Gardens as a Source of Infectious Disease: Reducing the Risk

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Introduction

The purpose of this publication is to review the risk of infectious disease from gardening in South Florida. Although written primarily as a resource for persons involved in organizing and running a community garden, the topics covered should be of interest to all active gardeners, small nursery owners as well as health professionals

The sources of infection are first briefly stated, followed by a review of the types of infectious agents that can cause disease. While much of the emphasis is on food borne infectious agents that can contaminate home grown produce, reference is also made to pathogens that may be encountered directly during the course of gardening activities. **Based upon the information reviewed a set of guidelines are presented at the end of the document as a basis for minimizing the risk of disease while gardening. If you are unable to read the entire review, please take the time to read this section.**

. In many instances those at greatest risk are young children or persons with an impaired immune response, due either to disease (e.g. AIDS, diabetes or alcoholism), chemotherapy, surgery (e.g. splenectomy) or age. For all however, certain precautions are warranted when gardening, so that what should be a pleasurable activity is not a source of discomfort or distress.

The Principal Sources of Infection Present in the Garden

Soil Naturally occurring soil dwelling microbes including bacteria (*Clostridia* and *Bacillus* species), as well as various saprophytic bacteria (*Listeria*), free living Protozoa (e.g. *Acanthamoeba spp*.) and fungi (causing mycetoma), are all documented as causes of illness in humans. Other fungal pathogens (e.g. *Histoplasma capsulatum* and *Blastomycoses dermatitidis)* have also been recovered from soil. Soil can also be a source of infection due to contamination with pathogens present in the urine or stools of either wild or domesticated animals. In such instances the risk of infection will depend on both the resilience of the pathogen and continuing contamination of the site.

Plants Plants can be a source of infection due to direct inoculation through spines or prickles (as with sporotrichosis), or ingestion of edible parts contaminated with organisms present in soil or manure. In addition certain organisms capable of causing illness can proliferate during the decomposition of plant material, including composting under certain conditions.

Animal Waste. Infectious organisms may be present in animal bye products (e.g. bone and blood meal), or waste (urine and feces) that are used to improve soil fertility. As well as the deliberate introduction of pathogens through the use of farm animal waste, the stools and urine of both pets and wildlife (including birds) can be a problem. Diseases of this type, where there is direct spread from animal to humans are termed zoonoses. The dangers posed by zoonotic pathogens present in raw manure can be considerably lessened if it is correctly composted before use.

Vector Borne Diseases. A mechanical vector is an animal involved in the passive transfer of a pathogen through prior contact with infective material, such as garbage, animal carcasses, or fecal material. Such vectors are usually arthropods (i.e. flies, cockroaches or beetles) or birds. In some instances a vector is a requisite part of the pathogen/parasite life cycle (developmental stages occur), and is referred to as an obligatory or biologic vector. This is the case with mosquito borne diseases such as malaria and certain viral diseases such as West Nile fever or St. Louis encephalitis.

Animal Manure and Garden Compost as Sources for Human Disease

Interest in the use of compost as a means of recycling plant and animal wastes is increasing. The use of compost as a soil amendment improves both soil structure and to a lesser extent nutrient content. On a global scale composting could help reduce the amount of energy expended in fixing

atmospheric nitrogen for use as a chemical fertilizer[1]. This in turn would help alleviate the problems caused by run-off of excess inorganic nitrate fertilizer into lakes, rivers and estuaries. Since the disposal of manure has become a major challenge for modern intensive animal production, recycling such waste as compost would seem a natural solution.

However commendable this approach may be, widespread use of composting, if not correctly managed, has the potential of posing a definite public health problem. Most of the concern is associated with the use of animal wastes, particularly manure, and the presence of pathogens capable of infecting humans. Infection can occur not only as a result of tainted food crops, but also the run off from improperly maintained compost piles contaminating water sources used for recreation, drinking and crop irrigation. A 1997 preliminary report for the National Advisory Committee on Microbiologic Criteria for Foods[2] stated that "the adequacy of existing methods and regulations governing the composting of manures for agriculture need to be reviewed". In the U.K. a similar warning regarding the use of animal manure was issued in 2001 by the Institute of Food Science and Technology[3]. There is unfortunately insufficient data on the survival of many of the pathogenic organisms found in manure (either raw or composted) used to grow crops. The American Public Health Association issued a legislative policy statement calling for a moratorium on concentrated animal feed operations based in part on the risk of human disease from manure borne pathogens[4]

Whilst composting for a backyard or community garden does not entail the problems of scale that face agricultural operations, there still remain health related matters that need to be addressed. These potential risks concern both the type of material used for composting, as well as the composting process itself. There is also the initial risk from direct contact with manure when it is moved, and the subsequent risk of indirect exposure from run off if the pile is exposed to rain. Insects, birds and rodents can also spread pathogens present in fresh manure to other parts of the garden site and surrounding areas.

The Threat of Food Borne Disease.

An increase in the frequency of food borne illness during summer has in part been ascribed to the greater consumption of fresh produce. The incidence of fruit and vegetables acting as vehicles for spreading food borne pathogens is rising[5].[6] For the period 1993 -1997 fresh fruits and vegetables accounted for 2.5 - 3.0% of all reported outbreaks of food poisoning in the U.S., and surprisingly this was more than reported for beef or poultry in most of those same years[7]. The total number of cases of food born disease that can be attributed to known pathogens has almost certainly been grossly under reported in the past, and is now estimated at about 14 million per year[8]. Up to two thirds of these cases involve gastrointestinal disease due to Norwalk type viruses which are solely associated with human fecal contamination, and would not be of concern when dealing with animal manure. This still leaves a large number of cases attributable to infection with zoonotic bacteria or parasites, and a substantial number of these pathogens are found in animal waste.

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[1] Socolow, R.H. 1999 Proc.Nat.Acad.Sci.USA **96** 6001-6008

[2] Tauxe, R.V. *et al* 1997 J.Food.Protect. **60** 1400-1408

[3] IFST Current Hot Topics: Organic Foods (www.ifst.org/hottop24)

4 Policy Statement 2003 American Public Health Association, www.apha.org/legislative

[5] Beuchat, L.R. & Ryu, 1997 Emerg.Infect.Dis **3** 459-465

6 Buck, J. W. 2003 *et al* Plant Health Progress (on line, doi: 10.1094/PHP-2003-0121-RV)

[7] MMWR **49**/No. SS-1, 27-31.

[8] Mead, P.S. *et al* 1999 Emerg.Infect..Dis. **5**, 607-625

The fact that fresh produce has been associated with cases of food borne illness should in no way dissuade gardeners from growing a range of vegetables, or preparing there own compost. Vegetables are too important an item in our diet not to be the focal point of any community garden, and composting is a most effective and beneficial means of improving soil fertility. Being aware of the potential problems and following the recommendations below, as well as those in the resources cited at the end of this document, will help ensure safe garden produce.

None-Food Borne Transmission of Disease

Apart from the presence of pathogens on fresh garden produce, disease transmission in the garden can involve direct infection from soil. This can be orally as a result of inadvertent transfer through soiled hands, inhalation or via the skin as a result of abrasion or more traumatic wounds. Puncture wounds from plant spines, prickles and thorns can introduce pathogens. Certain organic products used as growing media for plants, i.e. sphagnum moss, can harbor disease causing organisms.

There is also a risk of disease transmission through various arthropod vectors, in particular mosquitoes, and to a lesser extent biting flies, ticks and fleas. Scratches and bites from both domesticated and wild animals encountered in the garden can be a source of infection.

The Principal Groups of Organisms that Cause Disease

Before discussing specific health risks, some basic background information on the types of pathogens involved will be presented:

Bacteria These are unicellular micro organisms that lack a central membrane bound cell nucleus, chromatin material being dispersed (termed prokaryotic). The "naked" cell (protoplast) is enclosed in a rigid cell wall, part of the cell envelope which plays a major role as a determinant of bacterial virulence. Bacteria can be roughly differentiated on the basis of morphology and staining properties, but exact identification is based on biochemical, serological and molecular properties. Some soil inhabiting bacteria can form extremely resilient spores, whilst many of those that cause gastrointestinal disease can be destroyed by elevated temperatures.

Protozoa As with bacteria, protozoa are microscopic, unicellular organisms. However they possess many organizational features associated with animal cells, in particular the characteristic nucleus of a eukaryotic cell. There are about 66,000 known species of protozoa, of which about 10,000 are parasites. Amongst diseases caused by protozoan parasites are malaria, sleeping sickness, oriental sore and various gastrointestinal infections. It is this latter type of infection, spread through fecal contamination that is of principal concern to those involved in gardening. Some of the species causing such illness can form highly resistant cysts that are difficult to destroy. Protozoan parasites such as *Giardia* and *Cryptosporidium* only became recognized as significant causes of gastrointestinal disease during the past 30 years. Currently, attention is being focused on establishing the pathogenic potential for humans of several gut dwelling microsporidian protozoa, found in various animal species.

Helminths These are simple multicellular organisms composed of two Phyla: the Platyhelminthes (flat worms and tapeworms) and the Aschelminthes (round worms or nematodes). Some of these parasites have complex life cycles involving two or more hosts, and/or an extensive migratory phase within the host. While these worms are important causes of disease worldwide, for the purposes of this publication we are solely interested in various roundworms that normally occur in the gastrointestinal tract. The eggs produced by these parasites are passed in the stools, and infection occurs through ingestion of contaminated food or water, or poor hygiene after contact with contaminated soil or water. The eggs of some nematode parasites can be very difficult to destroy, and remain viable in the soil for at least 12 months.

