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ENTOMOTHERAPY, OR THE MEDICINAL USE OF INSECTS

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ABSTRACT.—Insects and the substances extracted from them have been used as medicinal resources by human cultures all over the world. Besides medicine, these organisms have also played mystical and magical roles in the treatment of several illnesses in a range of cultures. Science has already proven the existence of immunological, analgesic, antibacterial, diuretic, anesthetic, and antirheumatic properties in the bodies of insects. Several authors have surveyed the therapeutic potential of insects, either recording traditional medical practices or employing insects and their products at the laboratory and/or clinical level. Thus, insects seem to constitute an almost inexhaustible source for pharmacological research. Chemical studies are needed to discover which biologically active compounds are actually present within insect bodies. The therapeutic potential of insects represents a significant contribution to the debate on biodiversity conservation, as well as opening perspectives for the economic and cultural valorization of animals traditionally regarded as useless. Their use needs to be at a sustainable level to avoid overexploitation.

Key words: ethnoentomology, entomotherapy, folk medicine, insect conservation.

RESUMO.—Os insetos e as substâncias deles extraídos são usados como recursos medicinais em diferentes culturas humanas ao redor do mundo. Esses organismos também desempenham funções místicas e mágicas no tratamento de várias doenças em uma gama de culturas. A ciência já comprovou a existência de propriedades imunológicas, analgésicas, antibacterianas, diuréticas, anestésicas e antireumáticas nos corpos dos insetos. Diferentes autores vêm registrando o potencial terapêutico dos insetos tanto nas práticas médicas tradicionais quanto no emprego de seus produtos no nível clínico e/ou laboratorial. Os insetos, portanto, parecem constituir uma fonte quase inesgotável para a pesquisa farmacológica. Estudos químicos são necessários a fim de descobrir quais os compostos biologicamente ativos que estão presentes nos insetos. O potencial terapêutico dos insetos representa uma contribuição importante para o debate sobre conservação da biodiversidade, assim como abre perspectivas para a valorização econômica e cultural de animais tradicionalmente considerados como inúteis. Necessita-se buscar o uso sustentável desses recursos para evitar a super exploração.

RÉSUMÉ.—Les insectes ainsi que les substances qui en sont extraits ont été utilisé comme ressources thérapeutiques par différentes cultures partout dans le monde. En plus de la médecine, ces organismes ont aussi eu des fonctions mystiques et magiques dans le traitement de plusieurs maladies parmi de nombreuses cultures. La science a déjà démontré qu'il existait des propriétés immunologiques, analgésiques, antibactériennes, diurétiques, anesthésiques, et antirhumatismales issus du corps des insectes. Plusieurs auteurs ont examiné soit le potentiel thérapeu-

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tique des insectes soit les pratiques médicinales traditionnelles ou ont employé les insectes et leurs produits dans les laboratoires ou les cliniques. Ainsi, les insectes semblent constituer une source presque inépuisable pour la recherche pharmacologique. Les études chimiques sont nécessaires afin de découvrir des composantes biologiquement actives dans les corps des insectes. Le potentiel thérapeutique des insectes constitue une contribution significative quant au débat sur la conservation de la biodiversité. Ce potentiel met également en perspective la valeur économique et culturelle d'animaux considérés traditionnellement comme inutile. L'utilisation durable de cette ressource doit être prise en consideration afin d'éviter leur surexploitation.

INTRODUCTION

Since early times, insects and the substances extracted from them have been used as therapeutic resources in the medical systems of many cultures. Commonly considered to be disgusting and filthy animals, many insect species have been used live, cooked, ground, in infusions, in plasters, in salves, and as ointments, both in curative and preventive medicines, as well as in magico-religious rituals (Costa-Neto 2002). The therapeutic use of insects and insect-derived products is known as entomotherapy. Because medical systems are organized as cultural systems, the use of insect-based medicines should be viewed from a cultural perspective (Costa-Neto 1999).

The belief that insects exist for the benefit of human beings can be found in the book *Insectotheology,* published in 1699 (Berenbaum 1995). However, some references on the use of medicinal insects are even older. The Ebers papyrus, an Egyptian medical treatise dated to the sixteenth century B.C., contains several accounts of medicines obtained from insects and spiders (Weiss 1947). Silkworms (*Bombyx mori* L., 1758) have been used in Chinese traditional medicine for at least three thousand years (Zimian et al. 1997) and the larvae of certain flies have been recognized for centuries as beneficial agents for the healing of infected wounds (Sherman et al. 2000).

Several classical and traditional authors dealt with the medicinal uses of insects. In his *Naturalis historiae,* Pliny the Elder recorded some entomotherapeuticals (insect-derived medicines) that were employed for the treatment of several illnesses in the Roman Empire in the first century A.D. (Carrera 1993). In the second book of his *Materia medica,* Dioscorides mentioned some insect remedies (Morge 1973). For example, bedbugs were used against quartan fever; cockroaches when ground with oil or cooked were used against earache; fried cicadas were used against bladder complaints; locusts or grasshoppers were used for fumigation against anuresis of women, and dried and taken with wine they were used against scorpion stings; dyer's coccid of oaks was considered to be astringent for wounds. In another book, *On Poisonous Animals,* Dioscorides dealt with the treatment of people stung by wasps and bees (Morge 1973). Namba et al. (1988) have discussed 54 kinds of crude drugs derived from insects listed in the ''herbal'' *Jingshi Zhenglei Daguang Bencao* (A.D. 1108), edited during the Chinese Song dynasty (A.D. 960–1280). The list was extended to 73 species in Li Shizhen's *Bencao Kangmu* (*Compedium materia medica*) published in 1578, and 11 additional species were added

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in the *Supplement to Compendium Materia Medica* by Chao Xueming in 1756 (Chen 1994). Today, the 143 medicinal insects used in China are divided into 13 orders and 48 families (Zimian et al. 1997). Even this variety, however, is an underestimate.

During the seventeenth century, people in Europe believed that many kinds of insects had some healing power (Wigglesworth 1976). Examples include the belief that the oil obtained from the larvae of the May beetle, *Melolontha vulgaris* (L.) 1758, can be used topically on scratches and other wounds and as a cure for rheumatism and that the adult beetles soaked in wine are helpful in treating anemia; that pulverized cockroaches are a treatment for epilepsy; and that earwigs can be used against earaches (Ratcliffe 1990). More recently, Marie (1955) gave an outstanding contribution to the history of entomotherapy by describing the use of 33 kinds of medicinal insects.

