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## Infections Acquired from Animals Other Than Pets

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### KEY CONCEPTS

- Half of the estimated 1500 human infectious diseases are zoonotic in origin.
- As many zoonotic agents are uncommon in humans and, for a number, have been established as causes of laboratory-acquired infections, good communication with the clinical microbiology laboratory is essential.
- Although the number of infectious agents potentially transmissible from a specific animal to humans may be great, many of these infections are limited geographically and need not be considered unless a bioterrorist event or the introduction of an infection to a new area is a possibility.
- Bats are reservoirs for such emerging diseases as those caused by Nipah virus, Australian bat lyssavirus, the SARS coronavirus, and Ebola virus. While there are more rodent species than there are bat species, bats host more viral zoonoses per species than do rodents.
- The majority of potential agents of bioterrorism are zoonotic.

Zoonotic infections are defined as infections that are transmitted from nonhuman vertebrates to humans. These are acquired from farm animals, pets, beasts of burden, fish, and wild animals via a number of routes (Figure 74-1).

The approach to the patient with a potential zoonotic infection involves the generation of a differential diagnosis that includes those infectious agents that are potentially transmissible from the specific animal(s) to which the patient was exposed. Historical points to consider are summarized in Table 74-1.

Although the number of infectious agents potentially transmissible from a specific animal to humans may be great, many of these infections are limited geographically and need not be considered unless a bioterrorist event or the introduction of an infection to a new area is a possibility. Examples include the lack of plague transmission outside endemic areas, countries that are free of brucellosis, and the limitation of tularemia to the northern hemisphere.

In some cases a good animal exposure history will be elicited but a review of the medical literature will not be able to identify any relevant diseases from that specific animal.

The lack of an effective veterinary or human public health infrastructure in a given country may result in a lack of knowledge of those zoonotic infections transmitted from even commonly encountered animals. For example, camels have been noted to have serologic evidence of infection with *Coxiella burnetii*, but human cases of Q fever as a result of contact with camels or ingestion of camel milk have often been poorly documented.

When there are few data about a particular animal and its role as a reservoir of zoonotic agents, it is worth considering biologically similar animals from which zoonoses have been acquired; for example, *Escherichia coli* O157:H7 infections have been most commonly transmitted to humans via the ingestion of undercooked ground beef. Deer, like cattle, are large grazing herbivores. Humans have been infected after eating venison.

Other important clinical clues to consider include:

- The environment of the animal. For example, shark bite wounds may be infected with *Vibrio* spp., which are commonly found in salt water and as part of the normal oral flora of sharks, whereas freshwater alligator bites are most commonly infected with *Aeromonas hydrophila*, an organism that is found in fresh water and as part of the normal alligator oral flora.
- Consider the diet of the animal. Cattle that have been fed material that includes nervous tissue are at increased risk of having bovine spongiform encephalopathy (BSE).
- Consider other species with which the animal has had contact, including contact with humans while in captivity. Tuberculosis, measles and shigellosis are not normally infectious agents of nonhuman primates. Rather, they are acquired from human contact. Similarly, the housing of camels indoors with cattle increases the risk that the camels will acquire bovine tuberculosis.
- An occupational history, obtained in some detail, can provide important information on those zoonotic agents to which an individual may have been exposed.<sup>1</sup>

As many zoonotic agents are uncommon in humans and, for a number, have been established as causes of laboratory-acquired infections, good communication with the clinical microbiology laboratory is essential. In some cases the diagnosis is established serologically, whereas in others a particular pathogen, perhaps one that requires special culture media or handling, may be isolated. In addition to increasing the probability of correctly identifying the etiology of the patient's illness, good communication is essential for safety, especially when infections due to *Francisella tularensis*, *Brucella* spp., Macacine herpesvirus-1 (cercopithecine herpesvirus type 1; herpesvirus simiae; B virus) and other highly biohazardous agents are under consideration.<sup>2</sup> In those cases in which the pathogen is a potential agent of bioterrorism or is uncommon in humans, even a well-equipped clinical microbiology laboratory may be unable to perform the necessary testing on-site.

The following discussion is organized by type of animal, as this is helpful for the clinician who is attempting to generate a reasonable differential diagnosis.

### Domesticated Herbivores (Cattle, Sheep, Goats, Pigs, Camels, Horses and Related Animals)

#### BACTERIAL INFECTIONS

See also Chapter 72 for a further discussion of occupational risks associated with these infections.

*Brucella melitensis* is most commonly acquired from goats and has been acquired from sheep and dromedary camels. *Brucella abortus* is associated with cattle. Although horses can occasionally become infected, transmission to humans from horses, if it occurs, is very rare. *Brucella suis* has been transmitted to humans from both domesticated and feral pigs. The specificity of the association between the species of *Brucella* and the animal host is not absolute.

Anthrax is most commonly acquired from large domesticated herbivores. Cutaneous anthrax, inhalation anthrax (wool sorter's disease)

