Human Health Concerns

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Introduction

Field biologists preoccupied with their scientific objectives often fail to recognize the health risks to which they may be exposed (Constantine 1988). Investigators conducting mammalian biodiversity projects are particularly vulnerable because of the wide variety of potentially harmful species, techniques, and environments that can be involved in such studies. Those investigators, therefore, must actively seek to avoid potential health hazards or run the risk of undermining their field research through injury or illness.

In this appendix we discuss general precautions that one should take during a mammalian biodiversity project. We also consider disease risks encountered in different parts of the world and discuss preventive measures that can be taken against certain of them. Our treatment of disease risks is not intended to be comprehensive, however; rather, we highlight certain illnesses that are either common or particularly relevant to mammalian field studies.

Medical knowledge is increasing, and recommended treatments for injuries and illnesses of various types are constantly changing. In addition, none of us is a trained physician. Readers should, therefore, consult a physician and relevant medical textbooks for more detailed and up-to-date information.

General precautions

Mammals are known to transmit a wide range of pathogens, some of which can be life-threatening. The environment in which mammals live may also harbor certain diseases. Therefore, investigators should seek medical advice on disease risks related to their research and take appropriate precautions before commencing fieldwork. They should also consult a physician for an evaluation of their existing health conditions and assurance that they are physically and mentally capable of undertaking the field investigation. Medical advice is especially important
when research involves an area or region that is new to the investigator, such as a foreign country.

Investigators must learn to protect themselves from hazards that they may encounter in the field. Training and experience in the use and handling of equipment and chemicals are important to avert potential problems. Investigators should also protect themselves against injury from the animals that they study by wearing protective clothing, including gloves, chaps, headgear, and footwear. In addition, investigators should take precautions to avoid being bitten by venomous animals or exposed to poisonous plants. Learning the appropriate antidotes to toxic and poisonous substances can be invaluable.

Physical environments that pose special hazards to researchers include caves and mines, which may contain life-threatening levels of noxious gases. Physically challenging environments, such as those at high elevations, with steep terrain, or in humid forests, as well as prolonged exposure to severe cold or heat, also pose certain health risks. Investigators who expect to work in such environments should know how to deal with potential health problems and must obtain special training to minimize injury.

Prior knowledge of the potential hazards and health risks in a given region and steps needed to respond to life-threatening situations should be part of the overall training of a field biologist. In particular, investigators should be trained in first aid procedures and rescue operations for emergency situations. They should carry appropriate first aid materials and reference works (e.g., Tilton 1994; Werner 1994) that will help them to diagnose (and if necessary, treat) serious injury or illness if medical assistance is unavailable.

Immunizations

Immunization against various diseases is an important first step in preventing illness during field investigations. Children are routinely immunized in many countries, but periodic booster shots are often necessary to maintain immunity as adults. For example, although children in the United States are immunized against tetanus and diphtheria, the immune status of a significant number of adults is deficient (Jong 1993). Researchers must review their medical records and ensure that their immunizations remain effective throughout a field study. Most immunizations and booster vaccines can be received at a physician’s office or clinic, but vaccines cannot always be administered at one time. Thus, medical advice must be sought well in advance (at least 4–6 weeks) of a proposed project.

Some countries require specific immunizations. Relevant information can be obtained from a local health office, or from the World Health Organization (WHO) or the U.S. Centers for Disease Control, which regularly publish health warnings pertaining to different regions and countries and recommend immunizations for travelers. Member nations of WHO normally require foreign visitors to carry a valid certificate of immunization against yellow fever. They no longer require smallpox and cholera immunizations.

Investigators planning to carry out research in countries where it may be difficult to avoid contaminated food and water should obtain typhoid and immune globulin vaccinations. These vaccines are effective against the serious and sometimes life-threatening Salmonella typhi murium, bacterium and hepatitis A virus, respectively. Investigators planning to work in Saudi Arabia, Nepal, India, Kenya, or Tanzania and other sub-Saharan countries should consider immunization against meningococcal meningitis, a bacterial infection that enters through the respiratory system and infects the brain. Those intending to work for long periods in some rural areas of Asia should consider immunization against the Japanese encephalitis virus, which is spread by Culex mosquitoes. Vaccination against plague, which is caused by the bacterium Yersinia pestis, is important for biologists working with rodents and rabbits in areas where this disease is suspected. Plague still occurs in pockets throughout Asia, Africa, South America, and the United States (Kusinitz 1990). Immunization against rabies (see “Rabies,” below) is an important precaution for investigators working with bats and carnivores in most parts of the world, but especially in Central and South America, Southeast Asia, the Philippines, India, and Africa. Immunizations against numerous other diseases are also available.