The medicinal interaction between human beings and insects has recently aroused the interest of many researchers, who have recorded this unusual practice (at least for some individuals) and searched for compounds with pharmacological activity.[1] Robert L. Metcalf of the University of California wrote that insects have ''become the 'new frontier' for natural products chemistry'' (Evans 1993). Since insect blood, or hemolymph, contains a number of effective antitoxins, one is inclined to believe that the reported remedies rely on more than sheer guesswork (Harpaz 1973). It was found that in the passage from the cuticle to the haemocele (cavity of the insect's body) microorganisms confront several antimicrobial components such as proteins, lipids, hydrocarbons, diphenols, carbohydrates, chitin and melanin. These antimicrobials inhibit both the growth and the penetration of those agents into the haemocele. Insects, then, can supply important information for the fight against ills caused by microorganisms, such as malaria, dengue fever, tripanosomiasis, and leishmaniosis (Silva 2002).

Although entomotherapy is an ancient practice, it is still relatively unknown in the academic world. In fact, as Holt already stressed in 1885, the advance of medical science and the suppression of folk knowledge swept away belief in the medicinal qualities of insects (Holt 1992 [orig. 1885]). This paper contributes to our understanding of medicinal insects by discussing briefly the use of these natural resources in folk and magical medicines and their pharmacological importance, as well as the conservation and sustainable use of medicinal insect species. This review is far from complete; many more authors and examples could be added. I hope this review opens minds and hearts to the study of medicinal insects.

Folk Traditional Uses of Insects and Related Arthropods Around the World.—The traditional medical knowledge of local cultures throughout the world has played an important role in identifying biological resources worthy of commercial exploitation. In fact, the search for new pharmaceuticals from naturally occurring biological material has been guided by ethnobiological data (Blakeney 1999). Both the knowledge and practices concerning entomotherapy have been transmitted across generations, largely by oral tradition. They are well integrated with other aspects of the culture in which they occur (Costa-Neto 1999). In the words of Kanvee Viwatpanich of the National Institute of Thai Traditional Medicine: ''By

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spending time with traditional doctors and villagers we will have the chance to learn about the medicinal use of insects in real life situations.''[2] Table 1 provides the list of insect species mentioned as folk remedies and as magical resources.

Brazil. In Brazil, the practice of using insects as medicine has been reported since colonial times and was recorded in 13 states by a range of authors (Costa-Neto 2002). At least 50 insects have been reported as being used in folk medicines in the state of Bahia, northeastern Brazil (Costa-Neto 2003). These resources are distributed in nine orders, with Hymenopterans the most prevalent with 22 specimens. For example, the Pankararé Indians and rural people in general melt the nests of mud wasps (Sphecidae) in water and apply the mixture on mumps. They used to eat the honey of *Partamona* sp. and *Melipona scutellaris* Latr., 1811 to treat sore throats and the bites of snakes and rabid dogs, respectively. They boil a mixture of the wax of *Plebeia* sp. and human urine until the wax melts. After it cools, it is given to someone suffering from diabetes. Individuals who have had a stroke inhale the smoke of burnt wax (Costa-Neto 1998). Herbalists from the city of Feira de Santana recommend the use of tea made from the toasted exoskeleton of a grasshopper (*Tropidacris* sp.) to cure skin diseases and for people who have had a stroke. In addition, the powder of a whole toasted or sun-dried grasshopper is turned into a tea for the treatment of asthma and hepatitis (Costa-Neto 2002). The tenebrionid beetle *Palembus dermestoides* (Farmaire, 1893), which was introduced in Brazil by Asian immigrants, is usually taken to treat asthma, arthritis, tuberculosis, and sexual impotence (Costa-Neto 1999). This last prescription once was widely known, and the beetle was named ''love bug.''

Afro-Brazilian dwellers from the county of Remanso, in Chapada Diamantina National Park, used to eat wild honey of *Trigona spinipes* (Fabr., 1793), *Melipona scutellaris* and *Apis mellifera scutellata* Lep., 1836 to treat coughs (Costa-Neto 1996). In the county of Matinha dos Pretos, Bahia State, the powdered toasted legs of a spider wasp (Pompilidae) are turned into a tea for the treatment of asthma. A male bloodsucker bug (*Triatoma* sp.) made into a tea is prescribed for the treatment of all kinds of heart diseases. Some of the interviewees have said the mass of a crushed stinkbug of the family Pentatomidae is put near their noses to unblock them (Costa-Neto and Melo 1998).

Folk uses other than medicinal and magical were also recorded. For cosmetics, residents of the city of Tanquinho have mentioned that rubbing the head with a mass of crushed houseflies (*Musca domestica* L., 1758) treats baldness,[3] and acne is treated by washing the face with the infusion made from the *arapuá*'s scutellum[4] (Costa-Neto and Oliveira 2000).

Some folk prescriptions using entomotherapeuticals in the state of Alagoas, in the northeastern region of the country, include the following examples: puncture the abdomen of the palm beetle called *besouro-do-ouricuri* (*Pachymerus nucleorum* [Fabr., 1792]), extract the white mass, put it in a piece of cotton, and then introduce it inside the ear; it is useful for curing earaches. Mix the honey of *oropa* (*Apis mellifera scutellata*) with rum and drink the mixture to cure mumps. Cook the female leaf-cutting ant *tanajura* (*Atta* spp.) and then make a tea of it, which is useful for treating dizziness. Get the great ant *formigão* (*Dinoponera* sp.) and let it sting the gland for strengthening a flaccid penis (Marques and Costa-Neto 1994).

Mexico. Ramos-Elorduy (2001) recorded 210 insect species used in Mexican

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TABLE 1.—Insect types mentioned as folk medicines and magical resources in different human cultures.*

Taxon	English or local name	Malady treated	Reference
BLATTODEA			
*	Cockroach	Earache	Morge 1973
		Whooping cough, boils, dropsy, wart, Bright's disease, ulcers	Illingworth 1915
		Stimulate lactation	Lenko and Papavero 1996
		Epilepsy	Ratcliffe 1990
		Whooping cough	Weiss 1946
		Boils	Mbata 1991
Periplaneta americana (L., 1758)		Difficulty urinating, renal colic, asthma	Curto and Piermarocchi 1990
Eupolyphaga sinensis Walker and *Polyphaga plancyi* Bol.	Cockroach	Regulating menstruation	Lenko and Papavero 1996
ISOPTERA			
Termes bellicosus (Smeathman)	Termite	Suture wounds	Marie 1955
Macrotermes spp.	Termite	Child malnutrition	Mbata 1991
Cubitermes spp.	Termite	Heart pains	Mbata 1991
PHASMIDA			
*	Walking stick	Asthma, muscle pain, upset stomach	Boyle 1992
DERMATERA			
*	Earwig	Earache	Ratcliffe 1990
LEPIDOPTERA			
Bombyx mori L., 1758	Silkworm	Stroke	Pemberton 1999
Helicoverpa armigera (Hübner, 1805)	Pod borer	Panacea	Oudhia 2002 (see note 6)
Hepialus oblifurcus Chu and Wang	Ghost moth	Fortifier	Steinkraus and Whitfield 1994
Aegiale hesperiaris (Walker, 1856)	Giant skipper	Rheumatism, aphrodisiac	Maya 2000
COLEOPTERA			
Pachymerus nucleorum (Fabr., 1792)	Palm beetle	Earache	Marques and Costa-Neto 1994
Scarabaeus sacer L., 1758	Scarab	Good luck charm	Cherry 1985
Strategus aloeus (L., 1758)	Scarab	Aphrodisiac	Maya 2000
Megasona acaeon (L., 1758)	Scarab	Aphrodisiac	Posey 1986
Lytta vesicatoria (L., 1758)	Blister beetle	Urinary disorders, aphrodisiac	Berenbaum 1995