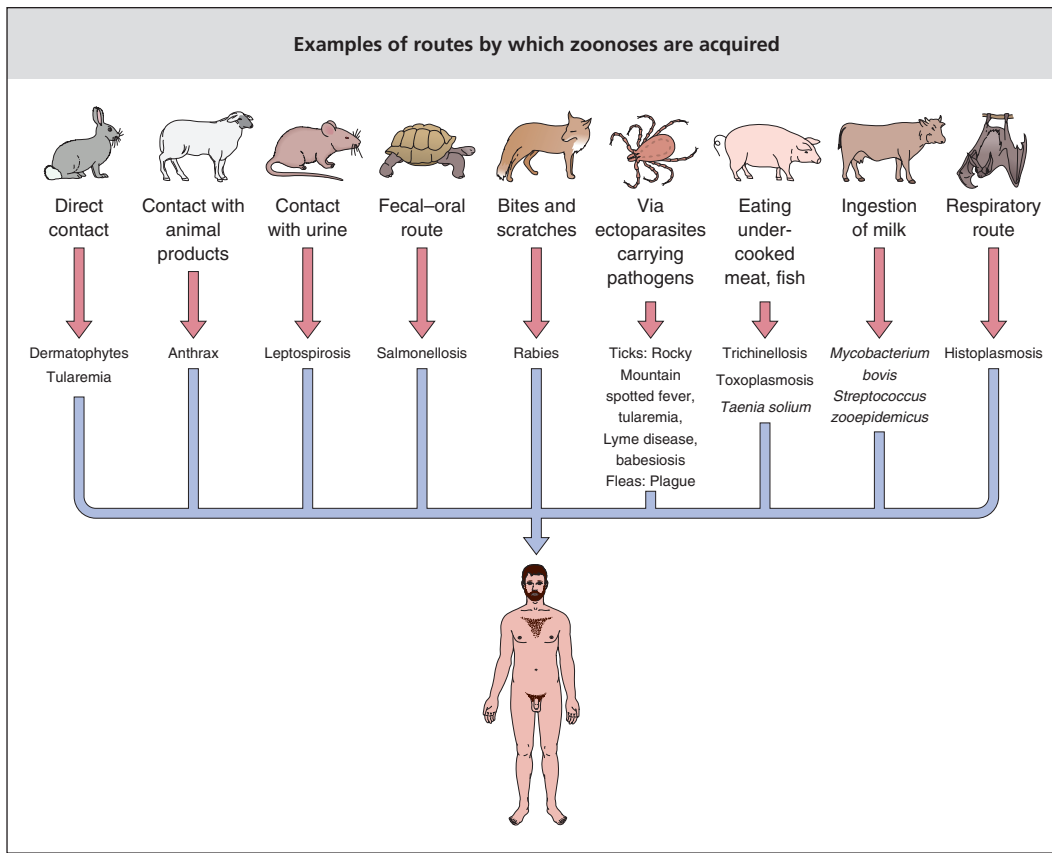


Figure 74-1 Examples of routes by which zoonoses are acquired.

TABLE 74-1 Selected Historical Points in Patient Exposure History	
Historical Finding	Worth Adding to Differential Diagnosis
Contact with any vertebrate, especially reptiles	Salmonellosis
Exposure to urine, either directly or via contaminated water	Leptospirosis, as essentially all mammals can become infected with <i>Leptospira interrogans</i> and shed infectious organisms in the urine
Bites from wild mammals, with the exception of those from rodents other than groundhogs ( <i>Marmota monax</i> )	Evaluate risk of rabies and the potential need for rabies prophylaxis
Itching and a history of cutaneous contact with a mammal	Allergic reaction, dermatophyte infection or infestation with ectoparasites, such as species-specific varieties of <i>Sarcoptes scabiei</i>
Consumption of undercooked wild mammals	Trichinellosis and toxoplasmosis
Consumption of fermented fish or marine mammals	Botulism, most commonly due to the type E toxin
Consumption of uncooked fish	Any of more than 50 parasitic infections, depending upon the species of fish eaten and the geographic locale

and gastrointestinal anthrax are associated with the domestication of sheep, goats, and cattle. In parts of the world in which water buffalo are domesticated they have served as the source of outbreaks of human anthrax, as have oxen. Animal products can transmit this disease.

Epizootics of tularemia, associated with heavy infestation by the wood tick, *Dermacentor andersoni*, occur in sheep. Human cases have included infections in sheep shearers, owners, and herders. In a review published in 1955, 189 human cases of tularemia were reported in association with the sheep industry.<sup>3</sup>

Tuberculosis due to *Mycobacterium bovis* subsp. *bovis* was the impetus for pasteurization of cow's milk. Infection with *M. bovis* subsp. *bovis* is also associated with occupational exposure, as in slaughterhouse workers.

Infection with *Listeria monocytogenes* occurs via ingestion of contaminated food, usually meat and dairy products, and rarely by direct cutaneous exposure during parturition. Cutaneous listeriosis has been reported among veterinarians and other individuals delivering animals.<sup>4</sup> Infections transmitted by ingestion of milk products are listed in Table 74-2.

*Yersinia enterocolitica*, normally found in the fecal flora of pigs, has been transmitted from pigs to humans via contact and by ingestion of chitterlings (pig intestines).<sup>5</sup>

*Erysipelothrix rhusiopathiae* has been acquired from many different animals and animal products. It typically is an occupational illness, often acquired via a hand wound while handling animal material. Alerting the clinical microbiology laboratory to its possibility is of great help, as the organism's identification is not difficult if it is suspected.<sup>6</sup>

*Streptococcus suis*, especially type 2, a pathogen of pigs, is a common cause of bacteremia and bacterial meningitis among individuals working with pigs in Asia.

*Rhodococcus equi* is commonly found in the feces of horses and in the soil. Exposure to farm animals, including horses, has been reported in some cases of human infection.

The association of leptospirosis with swine is well known. It has been called swineherd's disease. Cattle, goats, camels, dogs, and rats are all sources of human infection.