Fungi The more than 100,000 known fungi constitute a separate kingdom and whilst possessing the characteristics of a plant cell (defined cell nucleus, mitochondria and a rigid cell wall) do not possess chloroplasts and are therefore incapable of photosynthesis. For most fungi the cell wall is composed of chitin like polysaccharides rather than cellulose as found in plants. Fungi exist as either unicellular yeast cells or filamentous multicellular hyphae, producing spores by both asexual and sexual processes. Whilst fungi can act as pathogens, they are more likely to be an indirect cause of illness for those gardening, as a result of inhaling released toxic or allergenic compounds.

Viruses There are no known viral pathogens infective to humans that are transmitted from plants or through animal waste, though where night soil is used there is a definite risk from viruses present in human feces (e.g. rotaviruses and Hepatitis A). There are viral diseases, in particular West Nile virus (WNV), vectored by mosquitoes that can breed in South Florida yards. The hantavirus is present in dust contaminated with dried rodent droppings or urine and causes a rare, but frequently fatal pulmonary syndrome.

The infectious agent responsible for bovine spongiform encephalopathy (BSE, so called "mad cow disease"), a prion, could theoretically be present in animal bye products such as bone meal, though this is normally steamed[9] before use as a soil amendment[10].

Bacterial Pathogens Present in Animal Waste Potential bacterial pathogens that could be encountered during gardening are presented in Table 1, with an emphasis on those present in animal waste. Survival of pathogenic bacteria in manure, composted or used raw, depends on a variety of factors from animal source and the feed used, to climate and soil conditions. Added to the risk of disease there is also growing concern over the role of fecal waste from domesticated cats[11] and dogs[12] as well as farm animals[13] in spreading multi-drug resistant strains of enteric bacteria

Escherichia coli The Escherichia are small motile rod shaped bacteria (bacilli) that occur as part of the normal gut flora of most mammals. There are however certain strains capable of producing potent toxins, particularly the enterohemorrhagic strain O157:H7, infection with which causes a severe bloody diarrhea with cramps. In susceptible individuals, especially children under age 5, serious life threatening complications can occur (hemolytic-uremic syndrome, HUS, and thrombocytopenic purpura, TCP), HUS being the leading cause of acute kidney failure in young children. The number of persons infected with strain O157:H7 in the US is estimated to be about 75,000 annually[8.] Cases involving contaminated produce are increasing. While many of these involve cross contamination during food preparation, the other half were due to contamination prior to purchase.[14.]

Ruminants, in particular cattle, appear well adapted as reservoir hosts and the organism is shed in feces, particularly after calves are weaned. Since a low dose is capable of producing disease in humans, it is important to ensure complete destruction during the composting process. Extended exposure to temperatures in excess of 140°F are required in order to ensure effective killing. There were no *E.coli* O157:H7 detected after 3 days at 140°F using an artificial bench scale composting system[15], though conditions may not reflect those in an actual compost pile[16]. The organism can

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[9] Destruction of prions requires steam sterilizing at 132°C for 4.5 hs (Office of Health Safety, CDC)

[10] The use of steamed bone meal in the U.S. is not seen as hazardous by the Centers for Disease Control (person. comm.) , and is still recommended by the Royal National Rose Society (U.K.). K. Grapes (person. comm.).

11 Van Immerseel F. *et al* 2004. Emerg. Infect. Dis. **10** 2169 - 2174

12 Guardabassi, L. *et al.* 2004 J. Antimicrob. Chemother. 54 321-332

13 Burgos, J. M. *et al.* 2005 J. Dairy Sci. 88 1391 - 1398

14 Rangel, J. M. *et al.* 2005 Emerg. Infect. Dis. **11** 603 - 609

[15] Lung, A.J. *et a.l* 2001 J.Food.Protect**. 64** 1309-1314

remain viable for at least 5 months on pasture[17] and 2-3 months in aerated bovine manure[18]. Cattle manure was found to be free of *E. coli* when composted for 40 days during which the internal temperature of the pile was above 140°F for at least 5 days[19]. It is clear that if manure is to be used, it must be composted thoroughly before use. Survival appears to be greatly lessened if manure is allowed to become desiccated.

At least one out break of *E. coli* O157:H7 has been traced to vegetables grown in a home garden where contaminated cow manure was used.[20] The droppings of wild birds have been found to contain *E. coli* O157:H7 and other food born pathogens, and it is believed that these infections are contracted as a result of birds feeding in areas where fresh manure was present. This is another reason not to spread raw manure, particular in areas frequented by birds such as gulls.

Salmonella This genus is also made up of motile, rod shaped, enteric bacteria. The most widely known of these bacilli is *Salmonella* serotype Typhi, responsible for typhoid fever and restricted to humans. None-typhoid strains of *Salmonella* (e.g. serotype Typhimurium) are found widely in a variety of domestic and wild animals, and up to 50% of a herd or flock can be infected under intensive agricultural practices. Dogs and cats can serve as carriers, as well as many cold blooded animals. Recent survey data reveals serotypes associated with reptiles and amphibians to account for an increasing number of human cases of enteric disease[21]. The risk of contamination of produce from the *Salmonella* shed by the many lizards (including the increasing number of feral iguanas), toads and frogs found in Miami-Dade yards is unknown. Garden fertilizers based on animal products, including supposedly sterilized bone meal, have also been found to contain a range of salmonella serotypes[22]. Prudence again dictates washing all fresh garden produce prior to consumption. Most reported case of salmonella food poisoning are of serotype Enteriditis and are associated with poultry products, particularly the consumption of under cooked eggs. Since this a relatively mild disease it probably goes undiagnosed in most instances; the number of reported cases for 1998 was almost 44,000[23], but the total number of cases annually has been estimated at almost 1.5 million in the US[8]. Salmonella isolates have been found to survive for up to 6 months in untreated cattle manure, and up to 21 days if composted.[24] In composted chicken manure a 90% reduction in the number of *Salmonella* occurred in 2 days, and this was correlated with an increase in the concentration of free ammonia in the compost. Bovine manure does not produce such high levels of ammonia on composting.

Campylobacter jejuni The Campylobacter are slender, spirally curved, motile rods, and form part of the commensal gut flora of numerous animal species. *Campylobacter jejuni* is estimated to cause 2.5 million cases of gastrointestinal illnesses annually in the U.S.[8] ranging from mild enteritis to severe dysentry. Previous infection with *Campylobacter* has been associated with about 30% of all cases of Guillain-Barré syndrome[25], a comparatively rare but severe neurological disorder that involves the peripheral nervous system. Most cases of campylobacteriosis are due to the

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[16] Droffner, M.L. & Brinton, 1995 W.F. Zentralbl.Hyg.Umweltmed. **197** 387-397

17 Avery, S. M. *et al.* 2004 Lett. Appl. Microbiol. 38 355 - 359

[18] Kudva, I.T. *et al.* 1998 Appl.Environ.Micriol. **64** 3166-3174

[19] Johannessen, G. S. *et al.* 2005 FEMS Microbiol Lett**. 245** 369 - 375

[20] Cieslak, P.R. *et al.* 1993 Lancet **342**, 367

21 Mermin, J. *et al.* 2004 Clin. Infect. Dis. 38 (Suppl 3) S253 - 261

[22] Smith, H. W. *et al.* 1982 J. Hyg. (Lond). **89** 125 - 128

[23] MMWR **47**/No. 53, 79

[24] Forshell. L.P. & Eskesdo, I. 1993 Zentralbl.Veterinarmed B. **40** 654 - 658

[25] Allos, B.M. 2001 Clin.Inf.Dis. **32** 1201-1206

consumption of under cooked poultry. Fecal spread is possible since the organism is present in both cattle (especially young animals) and poultry manure. The number of organisms required to produce disease is high, and survival outside the host is poor[26], therefore it should not pose a problem in adequately composted manure. *Campylobacter jejuni* has been found in wild animals (especially birds) and on the exoskeleton of insects, hence providing a potential reservoir for the contamination of water and uncooked foodstuffs.

Listeria monocytogenes These are small, short rod shaped bacteria, and unlike the above organisms, are found naturally as saprophytes on decaying plant matter, as well as in soil and manure. There is evidence that at least some of the strains recovered from plant debris and soil are not pathogenic to humans, and that environmental triggers associated with decaying plant material suppress virulence[27]. Listeriosis presents a range of symptoms, from a mild influenza like illness to a severe life threatening form of meningitis, with 2500 cases estimated annually for the US according to the CDC[8]. The more severe course of the disease is much more likely in the elderly, those with an impaired immune system and the very young. In neonates there is up to 90% mortality, whilst AIDS patients are 300x more likely to develop symptoms if exposed to infection.

A link between animal waste and raw vegetables as vehicles for infection with *Listeria* was made in the early 1980's[28] in an outbreak involving cole slaw made from cabbage that had been grown with manure from infected sheep. More resistant to heat than other non-spore forming food borne bacteria, *Listeria* has been found to survive in food scrap compost for short periods at temperatures up to 173°F, well above the temperature of most compost piles[29].