TABLE 1.—Continued.

Taxon	English or local name	Malady treated	Reference
Brachycerus ornatus (Drury, 1773)	Weevil	Stomach pains	Green 1998
Melolontha vulgaris (L.) 1758	May beetle	Scratches, anemia, rheumatism	Ratcliffe 1990
Mylabris spp.	Blister beetle	Skin diseases	Berenbaum 1995
Scarites spp.	Ground beetle	Suture wounds	Gudger 1925
Palembus dermestoides (Farmaire, 1893)	Peanut beetle	Asthma, arthritis, tuberculosis, sexual impotence	Costa-Neto 1999
HEMIPTERA			
*	Bedbug	Quartan fever	Morge 1973
*	Bug	Goiter, tuberculosis, cough, skin diseases, whooping cough, and liver, stomach and kidney problems	Ramos-Elorduy et al. 2001
*	Stinkbug	Goiter	Metzner 2002 (see note 5)
*	Bloodsucker bug	Heart problems	Costa-Neto and Melo 1998
Pentatomidae	Stinkbug	Anticongestive	Costa-Neto and Melo 1998
DIPTERA			
Musca domestica L., 1758	Housefly	Eye cysts	Metzner 2002 (see note 5)
		Baldness	Costa-Neto and Oliveira 2000
		Scorpion bite	Oudhia 2002
HOMOPTERA			
*	Cicada	Bladder complaints	Morge 1973
Huechys sanguinea De Geer, 1773	Cicada	Migraine headache, ear infection	Kritsky 1987
ORTHOPTERA			
*	Locust	Anuresis of women, scorpion sting	Morge 1973
*	Grasshopper	Anemia	Metzner 2002 (see note 5)
*	***Mpay laar***	Violent headaches	Antonio 1994
Gryllotalpa africana Beauvois	Mole cricket	Foot inflammation, fertility	Fasoranti 1997
Lamarckiana spp.	***Bapu***	Bedwetting, nightmares	van der Waal 1999
Acrida bicolor (Thunberg, 1815)	Grasshopper	Hypertension	Mbata 1991
Gryllus assimilis (Fabr., 1775)	Cricket	Urine retention	Maya 2000
Gryllus sp.	***Ma'as***	***Kalwiix*** (difficulty in urination)	Ruiz and Castro 2000
Tropidacris sp.	Grasshopper	Skin diseases, stroke, asthma, hepatitis	Costa-Neto 2002
Brachytrupes sp.	Cricket	Mental development, pre- and post-natal care	Banjo et al. 2003

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TABLE 1.—Continued.

Taxon	English or local name	Malady treated	Reference
HYMENOPTERA			
Sphecidae	Mud wasp	Mumps	Costa-Neto 1998
Pompilidae	Spider wasp	Asthma	Costa-Neto and Melo 1998
Vespidae	Wasp	Wasp sting	Mekloy 2002 (see note 2)
Synagris sp. and *Sceliphron (Pelopoeus)* sp.	Mud wasps	Provide lime to the fetus	Adriaeus 1951
Trigona spinipes (Fabr., 1793)	Stingless bee	Cough	Costa-Neto 1996
		Acne	Costa-Neto and Oliveria 2000
Plebeia sp.	Stingless bee	Diabetes, stroke	Costa-Neto 1998
Melipona scutellaris Latr., 1811	Stingless bee	Cough	Costa-Neto 1996
		Snakebite, rabid dog's bite	Costa-Neto 1998
Apis mellifera scutellata Lep., 1836	Honeybee	Cough	Costa-Neto 1996
		Mumps	Marques and Costa-Neto 1994
		Joint problems	Berenbaum 1995
Partamona sp.	Stingless bee	Sore throat	Costa-Neto 1998
Atta spp.	Leaf-cutting ant	Suture wounds	Gudger 1925
		Dizziness	Marques and Costa-Neto 1994
Formicidae	Ant	Bad cold, paralysis	Hitchcock 1962
Dinoponera sp.	Giant hunting ant	Male impotence	Marques and Costa-Neto 1994
Paraponera clavata (Fabr., 1775)	Giant hunting ant	Ordeals	Anonymous 1982
Pachycondyla commutate (Roger, 1860)	Cobra ant	Ordeals	Balée 2000
Polyrhachis vicina Roger	Weaver ant	Arthritis, hepatitis, pain, aphrodisiac	Chen 1994
Pogonomyrmex californicus (Buckley, 1867)	Harvester ant	Panacea	Groark 2001
Pogonomyrmex sp.	Harvester ant	Rheumatism	Maya 2000
Dasymutilla ocidentalis (L., 1758)	Velvet ant	Chickenpox	Maya 2000
ACARI			
Boophilus microplus (Canestrini)	Cattle tick	Chickenpox	Morge 1973
Trombidium grandissimum Koch	Red velvet mite	Malaria, urogenital disorders, paralysis, aphrodisiac	Oudhia 2002 (see note 6)
CHILOPODA			
Scolopendra spp.	Centipede	Arthritis	Pemberton 1999
SCORPIONES			
Buthus martensii Karsch	Scorpion	Pain	Pemberton 1999

* Taxon not specified.