**TABLE 74-2** Agents Transmitted Via Milk Products and Cheese

Disease	Source
<i>Clostridium botulinum</i> toxin	Yogurt, cheese
<i>Brucella</i> spp.	Many animals' milk and cheese
<i>Campylobacter fetus</i>	Cow's milk
<i>Campylobacter jejuni</i>	Cow's milk, cheese from goats
<i>Campylobacter laridis</i>	Cow's milk, contaminated by birds
Central European tick-borne encephalitis	Goat's milk, cheese from goats and sheep
<i>Corynebacterium diphtheriae</i>	Cow's milk
<i>Corynebacterium ulcerans</i>	Cow's milk
<i>Escherichia coli</i> O157:H7 and other strains	Cow's and goat's milk, cream, cheese
<i>Listeria monocytogenes</i>	Cow's milk, cheese
<i>Mycobacterium bovis</i> subsp. <i>bovis</i>	Cow's milk
<i>Salmonella</i> spp.	Many animals' milk, cheese, ice cream
<i>Staphylococcus aureus</i>	Cow's milk
<i>Streptobacillus moniliformis</i>	Cow's milk (single outbreak in 1926)
<i>Streptococcus zooepidemicus</i>	Cow's milk, cheese
<i>Toxoplasma gondii</i>	Goat's milk
<i>Yersinia enterocolitica</i>	Cow's milk

Exposure of pregnant women to the birth products of sheep and goats that are infected with *Chlamydophila abortus* (*Chlamydia psittaci*, serotype 1) has been reported in both Europe and the USA, and can be severe, resulting in abortion.<sup>7</sup>

Salmonellosis has been transmitted to humans by each of these animals. Pigs have been documented as a source of human cases of multidrug-resistant *Salmonella enterica* serotype *typhimurium* definitive phage type 104 (DT104) infection.<sup>8</sup>

*Escherichia coli* O157:H7 is often present in the gastrointestinal tract of cattle and is most commonly acquired via ingestion of undercooked ground beef. Transmission due to fecal contamination of food products can occur, such as from unpasteurized apple cider prepared from apples that were on the ground in a cattle pasture and used for cider production. Deer, like cattle, are large grazing herbivores and have been reported to transmit this infection to humans who have consumed venison. Outbreaks have been associated with visits to petting zoos. Shiga toxin-producing *E. coli* other than *E. coli* O157:H7 cause approximately half of human Shiga toxin-producing *E. coli* infections.

*Pasteurella aerogenes* is the most commonly isolated organism from human infections following the bites of swine.<sup>9</sup> A number of other gram-negative organisms have also been isolated from these infections. Camel bite injuries typically become infected and are particularly likely from male camels during the rutting season. Members of the genus *Actinobacillus* have been recovered from bites of horses and cattle. *Pasteurella caballi* has been isolated from wounds following horse bites. Rabies has been reported in all of these animals as well as in llamas.

Human cases of Q fever are acquired from birth products of sheep, goats, and cattle, as well as from cats. Airborne infection can occur over significant distances. The data on human acquisition via contaminated milk are less compelling.

Glanders, due to *Burkholderia mallei*, has been transmitted to humans via equids. The disease is limited geographically so its isolation from a patient in North America or Europe must be assumed to be due to bioterrorism until proven otherwise.

## VIRAL INFECTIONS

Localized cutaneous involvement can be due to infection with parapoxviruses that include orf virus (which causes contagious ecthyma and is transmitted by sheep and goats either directly or via fomites), bovine papular stomatitis virus and pseudocowpox virus; and by the orthopoxviruses cowpox virus (which is more commonly transmitted to humans via cats than cattle) and buffalopox virus. The host range of influenza A virus includes many mammals, including marine mammals, swine and horses.

Variant Creutzfeldt–Jakob disease (variant CJD) has been reported from the UK, France, Japan and other countries. It is associated with the consumption of meat from cattle that were infected with BSE. Although cases of BSE have been identified in the USA, no cases of variant CJD have been identified from consumption of US cattle. Prion diseases of large herbivores in the USA, including chronic wasting disease of cervids, have raised the possibility of the introduction of additional prion diseases into the human food supply. A detailed discussion of the molecular aspects of prion-associated disease and the clinical manifestations of the spongiform encephalopathies is found in Chapter 23.

Many cases of the Middle East Respiratory Syndrome (MERS) have occurred in people who had contact with dromedary camels. Viruses isolated from infected camels are indistinguishable from those isolated from people. As of April 2015, 1123 cases and 463 deaths have been reported due to MERS. Cases from the Middle East have been imported into a number of countries. On the basis of DNA sequencing, there appear to be multiple independent viruses causing MERS.

Rift Valley fever, which infects domestic ruminants, can be transmitted to humans by mosquitoes and by contact with the tissues of slaughtered, infected animals such as sheep.<sup>10</sup> Similarly, Crimean–Congo hemorrhagic fever infects a variety of animals, including cattle and sheep, and is transmitted to humans via ticks (especially *Hyalomma* spp.), via contact with blood of infected animals, and in the hospital setting.

Hendra virus, a paramyxovirus, caused infections of horses and a few individuals in contact with these horses in Australia. The natural reservoir is a flying fox (bat). Nipah virus was the cause of an epidemic of encephalitis that affected more than 250 people in Malaysia and Singapore, killing 105 people. More recent outbreaks have occurred in India in West Bengal in 2001 when it killed three-quarters of the 66 infected people and in Bangladesh in 2004 when it killed 18 of 30 infected people. While in early outbreaks infected people had contact with pigs, which were culled to stop the epidemic, more recent outbreaks in Bangladesh have been associated with the consumption of fresh date palm sap that had been contaminated by bats. There has been concern about the possibility that some cases were due to person-to-person transmission. The natural reservoir of Nipah virus, a paramyxovirus that is related most closely to the Hendra virus, has been identified as a bat. Menangle virus, also a paramyxovirus, caused infections of pigs and in humans in contact with infected pigs in Australia. The natural reservoir has been identified as a flying fox (bat).

There is concern of the possibility of certain endogenous porcine retrovirus infections causing disease in humans following xenotransplantation of organ tissues from pigs. Some of these retroviruses can propagate in human cell lines and they could potentially induce immunodeficiency in experimental systems.<sup>11</sup> This poses a potential risk of activation of porcine retroviruses in the setting of an unnatural host such as an immunosuppressed, solid organ human transplant recipient. Porcine heterografts for heart valve replacement surgery are unlikely to be complicated by inadvertent activation of porcine retroviruses. Glutaraldehyde fixation and sterilization of porcine heart valves eliminates infectivity of endogenous retroviruses.<sup>12</sup>

There have been outbreaks in Brazil among cattle and people who had contact with cattle infected with strains of vaccinia virus. In some cases there have been significant deletions of parts of the viral genome.