Certain immunizations may not be compatible with particular health conditions (e.g., allergies, pregnancy). Other immunizations may be an important precaution for people at high risk for a particular disease because of their existing health status (e.g., people lacking a spleen or suffering from chronic illnesses). Furthermore, each vaccine has a specific period of effectiveness, and some vaccines (e.g., for rabies and hepatitis B) are relatively expensive. To
learn the details of relevant immunizations, investigators should consult a physician before commencing field investigations.

Disease risks
Most, if not all, mammals (including humans) and their arthropod parasites carry pathogens that may be transmitted through direct contact, bites, scratches, or exposure to body fluids (urine, blood, saliva). In rare instances pathogens may be inhaled. Other pathogens may be transmitted to humans when contaminated food or water is ingested. Field researchers should take precautions to avoid exposure to these pathogens, which include viruses, bacteria, fungi, protozoans, platyhelminths (flatworms), and nematodes (roundworms). In most instances, risks are minimal, and attention to personal hygiene and the type of food and water consumed, as well as the use of protective clothing and insect repellents, is sufficient to prevent infections. Nevertheless, it is important to know the symptoms and treatment of some of the potentially serious illnesses, so that one can deal with them effectively if necessary.

Common diseases
Malaria
Malaria is the single most important disease hazard for investigators conducting research in the tropics. It infects over 250 million people each year and is a leading cause of death in developing countries (Keystone 1993). Malaria is caused by the protozoan blood parasite *Plasmodium*, which is transmitted by the bite of *Anopheles* mosquitoes. The four species of *Plasmodium* that cause malaria are *P. falciparum*, *P. malariae*, *P. vivax*, and *P. ovale*. All species have an initial phase of development in the liver, after which they enter the bloodstream to undergo further development within red blood cells. *Plasmodium vivax* and *P. ovale* leave behind dormant forms in the liver that can cause relapses of malaria for up to 3 years after exposure. *Plasmodium falciparum* has the greatest potential to kill, because it can parasitize up to 80% of the red blood cells (Hall 1988). This condition can lead to severe anemia, and liver and kidney failure during the final stages before death. Principal symptoms of the early stages of malaria include recurring bouts of fever and chills with sweating, fatigue, and abdominal pains.

The battle against malaria continues, but there is still no vaccine to prevent the infection. As the first line of defense, investigators must avoid being bitten by the *Anopheles* mosquito, which is active between dusk and dawn. Preventive measures include sleeping under mosquito netting, wearing tightly woven clothing, and applying an insect repellent containing N,N-diethyl-meta-toluamide (DEET) to exposed areas of the skin every 3 to 4 hours. For additional protection clothing can be impregnated with DEET-containing repellents or with permethrin (Duraon or Permanone). Permethrin kills insects and other arthropods that alight on the treated fabric (Rose 1992).

Protection against mosquito bites alone may not be sufficient to prevent malaria, especially in areas with a high incidence of the disease. Before visiting such areas, an investigator must begin a course of antimalarial drugs. Medical advice is essential in choosing the appropriate drug(s), because *P. falciparum* strains that are resistant to certain drugs occur in some tropical regions; certain drugs may have adverse side effects on some people; and some drugs may be incompatible with a person's existing health condition (e.g., allergies, pregnancy) or medications taken for other ailments.

Antimalarial drugs do not prevent the disease but usually act on the parasite after it has been released from the liver into the bloodstream. Consequently, these drugs must be taken regularly during and also after a period of exposure. Postexposure prophylaxis should be continued for 4 weeks, to help kill the parasites released from the liver after the exposure. Ideally, investigators must also take the drugs for up to 2 weeks before entering a malaria area. This precaution ensures adequate drug levels in the blood before exposure and also enables one to switch drugs in case of adverse side effects.