traditional medicine. The orders most used are Coleoptera, Hymenoptera, Orthoptera, and Homoptera. Of 411 medicinal insect species recorded worldwide, 92.6% are utilized to relieve internal diseases, used in 353 disorders as follows: for skin (57), digestive (58), respiratory (34), kidney (22), reproductive (31), circulatory (31), nervous (28), eyes (21), neuromuscular (13), bones (19), immunological (6), hearing (4), endocrinological (4), and other diseases (43) (Ramos-Elorduy and Motte-Florac 2000). The Hñähñu people, who live in the state of Hidalgo, use several insect species in their medicinal practices (Maya 2000). For example, the sting of the ant *Pogonomyrmex* sp. heals rheumatism; *Aegiale hesperiaris* (Walker, 1856) is claimed to have digestive, antirheumatic, and aphrodisiac properties; the elephant beetle *Strategus aloeus* (L., 1758) is held to have aphrodisiac power, especially the projections of its pronotum. The velvet ant *Dasymutilla occidentalis* (L., 1758) is put inside a cloth and tied around a child's neck to heal chickenpox. The cricket *Gryllus assimilis* (Fabr., 1775) is used in the treatment of ailments of the urinary system. The Mayan people from X-Hazil Sur also use the black cricket ***ma'as*** to cure a locally diagnosed sickness called ***kalwiix***, which is characterized by urine retention (Ruiz and Castro 2000). It is widely known that in some kinds of insects, such as dragonflies, grasshoppers, and true bugs, the main electrolytes in their hemolymph are sodium and chloride ions. These ions, especially sodium, play an important role in regulating water balance in the bodies of human beings. The ancients found certain insects to be a concentrated source of salts and thus prescribed them for bladder and urinary complaints (Berenbaum 1995).

Eighteen species of true insects are currently used by different Mexican indigenous groups to treat several illnesses such as goiter, tuberculosis, whooping cough, cough, cutaneous eruptions, and liver, stomach, and kidney problems. These bugs are also considered to be an aphrodisiac and a fortifier (Ramos-Elorduy et al. 2001). These authors have isolated biodynamic compounds with different therapeutic activities both in the sacred bug *Edessa cordifera* Walker and in species of the genus *Euschistus.* The Mexican medical doctor Crisenzia Rodriguez Nieves treats goiters with stinkbugs because they are rich in iodine and goiter is caused by iodine deficiency. She also treats anemia with grasshoppers, rheumatism with beeswax, and eye cysts with flies.[5]

Africa. Insects comprise a significant component of traditional medical preparations used to heal several illnesses in Africa. In southwestern Nigeria, for example, an infected foot is treated by smearing and rubbing the gut contents of mole crickets (*Gryllotalpa africana* Beauvois) on it (Fasoranti 1997). According to van Huis (1996), honey is used to treat coughs and stomach problems all over Africa. He reports that traditional healers very often prescribe honey as a medium for all kinds of plant-derived medicines. In Somalia, the mandibles of termite soldiers of the species *Termes bellicosus* (Smeathman) are also used to suture wounds (Marie 1955). In the state of Kwango, Zaire, clay nests made by mud-daubing wasps of the genera *Synagris* and *Sceliphron* (= *Pelopoeus*) are ground and the clay is eaten by pregnant women. Apparently, this practice provides lime to the fetus (Adriaeus 1951). Van Huis (1996) also records the practice of pregnant women ingesting the clay of termite mounds or termite runways on trees and poles. Antonio (1994) records the folk uses of 18 kinds of insects in Zaire. For example, grasshoppers locally known as ***mpay laar*** are used to treat violent head-

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aches: the healer crushes the dry grasshoppers and ashes, mixes the ashes of the grasshopper with a little organic salt, and makes incisions on the nape and front of the patient. He then applies the solution to the incisions. This treatment stings and the patient must sleep a lot. Duration of treatment is at least three days. Mbata (1991) states that arthropod medicines in Zambia derive from five classes: Insecta, Arachnida, Crustacea, Diplopoda, and Chilopoda. He recorded 10 orders of insects serving as sources of traditional medicines. Six species of cockroaches are used to treat boils and other wounds. The grasshopper *Acrida bicolor* (Thunberg, 1815) is indicated for the treatment of hypertension. The termite *Cubitermes* spp. is used to cure heart pains and *Macrotermes* spp. are used to treat child malnutrition. The Venda people of the province of Transvaal, in South Africa, used to treat bedwetting in young children by giving them fried ***bapu*** grasshoppers (*Lamarckiana* spp.) to eat. Nightmares are also treated by drinking ground dried ***bapu*** in warm water (van der Waal 1999).

China. The use of insects and other arthropods as medicinal resources in China is quite varied (Kritsky 1987). The Chinese in Malaysia raise walking sticks (order Phasmida) for their excreta, which, when dried and mixed with herbs, make a treatment for asthma, upset stomach, and muscle pain (Boyle 1992). Children are given baked cattle ticks (*Boophilus microplus* [Canestrini]) as a remedy or prophylactic for chickenpox (Morge 1973). The caterpillars of *Hepialus oblifurcus* Chu and Wang (Hepialidae) infected with the fungus *Cordyceps sinensis* (Berk.) Sacc. Link (Ascomycetes) fortify and rejuvenate a system damaged by superexcitation or a long illness (Steinkraus and Whitfield 1994). These authors state that various biologically active compounds have been isolated from *Cordyceps* spp., such as cordycepin and ophiocordin. According to Zimian et al. (1997), fifteen kinds of medicinal insects are currently used on a regular basis by the Chinese people, with pharmacological studies being concentrated on the following species: *Malaphis chinensis* (Bell), *Bombyx mori, Hepialus armoricanus* (Oberthür, 1910), *Mylabris cichori* L., and *Buthus martensii* Karsch (this is a scorpion). Nowadays, many Chinese researchers are studying medicinal insects and considerable progress has been made both in the inventory and classification of biological resources and isolation of therapeutic compounds (Zimian et al. 1997).

India. Several authors have described the local uses of insect-based remedies in India (Azmi and Ali 1998; Oudhia 2002, see note 6 below; Singh et al. 1998). Sharma (1990) has surveyed nine tribal communities in Rajasthan. The results provide data on ten species of invertebrates (including insects and crustaceans), with information on what parts, extracts, or secretions of the animals are used, the mode of administration, the ailments and diseases against which they are prescribed, and the tribe where they were reported to be used. Over 500 species of insects, mites, and spiders are used as medicines to cure both common and complicated ailments in the state of Chhattisgarh.[6] For example, locals immediately apply the fresh housefly (*Musca domestica*) as a first aid measure against scorpion bites. The oil from the red velvet mite (*Trombidium grandissimum* Koch) is useful for the treatment of more than ten important diseases including malaria, urogenital disorders, and paralysis. These mites are called ''Indian Viagra'' due to their ability to increase sexual desire. The pod borer *Helicoverpa armigera* (Hüb-

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ner, 1805) alone or in combination with herbal drugs is used to treat more than 50 common diseases.