## PARASITIC INFECTION

A 1993 epidemic of cryptosporidiosis occurred in Milwaukee, Wisconsin, in which the public water supply was contaminated and infected more than 400 000 people. The epidemic was traced to untreated water from Lake Michigan from which the causative organism was incompletely removed by water filtration. Possible sources included cattle along two rivers, slaughterhouses and human sewage.<sup>13</sup> Human cases of cryptosporidiosis also occur via direct contact with cattle and sheep (the disease primarily occurs in lambs).

Echinococcal disease, although not transmitted to humans directly from sheep, occurs in areas of the world in which sheep serve as an intermediate host and in which dogs ingest sheep viscera, subsequently excreting infective eggs in their feces.

The pig ascarid *Ascaris suum* has caused human infection.<sup>14</sup>

*Taenia solium*, the pork tapeworm, is acquired via the ingestion of undercooked infected pork. Alternatively, infection may occur as a consequence of ingestion of infective eggs, as when someone infected by *T. solium* prepares food and contaminates the food with infective eggs that are present in his or her feces.<sup>15</sup> *Trichinella spiralis* is most commonly acquired from eating undercooked pork. Trichinellosis has also been acquired following the ingestion of horse meat.<sup>16</sup> *Taenia saginata*, the beef tapeworm, is acquired via the ingestion of undercooked beef. Toxoplasmosis can be acquired via the ingestion of undercooked meat, especially lamb, as well as from contaminated goat's milk.

## DERMATOPHYTE INFECTION

Infection with zoophilic dermatophytes commonly occurs following contact with these animals. This includes, for example, *Trichophyton verrucosum* spread from cattle to humans, and *T. equinum* from horses.<sup>17</sup>

## Bats

There is great interest in viral infections of bats. Rabies virus is known to occur in many species of bat. Transmission of rabies to humans follows bite, scratch and, far less often, inhalation of aerosolized saliva. Bats also account for many cases of rabies in livestock. Other Lyssaviruses that have been transmitted to humans from bats include European bat Lyssavirus-1, European bat Lyssavirus-2 and Australian bat Lyssavirus.<sup>18</sup> Most recent reports of human rabies from bat exposure find no clear evidence of a documented bat bite. Transmission apparently occurs from inadvertent bites or from unrecognized contact with the bat saliva. This forms the rationale for the administration of rabies immune globulin and rabies vaccine when a bat is found in the room upon awaking from sleep, in the room of a small child, or in the room of an intoxicated or mentally challenged person<sup>19</sup> (see Chapter 171). However, given the large number of people (approximately 2.7 million with bedroom exposure and without a bite) who would have to be treated with rabies immune globulin and the rabies vaccine in order to prevent a single case of human rabies, this recommendation is controversial.<sup>20</sup> As noted above, bats have been found to be reservoirs of the zoonotic paramyxoviruses Nipah virus, Hendra virus and Menangle virus.<sup>21</sup> In addition, after decades of active research, bats have been identified as the reservoirs of both Ebola virus<sup>22</sup> and Marburg virus.<sup>23</sup>

Outbreaks of histoplasmosis due to *Histoplasma capsulatum* have been associated with exposure to bat guano in caves, after disturbing piles of bat guano in old buildings<sup>24</sup> and clearing debris from a bridge.<sup>25</sup>

While bacteria that are established as pathogens of humans, including members of the genera *Salmonella*, *Shigella*, *Campylobacter*, *Yersinia*, *Leptospira*, and *Pasteurella*, have been isolated from bats, transmission from bats to humans of these organisms has not been documented.

## Nonhuman Primates

The pathogens found in nonhuman primates (NHPs) include many human pathogens that have subsequently caused human illness when the infected primates transmit these infections back to humans. These

pathogens include bacterial (*Shigella* and *Salmonella* spp.), mycobacterial (*M. tuberculosis*), viral (hepatitis A virus), parasitic (*Entamoeba histolytica*), and fungal (dermatophyte) agents. In addition, there are infectious agents of human origin that infect NHPs and that have not been reported to be transmitted back to humans. These include measles virus and (human) herpes simplex virus type 1.

The host range of viral pathogens of NHPs may include humans. Some of these viruses are particularly virulent in humans. Historically, it is worth noting that molecular evidence suggests that HIV-1 was originally a pathogen of chimpanzees, *Pan troglodytes troglodytes*, and that HIV-2 was originally a pathogen of sooty mangabeys. There are numerous simian immunodeficiency virus (SIV) strains and it is possible that one or more might be transmitted to humans via contact such as through butchering, ingestion or by growing the pathogen and subsequently spread from human to human. Transmission of SIV occurred in a laboratory worker.<sup>26</sup> Infections due to simian foamy viruses, which are also retroviruses, have been well documented following exposure to NHPs in zoos, primate centers, and in people who hunt and butcher primates in Africa. Human infections by simian foamy viruses originating in such diverse species as gorillas, chimpanzees, baboons and macaques (in Asia) have all been documented, though no long-term health effects on humans from these infections have been demonstrated.

The possibility of life-threatening infection with the neurotropic Macacine herpesvirus-1 (also known as B virus, as cercopithecine herpesvirus-1, and as herpesvirus simiae) must be considered in bites, scratches and contact with tissue or saliva from the rhesus monkey, *Macaca mulatta*.<sup>27</sup> There are distinct genotypes of the virus and the isolates from different primate species vary in their pathogenicity for humans. The National B Virus Resource Center at Georgia State University (website: <http://www2.gsu.edu/~wwwvir/>) is the reference laboratory for the USA.