Chloroquine (Aralen) is the prophylactic drug of choice for all four species of the malaria parasite, except in areas where chloroquine-resistant *P. falciparum* strains occur. Adult dosage for chloroquine-sensitive areas is 300 mg of chloroquine (found in a 500-mg tablet of chloroquine phosphate) taken each week during and after exposure (Rose 1992). In areas with chloroquine-resistant *P. falciparum* strains, adults may take weekly dosages of 250 mg of mefloquine (Lariam). However, the efficacy of mefloquine is low against the chloroquine-resistant strains of *P. falciparum* found along Thailand's borders with Myanmar and Cambo-
dia (Keystone 1993). In such areas, where multidrug-resistant P. falciparum strains occur, daily doses of 100 mg of doxycycline (Vibramycin) are effective as a prophylactic. Those who cannot tolerate or take the above-mentioned drugs can take daily doses of 200 mg of proguanil (Paludrine), but this drug is effective only in areas where chloroquine-sensitive strains occur. Proguanil is one of the safest antimalarial drugs available and can be used even during pregnancy (Keystone 1993). Primaquine is used as a postexposure prophylactic to eradicate P. vivax and P. ovale parasites that lie dormant in the liver. Its use must be preceded by a blood test because of the risk of primaquine toxicity in people whose red blood cells are deficient in the enzyme glucose-6-phosphate dehydrogenase.

Pyrimethamine/sulfadoxine (Fansidar) is no longer used as a prophylactic, but it is sometimes taken with other drugs for the actual treatment of malaria when immediate medical assistance is unavailable. Halofantrine (Halofan) is a new drug that is also effective in the treatment of malaria. Other drugs that can be used in the self-treatment of malaria include mefloquine and combinations of quinine with either doxycycline or tetracycline (Rose 1992). It is wise to consult a physician and be prepared for the self-treatment of malaria, especially when working in remote areas. Nevertheless, investigators must seek expert medical attention as soon as possible if afflicted with the disease.

Diseases from Contaminated Water or Food

As indicated earlier, typhoid and hepatitis A infections are transmitted via contaminated water or food, and both diseases can be avoided by taking appropriate immunizations. Cholera is another health hazard that can be transmitted by contaminated water or food. Immunization for cholera is not recommended by WHO or the Centers for Disease Control, because the vaccine that is currently available is not very effective in preventing the disease (Jong 1993). Instead, biologists working in countries with recent cholera outbreaks should pay particular attention to the water and food that they consume. Undercooked or raw pork, sausage, beef, and fish can cause diseases such as trichinosis, tapeworm, and fluke infections. Meat and fish must be cooked for at least 1 hour at a temperature of 55°C or more before being eaten.

One of the most common ailments in the field is diarrhea. Noninfectious types of diarrhea are caused by food poisoning, overindulgence in food, and even exhaustion at high elevations. Infectious diarrhea is caused by a variety of microorganisms, the most common of which is the Escherichia coli bacterium (Kammerer 1993). Other organisms causing infectious diarrhea include certain viruses, bacteria such as Shigella and Campylobacter, and protozoans including Giardia lamblia and Entamoeba histolytica. Diarrhea is often accompanied by stomach cramps, nausea, vomiting, and fever. High fever and blood, pus, or mucus in the stool are symptoms of dysentery caused by bacteria such as Shigella or Campylobacter.

Microorganisms causing diarrhea may be found in untreated tap water and ice or fruit drinks made from it, raw vegetables, fruits, seafood, meat, dairy products, and foods left in the open for several hours, such as those sold by street vendors. Such foods and drinks must be avoided if there is even the slightest suspicion of contamination. As a precaution against diarrhea, researchers should eat only hot, cooked food and fruits with unbroken skins that can be peeled, and they should drink only carbonated beverages or beverages such as beer, tea, and coffee. Water used for making tea or coffee and brushing teeth must be boiled for at least 5 minutes to kill dangerous microorganisms including hepatitis viruses (Kammerer 1993). Water can also be chemically treated with iodine tablets (Potable-Aqua), which are superior to chlorine tablets (Halazone) in killing parasitic cysts (Wolfe 1993).

Even with precautions, it may be difficult to avoid diarrhea in the field. The first step in treating diarrhea is the replacement of lost fluids and electrolytes. Commercially available rehydration salts are ideal for this purpose, but fruit drinks and caffeine-free beverages can also be used. Dairy products, alcoholic drinks, and fatty or spicy foods must be avoided during treatment. This may be the only treatment necessary, but if bowel movements are frequent and accompanied by abdominal cramps, an antimitotic agent such as loperamide (Imodium) or diphenoxylate (Lomotil) may be taken. Commonly used treatments such as Kapectate, activated charcoal, and yogurt are not recommended, because they have not been shown to be effective in reducing cramps or frequency of stools. If diarrhea continues for more than 3 days without improvement, medical advice must be sought. A physician should also be consulted if blood, mucus, or pus occurs in the stool,
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or if diarrhea is accompanied by severe cramps or high fever with chills. If medical advice is unavailability, antibiotic drugs such as trimethoprim (Trim-pex), trimethoprim-sulfamethoxazole (Bactrim or Septra), or ciprofloxacin (Cipro) may be taken. It is crucial, however, that these drugs be taken only on the basis of prior consultation with a physician, because they may be incompatible with certain health conditions. Furthermore, medical attention must be sought as soon as possible after a bout of severe diarrhea.