Organism	Source	Survival	Human Disease
Salmonella (non-typhoid strains)	cattle, poultry, dogs, wild birds and reptiles.	Extended exposure to >140°F required to kill organism.	Usually mild gastroenteritis within 6- 48h
Escherichia coli 0157:H7	ruminants, especially cattle	Up to 70 days in raw manure	bloody diarrhea severe cramps HUS and TPC
Brucella spp.	urine: cattle, sheep, pigs, goats	2½mos. in moist soil, rapidly killed in sun	General malaise up to 1 year
Campylobacter jejuni	stools: poultry, wild birds, sheep, cattle, pigs	Rapidly killed by heat, drying and freezing	Mild to severe (bloody) diarrhea
Listeria monocytogenes	soil, manure, food scraps.	Saprophyte on vegetation - can survive in food	Mild flu-like to severe meningitis,
Bacillus cereus	soil, seed sprouts, prepared foods	highly resistant spores	Mild gastroenteritis
Rhodococcus equi	Horse manure, particularly foals, horse pastures	Found naturally in soil	Severe pneumonia if susceptible
Leptospira	Urine of various wild animals, especially rodents	Long term survival in water and moist soil	Usually mild, can be complications
Yersinia enterocolitica	Various wild animals as well as dogs and pigs. Pork	Survival in soil or manure not known.	Gastroenteritis.

Table 1 Bacterial Pathogens Associated with Animal Waste

[26] Altekruse, S.F. *et al.* 1999 Emerg.Infect.Dis **5** 28-35

[27] Brehm, K. *et al* J.Bacteriol. 1999 **181** 5024-5032

[28] Schlech, W.F. *et al* 1983 N.Eng.J.Med. 308 203-206

[29] Droffner, M.L. & Brinton, W.F. 1996 Zentralbl.Hyg.Umweltmed. **199** 51-59

Unlike most other organisms associated with food born disease, *Listeria* can survive and even multiply at much lower temperatures[30]. There is only sparse information available on survival in animal manure or compost. One study reported survival in fresh cow manure for at least 3 weeks and found *L. monocytogenes* after 3 months on radishes grown in artificially contaminated soil[31].

Although some of the remaining bacterial pathogens listed in Table 1, are capable of causing serious disease they are of far less concern as possible contaminants of yard compost:

Bacillus cereus Large, motile, rod shaped bacteria characterized by the ability to form resistant spores. The number of food born infections attributable to *B. cereus* has increased in recent years to an estimated 27,000 annually[8]. For most known outbreaks fresh produce was not implicated, however spores are routinely found in soil samples which could be a source of infection if fresh vegetables are not adequately washed. The presence of *B. cereus* spores on seeds used for growing seed sprouts has been a cause of outbreaks of gastrointestinal disease[32].

Brucella spp. These are small, non-motile coccobacilli found in various wild and domesticated animals, and can be the cause of serious disease in humans. Brucellosis is a reportable disease through out the US however the incidence of human infection in this country is extremely low. Most reported cases result from the consumption of none pasteurized dairy products. The organism can be found in various bodily fluids and in animal manure, the latter having been implicated in at least one disease outbreak[33]. Survival for as long as 10 weeks is observed in moist soil, but the bacterium is rapidly destroyed on exposure to direct sunlight.

Yersinia enterocolitica This is an ovoid to rod shaped bacterium, and is estimated to cause more than 96,000 cases annually of food borne illness, most of which are contracted through eating pork products. Since this organism is passed in the stools of various wild and domestic animals (including dogs and pigs), it could pose a potential problem if contaminated pig manure were used to grow fresh produce. There is however little known concerning the survival of *Y. enterocolitica* in manure, either fresh or after composting[34]

The remaining bacterial diseases in this section whilst present in animal feces are usually not contracted through eating contaminated foodstuffs. Infection is more likely to be through inhaling dried stools in dust, or via existing skin abrasions or animal or arthropod bites.

Rhodococcus equi This organism transforms between rod and cocci, and is found naturally in soil. It is also commonly found in the stools of a variety of herbivores, particularly horses where it is a well documented pathogen of foals. In humans it causes a rare but serious form of pneumonia, and is almost exclusively found in persons with a compromised immune system[35]. The number *R. equi* found in soil is particularly high in localities where there are grazing animals. Inhalation of dust

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[30] Schlech, W.F. 2000 Clin.Inf.Dis. **31** 770-775

[31] Van Renterghem, B. *et al* 1991 J.Appl..Bacteriol. **71** 71 211-217

[32] Taormina, P.J. *et al* 1999 Emerg.Infect.Dis **5** 626-634

[33] Wallach et al., 1997 FEMS Immunol.Med..Microbiol. **19** 315-321

[34] Guan, T. Y. and Holley, R. A. J. 2003 Environ. Qual. *32* 383-392

[35] Linder, R. 1997 Emerg.Infect. Dis. 3 145-153

containing dried horse manure or heavily contaminated soil is the usual mode of infection. The few cases reported in healthy individuals were due to contamination of wounds, where it produces cutaneous lesions.

Franciscella tularensis This is a small nonmotile coccobacillus and is responsible for a zoonotic disease commonly referred to as tularemia. In humans it is seen as a severe, sometimes fatal illness, and is found in a wide range of wild animals. It is usually associated with rabbits and almost all known human infections involve an animal bite, or that of a tick or deer fly that has fed on an infected host animal. The organism is capable of surviving in dried animal stools, thereby potentially facilitating infection through inhalation of contaminated dust. Incidence of infection has been declining and only 96 cases were reported in 1994, the last year it was on the C.D.C. list of notifiable diseases. In 1996 the disease was removed from the Florida list of notifiable diseases.

Chlamydophylla psittaci This nonmotile, coccoidal, intracellular parasite causes a zoonotic disease, psittacosis (also known as ornithosis), of cosmopolitan distribution. The bacterium was first associated with psittacine birds (parrots), but is now known to occur in many other wild and domesticated birds. Infection in humans is due to inhalation of bacteria, either directly from infected birds or those present in stools. Care should be exercised when working with previously undisturbed soil that may be contaminated with bird manure, as could occur on garden sites where birds have been known to roost. As with tularemia, this is another zoonotic disease that has also declined in incidence, with 48 cases reported in 1998.

Leptospira interrogans This bacterium is a tightly coiled motile rod, a spirochete, and is responsible for a comparatively rare zoonotic disease (leptospirosis), that can range from a mild fever, to a severe condition sometimes referred to as Weil's Disease. In this latter instance symptoms include hepatitis(with associated jaundice), meningitis and kidney involvement with renal failure being the usual cause of fatalities. Although associated with various wild animals, especially rodents, it also occurs in cats, dogs and domesticated livestock. The bacteria are found in the urine of infected animals; humans contract the disease via mucosal surfaces or skin abrasions. This can involve direct contact with contaminated water (the usual route), soil or vegetation, or indirectly through consumption of foodstuffs exposed to tainted soil or water. The organism is able to survive for weeks if not months in contaminated soil or water.

The risk of disease can be greatly reduced through care over hygiene in handling manure, and paying particular attention to controlling rodents and wearing gloves and appropriate footwear when gardening. Control of rodents is important, not only to prevent direct spread, but also to prevent infecting populations of stray and feral dogs. There has been a recent increase in the numbers of dogs infected with leptospires One survey found outbreaks in dogs to be associated with areas that had most recently become urbanized. Whilst leptospirosis is no longer a notifiable disease, only 38 cases being reported by the CDC for 1994 the last year for which data is available, it is potentially life threatening.

Thermophilic Actinomyces These are a group of bacilli that thrive at elevated temperatures. They multiply rapidly in compost piles that reach temperatures of more than 60C, but this is unrelated to the presence of manure, since they are commonly found in silage pits. Actinomyces produce allergens that can cause various forms of respiratory distress. The elevated temperatures required for proliferation of these bacteria are unlikely to be produced during small scale yard composting.

Protozoan Parasites Present in Animal Feces There are three zoonotic infections involving protozoan parasites that could be potentially contracted while gardening.

Giardia duodenalis (syn *G. lamblia*; *G. intestinalis*). The feeding stage (trophozoite) of this

flagellate protozoan is found next to the luminal surface of the small intestine. Trophozoites can transform into a resistant cyst that is then eliminated with the feces. There is no intermediate host, and no resting stage, so the cysts are immediately infective upon being ingested by a new host. Disease symptoms include diarrhea (stools are particularly malodorous), steatorrhea (greasy stools), nausea, bloating, and in long term infections malabsorption and weakness.

Based on surveillance data, the CDC has estimated 2 million cases of infection with *G. duodenalis* annually for the U.S. Whilst 90% of these cases are probably water borne, that still leaves 200,000 potential cases of food borne giardiasis per year. In Miami-Dade there were 321 cases reported during 2004. *Giardia sp.* are found widely in vertebrate hosts, though *G. duodenalis* is the only species recognized as parasitizing mammals, where it is found in dogs, cats, various herbivores and ruminants. Infection rates of up to 100% have been found in dairy calves, whilst infection rates for dogs and cats have seen a steady increase.

Organism	**Animal Source**	**Survival**	**Human Disease**
Protozoa			
Giardia duodenalis	Widespread in many vertebrate hosts, especially ruminants, dogs	Long term survival of cysts, resistant to drying	Diarrhea, cramps, nausea, can be protracted.
Cryptosporidium parvum	Cattle of primary importance	At least 6 months in manure - susceptible to drying.	Self limiting gastroenteritis if immuno-competent
Toxoplasma gondii	Cat feces, undercooked meat	Cysts survive at least 1 year in a variety of soils	Often asymptomatic, but can be serious complications
Cyclospora cayatensis	Existence of animal reservoir has not been established as yet.	Long term survival in water	Watery, protracted diarrhea debilitating if susceptible
Helminth			
Ascaris suum	Pig feces	At least 8 weeks in moist pig feces	Pnemonitis, gastric symptoms
Toxacara spp.	Dog (*T. canis*) and cat (*T. cati*) feces	A year during composting, 4 years in garden soil.	Visceral larva migrans, usually in children.