South Korea. Pemberton (1999) carried out interviews with 20 traditional medical doctors at clinics in South Korea's Kyeong Dong Shijang in Seoul in order to learn about current patterns of usage of insects and other arthropods as traditional medicines. He recorded 17 products that are prescribed to treat several ailments. According to him, centipedes (*Scolopendra* spp.) used specially to treat arthritis and the silk moth larvae infected with fungus used to treat stroke, were the most frequently prescribed and medically important arthropod medicines. He comments, ''South Korean use of arthropods as drugs (as well as for food and enjoyment) is due, in part, to more positive attitudes towards these animals compared to many cultures.''

Folk Traditional Uses of Roaches and Ants.—In Manchuria, China, roaches are sold in drugstores because they are thought to stimulate lactation, and in Harbin the species *Eupolyphaga sinensis* Walker and *Polyphaga plancyi* Bol. are said to regulate menstruation (Lenko and Papavero 1996). In south China, boiled *Periplaneta* spp. are given to children for minor diseases, especially when the children are suspected of malingering to avoid school—the threat of cockroach tea ends that problem![7] In the Amazon region, the powder of *Periplaneta americana* (L., 1758) dissolved into wine, sugarcane brandy, or simply water, is used in cases of urine retention, renal colic, and asthma attacks (Curto and Piermarocchi 1990). Among the Nanticoke Indians a roach was put in a thimble, tied up in a cloth, and worn around the neck. This was supposed to stop whooping cough (Weiss 1946). Roth and Willis (1957) discussed the diseases and disorders reputedly cured by cockroaches and the specific uses of these insects in medicine until the 1950s.

Certain species of ants are used as an aphrodisiac in Colombia, as well as the heads of some species of termites among the Yekuana Indians (Cesard et al. 2003). The venom of the ants known as fire ants (*Azteca, Solenopsis, Wasmannia,* and *Pseudomyrma*) and those of the tribe Ponerini is used in the Amazonian indigenous pharmacopoeia (Cesard et al. 2003). The Zuruahá people, who live in Brazil, use the sting of the ant ***takarisi*** as an analgesic and anesthetic (Kroemer 1994). According to Gudger (1925), the mandibles of ants of the genus *Atta* are used to stitch wounds in South America, Europe, the Mediterranean region, and India. He says that the use of live ants in operative surgery reaches back to remote antiquity in India—from A.D. 1921 to 1000 B.C., nearly 3,000 years. Their jaws were used as surgical clamps and infection was prevented by the bacteriocidal substances produced by their mandibular glands. Similarly, certain beetles, particularly of the genus *Scarites,* have been used for a long time in Algeria, Anatolia, and even in Europe (Gudger 1925). Their mandibles end in small pincers which closely approach each other.

In China, ant medicine is considered to be a useful treatment for several liver-related health conditions, such as chronic hepatitis; it is said to improve sexual performance in both men and women, and to increase the appetite of patients suffering from cancer by relieving their pain, improving digestion, and increasing the number of white blood cells (Chen 1994). It was believed that eating 6–10 g of ants per day could rejuvenate old people and increase milk production in

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women (Chen 1994). *Polyrhachis vicina* Roger was used by Chinese royalty and in Tibet as a tonic drink to boost the immunological system and alleviate rheumatoid arthritis (Chen 1994). Indeed, ant venom may act as an anti-inflammatory agent in rheumatoid arthritis because of its action on the proteins of the complement system (Schultz and Arnold 1977). It is said that these ants contain a lot of zinc, and this mineral has been identified for some time as an immune stimulant and an antioxidant.[8] Because of its alleged medicinal properties, the weaver ant *P. vicina* is being threatened by overexploitation (Thémis 1997).

Bees as Sources of Folk Medicines.—Besides honey, other bee by-products are highly prized as folk medicines and as potential sources of drugs. The Raji, an ethnic group from mid-western Nepal known as the Bee People, use pollen as a tonic for old people and mothers or as an ointment to treat wounds (Valli 1998). Pollen (collected by bees), larvae and pupae have medicinal qualities in Kayapó Indian medicine (Posey 1986). Smoke produced from different waxes is the most important and powerful curative substance: patients are either 'bathed' in the smoke or inhale it.

Propolis, which is a resinous substance collected from the buds of some trees and flowers by bees to repair damage to their hives and to protect the hive from disease, is a natural remedy that has been employed since ancient times. Egyptians knew the antiputrefactive properties of propolis and used it to embalm corpses. It has been used in Eastern Europe as an antiseptic and an anti-inflammatory agent for the treatment of wounds and burns (Bankova et al. 1999). According to Castaldo and Capasso (2002), the pharmacologically active molecules in propolis are flavonoids and phenolic acids and their esters. These components have multiple effects on bacteria, protozoa, fungi, and viruses. In addition, they say, propolis has been shown to lower blood pressure and cholesterol levels. However, adverse affects are common at doses over 15 g per day. The adverse effects most commonly experienced are allergic reactions, as well as skin or mucous membrane irritation.

The ancient Mexicans used the royal jelly, which is produced by bees specifically to feed their queen,[9] to reestablish healthy conditions in cases of anemia. Now it is used for asthma, anorexia, gastrointestinal ulcers, arteriosclerosis, anemia, hypo- or hypertension, and neurasthenia or inhibition of sexual libido (Conconi and Pino 1988).

Bee venom is another product used in medicine. The anti-arthritic properties of apitoxin have been known for millennia (Maia 2002). About 2,500 years ago Hippocrates employed bee stings in his therapeutic activities. The mode of action of apitoxin is thought to involve blockage of sensory nerves and, because of the presence of the enzyme hyaluronidase, increased capillary permeability. For this reason, the long-established habit of administering bee stings to heal rheumatism has a possible physiological basis: ''increased capillary permeability means enhanced blood flow to afflicted areas and ganglionic blockage means reduced perception of neuralgic pain'' (Berenbaum 1995:175). Maia (2002) provides a review of the chemical composition of bee venom, its therapeutic value, and some procedures to reduce its allergenicity.

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Use of Insects for Magic.—Entomotherapy integrates a complex traditional medical system in which other folk health practices are included, such as amulets, charms, gestures, and transferences (Araújo 1977). Thus, insects have played important mystical and magical roles in the treatment of several illnesses in many different cultures throughout the world (Clausen 1954).