Recurrent diarrhea may be a symptom of a parasitic infection. Intestinal parasites that cause diarrhea include Giardia lamblia, Entamoeba histolytica, Cryptosporidium, and Dientamoeba fragilis. Stool examination is required for identification of the parasite causing the infection and determination of the appropriate treatment.

Skin Diseases

Investigators working in the humid tropics are often susceptible to skin diseases. Most of these diseases can be prevented by maintaining high standards of personal hygiene. Perhaps the most important preventive measure is keeping one’s skin and clothes clean and dry. One of the most common skin problems is “athlete’s foot,” a fungal infection that can be prevented by regular use of foot powder and frequent changes of socks. Foot infections can also be caused by sand fleas and hookworms. The best way to prevent these problems is to wear shoes that adequately protect the feet.

In tropical Africa, Tumbu fly larvae may pose health problems by penetrating the skin and causing painful swellings. The larvae hatch from eggs deposited on clothes left out in the sun to dry. To prevent the larvae from penetrating the skin, clothes that are sun-dried must be pressed with a hot iron before they are worn. A similar fly-larva infection also occurs in the tropical areas of Latin America.

Diseases involving wild mammals

Rabies

One of the most feared and respected diseases of animals that can be transmitted to humans is rabies (lyssavirus), an acute viral infection of the central nervous system. Rabies occurs mostly in warm-blooded animals, although susceptibility to the virus differs considerably among species. The rabies virus typically enters a host’s body via the saliva of an infected animal, which contaminates a bite wound or contacts broken skin. Liquid saliva remains infectious for 24 hours at room temperature. Rabies virus in dry saliva can survive for up to 14 hours. The virus may also enter the body via the digestive tract, the respiratory system, or through contact with mucous membranes (Constantine 1988). The rabies virus progresses along the nerves to the spinal cord and brain and then reverses direction, moving centrifugally and eventually invading the nerves in all organs including the skin. Infected animals may engage in savage attacks, thereby transmitting the virus and continuing the cycle (Constantine 1988). Infected bats are only rarely involved in unprovoked attacks and may appear normal before developing paralysis, followed by death.

The incubation period of the disease is usually from 2 to 12 weeks in humans, although this can vary from 10 days to 15 months. Because of this relatively long incubation period, vaccine treatment (active immunization) can be administered after infection. If the disease appears, it is generally fatal to humans and most mammals within 3 to 7 days following the appearance of the first symptoms. Only two humans are known to have survived an infection with the rabies virus.

The virus cannot survive for long outside the body and is typically inactivated at temperatures in excess of 56°C, and by ultraviolet and solar rays. It is not killed by low temperatures (e.g., by freezing infected animals). Treatment should be initiated as soon as possible following exposure. National and international health authorities recommend immediate prophylactic treatment with rabies vaccine following bites or other potential exposures from bats and wild carnivores. The decision to treat an individual, however, may be influenced by knowledge of the presence or absence of the disease in the geographic area or in the species of interest, and the circumstances of the bite (Constantine 1988).

WHO and the Centers for Disease Control recommend that all individuals who have regular contact with bats or with other high-risk mammals (carnivores) be immunized against rabies. Investigators should follow the immunization recommendations of the Advisory Committee on Immunization Practices of the U.S. Public Health Service. Preexposure immunization resulting in a serum rabies neutralizing
antibody titer of at least 1:5 is an appropriate precaution for most bat researchers (Constantine 1988). Prophylactic vaccination with human diploid cell vaccine consists of one intramuscular injection on days 0, 28, and 56, or in an accelerated form on days 0, 7, and 28. Reinforcing (booster) doses are advisable every 1 to 3 years. Individuals who do not have regular contact with bats should wear nonpenetrable gloves when handling these animals.

If a person is bitten by a suspect mammal, the wound should be washed thoroughly with detergent and water. The detergent inactivates the virus particles, whose outer membranes are high in lipids. Alcohol (70%) or other skin disinfectants should then be applied. Postexposure vaccination against rabies is advisable. Treatment consists of six injections on days 0, 3, 7, 14, 30, and 90. If bites have occurred on or near the head (neck or face), or if there has been mucosa contact with the animal’s saliva, rabies hyperimmunoglobulin should be administered as passive immunization.