Table 2. ***Protozoan and Helminth Parasites of Possible Concern to Gardeners***

Genetically distinct sub groups of the parasite have been recognized, some of which are associated with a single animal host, whilst others are found in more than one host. The genotypes found in human infections are contained within two assemblages, A and B. Sub-typing of *G. duodenalis* reveals cattle[36], apart from pre-weaned calves[37], to be of only slight public health importance as a source of human giardiasis. Of more concern are companion animals, especially dogs[38] and cats, and horses[39]. Genotypes known to cause disease in humans have been found in these animals as well as wild rabbits, mice, muskrats and white tail deer.

Care should be taken to remove dog and cat feces from garden sites, and while manure from adult cattle now appears to pose less of a risk, that from horses may need to be handled with more care. Horse manure has always been assumed to be of comparatively low risk as a source of human disease. It is important to prevent contamination of a garden site through rain water washing parasite cysts from manure or a compost pile onto the surrounding ground. This is particularly so if well water is being used to irrigate the garden, since contaminated water supplies have been implicated in most outbreaks of giardiasis. The cysts are resistant to drying, chlorination and temperature extremes, can survive for months in water, and are relatively persistent during

36Sulaiman, I. M. *et al* 2003 Emerg. Infect. Dis. 9 1444 - 1451
37Trout, J. M. *et al* 2004 Vet. Parasitol. **124** 179 - 186
38Lalle, M. *et al* 2005 J. Parasitol. **91** 203 - 205
39Traub, R. *et al* 2005 Vet. Parasitol. 130 317 -321

treatment of waste water[40]. There is little information concerning survival of cysts in manure or compost; a survival of at least 16 days was noted in pig manure slurry, less than for water[41]. Whilst the potential contamination of garden produce with *Giardia* through manure/compost or contaminated well water is possible, the exact nature of the risk is unknown. It is however worth noting that ingestion of as few as 10-25 cysts has been documented to produce disease in humans[42].

Cryptosporidium parvum The Cryptosporidia are found in a wide range of animals, from reptiles to birds and mammals, including humans. In man, *Crptosporidium* is an intracellular parasite of the epithelial absorptive cells of the small intestine. Infection occurs through the ingestion of oocysts, which rupture to release four sporozoites. These become motile and attach to and invade the epithelial cells of the small intestine, destroying the microvilli in the process. Within the host cell, the parasite is contained in a parasitophagous vesicle (a fact which complicates development of successful chemotherapy), where it divides to produce merozoites which in turn invade further epithelial cells. Eventually the merozoites differentiate into male and female gamonts, which fuse to produce a zygote. After encystment, the resulting oocysts,are then passed out with the stools. The cysts are immediately infective once voided, there being no resting phase. Ingestion of very few parasites can produce disease (median infective dose 132 oocysts[43]) though this is probably dependent on the isolate. In immuno-competent individuals infection is a self- limiting gastroenteritis lasting at most 2-3 weeks, whereas in those with an impaired immune system it can produce a severe, persistent form of watery diarrhea.[44]

Most documented cases of disease are associated with contaminated water[45] (used for drinking, food preparation or recreation), the CDC having estimated 300,000 cases per year. Of these 30,000 are due to food borne infections, and many of these probably involve food exposed to contaminated water. During 2004 there were 19 reported cases of cryptosporidiosis in Miami-Dade. Consumption of fresh produce has been linked to disease outbreaks[45] however there is no evidence that this involved the use of compost or raw manure.

Several genotypes of *C. parvum* have been recognized, with two regarded as responsible for human disease: the most prevalent is recovered only from humans (anthroponotic), whilst a zoonotic genotype occurs that involves domestic livestock including cattle. Since the parasite was thought to be of ubiquitous occurrence in cattle[46], cryptosporidiosis appeared to be a potential risk when using cattle manure as a soil amendment. Especially large numbers of oocysts are shed by young calves, the numbers declining rapidly by the time the animals are 4 weeks old. Not only do the numbers decline, but the cryptosporidia now found are species/genotypes known not to infect humans[47].

There have been scattered disease outbreaks in humans implicating eight *Cryptosporidia* species

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[40] Chauret, C. *et al* 1999 Can J. Microbiol. **45** 257-262

[41] Deng, M.Y. & Cliver, D.O. 1992 Appl. Environ. Microbiol. **58** 2368-2374

[42] Wolfe, M. S. 1992 Clin. Microbiol. Rev. **5** 93-100

[43] DuPont, H.L. *et al* 1995 N.Eng.J.Med. **332** 855-859

[44] Nichols, G.L. 2000 Brit.Med.Bull. **55** 209-235

[45] In the largest U.S. outbreak of a water borne disease, cryptosporidiosis affected 25% (403,000) of the total population of Milwaukee in 1993 (MacKenzie, W.R. *et al* N.Engl.J.Med**. 331** 161-167).

[46] Casemore, D.P. *et al* 1997 In *Cryptosporidium* and Cryptosporidiosis. R. Fayer, Ed. : 65 - 92. CRC Press, Boca Raton, FL.

47 Santin, M. *et al* 2004 Vet Parasitol. **122** 103-117

found in animals other than cattle (dogs, cats, mice, birds pigs and deer)[48]. A survey of HIV patients found zoonotically transmitted *Cryptosporidia* to be as common as anthroponotic transmission[49]. At present therefore, the zoonotic component of cryptosporidiosis is not fully understood, however the principal risk seems to involve cattle (calves up to 2 months old), with a possible risk from cats, dogs, pigs and birds.

Survival of *Cryptosporidia* oocysts in either raw manure or compost has received scant attention; laboratory studies have found survival for at least 6 months at 20°C, with loss of infectivity noted on slowly raising the temperature to 55°C. Dessication is also extremely lethal, with no infective organisms found after drying contaminated calf feces for 4 hours[50]. Cryptosporidiosis has been a reportable disease in Florida since 1992, and since that time the number of cases has noticeably increased, with most reports coming from Miami-Dade, Broward and Palm Beach counties.

Toxoplasma gondii Unlike the protozoan parasites discussed above, *T. gondii* has a life cycle involving two sets of hosts. The definitive (sexual stage) occurs in felines, including the domestic cat, whilst the asexual stage occurs as a tissue parasite in a wide variety of mammalian intermediate hosts including humans. In cats, Toxoplasma parasitize epithelial cells of the small intestine, eventually forming gametocytes which after fusing to produce oocysts, pass out with the stools. Large numbers of oocysts are voided with the feces for up to 2 weeks after which none are present., Once outside it takes 4-5 days for the oocyst to sporulate (become infective), after which it is infective to other cats and to intermediate hosts, including man.

In the intermediate host the asexual part of the life cycle then commences. The oocyst wall is digested in the small intestine and the released parasites penetrate the gut wall, enter the bloodstream (intracellular parasite of macrophages), and are spread throughout the body. At this time they are able to infect virtually all host cell types, but particularly muscle and nerve cells. These tissue stages are referred to as trophozoites, and are of two types: rapidly multiplying tachyzoites which spread the infection throughout the host, and slower reproducing bradyzoites which form tissue cysts. These latter cysts are infective to cats on eating infected prey animals, or raw or undercooked meat.

Infection in humans can occur as a result of consuming tissue cysts in undercooked meat, or from food or water contaminated with oocysts from cat feces. In a healthy person the disease has always been regarded as largely asymptomatic, at most producing flu like symptoms. However evidence over the past 10 years has implicated *T. gondii* in several maladies from general weakness and debility to altered brain function[51] suggesting infection may not be so benign. There is no doubt that for those with an impaired immune system, toxoplasmosis results in serious illness. It occurs in 75% of all terminal AIDS patients[52], leading to central nervous system (encephalitis) as well as ocular and respiratory system complications. Another serious complication, congenitally acquired toxoplasmosis, occurs if infection is acquired during pregnancy. Trans-placental passage of the parasite is more likely during the latter half of pregnancy, at which time damage to the fetus is less profound than if exposure occurs during the first trimester. Infection can cause intrauterine death, severe disease in the neonate, and a range of developmental problems as the infant ages if the infection goes undiagnosed.

The CDC estimates there are 225,000 US cases annually of toxoplasmosis, of which 12,100 develop chronic symptoms, and 50% are food-borne[8]. In Miami-Dade during 2004 there were 7 reported cases of toxoplasmosis. Most food borne cases involve consumption of undercooked meat, however

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48Akiyoshi, D.E. *et al* 2003 Infect. Immun. **71** 1828 - 1832 (plus cited references)

49 Gaeti, W. *et al* 2002 Ann. Trop. Med. Parasitol. **96** 797 - 802

50Fayer, R. *et al* 2000 Int.J.Parasitol. **30** 1305-1322

51 McAllister, M. M. 2005 Vet Parasitol (in press – doi 10. 1016/j.vetpar.2005.07.003)

52Welch, K. *et al* 1998 AIDS Patient Care STDS **12** 125-129

more recently contamination of foodstuffs with oocysts has been implicated. A survey of toxoplasmosis amongst pregnant women found that whilst undercooked meat was still the primary risk, contaminated soil was also an important source of infection[53]. Contact with cats *per se* was not seen as a risk factor since they pass oocysts for a comparatively short period. However soil that is contaminated by oocysts from infected cat feces could be a potential problem. Cysts have been found to survive for at least one year in different sites (Costa Rica and Kansas), regardless of whether the soil was moist, dry or shaded[54]. The intentional use of cat feces for composting should be avoided, and measures taken to exclude stray and feral cats from the garden site. Cats that are kept indoors and do not consume prey animals or raw meat pose a minimal risk of spreading toxoplasmosis. Toxoplasmosis has been a reportable disease in Florida since 1964.