There has been transmission from NHPs of filovirus infections, including both Ebola strains of African origin and the Reston strain of Ebola, which is less pathogenic for humans than other strains of Ebola. Marburg virus, a filovirus causing hemorrhagic fever with high mortality, was first transmitted from vervet (or green) monkeys to humans.

Monkeypox, an orthopoxvirus, was initially identified in human cases of illness that were clinically consistent with smallpox, though adenopathy occurs in these infections. It is found in NHPs and in squirrels and other rodents in Africa and has been transmitted from human to human. Tanapox (benign epidermal monkeypox) has been transmitted to humans both via mosquitoes and by direct contact with monkeys in primate centers in the USA, but has not been transmitted from human to human. Yabapox virus has, rarely, caused subcutaneous growths at the site of inoculation.

Kyasanur forest disease virus, a member of the tick-borne encephalitis subgroup, is found in Karnataka, a state in India, and has a number of NHP reservoirs. The presence of dead monkeys in the endemic area, which is expanding, may precede an epidemic.

Rabies has been reported in NHPs. With the exception of a report in which the white-tufted-ear marmoset (*Callithrix jacchus*) was the source of eight human cases of rabies in Brazil,<sup>28</sup> transmission of rabies from NHPs to humans is rare.

## Mustelids (Ferrets, Skunks, Otters, Mink, Weasels, Badgers, Martens)

Influenza A virus was transmitted in a laboratory setting when a researcher was infected by a ferret that had been infected with a strain of influenza A virus and which 'sneezed violently at close range' while it was being examined.<sup>29</sup> Ferrets are susceptible to influenza A and B viruses. Mink that are in mink farms have been found to be infected with influenza A viruses.<sup>30</sup>

There is a report of *M. bovis* subsp. *bovis* infection of the right palm more than 20 years following a ferret bite.<sup>31</sup> *M. bovis* subsp. *bovis* is known to infect wild ferrets and badgers. There is a case report of sporotrichosis complicating a badger bite. Rabies infection is known

to occur in skunks, otters, badgers, weasels, mink and ferrets (including pet ferrets). Transmission of rabies from skunks to humans has been documented.<sup>32</sup> A rabies vaccine has been licensed in the USA for use in ferrets; recommendations are for primary immunization at 3 months and booster immunizations annually.<sup>33</sup> The recommendations regarding a healthy ferret that bites a human are the same as those for dogs and cats with respect to confinement and observation for 10 days, with evaluation by a veterinarian at the first sign of illness.<sup>33</sup>

Rat-bite fever as a result of ferret and weasel bites was reported in the medical literature between 1910 and 1920. Only in a report of a weasel bite was there isolation of an organism from the patient's blood.<sup>34</sup> Trichinellosis has been reported in people who ate inadequately cooked or raw liver, spleen, blood and muscle of a badger.<sup>35</sup>

## Rodents

*Yersinia pestis* is transmitted in epidemics from rats to humans via the rat flea, *Xenopsylla cheopis*. Numerous rodents and other mammals serve as reservoirs of *Y. pestis*, some of which have been responsible for cases of human plague. Similarly, tularemia is widely distributed in nature and has been transmitted to humans by many different rodents.

Leptospirosis is commonly associated with skin or mucous membrane exposure to water contaminated by the urine of rodents, including rats, mice and voles. It has rarely been reported to be transmitted via rodent bite.<sup>36</sup> Other uncommonly reported bacterial infections following rodent bites include *Pasteurella multocida*, the *Pasteurella* 'SP' group and sporotrichosis. Rat-bite fever can be due to either *Streptobacillus moniliformis* or *Spirillum minus*. The former has been transmitted to humans not only by wild rats but also by laboratory rats, mice and other rodents.

It is unclear how often rodents cause cases or outbreaks of human salmonellosis. There have been multi-state outbreaks of human salmonellosis that originated in frozen 'feeder' mice that were fed to reptile and amphibian pets<sup>37</sup> and from pet rodents.<sup>38</sup> Given that *Salmonella* spp. are commonly recovered from rodent feces, the serotypes commonly recovered from rodents are similar to those recovered from cases of human disease, and as rodents often infest human dwellings, restaurants and food production facilities, it is likely that rodents account for some fraction of human salmonellosis cases.

Many of the tick-borne relapsing fevers have wild rodents as reservoirs. This is also the case for *Babesia microti*, Lyme disease and human granulocytic anaplasmosis. The reservoirs of Colorado tick fever include squirrels, chipmunks and other rodents. Similarly, Powassan encephalitis, tick-borne encephalitis, and Omsk hemorrhagic fever virus are transmitted via ticks and have small mammals as reservoirs. *Leishmania* spp. often have rodents as reservoirs.

Those members of the Hantavirus genus that are known to cause hantavirus pulmonary syndrome (HPS) are carried by New World rats and mice, family Muridae, subfamily Sigmodontinae, and are transmitted via the inhalation of rodent excreta or saliva or, rarely, via rodent bite. In the USA and Canada, the viruses include Sin Nombre virus, the main cause of HPS, transmitted by the deer mouse (*Peromyscus maniculatus*) and other less common rodent-borne hantaviruses. In South America, viruses include Andes virus in Argentina, Chile and Uruguay transmitted by the long-tailed pygmy rice rat (*Oligoryzomys longicaudatus*), a virus for which there is epidemiologic evidence of person-to-person transmission; Jucuitiba virus in Brazil; Laguna Negra virus in Paraguay, transmitted by the vesper mouse (*Calomys laucha*); and Bermejo virus in Bolivia. Additional hantaviruses have been discovered as well. Hantaviruses that are associated with hemorrhagic fever with renal syndrome in Europe and Asia include Hantaan virus, transmitted by the murine field mouse (*Apodemus agrarius*); Dobrava virus transmitted by the murine field mouse (*Apodemus flavicollis*); Seoul virus, transmitted by the Norway rat (*Rattus norvegicus*) in Asia; and Puumala virus transmitted by the bank vole (*Clethrionomys glareolus*).<sup>39</sup>

