which a microbe attempts to drive other microbe species and scavenging animals off the battlefield. The best-known such weapon is penicillin, a potent chemical secreted by a mold to kill bacteria (and now

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one of the most valuable natural products ever appropriated by humans).

For a microbe, a stinky chemical represents a flag of possession. For a hyena, it's a deterrent. But what about the dead bird itself? If the bird had wanted to deter potential predators by a stink, shouldn't it have had to stink while it was still alive? Perhaps the post-mortem stink should be viewed as just a chemical weapon evolved by a microbe without any cooperation from the dead bird.

Nevertheless, I'm suspicious because the only two New Guinea bird species that I've known to stink so quickly are both big, clumsy, noisy, slow-moving species that represent lots of meat for a potential predator, and that seem otherwise ill-equipped to deter predators. If you fill yourself with a stinking poisonous chemical while you're still alive, you have to develop resistance to the chemical yourself. You might find it much better to harbor potentially stinky microbes and keep them suppressed while you're alive, but ready to stink as soon as you die. Or you could design your tissue chemistry to attract a stinky microbe after you die. If a predator then makes the mistake of killing and eating you, it will get sick and learn to avoid killing your relatives in the future. In the language of population genetics, that's called "increasing your inclusive fitness," or passing on your genes by aiding the survival of relatives sharing your genes, even though you yourself don't survive. That's why animal parents risk their lives to defend their young, and why worker ants in an ant colony forgo reproduction.

A female crested bird of paradise: does her plain plumage encode an untold evolutionary story?

Frithfoto; Bruce Coleman, Inc.

Naturally, all that I can offer at present to explain stinking birds is this speculation without evidence. It might prove to be nothing more than one of those "just-so stories" that biologists are often accused of dreaming up to provide a functional explanation where there really is none. But I have a clearly formulated, testable hypothesis. I propose that an ambitious chemical ecologist with a weak nose and strong stomach (1) measure the rates at which e-yos and pínis stink after death, compared with other birds, (2) identify the stinking chemical, (3) identify the microbe or enzyme synthesizing the stinking chemical, (4) test the stinking chemical or other chemicals in a dead e-yo or píni carcass on various microbe and scavenger species, and (5) do feeding trials to see if experienced New Guinea predators avoid e-yos and pínis when given a choice of non-stinking, similar-sized birds. Might stinking birds prove to harbor another drug like penicillin?

The "Case of the Living Flytrap" is my other speculative example, designed to tantalize chemical ecology graduate students still searching for a thesis project. This case began one afternoon in August 1965, when the Foré tribesman Paran brought in a Papuan frogmouth (yása in the Foré language) that he had shot. As its name implies, this raven-sized bird has a very wide mouth reminiscent of a frog's. Supposedly, the bird is strictly nocturnal, catches large prey like mice, lizards, and large beetles, and sleeps during the day. Paran insisted that this yása, which he had just shot that afternoon, had been sitting motionless on a branch of a tree, with its mouth wide open. He explained that he had often seen yásas in that posture during daylight hours, and that insects flew into the bird's cavernous maw, attracted by a smelly, sticky paste on its palate.

My first thought was, nonsense! If so, frogmouths would have achieved every species' evolutionary dream—getting food without work or cost. Then I reflected that there was indeed a cost, that of synthesizing the sticky chemical bait. On the other hand, a raven-sized bird would have to attract a lot of flying insects before its strategy of setting itself up as a living flytrap could rate as successful. Then again, Paran was a cautious observer who had been right about everything else that he reported to me. My confidence in Paran increased when I read a note by an Aus-

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tralian birdwatcher who had a pet frogmouth, and who saw it sit during the day with its mouth open, snapping its mouth shut when an insect flew in. Since no further information came to my attention, all I could do was to mention the behavior briefly in a book on New Guinea highland birds that I published in 1972.