Other Zoonotic Protozoan Parasites Spread of the remaining zoonotic protozoan parasites through stool contamination of garden produce is not known. Various Microsporidia spp. have recently been identified in immunologically compromised individuals, particularly AIDS patients, as responsible for diarrhea, malabsorption and, depending on the species, dissemination to other organs. Some of these parasites such as *Encephalitozoon intestinalis* have been found in dog and livestock feces and are believed to occur normally in various wild animals[55]. It is not known however to what extent dispersal in humans involves food and/or water, or the role of animals as reservoir hosts. The limited information available has demonstrated long term survival of the spore stage in the external environment.

Balantidium coli is a ciliated protozoan parasite found in the lumen of the large intestine and is contracted through ingestion of cysts present in water or fresh food. It can cause an ulcerative colitis in those susceptible to infection, but is usually asymptomatic in healthy individuals. Pigs are the most important animal reservoir, infective cysts being passed in their feces.

Cyclospora cayatensis The *Cyclospora* spp are grouped with the *Toxoplasma* and *Cryptosporidia*, all being in the Protozoan Phylum Apicomplexa, and are believed to be most closely related to the *Eimeria*, important parasites of poultry and livestock. *Cyclospora cayatensis* causes watery, often protracted diarrhea, nausea and anorexia and is particularly serious for persons with an impaired immune response. There have been an increasing number of outbreaks associated with fresh fruits and produce, and the parasite is becoming an important cause of travelers' diarrhea. In Miami-Dade during 2004 there were 2 reported cases of cyclosporosis. There is one report that suggests a link between parasite acquisition, soil and gardening[56]. An extensive study of livestock and other domesticated animals in Haiti, where human infection with Cyclospora is endemic, failed to find oocysts in stool samples from any of these animals[57]. A more recent report using molecular probes found *C. cayatensis* in fecal smears from dogs, chickens and a monkey[58]. To be considered natural reservoir hosts would require examination of gut tissue samples for the presence of intracellular stages of the parasite. The consensus at present is that transmission to humans in most instances is direct with some suggestive evidence of animal reservoir hosts. Manure from domestic livestock is not considered a source of human infection.

Helminth Parasites Dispersed in Animal Feces The two zoonotic helminth parasites that are

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[53] Cook, A.J. *et al* 2000 Brit.Med.J. **321** 142-147

[54] Frenkel, J. K. *et al* 1975 Am.J.Trop.Med.Hyg. **24** 439-434

[55] Wasson, K. and Peper, R. L. 2000 Vet Pathol. **37** 113 - 128

[56] Sterling, C.R. & Ortega, Y.R. 1999 Emerg.Inf.Dis **5** 48-53

[57] Eberhard, M.L. *et al* 1999 J.Parasitol. **85** 562-563

[58] Chu, D. M. *et al* 2004 Am.J.Trop.Med.Hyg. 71 373 - 379

most likely to be encountered as a result of gardening are Ascaris *suum* and *Toxacara spp*. The spread of the former is more likely to involve the food borne route, whilst infection with the latter usually involves direct contact with contaminated soil.

Ascaris suum This is a nematode parasite (roundworm) normally found in the small intestine of pigs. The adult worms produce eggs which are passed with the feces. After 2-3 weeks when they have embryonated, they are capable of infecting a suitable host on ingestion. The eggs hatch in the small intestine, the released larval worms penetrating the wall of the duodenum, passing via the circulatory system to the liver and heart, and then to the lungs. Here the larvae break out into the alveoli where they molt, then migrate through the air passages to the trachea and thus to the oesophagus where they are swallowed. They finally mature in the small intestine as adult, egg producing worms. In humans full migration is often not completed and depending on the initial dose the only symptom may be pneumonitis. Complete migration can occur however, with adult worms capable of causing intestinal obstruction in some instances.

Survival of *A. suum* eggs was observed for at least 2-4 weeks in slurried pig manure allowed to dry in direct sun, whereas 90% were still viable after 8 weeks if the slurry remained moist and away from direct sun[59]. *Ascaris lumbricoides* is the ascarid found normally in humans, and dissemination is through fecal contamination of food or water. (e.g night soil or improperly treated sewage).

Toxocara spp These roundworms are found in the small intestine of domestic dogs (*T. canis*) and cats (*T. cati*), where they undergo a migratory phase similar to that described for Ascaris. In humans, the migrating larvae never reach the gut but migrate through various tissues (including the liver, lungs, heart and kidneys), a condition known as visceral larva migrans (VLM). This aberrant migration can cause hepatomegaly, myocarditis, nephritis and pulmonary inflamation. Serious ocular complications can occur when larvae migrate across the retina, with blindness being a common outcome. These sequelae are far more common in young children, and are usually due to *T. canis*. Incomplete migration also occurs in dogs older than 10 weeks. However in pregnant dogs, development of the parasite resumes with subsequent transplacental infection of the pups in utero, and viable egg producing worms in the lactating dam. While *Toxocara* from dogs have received more attention there is evidence that infection due to cats has been underestimated[60]

Toxacara are ubiquitous, with parasite eggs being recovered from the soil in up to 11% of all backyards sampled in one study, whilst in a separate investigation of a mixed population of cats (strays and house cats) *T. cati* eggs were found in about 20% of all fecal samples[61]. Prompt removal of cat and dog feces is essential, since parasite ova can be spread by coprophagous insects, especially flies, or run off after heavy rain. Once more it should be evident that dog and cat feces should on no account be used for compost. *Toxacara* ova have been found to survive for a year during composting, and up to 4 years in garden soil[62].

In view of the high rate of infection in both cats and dogs, those with gardens in locations where stray/feral animals are common should pay particular attention to excluding them from the garden site. Although infection through consumption of contaminated produce is possible, exposure of children to infection through contact with soil is of more concern. VLM is primarily seen in young children. Supervise children, making sure that they wash their hands as soon as gardening activities cease and be alert for any showing signs of pica. If the garden has a sandpit, keep it covered when not in use since it will act as a large litter box for neighborhood cats. This will also

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[59] Gaasenbeek, C.P. & Borgsteede, F.H. 1998 Vet. Parasitol. **75** 227-234

[60] Fisher, M. 2003 Trends. Parasitol. **19** 167 - 170

[61] Nutter, F. B. et al 2004 J.Am.Vet.Med.Assoc. **225** 1394-1398

[62] Referenced in Slifko, T. R. *et al* 2000 Int.J.Parasitol. **30** 1379-1393

help to prevent contamination with *Toxoplasma* cysts (see above). Do not use this sand as a soil amendment.

Baylisascaris procyonis This round worm is found in racoons, and is the cause of an especially severe, sometimes fatal neurological form of VLM, especially in young children[63]. Worms have been recovered from 90 species of wild and domesticated animals, where it can also result in fatalities, and is seen as representing a growing public health threat.[64]. The parasite is found throughout the U.S and Canada, most frequently in the mid-west and western states, with infection rates of up to 100% in fecal samples from young raccoons in California.[65] To date there have been no published cases of human disease in Florida and in one survey fecal samples taken from raccoons on Key Largo were all negative[66]. A related species, *B. transfuga* has been found in Florida black bears[67] but it is of uncertain importance as a cause of human disease. Especially high numbers of *B. procyonis* eggs are associated with communal areas where racoons defecate, so called latrines, which in an urban setting, can be a raised wood deck, woodpile or a large tree stump. Adding to the problem is the fact that the eggs can survive for many years in soil.

Creeping Eruption As well as VLM, there is CLM (cutaneous larval migrans), caused by the aberrant infection of humans with dog or cat hookworms. Of the four species of hookworm present in Florida, *Ancylostoma braziliense* is found in both dogs and cats, and is the most common cause of CLM. Infective (third stage) larvae, present in dog feces, penetrate the skin causing a serpigenous (spreading) lesion and severe pruritus, as the larvae wander through subcutaneous tissue and eventually die. *Ancylostoma canium*, which is the most frequently found hookworm in dogs, can in very rare instances migrate to deeper tissues and cause symptoms more like those of VLM.
Once voided with host animal feces, infective larvae can survive for several days in sandy soil, but are rarely found far from the immediate spot where the animal defecated. *Ancylostoma canium* can be passed from a lactating bitch to pups by trans-mammary passage. As with *Toxocara*, puppies are a significant source of infection, very large numbers of infective larvae being passed during the first 2-3 weeks of life. Stray and feral animals that have never been treated with appropriate anthelmintics (wormed) pose the greatest threat.

There are no effective chemicals that will rid contaminated soil of any of the above helminth eggs or infective larvae. Turf pesticides will not destroy hookworm larvae or kill any other nematode parasite. Use of such chemicals for this purpose is not only a waste of time and money but unnecessarily adds to the potential pollution of surface and ground water supplies. Prompt removal of dog and cat feces will greatly reduce any risk of infection.

Other Food Borne Zoonotic Helminth Parasites There are other diseases caused by animal parasites that have been associated with the consumption of fresh produce, however domestic cases have been the result of exposure whilst outside of the U.S. Increasing international travel and trade, raises the likelihood that some of these diseases will spread beyond their present borders.