Arenaviruses are transmitted from rodents via the excreta and urine. These include lymphocytic choriomeningitis virus, which is

found worldwide and has been transmitted to humans by hamsters<sup>40</sup> as well as mice; Machupo virus, which causes Bolivian hemorrhagic fever and is transmitted by *Calomys callosus*; Junin virus, which causes Argentinian hemorrhagic fever and is transmitted by *Calomys* spp.; Guanarito virus, which is found in Venezuela; Lassa fever virus, which is found in Africa and is transmitted by the multimammate rat, *Mastomys natalensis*; and a recently described New World arenavirus that caused three fatal infections in California and shared 87% identity with the Whitewater Arroyo virus at the nucleotide level.<sup>39</sup>

Reservoirs of cowpox virus include several rodents. This is consistent with the epidemiology of cowpox in which cat contact is implicated. Cowpox, or a similar virus, has also been transmitted via rat bite.<sup>41</sup>

A multi-state outbreak of more than 70 cases of monkeypox occurred in the USA following the importation of exotic rodents from Ghana and affected people who had contact with pet prairie dogs that had been in contact with the African rodents at an animal distributor.

Rickettsialpox has been associated with infestation of mice (*Mus musculus*) with mites which serve as the vector for human disease.<sup>42</sup> Rodents serve as reservoirs for many other rickettsial diseases, including murine typhus in which rats have historically been the reservoir, though in areas of California and Texas cats and opossums serve that role; *Rickettsia prowazekii*, which has been associated with flying squirrels;<sup>43</sup> scrub typhus, in which rats are hosts of the trombiculid mite vectors; and members of the spotted fever group.

Although the issue of whether giardiasis is commonly zoonotic in origin is debated, beavers may have been the source of an outbreak of water-borne giardiasis.<sup>44</sup>

Ingestion of rodents has been associated with rare cases of trichinellosis, such as following the ingestion of squirrel and bamboo rat.<sup>45</sup> There has been speculation on whether consumption of squirrel brains causes a spongiform encephalopathy, but data are limited.<sup>46</sup> Eating fermented beaver has resulted in botulism.<sup>47</sup>

*Trichophyton mentagrophytes* var. *mentagrophytes* is a common zoonophilic dermatophyte, infecting humans and domestic animals. Rodents are regarded as the reservoir of this mold.

## Lagomorphs (Rabbits, Hares)

Tularemia, also known as rabbit fever, has been acquired from rabbits and hares as a result of cutaneous contact and skinning of the animals, presumably by entering via microabrasions in the skin or via the conjunctiva, and following ingestion.<sup>4,48</sup> Transmission via infectious aerosol has been reported as a result of mowing over a rabbit.<sup>49</sup> Tularemia transmission to humans has not been reported from domesticated rabbits. Although uncommon, eight cases of human bubonic plague from 1950 to 1974 were reported as a result of contact (e.g. skinning) with rabbits and hares<sup>50</sup> in plague-endemic areas of the USA. Q fever has been transmitted to humans following contact with wild rabbits.<sup>51</sup>

A patient with *Bordetella bronchiseptica* respiratory infection was shown to be due to a strain that was indistinguishable by pulsed-field gel electrophoresis from the strain isolated from a respiratory tract isolate from one of 20 farm rabbits that slept with a cat with which the patient had contact.<sup>52</sup>

## Raccoons

The raccoon ascarid, *Baylisascaris procyonis*, has caused cases, including fatal ones, of meningoencephalitis, often with an associated cerebral spinal fluid (CSF) eosinophilia and usually in young children who accidentally ingest infectious ova.<sup>53</sup> Ocular involvement has also been reported. Leptospirosis has been reported from contact with raccoons.<sup>54</sup> Rabies is common in raccoons, although transmission of the strain found in raccoons to humans in the USA has only been rarely reported.

## Mongoose

Leptospirosis is common among mongooses in Hawaii<sup>55</sup> and a number of Caribbean islands.<sup>56</sup> Rabies is quite common among many species

of mongoose and accounts for a significant number of cases of human exposure to rabies in the Caribbean. It is the principal rabies reservoir in South Africa and it may be an important source of wildlife rabies in India.<sup>57</sup>

## Insectivores

Hedgehog contact, notably with pet hedgehogs, has transmitted salmonellosis<sup>58</sup> and dermatophyte infections due to *Trichophyton erinacei*.<sup>59</sup> In an outbreak of leptospirosis in Italy in which 32 of 33 confirmed cases were contracted by drinking water at the same water fountain, a dead hedgehog was found in a water reservoir connected to the system, although isolation of *Leptospira* spp. from the hedgehog was not attempted.<sup>59</sup>

The Asian house shrew, *Suncus murinus*, may be infested with the oriental rat flea, *Xenopsylla cheopis*, and infected with *Yersinia pestis*. It may well be important in the maintenance of plague between epidemics. Insectivores also appear to be reservoirs of tick-borne encephalitis and tularemia.

## Marine Mammals (Seals, Sea Lions, Walrus, Whales, Dolphins, Porpoises, Manatees)

At the case report level, there are several infections that have been transmitted from marine mammals to humans. Leptospirosis, which is commonly encountered in seals and the California sea lion, was transmitted from an infected sea lion pup to a human. Two people developed leptospirosis after performing a necropsy on a sea lion that died of leptospirosis.<sup>60</sup> Human infection with *Erysipelothrix rhusiopathiae* has been reported among veterinarians and veterinary students caring for or performing autopsies on cetaceans.<sup>61</sup> In these reports, the isolation of the organism was not made from the human cases. Two of three people who cared for affected gray seals developed 'single milker's nodule-like lesions' on the fifth finger of the right hand. The lesions from the seal handlers demonstrated virus particles that were identical to the virus particles from the seals' pox lesions and were characteristic of the paravaccinia subgroup of poxviruses.<sup>62</sup> In 2005, a marine mammal technician who was bitten by a seal developed an orf-like lesion that was ultimately demonstrated to be due to seal pox on the basis of polymerase chain reaction (PCR) and sequencing of the amplified DNA.