As Maria y Campos (1972) points out, magic has a practical use and makes sense in ordinary life, and most of the associations between the body parts of humans and insects seem to have originated from sympathetic magic. That is the reason larvae and snakelike insects are usually recommended for treating impotence. The exuviae of the cicada *Huechys sanguinea* De Geer, 1773 are used in prescriptions for migraine headaches and ear infections in China (Kritsky 1987). Crickets, katydids, and some grasshoppers are frequently recommended for illnesses of the throat and ears (Berenbaum 1995). Centipedes, which have many legs, are used for leg problems. Blister beetles (*Mylabris* spp.), which cause human skin to blister, are used to treat skin diseases. Scorpions (*B. martensii*), whose sting is painful, are used to treat pain (Pemberton 1999). Another interpretation of the association between arthropod characteristics and drugs is that the arthropods' characteristics serve as mnemonic devices to mark and recall specific uses of these medicines (Pemberton 1999).

In some parts of Africa every aspect of an individual's life is influenced by his beliefs about the magical powers of animals (Shampo and Kyle 1991). Among the Bafia people from Cameroon, certain insects attract attention by their malefic effects on men or their belongings, or as bearers of threatening spirits or diseases; others are beneficial as remedies, protectors, or bringers of good luck (Guarisma 2003). The Bushmen Ju/'hoansi, who live in the Nyae Nyae area of Namibia, attribute healing powers to the beetle *Brachycerus ornatus* (Drury, 1773). Women's stomach pains are alleviated when they use it as an ornament (Green 1998). In Ado-Ekiti district, southwestern Nigeria, barren women mix burnet mole crickets (*Gryllotalpa africana* Beauvois) with special soup to increase the chance of pregnancy (Fasoranti 1997). In Ijebuland, Nigeria, crickets (*Brachytrupes* sp.) are consumed as food items in order to aid mental development and for pre- and post-natal care purposes (Banjo et al. 2003). For the Dogon people from Mali the rites of fecundity are linked to the ants. Sterile women sit on anthills and beg the god Amma to make them fertile (Werber 1992). The sacred scarab (*Scarabaeus sacer* L., 1758) in ancient Egypt was used in religious rites, tomb hieroglyphics and drawings, and as amulets, commemoratives and good luck charms; hand-carved scarabs were buried with the dead (Cherry 1985).

Ingestion of the California harvester ants (*Pogonomyrmex californicus* [Buckley, 1867]) for visionary and shamanic ends was developed among the indigenous groups of south-central California (Groark 2001). The ants were swallowed alive and unmasticated, in massive quantities (often exceeding 400 ants), in order to induce a prolonged state of unconsciousness during which tutelary spirits (usually referred to as ''dream helpers'' or ''suertes'') appeared to the aspirant, often becoming life-long supernatural allies. The ants played an important role in both curative and preventive medicine, treating a diverse inventory of common ailments, including paralysis, gastrointestinal ailments, severe colds, pain, arthritis, and gynecological disorders (particularly those occasioned by childbirth).

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Ingestion of ants for medicinal purposes was also a usual practice for the Tübatulabal Indians, who live in the northeastern part of Kern County, California (Hitchcock 1962:183): ''For a bad cold or paralysis they wrapped four or five ants in a little ball of eagle down and the patient swallowed it. Over a period of two to three days the patient swallowed 15 to 20 of these balls washed down with sips of water. Every 24 hours after swallowing the balls the doctor induced vomiting and the patient's recovery depended on the number of ants found still alive.'' Hitchcock does not make it clear how this treatment was supposed to help the patient's recovery.

Social insects also play a crucial role both in symbolic systems and traditional rituals all over Amazonia (Cesard et al. 2003). Lauck (2002) records that the Arawak Indians of Guiana welcome the bite of the local black ant and place it on newborns, believing that the bite will stimulate the baby to walk early. In some native indigenous tribes children and adults submit to the painful stings of the ant ***tocandira*** (*Paraponera clavata* [Fabr., 1775]) (Anonymous 1982). People undergo the ***tocandira*** rite primarily to become resistant to the stings of venomous insects and to some illnesses, as well as to feel stronger. In fact, the use of ant stings in medicine, magic, and ritual has been long known. Balée (2000) discusses the use of ants in Amazonian ordeals. As he says, ''After the Ka'apor initiate's hair is shaven, adult members of her uterine kin group tie long strings made from *kïrawa* fiber (*Neoglaziovia variegata* [Arruda] Mez) snugly about her forehead and chest. Carefully knotted about their thoraxes, on each of these strings are about six *tapiña'i* ants (*Pachycondyla commutate* [Roger, 1860]). They sting the girl repeatedly'' (Balée 2000:410). Nimuendajú (1952 cited by Hitchcock 1962) states that ''the close relationship between venomous insects and magic power is illustrated when a shaman of the Tucuna dies. The magic songs that he knows leave his mouth in the form of wasps or other small creatures and silently disappear.''

Pharmacological Significance of Insects.—Modern minds may question the efficacy of insect-based medicines in bringing about healing or relief to the sufferer, as most have yet to be proven effective scientifically. However, it is known that these animals are very prolific in the synthesis of chemical compounds—alarm and mating pheromones, defensive sprays, venoms and toxins sequestered from plants or their prey and later concentrated or transformed for their own use (Pemberton 1999). This huge quantity of chemicals includes compounds that are emetic, vesicant, irritating, cardioactive, or neurotoxic (Berenbaum 1995). According to Stephen Trowell (2003), who heads the CSIRO's new insect research center Entocosm Pty Ltd., ''insects have large arsenals of biologically active compounds, such as molecules that kill cancer cells, proteins that prevent blood from clotting, enzymes that degrade pesticides, proteins that glow in the dark, and antimicrobial peptides and toxins.''

Considerable progress has been made in isolating the active chemicals and evaluating them pharmacologically (Table 2). Chemical screening applied to 14 insect species has confirmed the presence of proteins, terpenoids (triterpenoids and steroids, carotenoids, iridoids, tropolones), sugars, polyols and mucilages, saponins, polyphenolic glycosides, quinones, anthraquinone glycosides, cyanogenic glycosides, and alkaloids (Ramos-Elorduy et al. 1999). Antibacterial proteins

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TABLE 2.—Examples of insect-derived chemicals and products proven pharmacologically active.