Rabies-related viruses, including Mokola, Dubenhage, and Lagos bat virus, have been reported from wildlife, humans, and domesticated animals. Diseases produced by these viruses resemble paralytic rabies, but whether rabies vaccines provide protection against these viruses is questionable. All such viruses appear to be restricted to Africa (Constantine 1988).

**Arboviral Fevers**

There are several types of arboviral fever, of which the best known is yellow fever. These fevers are caused by arboviruses, which are transmitted by arthropod vectors such as mosquitoes, ticks, and sand flies (Kusinitz 1990). In Latin America and Africa, the yellow fever virus is spread among humans by the mosquito vector *Aedes aegypti*, which is usually active in the morning and at twilight. The virus can also be transmitted from infected nonhuman primates to humans by *A. simpsonti* in Africa, and by *Haemagogus* and *Sabethes* mosquitoes in Latin America. Symptoms of the disease include the characteristic yellow-green color of the skin, mucous membranes, and eyes. This is accompanied by nausea, muscle aches, and fever, which can be very high and followed by vomiting of blood in the most serious cases. Fortunately, the vaccine available for yellow fever is highly effective against the disease and provides 10 years of protection.

Other arboviral fevers include dengue and Japanese encephalitis. The latter illness occurs regularly in Asia and the eastern part of the former Soviet Union, whereas dengue is present in Asia, Pacific islands, several Latin American countries, and parts of tropical Africa. Dengue, which is spread by the *Aedes aegypti* mosquito, causes as much illness as all other arboviral fevers put together (Welsby 1988). The symptoms of dengue include sudden high fever, severe headache, fatigue, and muscle and joint pains. The *Culex* mosquitoes that spread Japanese encephalitis are most abundant during the summer months in temperate areas and during the rainy season in the tropics. Symptoms of the illness include nausea, vomiting, headache, and fever. The most serious cases may result in permanent brain damage and sometimes death. Because the viruses that cause both illnesses are biologically similar, the vaccination against Japanese encephalitis may provide some protection against the hemorrhagic form of the dengue fever, which can sometimes be fatal (Rose 1992). Nevertheless, avoiding mosquito bites is still the best protection against disease.

African hemorrhagic fevers, such as Lassa, Crimean-Congo, Ebola, and Marburg, are also caused by arboviruses. They produce high fevers, muscle aches, headaches, and internal bleeding that can be fatal. The vector for Crimean-Congo fever is a tick that spreads the virus to humans from wild and domestic animals. The vectors for the other fevers are not known, but the rodent *Mastomys natalensis* serves as an intermediate host for Lassa fever virus (Kusinitz 1990). There is no reliable cure for these illnesses, although Lassa fever has responded to the antiviral drug ribavirin in experimental trials. As there is no cure, it is essential to prevent arthropod bites by taking the previously mentioned precautions (see “Malaria,” above). Investigators intending to work in western and central Africa should be especially careful, because Lassa fever is a major health problem in those areas.

**Hantavirus**

The hantavirus receives its name from the Hantaan river in South Korea, where it was first identified among U.S. military personnel nearly 40 years ago (Anonymous 1994). Since that time about 200,000 cases of hantavirus infection have been reported annually, mainly from the People’s Republic of China and to a lesser extent from Korea, Russia, Scandina-
via, Europe, and the Balkan region (Morris et al. 1994). The best-known hantavirus infection is hemorrhagic fever with renal syndrome (HFRS), an illness of varying severity characterized by high fever, hemorrhage, and kidney malfunction.

In May 1993, another type of hantavirus infection, called the hantavirus pulmonary syndrome (HPS), was discovered in the southwestern United States. This infection is caused by a recently identified strain of hantavirus and is 10 times more likely to cause death than HFRS. The onset of HPS occurs within 45 days after exposure, and early symptoms include fever, headache, muscle ache, fatigue, vomiting, shortness of breath, and a dry cough. Later symptoms include rapid heartbeat and breathing difficulty, which may lead to abrupt respiratory failure.

Rodents are the primary reservoirs of hantaviruses. The hantavirus strains causing HFRS are carried by murine rodents, particularly Apodemus and Rattus. The principal carrier of the HPS-causing hantavirus strain is the deer mouse (Peromyscus maniculatus), although other species of Peromyscus have also been implicated. The 1993 outbreak of HPS in the United States was attributed to a sharp increase in deer mouse populations resulting from high precipitation and heavy seed set in previous years (Anonymous 1995). Hantaviruses are transmitted from rodent to rodent and from rodent to human through inhalation of viral particles released into the air when infected rodents, their nests, or materials contaminated with their urine, feces, or saliva are disturbed. Disease transmission may also occur through contact of contaminated materials with broken skin or the conjunctiva of the eye.