Pulmonary tuberculosis due to a member of the *Mycobacterium tuberculosis* complex that is similar to *M. bovis* has been transmitted from seals in a marine park in Western Australia to a seal trainer who developed pulmonary tuberculosis 3 years after his last exposure to the animals with an isolate of the *Mycobacterium* that could not be distinguished from the seal isolates on the basis of DNA restriction endonuclease analysis.<sup>63</sup> Seal trainers are in very close contact with seals which, by barking and coughing, are potentially able to transmit infection via the aerosol route.

Four people involved in necropsies of harbor seals from which influenza A virus A/Seal/Mass/1/80 (H7N7) was isolated developed purulent conjunctivitis but did not have detectable antibodies in single serum samples 3–6 months after the exposure to the influenza A virus isolated from the seals.<sup>64</sup> A seal that was known to be infected with the influenza A virus sneezed into the face and right eye of a person who subsequently developed conjunctivitis from which the virus was isolated.<sup>65</sup> Influenza A virus has also been isolated from cetaceans.

Numerous cases of 'seal finger' have been reported in people who have been bitten or scratched by seals and from skinning or handling seals. Seal finger often responds to tetracycline therapy. The etiologic agent has not been established. Other organisms that have been transmitted via the bite of marine mammals include a single case report of *Mycoplasma phocacerebrale*, which was isolated from the drainage material from a patient's fingers and swabs from the seal's front teeth.<sup>66</sup>

Consumption of whale, seal and walrus meat is not uncommon among the Inuit in Canada, Alaska, Greenland and Siberia. There have

been large epidemics of salmonellosis resulting from consumption of whale meat from floating and beached whale carcasses that have been used as the source of food. Trichinellosis (trichinosis) has been acquired following the consumption of raw or undercooked walrus meat. The clinical presentation in arctic trichinellosis due to *Trichinella nativa* differs from that of classic trichinellosis caused by *Trichinella spiralis* in that the most prominent clinical symptoms in arctic trichinellosis are gastrointestinal, with prolonged diarrhea.<sup>67</sup> Food-borne botulism, typically due to *Clostridium botulinum* type E, has been acquired from the consumption of fermented foods including beluga whale meat, seal meat, seal flippers and walrus meat.

## Armadillos

Both experimental and naturally occurring leprosy in nine-banded armadillos has been noted and there has been a body of literature (reviewed by Blake *et al.*<sup>68</sup>) that suggests that contact with armadillos may have been the source of leprosy in some patients in the USA and Mexico. Sporotrichosis has been found to be highly associated with armadillo contact in Uruguay.<sup>69</sup>

## Birds

Psittacosis is transmitted to humans not only via pet birds, but also via turkeys, wild and domestic pigeons, ducks, and other birds.<sup>70</sup>

Salmonellosis has been acquired from contact with birds and from consumption of birds (e.g. chicken, turkey) and eggs.<sup>71</sup> *Campylobacter jejuni* and *C. laridis* infections have been associated with both the consumption of birds and, interestingly, consumption of milk that has been pecked by magpies (*Pica pica*) and jackdaws (*Corvus monedula*).<sup>72</sup> *Erysipelothrix rhusiopathiae* has been acquired from bird contact. Newcastle disease virus of fowl, an occupational disease, causes an acute conjunctivitis that may be associated with preauricular adenitis.<sup>73</sup>

Histoplasmosis, often in large outbreaks, has been the result of inhalation of bird excreta.<sup>74</sup> Infection with *Cryptococcus neoformans*, which is known to be found in bird droppings, has at the case report level been linked to exposure to pet birds<sup>75</sup> and fancy pigeons.<sup>76</sup>

Avian strains of influenza A virus represent a global concern, as the host range of the viruses may include humans. There exists the potential for pandemic influenza as a result of the introduction of an avian virus with a hemagglutinin to which humans lack immunity.<sup>77</sup> For a detailed discussion of the risks associated with avian influenza please refer to Chapter 172.

The epidemic of West Nile virus infection in the USA and Canada is largely attributable to the introduction of this flavivirus into a new ecologic niche in wild birds in North America.<sup>78</sup> Blackbirds, crows, other wild birds and domestic chickens are susceptible to this viral illness and this forms the reservoir for this mosquito-transmitted infection that is responsible for a potentially lethal form of viral encephalitis.<sup>79</sup>

Tularemia has been, at the several case report level, acquired from wild birds. A case of Crimean–Congo hemorrhagic fever in an ostrich farm worker who was involved in the slaughter of ostriches, *Struthio camelus*, and handled the fresh blood and tissues of the birds, has been reported. There were numerous adult *Hyalomma* ticks on the ostriches and he likely was infected either directly due to skinning the ostriches or as a result of the presence of the ticks on the ostriches.<sup>80</sup>

## Fish

In addition to the normal flora of the fish, a wound can become infected with environmental bacteria. The species of bacteria that live in water are dependent on both salinity and temperature. Estuarine and freshwater bacteria include members of the genera *Vibrio*, *Aeromonas* and *Plesiomonas*. As a result, the etiologic agents isolated from an infected wound from a fish bite, spine, or fin injury that occurs in salt water may well be different from one that occurs in fresh water. The normal flora of teeth in salt-water sharks includes, for example, *Vibrio* spp., including *V. harveyi* (formerly *V. carchariae*), an organism that was the cause of infection following the bite of a great white shark.<sup>81</sup>

By contrast, *Edwardsiella tarda* is commonly isolated from catfish injuries occurring in fresh water. Other organisms that have caused wound injuries as a result of injuries from fish include *Aeromonas* spp., *Erysipelothrix rhusiopathiae*, *Mycobacterium marinum*, *Mycobacterium terrae*, *Streptococcus iniae*, *Vibrio vulnificus* and *Vibrio vulnificus* serovar E (biotype 2; indole-negative) from eels.<sup>82</sup> *Vibrio alginolyticus*, *Photobacterium damsela* subsp. *damsela* (formerly *Vibrio damsela*), *Shewanella putrefaciens*, *Pseudomonas aeruginosa* and *Halomonas venusta* have been isolated from fish bites and injuries. It is not always clear whether the source of the organism is the fish or the water.