Insect taxon	Chemicals	Pharmacological action
Hyalophora cecropia (L., 1758)	Cecropin A and B	Antibacterial
Sarcophaga peregrine (Robineau-Desvoidy, 1830)	Sarcotoxin IA, IB, IC; sapecin	Antibacterial
Drosophyla melanogaster Meiger, 1830)	Defensin, diptericin	Antibacterial
Bombyx mori L., 1758	Attacin, moricin, drosocin	Antibacterial
Anoplius samariensis Pal.	Pompilidotoxin	Neurotoxin
Pseudagenia (Batozonellus) maculifrons Sm.	Pompilidotoxin	Neurotoxin
Anterhynchium flavomarginatum micado Kirsch	Eumenine mastoparan-AF	A mast cell degranulating peptide
Lytta vesicatoria (L., 1758)	Cantharidin	Vesicant
Phoenicia sericata (Meigen)	Allantoin	Antibacterial
Catopsilia crocale Cr., 1775	Isoxanthopterin	Anticancer
Allomyrina dichotomus (L., 1771)	Dichostatin	Anticancer
Tetragonisca angustula angustula (Latreille, 1811)	Honey	Antibacterial
Apis mellifera L., 1758	Propolis	Anticancer, anti-HIV

extracted from insects include cecropin A and B (from *Hyalophora cecropia* [L., 1758]), sarcotoxin IA, IB, IC (*Sarcophaga peregrine* [(Robineau-Desvoidy, 1830)]), sapecin (*S. peregrina*), defensin (*Drosophila melanogaster* [Meigen, 1830]), attacin (*Bombyx mori*), diptericin (*D. melanogaster*), moricin (*B. mori*), and drosocin (*B. mori*) (Yamakawa 1998). As Montaño-Pérez and Vargas-Albores (2002) point out, cecropins are able to inhibit the growth of Gram$^-$ bacteria, while defensins are specific against Gram$^+$ bacteria. A systematic survey of biologically active substances in solitary wasp venoms has identified novel peptide neurotoxins, pompilidotoxins (PMTXs), from the venom of the spider wasps *Anoplius samariensis* Pal. and *Pseudagenia* (*Batozonellus*) *maculifrons* Sm. in Japan (Konno et al. 1998). During this survey, a new mast cell degranulating peptide designated as eumenine mastoparan-AF (EMP-AF) was identified in the venom of the wasp *Anterhynchium flavomarginatum micado* Kirsch, the most abundant eumenine wasp in Japan (Konno et al. 2000). These authors state that these toxins may be useful not only for basic neuroscience research but also for the development of therapeutic agents for neurological disorders.

Promising anticancer drugs, such as isoxanthopterin and dichostatin, have been isolated from the wings of Asian sulphur butterflies (*Catopsilia crocale* Cr., 1775) and the legs of Taiwanese stag beetles (*Allomyrina dichotomus* [L., 1771]) respectively (Kunin and Lawton 1996). About 4% of the extracts evaluated in the 1970s from 800 species of terrestrial arthropods (insects included) showed some anticancer activity (Oldfield 1989). Chitosan, a compound derived from chitin, has been used to repair tissues and to lower serum cholesterol level, as an anticoagulant, as an agent that accelerates scarring and works against pathogens in the blood or on the skin, and as a carrier of medicinal substances. It is even used to fabricate contact lenses (Goodman 1989; Ramos-Elorduy 1998).

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One of the most interesting applications of insects as therapeutic agents is maggot therapy, which is the treatment of superficial and deep wounds with the help of blowfly larvae. This medicinal use of live organisms, such as maggots, leeches, or fish, is known sometimes as biotherapy. Maggots, like those of *Phoenicia sericata* (Meigen), feed on dead tissue where gangrene-causing bacteria thrive. As they eat they secrete allantoin, a chemical that inhibits bacterial growth. They are primarily used to treat tumor-killed tissue and burns in people who would be endangered by surgery. Synthetically produced allantoin was commonly used as an antibacterial ointment until penicillin and other antibiotics became commercially available in the 1940s.[10] Nowadays, maggot therapy is increasing around the world due to its efficacy, safety, and simplicity. Medicinal maggots have three actions: they clean wounds by dissolving the dead (necrotic) infected tissue, they disinfect the wound by killing bacteria, and they stimulate wound healing (Sherman et al. 2000). Theoretical surveys recently carried out by researchers of the Universidade Estadual Paulista in Rio Claro, São Paulo State, have confirmed the benefits of this kind of therapy and state that it could be adopted widely in Brazil and overseas in the near future (Beraldo and von Zuben 2004).

The blister beetle known as Spanish fly, *Lytta vesicatoria* (L., 1758), contains relatively high concentrations of cantharidin, a compound with notable effects on the urogenital system of vertebrates. In the past it was prescribed as a remarkable aphrodisiac, but now it is used to induce mating in some domestic animals and as a therapy for some disorders of the urinary tract. Hippocrates prescribed *L. vesicatoria* as medicine to treat his hydropic patients (Carrera 1993). However, cantharidin is extremely toxic even at low dosages. Clausen (1954) mentioned that meloid beetles, when taken internally, can affect the kidneys. In fact, they can cause serious gastroenteritis and nephritis; as little as 30 mg can be lethal (Berenbaum 1995). Nevertheless, the insect is widely sold (dried) and used in Mexico.[11] Biologically, cantharidin has two main functions in the life of insects: as a defensive and as an aphrodisiac.

Recent studies are proving that honey has good effects on human health. The honey of *Tetragonisca angustula angustula* shows bactericidal action against *Escherichia coli* (Migula, 1895) and *Staphilococcus aureus* Rosenbach, 1884 (Aidar 2002). Park et al. (2000) have discovered anticancer and anti-HIV activities in ethanolic extracts of propolis of *Apis mellifera* L., 1758 collected from different parts of Brazil.

The wide variety of bioactive molecules apparently contained in the saliva of blood-sucking arthropods is of general clinical therapeutic interest (Jones 1998). For instance, the salivary components of mosquitoes are becoming better characterized, and there exists in the mosquito saliva vasodilators, apyrases, amylases, and other tissue regulatory factors. The discovery of maxidilian in the saliva of biting sandflies has been very exciting, as it is the most potent vasodilator known to science (Jones 1996). A tick salivary anticoagulant has been explored as a model agent to prevent undesired blood clotting during open heart surgery (Jones 1998).

Much more pharmacological and biochemical study needs to be done to evaluate the true effectiveness of the hundreds of medicinal insect species regularly used both in traditional and modern medicines.

"Biorational" Deduction.—Insect behavior can help to discover useful compounds by leading an observer to an unusual chemical (Joyce 1992). Eisner (cited in Beattie

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1992) calls this the ''biorational'' approach to chemical prospecting, the systematic application of knowledge of the adaptive biology of organisms for the solution of human problems. Studies for the discovery of bioactive compounds from arthropods have been focusing on social insects: bees, ants, wasps, and termites. Biorational deduction allows one to analyze species and natural products for food, medicine, fiber, and many other necessities, as well as to discover new biological resources (Beattie 1992).