As an example, *Angiostrogylus costariciensis* is a small roundworm parasite of rodents, notably the cotton rat, adult worms being located in the mesenteric artery. It is here that egg laying occurs, the hatched larval worms then penetrating the wall of the small intestine to be subsequently eliminated with the stools. Further development requires the larval worms to be eaten by an intermediate host, usually a veronicellid slug but snails too can be infected. Vegetables become contaminated with infective third stage larvae that are deposited in the mucous secreted by feeding slugs/snails.

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[63] Park, S.Y. *et al* 2000 Pediatrics **106** E56

64 Sorvillo, F. *et al* 2002 Emerg. Infect. Dis. **8** 355 - 359
65Roussere, G.P. *et al* 2003 Emerg. Infect. Dis. **9** 1516 - 1522
66 McCleery, R. A. *et al* 2005 J. Wildl. Dis. **41** 250 - 252
67Foster, G. W. *et al* 2004 J. Parasitol. 90 173 - 175

Disease outbreaks in humans are usually associated with eating fresh vegetables, the first documented outbreak of disease involving fresh mint[68] in Guatemala. Since that time there have other disease outbreaks reported from various areas of Central and South America, especially Costa Rica and the Yucatan. In humans the eggs and first stage larvae induce severe local inflammatory reactions, leading to the production of granulomatous masses in the intestinal wall, and symptoms that mimic appendicitis (abdominal angiostrongyliasis). Because of this host response, first stage larvae are unable to break out into the gut and the thus humans play no role in spreading the disease, being a dead end host as far as the life cycle is concerned.

At present there have been no reports of this disease being contracted within the U.S. A related nematode parasite, *Parastrongylus cantonensis*, a rat lungworm is now endemic in Louisiana wildlife, probably brought in via ships carrying infected rats[69]. Ingestion of larval worms, which again first develop in land snails and slugs, migrate from the intestine to the meninges (brain lining) where they stay briefly before finally migrating to the pulmonary artery. In abnormal definitive hosts such as primates the migrating worms die once they reach the meninges resulting in a severe inflammatory reaction with resulting meningoencephalitis. Although infection in humans is normally through eating raw snails, infective larvae are shed in the mucous trails of slugs and snails which can then contaminate fresh produce. At least one outbreak of disease that occurred in Jamaica had such an etiology[70] There is evidence that the parasite could be present in south Florida. Severe neurological impairment of a captive primate in Miami was on autopsy found to be due to infection with *P. cantonensis*[71] .

Soil Borne Infections

Clostridia There are a number of naturally occurring soil microbes that can cause disease in humans, a well known example being *Clostridium tetani*, the bacillus responsible for tetanus (lockjaw). In this instance infection is acquired through skin abrasions or cuts, with tetanus symptoms occurring after about 8 days. Whilst the bacterium is readily killed by heat and oxygen, it produces an extremely resistant spore which will germinate and divide only under suitable conditions, i.e. low oxygen concentrations (anaerobic). Although cosmopolitan in distribution, *C. tetani* is especially prevalent in warm, humid climates and in soil with a high content of organic matter. The bacterium is found in the gut and feces of a range of animals, and high spore counts are associated with soil that receives regular applications of manure. The heat developed during backyard composting of animal manure will not destroy *C. tetani* spores[72].

The number of U.S. tetanus cases have declined dramatically, particular with the introduction of an effective vaccine in the 1940's, and almost all cases currently reported are found in those who have not been vaccinated. It is currently recommended that after the initial series of vaccinations, booster shots be administered at 10 year intervals[73]. Apart from ensuring that all persons working in a community garden have current vaccinations, gloves should be provided for those handling soil and nobody allowed on site unless they have appropriate footwear. A majority of the tetanus cases that are reported involve puncture wounds resulting from persons stepping on dirty nails. Be particularly

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68Kramer, M. H. *et al* 1998 Clin. Infect. Dis. **26** 365 - 372
69Kim, D. Y. *et al* 2002 J. Parasitol. **88** 1024 - 6
70Slom, T. J. *et al* 2002 N. Engl. J. Med. **346** 668 -765

71 Duffy, M. S. et al Emerg. Infect. Dis. 10 2207 - 2210

72 Spores survive 15 minute steam sterilizing at 121°C.

73 Epidemiology and Prevention of Vaccine-Preventable Diseases, 8thth Edition, Public Health Foundation, Maryland, 2005.

careful when preparing a new garden site on land that has stood vacant, particularly in urban areas cleared of derelict buildings, for objects with pointed or sharp edges.

Other, histotoxic Clostridia, are found in soil and can cause extensive tissue destruction (myonecrosis) as a result of injuries involving crushed limbs or deep muscle wounds. The bacterium most often associated with this condition, *C. perfringens* also causes a mild form of food poisoning usually associated with improperly heated meat dishes.

Legionnaires' Disease The source of the bacterium (*Legionella*) identified as the cause of legionnaires' disease was originally associated with aerosolized water from an air conditioning cooling tower. Usually found as a biofilm on surfaces in aquatic environments, species of *Legionella* have more recently been found in soil. An outbreak of legionnaires' disease in South Australia in 1991 did not exhibit the geographic clustering associated with a point source of infection. Cases were scattered and patients had in common the fact they were keen gardeners[74]. Subsequent testing found Legionella in various Australian potting soils[75]. The potting soil components found to be associated with the presence of *Legionella* spp. were composted leaves or sawdust rather than peat moss. It has been theorized that watering with a vigorous stream of water could aerosolize bacteria present in the soil. The first two cases of legionnaires disease in the United States associated with gardening were reported in 2000[76]. Potting soil removed from the site of at least one of these cases was found to contain *L. longbeachae*. More recently *Legionella* have been found in water aerosolized during operation of garden sprinkler heads[77], adding a further potential source of infection to be aware of while gardening. Legionnaires disease can be asymptomatic or cause flu like symptoms leading to a potentially fatal pneumonia. All age groups are at risk, but disease is more likely in middle aged to elderly individuals especially if they smoke or consume large amounts of alcohol. Persons with chronic lung disease, diabetes, severe kidney disease requiring dialysis, on immunosuppressive therapy or with AIDS are at increased risk of infection.

Fungi Many types of fungi occur naturally in the garden, where they play an important role in the breakdown of organic matter in the soil. Some molds, although not infectious to humans, produce compounds that act as allergens when inhaled. This results in a variety of symptoms in susceptible individuals, including nasal discharge, asthma or pneumonitis. Repeated exposure can cause symptoms to worsen as the individual becomes more sensitized to the fungal allergens.

There are fungi capable of growing in or on the human body, where they cause diseases referred to as mycoses. **Histoplasmosis** is primarily a disease of the respiratory system caused by inhalation of spores of *Histoplasma capsulatum*. In most people there are no symptoms, whilst in others infection produces a mild flu like illness. Infections can in some cases produce a chronic disease that worsens with time and resembles tuberculosis. In rare cases a disseminated form of the disease can occur, and this is fatal if not treated. Serious complications are more likely in persons with weakened immune systems, and the disease is recognized as a risk factor for AIDS patients. Spores of *H. capsulatum* are found in soils throughout the U.S, particular in those having high nitrogen content and an acid pH. Histoplasmosis is endemic to areas bordering the Mississippi and Ohio River valleys and cases outside those areas are rare and usually involve persons with AIDS[78]. Disseminated histoplasmosis has been reported in South Florida AIDS patients[79] without any history of prior travel to an area where the disease is endemic.

Sites enriched with bird droppings are particularly likely to have elevated numbers of spores, and areas under roosting sites of blackbirds, grackles and pigeons are especially prone to be

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74Cameron, S. *et al*. 1991 Aust. NZ J. Med. **21** 65-70
75Steele *et al* 1990 Appl. Environ. Microbiol. **56** 2984 - 2988
76 MMWR September 01 49 (34) 777 - 778
77 Stojek, N. M. and Dutkiewicz, J. 2002 Ann. Agric. Environ. Med**. 9** 261 - 264
78Cano, M.V. and Hajjeh, R.A. 2001 Semin.Respir.Infect. **16** 109 -118
79 Bellman, B. *et al* 1997 Int. J. Dermatol. **36** 599 - 603

contaminated. Fresh droppings are not infective, but as they dry out the growth of the fungus already present in the soil is encouraged. Due care needs to be exercised when disturbing soil on any site where birds are known to have roosted for three or more years. Gardening is listed as a risk activity for contracting histoplasmois by the National Institute for Occupational Health and Safety[80].

Aspergillosis is primarily a localized pulmonary infection caused by inhalation of fungal spores produced by *Aspergillus spp.* (usually *A. flavus* or *A. fumigatus*) and most frequently becomes manifest in those with some underlying lung disorder. In persons with a suppressed immune system, infection can spread to other sites such as the brain and bone. The fungus is widespread in the environment both indoors and outside, but is especially prevalent in decomposing vegetation.

One other fungal disease that has recently become of much greater significance as an opportunistic mycosis is **cryptococcosis**, caused by the soil fungus *Cryptococcus neoformans*. Infection occurs through inhalation of spores or yeast cells, with most cases being asymptomatic. In those persons with a compromised immune system (particularly AIDS patients), a serious disseminated form of the disease occurs, usually as a meningoencephalitis. *Cryptococcus neoformans* like *H. capitulatum* thrives in ageing bird manure particularly that from pigeons, in sites not exposed to direct sun. However, survey data has been unable to establish any clear risk between sites where bird droppings are plentiful and the acquisition of disseminated cryptococcosis[81]. A subsequent extensive literature review found that proximity to feral pigeons and the risk of contracting cryptococcosis was minimal in healthy individuals, but almost 1000 fold more for those with a compromised immune system.[82] At present it is advisable for anybody at risk for this disease to consult a health professional before working with soil, particularly on a site known to have had a previous resident bird population.