An experimental drug, ribavirin, shows promise in the treatment of hantavirus infections, but its effectiveness has still to be proven. Therefore, disease prevention is essential, and adequate precautions must be taken to avoid contracting the infection. We recommend that investigators wear disposable aprons or coveralls, shoe covers, gloves, and protective goggles when working with rodents. In addition, investigators must wear air-purifying respirators with high-efficiency, particulate air filters, and they must be trained in the proper use and care of this equipment. Similar precautions must be taken when investigators expect to come in contact with the nests or excreta of rodents. Those who fall ill after working with rodents should consult a physician immediately, because early diagnosis and prompt hospitalization can greatly reduce mortality risk.

Leishmaniasis

Leishmaniasis is one of the most common parasitic diseases in the world and is an important health concern in Latin America, Africa, the Middle East, Mediterranean countries, central Asia, northern China, and India and neighboring countries. The disease has several forms, each of which is caused by a different species of protozoan parasite belonging to the genus *Leishmania*. The parasites may be found in domestic dogs, some rodents, foxes, jackals, and rock and tree hyraxes. They are transmitted to humans by bloodsucking sand flies (Manson-Bahr 1988; Kusinitz 1990). They then invade macrophage cells located in the liver, spleen, bone marrow, skin, and mucous membranes. The form of the disease depends on the organs that are affected and the species responsible for the infection. The three main forms of the disease are visceral, cutaneous, and mucocutaneous leishmaniasis.

Visceral leishmaniasis (kala azar) results in anemia and enlargement of the liver and spleen. It develops relatively slowly after the infection; symptoms include muscle aches, chills and fever, weight loss, cough, and diarrhea. Warty skin nodules or skin ulcers may also occur. This form of leishmaniasis can be confused with several other diseases (lymphoma, leukemia, malaria, typhoid) and can be fatal if untreated. Cutaneous leishmaniasis is characterized by ulcerative skin lesions or nodules, which may heal by themselves. However, ulcers caused by *L. mexicana mexicana*, which usually infects the ear, can persist and ultimately destroy the pinna. This form of leishmaniasis is common among forest dwellers of Guatemala and Mexico. Mucocutaneous leishmaniasis is caused by *L. braziliensis*, which can affect the mucous membranes of the mouth, nose, and throat and cause severe disfigurement of these areas. The disease is becoming increasingly common in Paraguay.

Leishmaniasis can be prevented by avoiding the bite of sand flies. Application of DEET-containing insect repellents is effective for this purpose. Because sand flies are active from dusk to dawn, sleeping under a mosquito net is also effective, but the net must either have a very small mesh or be treated with permethrin. It is also advisable to sleep at least 60 cm above the ground, because sand flies can rarely jump to this height. Camping in areas with sand flies should be avoided as well. Treatment of the disease involves a course of antimony drugs such as sodium stibogluconate (Pentostam) or sodium antimony gluconate. Other drugs such as amphotericin
B and allopurinol are also available for treatment. These drugs can have serious side effects and should be taken only under the supervision of a physician.

**Histoplasmosis**

Histoplasmosis is a disease of humans and other mammals caused by a fungus, *Histoplasma capsulatum* (Constantine 1988). The fungus occurs naturally as a soil saprophyte in warm, humid regions on all continents. Its development is enhanced by suitable organic matter such as the feces of bats and birds. Infection occurs upon inhalation of the fungal spores, which become airborne when dry deposits of guano are disturbed.

Researchers entering potentially contaminated bat roosts should wear respirators with filter cartridges capable of filtering out particles as small as 2 microns in diameter, or they should use a self-contained air supply unit (Constantine 1988). There is no vaccine against histoplasmosis. Most people who have visited contaminated bat roosts have positive histoplasmin skin tests, probably reflecting resistance to subsequent infection. Reinfection can occur, however, after exposure to large doses of spores. Care should be taken to avoid creating airborne dust from guano or soil.

**Lyme Disease**

Lyme disease is caused by the bacterium *Borrelia burgdorferi*, a spirochete similar to the organism that causes syphilis. In the United States, the primary vectors that transfer the pathogen to humans are ticks in the *Ixodes ricinus* complex. The disease is usually passed to humans by tiny juvenile (nymphal) ticks, which, unlike the adults, may be unnoticed for the 24 to 48 hours it takes to transmit the disease.