There the matter rested until last month, when my Ketengban guide, Robert Uropka, was lecturing me on the habits of birds. He eventually described a big, nocturnal bird with a large mouth, convincingly imitated the call of the Papuan frogmouth, and called it sumé in the Ketengban language. "And by the way," he said, "the sumé sits during the day with its mouth wide open and"—I held my breath—"Binatang masuk sendiri!" he concluded in Indonesian ("insects fly in of their own accord!").

Does the Papuan frogmouth really secrete a chemical insect attractant and fly-catching paste on its palate? If so, I'd invest my pension in the stock of the chemical company that isolates and manufactures the attractant and paste. Or did Paran and Robert and the Australian birdwatcher all misinterpret the frogmouth's behavior? And did Paran misinterpret the paste on its palate? I've done what I can as an ethnobiologist; it's now up to a chemical ecologist to confirm or explode the "Case of the Living Flytrap."

We think of human knowledge today as undergoing explosive growth. In many respects, that's true. Laboratory biologists, for instance, are learning more about a few species that are superabundant—lab rats, lab mice, fruit flies, the bacterium *Escherichia coli,* and *Homo sapiens.*

In other respects, though, our knowledge is shrinking. Over the course of millions of years, humans throughout the world have built up a knowledge of their local natural environment so extensive that not even professional biologists can hope to capture more than a small fraction of it, and other members of urban and industrialized societies can scarcely imagine it. At the end of the twenty-four days that I spent with the Ketengban people, I felt like a Philistine because I had so often nudged the subject back to birds when they began to talk of anything else. Even for very rare bird species, such as New Guinea's leaden honey-eater and garnet robin, they rattled off the altitudes at which the birds lived, the other species with which they associated, the height above the ground at which they foraged, their diet, adult call, juvenile call, seasonal movements, and so on. Only by cutting short the Ketengbans' attempts to share with me their equally detailed knowledge of local plant, rat, and frog species could I record even fragments of their knowledge of birds in twenty-four days.

Traditionally, the Ketengbans acquired this knowledge by spending much of their time in the forest, from childhood on. When I asked Robert Uropka how, lacking binoculars and the sight of one eye, he had come to know so much about a tiny, dull-plumed warbler species that lives in the treetops, he told me that as children he and his playmates used to climb trees, build blinds in the canopy, and observe and hunt up there. But all that is changing, he explained, as he pointed to his eight-year-old son. Children go to school now, and only at vacation times can they live in the forest. The results, as I have seen elsewhere in New Guinea, are adult New Guineans who know scarcely more about birds than do most American inner-city dwellers. Within a decade or two, drug companies carrying out chemical prospecting will have to go in blind, lacking guidance as to which of tens of thousands of species to collect or what to test each species for.

Compounding this problem, education throughout Indonesian New Guinea is in the national language, not in Ketengban and the 300 other indigenous languages. Radio, TV, newspapers, commerce, and government also use the Indonesian language. While the reasoning behind such decisions is, of course, understandable, the outcome is that all but about 200 of the modern world's 6,000 languages are likely to be extinct or moribund by the end of the next century. As humanity's linguistic heritage disintegrates, much of our traditional, mostly unrecorded knowledge base vanishes with it.

The analogy that occurs to me is the final destruction, in A.D. 391, of the largest library of the ancient world, at Alexandria. That library housed all the literature of Greece, plus much literature of other cultures. As a result of that library's burning, later generations lost all but the *Iliad* and *Odyssey* among Greek epics, most of the poetry of Pindar and Sappho, and dozens of plays by Aeschylus and Euripides—to mention just a few examples.

The ongoing loss today that draws most public attention is the loss of biodiversity. In that loss, nature is viewed as the victim, humans as the villains. But there is also a parallel loss in which humans are both victims and unwitting villains. Not only are species going extinct, but so is much of our information about those species that survive. In the future, no children will grow up in the forest, where they could receive or rediscover that knowledge. Certainly, professional biologists don't have the necessary time—I count myself lucky if I can spend one month every year or two in New Guinea. It is as if we are burning most of our books, while the languages of those books that remain become as lost to us as the undeciphered Linear A of ancient Crete.

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