An increasing number of **other opportunistic fungi** are being implicated as causes of serious complications in immune compromised individuals. Some of these organisms are well known as causes of plant diseases (i.e. *Alternaria*, *Bipolaris* and *Fusarium*), and are of ubiquitous occurrence. Any increased risk of infection with these fungi as a result of gardening has not been established.

Although the above mycoses are contracted through inhalation of spores or yeast cells, infection with some fungi is through skin abrasions and cuts. **Sporotrichosis**, a subcutaneous mycosis caused by *Sporothrix schenckii*, is such a disease and is often associated with handling plants having spines, prickles or thorns. It is usually identified with persons who are debilitated through disease, poor diet, old age or alcoholism. Symptoms of infection are seen within days to weeks as a hard skin nodule, which darkens and erupts to form an ulcer. Involvement of the lymphatic system results in the infection spreading to adjacent sites, where new lesions are formed. The disease may resolve without treatment or on rare occasions become disseminated. Disseminated sporotrichosis is seen in those with a severe underlying immunological deficit, and was typically associated with alcoholics and those receiving immuno-suppressive therapy. It is now recognized as a potential complication of HIV infection[83].

In the U.S cases of sporotrichosis are few, and it has been referred to in the past as "alcoholic rose-gardeners' syndrome", having had an association with middle age, white gardeners with a drinking problem. Rose prickles have been identified as a potential source for infection; a survey of prickles recovered from rose plants in Oklahoma revealed the presence of numerous opportunistic fungi (see above) as well as a lesser incidence of *S. shenckii*[84]. Other sources of infection that have been

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[80] DHHS (NIOSH) Publication No. 97-146 September 1997

[81] Hajjeh, R.A. *et al* 1999 J.Infect.Dis **179** 449-454

[82] Haag-Wackernagel, D. and Moch, H. 2004 J. Infect. 48 307 - 313

[83] Heller, H.M. & Fuhrer, 1991 J. AIDS **5** 1243-1246

[84] Flournoy, D.J. *et al* 2000 J.Okla.StateMed Assoc. **93** 271-274

identified include pine needles, as when handling seedling pine trees, and dried sphagnum moss, widely used as a growth medium for plants. Several workers at a Florida nursery became infected after handling dried sphagnum moss[85] used to pack seedling evergreen trees. Precautions such as wearing long gauntlet style gloves should be taken when garden activities involve handling plants or other items (i.e. baling wire) that could cause cuts or abrasions. Limit skin contact with products such as sphagnum moss by wearing gloves and long sleeved clothing, and avoid working with this material if you have recent skin abrasions.

Free Living Amoebae A number of free living amoebae have been found worldwide in soil, water and even air samples that are capable of causing disease in humans. One of these, ***Naegleria fowleri***, causes a rare but rapidly fatal form of meningoencephalitis (PAM: primary amoebic meningoencephalitis). The majority of cases involve young, active, otherwise healthy individuals, with an immediate history of bathing or swimming in polluted bodies of warm fresh water. Infection occurs through the nasal passages, amoebae penetrating the olfactory neuroepithelium and migrating up the olfactory nerve to the brain. Death occurs 3-7 days after infection. Gardening poses no risk of contracting PAM.

Various ***Acanthamoeba* sp**. can cause opportunistic infections, including a sight threatening keratitis (particularly in contact lens wearers), and are of ubiquitous occurrence. In individuals who are severely weakened and/or immuno-compromised, a disseminated form of acanthamebiasis occurs involving the skin and various internal organs, particularly the brain. Infection is thought to occur usually via the respiratory tract, although the spread of amoebae by means of the circulatory system from skin ulcers is also believed to be a factor[86]. One other free living amoebae, *Balamuthia mandrillaris* also causes encephalitis, but less frequently than *Acanthamoeba*. Although found in soil, there is as yet no evidence to suggest an increased risk of infection with either *Acanthamoeba* or *Balamuthia* when gardening.

Amebic dysentery is caused by a parasitic amoeba, *Entamoeba histolytica,* and is contracted through food or water contaminated with cysts passed in human feces. There is no animal reservoir and gardening should not increase the risk of infection if due attention is paid to personal hygiene.

Hantavirus Pulmonary Syndrome This viral disease is not necessarily soil borne, but is included in this section more for convenience. The virus is most often contracted through inhaling dust containing dried rodent feces, saliva or urine. Infection is rare but has an overall 30% fatality rate. After an initial 3-5 day period of fever, chills and muscle aches, the cardiopulmonary phase of the disease progresses rapidly with marked pulmonary oedema, death usually being due to respiratory failure.

One case has been reported in Florida (south Miami-Dade County, 1994)[87], at which time a new hantavirus was identified (Black Creek Canal Virus) in local cotton rats. Extensive surveillance for evidence of further cases revealed this to be an isolated event, and no further incidents have been reported in Miami-Dade. However since hantavirus infection is sufficiently serious, and up to 60% of all cotton rats sampled in certain south Miami-Dade locations were positive for the virus, care should be exercised. Renovation of previously undisturbed garden sites, with a known rodent population, requires special care, particular if dust is present. When clearing an area for use as a garden, wet down any dust and wear an appropriate protective mask. Be particularly careful if the site includes abandoned structures that need to be cleaned out for future use as storage areas for garden tools and supplies.

85Hajjeh, R. *et al* 1997 J. Infect. Dis. **176** 499-504

86Martinez, A. J. and Visvesvara, G. S. 1997 Brain Pathol. **7** 583-598

87Glass, G.E. *et al.* 1998 Am.J.Trop.Med.Hyg. **59** 699-703

Vector Borne Infections

As was mentioned above, mechanical transfer of pathogens by animals, especially insects and birds can be greatly reduced by covering garden refuse and compost piles, and not spreading raw manure. Apart from the more obvious mechanical vectors, such as filth flies, cockroaches and beetles that are normally associated with dispersing pathogens from contaminated waste, less obvious vectors have been implicated. For instance fruit flies were found capable of transferring *E. coli* from a compost pile containing spoilt fruit, to wounds on uncontaminated fruit where the bacteria then grew exponentially[88].

Mosquitoes These are the most important biologic arthropod vectors in South Florida, and the Culicine mosquito, *Culex nigripalpus* the most significant species for spreading human disease. It is responsible for the transmission of **St. Louis Encephalitis (SLE)** in South Florida, and more recently has emerged as a vector of **West Nile Virus (WNV)**[89] in this part of the state. Eastern Encephalitis (EE) is of more concern north of Lake Okeechobee, and involves different mosquito vectors. All of these diseases are due to a group of viruses collectively known as arbor viruses, a term which refers to their mode of transmission (abbreviation of arthropod borne). All three of the above viral diseases are normally found in birds, where the symptoms can vary from none (SLE) to numerous fatalities (WNV). In humans, symptoms of WNV can range from a mild flu like illness, to fatal encephalitis. About 80% of all infections are asymptomatic, with most of the remainder experiencing flu-like symptoms. Less than 1% of those infected develop neurological symptoms, and for these there is a 20% fatality rate. For persons over age 50 there is a much greater risk of encephalitis from WNV infection, similar to what has been observed for SLE. However WVN can also cause polio-like symptoms of flaccid paralysis and these appear to exhibit no relation to either age or previous medical history[90]. Infection with WNV is especially serious for those having an organ transplant. Neither SLE or WNV is vectored from person to person, since the number of circulating viruses (viremia) is never sufficient to develop in a mosquito after it has taken a blood meal. Transmission to mosquitoes only occurs from birds and is restricted to a limited period of 1-3 days post infection when the viremia is sufficiently high, after which the virus disappears from the circulating blood.

Culex nigripalpus is found year round in hammocks and other moist wooded areas and breeds in semi-permanent bodies of water. During the wetter months of the year as humidity levels rise, this species will move out into more open areas, particularly after heavy rain and deposit eggs in areas of temporary standing water. These could be freshly flooded ditches, hollows in the ground, old tires or any receptacle in the yard where water will collect and could be expected to remain for 10-14 days. Feeding occurs in the period just after sunrise and before sunset. Only the female mosquito requires a blood meal, this in order to develop each batch of eggs. Otherwise both male and female insects will feed on nectar and plant secretions.

During a summer drought, gravid female mosquitoes will refrain from laying eggs or feeding, however once there is adequate rainfall, about 2", they will deposit masses of eggs in a suitable site, and then take a blood meal to develop further eggs. Periods without significant rain that last for more than 10 days (the incubation period for the SLE virus in *Cx. nigripalpus)*, will lead to increased infectivity of mosquitoes once they take a blood meal. Under such summer climatic conditions (i.e. a 15 -20 day period of little rain, followed by a downpour) the chance of being bitten by an infected mosquito is greatly increased. From an analysis of both climate data and the extent of WNV transmission to sentinel chickens in 31 south Florida counties, it appears that severe drought during spring followed by normal summer rainfall will increase the likelihood of a WNV epidemic[91].

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88 Janisiewicz, W.J. et al 1999 Appl. Environ. Microbiol. **65** 1-5

89 Godsey, M. S. *et al* 2005 Vector Borne Zoonotic Dis. **5** 82 - 89
90 Bhangoo, S. *et al* 2005 J. Neurol. Sci. **234** 93 – 98
91 Shaman, J. *et al* 2005 J. Med. Entomol. **42** 134 - 141

Prolonged drought causes more intimate contact between mosquito and bird populations resulting in greater amplification of the virus. Throughout winter and spring, birds (notably pigeons, mourning doves, blue jays, cardinals and sparrows) predominate as hosts for *Cx. nigripalpus.* However in summer, birds and mammals are of equal importance. A similar scenario exists regarding epidemics of SLE.