The incidence of Lyme disease has increased steadily in the United States following its original discovery in 1975 in the town of Lyme, Connecticut. Currently Lyme disease is most commonly reported in the northeastern United States, although it has been reported from nearly every part of the country. In the Northeast, the disease is maintained by the white-footed mouse (*Peromyscus leucopus*) and the deer tick (*Ixodes dammini*). The deer mouse provides a meal for the deer tick, and the feeding process keeps the disease thriving by infecting each generation of mice with the Lyme disease–causing spirochete. In southern California, Lyme disease appears to be maintained by the dusky-footed wood rat (*Neotoma*) and by two species of ticks: *Ixodes pacificus*, which feeds on *Neotoma* and humans, and *I. neotoma*, which feeds only on the wood rat. Lyme disease is much more common in the Northeast because only one tick is involved in the cycle. In the East, 25% to 50% of *I. dammini* are infected with the Lyme spirochete, whereas in the West only 1% to 5% of *I. pacificus* are infected.

The occurrence of the nymphal (and biting) stage of the deer tick in the Northeast is highly seasonal. The spring and early summer nymphal stage is about the size of a sesame seed or the period at the end of this sentence. By early fall, when it has become an adult, the tick is larger, but still only about half the size of a dog tick (ca. 2 mm in diameter, although adults engorged with blood may reach 6 mm in diameter). Deer ticks can be found wherever white-tailed deer, on which the adults feed, are found. Because the deer population in the United States has exploded in recent years, the risk of Lyme disease has increased.

The clinical symptoms of Lyme disease usually include a red, ring-shaped expanding rash that develops 2 to 5 days after the bite. Other symptoms include weakness, dizziness, muscle aches, sore throat, and swollen lymph glands. Common sense is the best preventive measure. Investigators must wear light-colored clothes so that ticks will be visible, long-sleeved shirts, and long pants tucked tightly into socks and apply DEET-containing insect repellents to the skin. The body should be searched daily for ticks. Ticks are found most commonly on the legs or thighs, in the groin and armpits, along the hairline, and in or behind the ears. A tick can be removed by grasping its body firmly with forceps and pulling straight out. Antiseptic should be applied to the bite, and the tick drowned in alcohol. Investigators who suspect that they have been exposed to a tick-borne disease should consult a physician.

**Other health hazards**

**Hazards in Caves and Mines**

It is sometimes necessary to census or monitor bat populations in caves and mines. Gases such as am-
monia, sulfur dioxide, carbon monoxide, carbon dioxide, and methane can accumulate in bat caves and mine tunnels and may threaten the health of an investigator (Constantine 1988). These gases may irritate the skin, lungs, and eyes or block access to atmospheric oxygen. Some of the gases are odorless and, if present in high concentrations, may overcome an investigator without warning. Oxygen may be deficient in some caves and mines, and strenuous exercise in such places, coupled with excessive heat and humidity, may adversely affect the depth and frequency of breathing.

Methods for detecting and measuring atmospheric gases are summarized by Constantine (1988), along with recommended limits for human exposure. Researchers are advised to adhere to these standards or risk brain damage, pulmonary impairment, or death. Devices that sound an alarm when they detect a noxious gas or oxygen deficit can be worn. Some species of bats can live in cave environments with concentrations of ammonia or carbon dioxide that would soon kill a person. Thus, one cannot assume that the presence of bats signifies a safe atmosphere (Constantine 1988).

Investigators working in caves with noxious gases or low concentrations of oxygen should wear a respiratory apparatus appropriate for the contaminant gas (Constantine 1988). Protective wear ranges from a simple respirator mask with a filter for each type of gas to a self-contained breathing apparatus with a supply of atmospheric oxygen. Various kinds of respiratory protection systems for use with particular concentrations of gas are described in Mackison et al. (1981). Respirator masks and facepieces are usually available in different sizes and must be individually fitted to ensure effectiveness. If cartridge filters are used, care should be taken not to exceed their useful lives.

Appropriate clothing and at least two sources of lighting should be carried by individuals working in caves. In addition, knowledge of first aid as practiced by cavers and familiarity with cave rescue techniques is recommended (Halliday 1982). No one should ever enter a cave alone, and someone should always be notified if caves and mines are to be entered by research personnel. The National Speleological Society recommends that individuals in the United States notify the National Cave Rescue Commission (by contacting the United States Air Force Rescue Coordination Center) prior to entering caves, to ensure a successful rescue in the event of an emergency.