Dunn and Sanchez (2002) have argued for the use of social insects as medicine, particularly ants and termites, by comparing their social behavior and nature to those of human beings. Like humans, social insects are susceptible to pathogens of various types, so they have evolved the use of different antibiotics and fungicides that can be directly used by humans. Soil-dwelling ants have been shown to make and employ compounds that kill both fungi and bacteria in their underground nests, and the predatory water beetle (*Cybister tripunctatus* Olivier, 1795) is known to use phenolic compounds to repel microbial attacks (Pemberton 1999). The secretion of the metapleural gland of the ant *Myrmecia nigriscapa* Roger, 1861 is possibly a source of antibiotics (Beattie et al. 1986). And biocidal compounds have been isolated from nematodes, slugs, millipedes, cockroaches, and flies (Kunin and Lawton 1996). Antimicrobial peptides were first discovered in insect larvae by Dr. Hans Boman of the Karolinska Institute (Diamond 2001).

Both the biological and behavioral characteristics of arthropods suggest the presence of chemicals that can be pharmacologically active. The diverse defensive chemicals of arthropods have different origins: some are products manufactured by the insects themselves while others are defensive chemicals obtained from plants or prey that are sequestered, concentrated, or transformed for the insect's defense (Berenbaum 1995). Since plants or their chemicals constitute one of our largest sources of drug material, it is reasonable to expect pharmacological activity from arthropods that feed on these drug-producing plants and incorporate phytochemicals or make similar chemicals (Pemberton 1999). Additionally, insect species that show an aposematic coloration[12] might be used as probes to survey for medicines or other useful biochemicals (van Hook 1997).

Conservation and Sustainability.—Thousands of useful creatures are being killed and exported illegally to developed countries like United States to be used in diverse ways, medicines included. The commercial value of products based on medicinal insects comprises about US$100 million per year (Thémis 1997). Indeed, many animal species other than arthropods have been overexploited as sources of medicines for the folk medicine trade (Oldfield 1989).

Unfortunately, insects and related organisms often come low on the list of priorities for conservation, particularly in the eyes of the public (Cheesman and Brown 1999). As van Hook (1997) says, ''Humans most readily learn about, care about, and make sacrifices for animals that are apparent, familiar, aesthetically appealing, and demonstrate positive benefits to mankind.'' For this reason, the conservation of insect species could also be promoted through their value in the treatment of human ailments and diseases (Cheesman and Brown 1999). In addition, species involved in traditional remedies should be among the highest priorities for conservation (Kunin and Lawton 1996). Zimian et al. (1997) believe that

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there are two main ways to protect natural insect resources from over-collecting. One is to develop mass-rearing methods to enhance commercial production of valued insects in order to meet growing market needs. The second is to find natural substitutes and to develop synthetics through basic research. Some active components have been already synthesized artificially and are used as substitutes in clinical use. For example, researchers synthesized sodium of cantharidin, which is used to treat lung and liver cancers (Zimian et al. 1997).

Perspectives on Entomotherapy.—The discovery of pharmaceuticals coming from insects should follow the same general principles that are known in phytochemical research. As with plants, a number of screening processes must identify the ways a drug extracted from a given insect species may be useful (Pemberton 1999). Paraphrasing Zimian et al. (1997), we shall expect the following steps:

- Theoretical and basic research, especially in the fields of toxicology, pharmacology, and chemical components of medicinal insects;
- Identification of insects and their taxonomic classification;
- Protection from over-collecting to guarantee their sustainable use and to avoid destruction of natural food chains, especially where natural enemies of pests are involved;
- Reduction in the application of pesticides by developing more efficient methods for collecting insect pests that are also traditional foods and medicines, such as locusts and grasshoppers;
- Development of a quality control standard for commercial species to guarantee the safety and effectiveness of the medicine for people.

CONCLUSION

Insects seem to constitute an almost inexhaustible resource for pharmacological research thanks to the defensive chemicals they have developed over millennia of co-evolution with plants and predators. However, medicinal insect species have received little attention probably due to the disdain that the majority of people show toward these animals. In accordance with a referee's comment, I do hope that ''this paper will stimulate others to look further and explore this important, but neglected area of research from both an ethnographic focus and a pharmacological perspective.''

The exploitation of animal resources for medicinal purposes has ecological and cultural dimensions. It is imperative that insect diversity be maintained to provide future biological diversity and substances for new sources of pharmacological exploration in the coming years. These issues should be discussed in scientific meetings related to conservation biology, public health, sustainable management of resources, biological prospecting, and patent law.

The zootherapeutic potential of insects can make an important contribution to the biodiversity debate, as well as lead to the economic and cultural valorization of animals usually regarded as useless. We must pay attention to the sustainable use of insects to avoid their extinction.

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NOTES

[1] Some institutions have been developing projects to identify medically important insects, such as the Wistar Institute of the University of Pennsylvania (www.wistar.upenn.edu), the Transvaal Museum in South Africa (www.nfi.org.za/Ethnobiology/ethno.htm), the Commonwealth Scientific and Industrial Research Organization in Australia, and the National Research Council of Thailand.

[2] Mekloy, Pongpet. 2002. Bug drugs. *Bangkok Post,* 12 March 2000. [Online: http://www.thaibugs.com/Articles/Bangkok%20Post%20Mar%2012,%202000%20-%20Bug%20drugs.htm] (verified 2 July 2002).

[3] It is amazing that this recommendation has been recorded since the first century A.D. (Carrera 1993).

[4] Scutellum refers to the part of the *arapuá* (*Trigona spinipes*) hive. This is a hard mass comprised of resin, dead bees, and other detritus.

[5] Metzner, Jim. 2002. Edible insects: medicinal bugs. *Pulse of the Planet,* April 1999. [Online: http://www.pulseplanet.com/archive/Apr99/1853.html] (verified 2 July 2002).

[6] Oudhia, Pankaj. 2002. Traditional knowledge about medicinal insects, mites and spiders in Chhattisgarh, India. [Online: http://www.botanical.com/site/column_poudhia/06_medicinal;llinsects.html] (verified 23 July 2002).

[7] Anonymous referee's comment.

[8] Kenyon, Georgina. 2002. Insects boost immune system. BBC News, 10 February, 2002. [Online: http://news.bbc.co.uk/1/hi/health/1809450.stm] (verified 5 March 2002).

[9] The royal jelly is a ''white gelatinous product derived from pharyngeal glands of worker bees'' (Conconi and Pino 1998).

[10] Sherman, Ronald A. 2001. Maggot therapy project. [Online: http://www.ucihs.uci.edu/com/pathology/sherman/home_pg.htm] (verified 18 October 2001).

[11] Anonymous referees's comment.

[12] Aposematism is an antipredator defense, combining a warning signal, usually a bright coloration, with unpalatability (Merilaita and Kaitala 2002).

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