Ingestion of fish or fish products can pose a significant risk of acquiring both bacterial and parasitic infections unless the fish has been well cooked.

*Vibrio* spp., including *V. fluvialis*, *V. hollisae*, *V. parahaemolyticus* and *V. cholerae* O1,<sup>83</sup> have all been associated with fish consumption, as has *P. shigelloides*. Eel consumption has been associated with *Photobacterium damsela* subsp. *damsela* (formerly *Vibrio damsela*).<sup>84</sup> *Listeria monocytogenes* infections have been associated with the consumption of fish, including vacuum-packed salmon and cold-smoked rainbow trout.<sup>85</sup>

Fish-associated botulism is usually due to type E toxin and in the USA is most common among Alaskans. Fermented fish eggs, fish eggs, home-marinated fish and dry salted fish have all been implicated. Consumption of apparently fresh (unpreserved and unfermented) fish in Hawaii resulted in three adults with botulism due to type B toxin.<sup>86</sup> Numerous parasitic infections have been reported following the consumption of raw, undercooked, pickled and lightly or cold-smoked fish. Selected cestodes, trematodes and nematodes acquired from the consumption of fish are listed in Table 74-3.

## Amphibians

Contact with amphibians has rarely transmitted salmonellosis, but has transmitted sparganosis due to *Diphyllobothrium (Spirometra) mansoni* via the use of contaminated frog flesh as a poultice (reviewed by Huang and Kirk<sup>87</sup>) and, rarely, intraocular *Alaria* spp., as reported in a woman with a long history of frog collection and food preparation.<sup>88</sup>

Ingestion of frogs has transmitted sparganosis. Infection with the trematode *Fibricola seoulensis* occurred after 10 Korean soldiers ate raw or undercooked flesh of snakes or frogs during survival training.<sup>89</sup> Two cases of intraocular infection with an *Alaria* spp. occurred in Asian-Americans in California who consumed cooked frogs' legs in Chinese dishes.<sup>90</sup> Frogs' legs have a very high rate of contamination with *Salmonella*.

## Bears

There is a published report of transmission of leptospirosis to two zoo employees in which the most likely source was an ill polar bear cub.<sup>91</sup> There are few published reports on infections following bear bites. A man shot and killed a grizzly bear in Alaska and scratched his left index finger on one of the bear's teeth while removing the bear's tongue, resulting in a *Mycobacterium chelonae* subsp. *abscessus* infection.<sup>92</sup>

In multiple reports, consumption of undercooked bear meat has caused trichinellosis. Bear steaks are often served rare, in part because

TABLE 74-3 Selected Parasites Transmitted Via Consumption of Fish

Parasite	Type of Parasite	Types of Fish
<i>Diphyllobothrium latum</i>	Cestode	Salmon, pike, perch, burbot
<i>Diphyllobothrium pacificum</i>	Cestode	Marine fish
<i>Diphyllobothrium ursi</i>	Cestode	Salmon
<i>Nanophyetus salmincola</i>	Trematode	Usually salmonids
<i>Heterophyes heterophyes</i>	Trematode	Mullet, tilapia, mosquito fish
<i>Haplorchis yokogawai</i>	Trematode	Mullet
<i>Haplorchis taichui</i>	Trematode	Mullet
<i>Opisthorchis sinensis</i>	Trematode	Freshwater fish
<i>Opisthorchis viverrini</i>	Trematode	Freshwater fish
<i>Opisthorchis felineus</i>	Trematode	Freshwater fish
<i>Metorchis conjunctus</i>	Trematode	Freshwater fish
<i>Anisakis simplex</i>	Nematode	Salmon, tuna, herring, mackerel, others
<i>Pseudoterranova decipiens</i>	Nematode	Cod, pollock, haddock, salmon, Pacific rockfish
<i>Eustrongyloides</i> spp.	Nematode	Killifish, estuarine fish, minnows
<i>Diocotophya renale</i>	Nematode	Freshwater, estuarine fish
<i>Capillaria philippinensis</i>	Nematode	Freshwater, estuarine fish
<i>Gnathostoma spinigerum</i>	Nematode	Freshwater fish

they are somewhat 'tough' if they are fully cooked. Bears are known to have a high rate of toxoplasmosis and the possibility of a dual infection (trichinellosis and toxoplasmosis) in a person who ingested undercooked bear meat has been reported.<sup>93</sup> Note that acute hypervitaminosis A occurs following the ingestion of polar bear liver.

## Large Herbivores (Elephants, Rhinoceroses)

The few infections transmitted to humans include *M. tuberculosis* from elephants,<sup>94</sup> *M. bovis* from rhinoceroses<sup>95</sup> and an orthopoxvirus (possibly cowpox) from elephants to humans. It is likely that many cases of tuberculosis in elephants, which are almost all due to *M. tuberculosis*, are due to human-to-elephant transmission. In the USA, approximately 3% percent of elephants are infected with *M. tuberculosis*.<sup>96</sup>

References available online at [expertconsult.com](http://expertconsult.com).



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