Climatic Hazards

In cold climates, proper clothing is essential to prevent health problems such as hypothermia and frostbite. Clothing should fit well and be worn in layers, which can be shed when physical activity leads to sweating. During physical activity, the neck and wrist areas should be opened to permit ventilation of the inner layers, so that they do not become wet with sweat and cause chills. Appropriate protection for the head, feet, and hands is also essential in cold climates. In addition, investigators working at elevations over 2,000 m must take precautions against acute mountain sickness (AMS), which is triggered by low blood oxygen levels brought about by rapid ascent. Symptoms include headache, insomnia, fatigue, and gastrointestinal discomfort. Severe cases of AMS can lead to pulmonary and cerebral edema. They can be prevented by eating high-carbohydrate diets, maintaining high fluid intakes, reducing strenuous activity, and ascending gradually. Acetazolamide (Diamox) may be taken as a prophylactic by those who are not allergic to sulpha drugs.

In hot climates, investigators must take precautions against heat exhaustion and heat stroke. Symptoms of water-deficiency heat exhaustion include lack of appetite, restlessness, giddiness, and the passage of small quantities of deeply colored urine. Salt-deficiency heat exhaustion leads to severe muscle cramps, headache, and fatigue. Symptoms of both types of heat exhaustion can be prevented by adding salt to food and regularly drinking fluids in excess of those required to quench thirst. Heat exhaustion due to a sweating disorder (anhidrotic heat exhaustion) can result from working in hot climates for extended periods. Symptoms include a skin rash mainly in the trunk and upper arms, fatigue, rapid breathing, and a frequent urge to urinate (Adam 1988). Individuals with these symptoms must be moved to a cool environment and rest for at least several weeks.

Heat stroke is a life-threatening condition that can be brought about by continuous heat stress (during day and night), a sweating disorder, overindulgence in alcohol and overly strenuous exercise in hot climates. Symptoms include a pounding headache, confusion, a staggering walk, and a high fever without sweating. In the absence of sweating, the person suffering from heat stroke must be fanned to promote cooling by evaporation. The patient must also be wrapped in wet sheets and transferred to a hospital immediately. Heat stroke can occur without direct exposure to the sun, although it is often referred to as sunstroke.
Investigators should take precautions against the harmful ultraviolet rays of the sun, regardless of whether they work in hot or cold climates. Protection against ultraviolet A and ultraviolet B rays can be obtained by applying a broad-spectrum sunscreen cream, oil, or lotion. Sunscreens with a sun protective factor of at least 15 should be used and reapplied every few hours after sweating. A hat or a cap should also be worn to protect the head from the sun.

Venomous Animals

Venomous animals such as snakes, spiders, scorpions, bees, wasps, hornets, and centipedes can cause serious health problems. The probability of encountering these animals, however, is low, unless one goes looking for them.

Victims of venomous snake bites should be reassured; the speed with which snake venom kills has been greatly exaggerated (Warrell 1988). They should then be quickly transported to a hospital, along with the dead snake. Antivenom should never be administered unless epinephrine (0.5 ml of a 1:1,000 solution) is available to combat potential allergic reactions to the antivenom. Additional information on treatment of snake bite can be found in Hardy (1992, 1994a, 1994b).

Bee or wasp stingers should be scraped rather than pulled from the affected site, because the latter action may inject more venom into the skin. Those who are allergic to bee or wasp stings should always carry supplies for the self-administration of epinephrine.

Conclusions

Health problems during field investigations will be minimal for anyone who takes appropriate precautions against potential diseases and health hazards. Seeking timely medical advice, taking the required immunizations, preparing a kit containing all the necessary medications, training in administering first aid and the use of equipment, and mental and physical conditioning are important preliminaries to fieldwork. When fieldwork commences, special attention must be paid to personal hygiene and precautions must be taken against arthropod bites and the consumption of contaminated food and water. A schedule must be developed for medicines that are to be taken at regular intervals. Even ailments that may seem minor must be attended to promptly. In the case of serious illnesses, investigators must seek expert medical attention immediately or as soon as possible. If several investigators work as a team, at least the team leader must be aware of the health status (including allergies and ailments) of every member. The team leader must also develop a plan for emergency evacuations and discuss it with team members.

After extended periods of fieldwork, investigators should consult a physician and have a complete medical examination, including a complete blood count, a test for liver function, and stool examination for intestinal parasites. Serologic tests that screen for malaria, filariasis, hepatitis, schistosomiasis, and other infections should be carried out if investigators suspect that they may have been exposed to these diseases.

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