World wide, mosquitoes are vectors of many other diseases however none, including malaria and dengue, are important at this time in South Florida. There is also no evidence to suggest that mosquitoes or any other arthropod vectors are involved in the spread of HIV 1 or 2 (human immunodeficiency virus).

It is the responsibility of gardeners to minimize potential mosquito breeding sites by removing objects favoring the accumulation of standing water. Failure to do so will in many instances violate local mosquito control ordinances, with violators being subject to fines. In certain counties, such as Miami-Dade, this includes a ban on cisterns designed to collect rain water for irrigation use. If outdoors when mosquitoes are active use a repellant containing DEET (especially on clothing) or picaridin (less objectionable odor).

Ticks and Mites. These are members of a group of arthropods (the Acarina) that also includes spiders, with ticks being divided into soft and hard bodied types. Depending on the species, development of the tick through nymphal stages to adult can occur on the same host or may involve two or more different types of host. Both types of ticks take blood meals and are capable of vectoring a variety of diseases to both humans and animals, however it is the hard ticks that are of most importance in the US. In South Florida the hard ticks most commonly encountered include the **brown dog tick** *Rhipicephalus sanguineus*, the **American dog tick** (*Dermacentor variabilis*) and the **black legged tick** (*Ixodes scapularis*). The brown dog tick rarely attacks human and is not known to vector human disease in Florida, however it is implicated in spreading canine ehrlichiosis.

The American dog tick will attack humans and can spread *Rickettsia rickettsii*, the organism responsible for **Rocky Mountain spotted fever**, as well *Ehrlichia chafeensis*[92] the bacterium responsible for **human monocytic ehrlichiosis**. Rocky Mountain spotted fever occurs more frequently in northern Florida, though it is a potential risk throughout the state. Human ehrlichiosis (a febrile often fatal illness that is difficult to diagnose) has been a notifiable disease in Florida since 1996. However it's distribution in the state is uncertain, most reported cases to date being found in central and north Florida This correlates with the distribution of the principal tick vector *Amblyomma americanum* (lone star tick).

Whilst the American dog tick can be found in overgrown undisturbed urban and rural sites, the black legged tick is restricted to more wooded areas. Both of these ticks produce neurotoxins in their saliva which, with prolonged attachment during feeding, can cause tick paralysis. The few cases reported are usually found in young children and are more prevalent in the Rocky Mountain and north western states of the US. The black legged tick is the principal vector of *Borrelia burgdorferi*, (the bacterium responsible for **Lyme disease**) in the eastern US. Disease outbreaks in Florida are far fewer than in north eastern states, a fact that could well be due to differences in the ecology of the tick as it pertains to its role as a vector in Florida. For instance in the south, the nymphal stages do not feed on humans, thus transmission of *B. burgdorferi* is restricted to feeding of the adult tick.

Mites are microscopic members of the Acarina, and though most are free living many are found as ecto and endoparasites of both vertebrate and invertebrate hosts. As a group they are not known to be important disease vectors in the US, however they are significant causes of severe dermatitis and produce allergens that can cause pronounced hypersensitivity reactions. *Sarcoptes scabei* causes **scabies** in humans and **mange** in various domestic and wild animals. Different races of the scabies mite are found on animals, none of which are able to become established and reproduce on humans.

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[92] Walker, D.H. & Dumler, J.S. Emerg.Infect..Dis. **2** 18-29.

Close contact with an infected animal (i.e. a stray dog) can however cause a transitory infection resulting in urticaria that may last several days. A variety of mites are found on wild animals, including mammals, birds and even insects, and can be responsible for temporary but severe itching in humans.

Wild Birds Apart from mites other bird ectoparasites such as **soft ticks** (*Argas* sp.) and fleas have been known to affect humans. Unlike hard ticks, *Argas* sp feed at night while the host is resting, and are much less a human problem when outdoors compared to hard ticks. Attention has frequently been drawn to the role of wild birds, especially pigeons[93], in spreading disease. Migrating birds can not only disperse vectors of human disease (Lyme disease) but also act as both amplifying hosts (WNV) and reservoir hosts (enteric diseases)[94].

Animal Bites and Scratches

Working in a garden can involve unpleasant encounters with animals, and if this results in bites or scratches, the risk of contracting a serious illness. The Florida Health Department estimates that annually about 60,000 persons suffer animal bites (both wild and domestic) in the state (51 incidents actually reported during 2004 in Miami-Dade). From 12 - 20% of all dog bites become infected, whilst for cats the number is more than double. Although dogs have far more powerful jaws, their teeth are quite blunt compared to the sharp pointed teeth of a cat, which can easily penetrate joint capsules and bone. The oral cavity of all mammals supports a variety of normally commensal bacteria (at least 40 species/ types are present in the dog[95 ,96]), so the poly microbial nature of an infected bite wound would be expected. Typically 4 or 5 different species of bacteria are isolated from bite wounds, some of which are more commonly encountered than others and can lead to more significant complications. Cat bites, although less numerous than those due to dogs, are far more likely to become infected and in all cases the outcome is more serious for young children[96]

Pasteurella multocida, This coccobacillus is found in the oral cavity of 70 -90% of domestic cats, and is the most frequently encountered species in cat bite infections , being present in more than 50% of all cases investigated[97]. It is also often though less frequently encountered in dog bites. The onset of symptoms is rapid with acute pain, swelling and diffuse redness of the skin being noticeable within 6 hours, all symptoms highly suggestive of *P. multocida*[98]. Complications including wound abcesses, joint diseases, endocarditis, meningitis and bacteremia are most often observed with those having a predisposing illness such as diabetes, cirrhosis of the liver, or compromised immune systems. A 30% fatality rate is associated with blood infections.

Capnocytophaga canimorsus is a normal part of the microflora of the canine oral cavity, and can also be found in cats. Infection can cause a range of symptoms including fever, cellulitis, endocarditis, meningitis and septicemia. Existing conditions such as alcoholism, diabetes, severe pulmonary disease and splenectomy predispose a person to developing the above symptoms[99]. Whilst a bite or scratch is associated with most infections, the saliva from the lick of an animal can

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93Haag-Wackernagel, D. & Spiewak, R. 2004 Ann. Agric. Environ. Med. 11 343 – 346 (see references cited)
94Reed, K. *et al*. 2003 Clin. Med. Res 1 5-12
95Smith, P.F. *et al* 2000 J.Clin.Pharm.Therapeut. **25** 85-99

96Garcia, C. F. 1997 Pediatr. Rev. **18** 127-130
97Weber, D.J. et al. 1984 Medicine (Baltimore) 63 133-154
98Westling, K. *et al* J. Infect. **40** 97-98

99Lion, C. *et al* 1996 Eur. J. Epidemiol. **12** 521-533

result in infection in a susceptible person.

Cat Scratch Disease(CSD) Also known as bartonellosis, infection is due to *Bartonella henslae* one of a group of bacilli that have adapted to an intracellular existence within the cells of various mammalian species. Infection results in fever with localized pain and swelling (lymphadenopathy) sometimes with papule formation. Most cases of CSD resolve without further complications, though up to a quarter can involve ocular, hepatic and cardiac symptoms. Persons with a compromised immune system may develop bacillary angiomatosis (benign tumor like growths composed of blood vessels), bacillary peliosis (purpurea of skin and mucous membranes) and a relapsing bacteremia[100,101]. From survey data it appears that *B. henslae* is a widespread and persistent parasite of cats there being no overt signs of infection, bacteremias being detected for at least 15 months. The disease is spread amongst cats by the cat flea *Ctenocephalides felis*, and this may pose a threat to certain cat owners, especially those with immune deficiencies. Far more significant for the spread of *B. henslae* to humans however, are wounds resulting from cat scratches or bites. It is believed that transmission occurs when cat flea feces, which is known to contain viable bacilli, contaminates the animal's claws or teeth[102]. Bartonellosis is one of several zoonoses involving Rickettsia like organisms that are of increasing occurrence in urban centers[103]

Apart from contamination of wounds with microbes that are a normal part of the microflora/fauna of the oral cavity, there are pathogenic organisms not normally resident in the mouth that can also be introduced by way of an animal bite. Previous reference has been made to diseases such as tularemia and tetanus, both of which can be contracted from animal bites. The most serious infection by far that can result from an animal bite is rabies.

Rabies Rabies is a rapidly fatal encephalitis caused by a neurotropic rhabdovirus. Although there have been no human cases contracted within Florida since 1948, rabies is now endemic in portions of the state's wildlife population. A number of variants of the rabies virus have been identified as being associated with certain wildlife species such as the raccoon, grey fox and coyote. Racoons and to a lesser extent foxes are now the major reservoir of rabies in Florida wildlife. Coyotes have now extended their range into south Florida and could become a future factor influencing the dynamics of rabies in Florida's wildlife. With the rapid urbanization of south Florida encroaching on wildlife habitat, the risk of stray dogs and cats becoming infected with rabies increases. State law mandates that all cats and dogs must have a current rabies vaccination. Baited vaccine has been used in attempt to control raccoon rabies. The incidence of rabies in feral cats in Florida now exceeds that in stray dogs[104]. This is ample reason to be cautious when in the vicinity of stray animals, particularly if they appear overly aggressive. In contrast, infected wild animals may appear unusually docile.

Rabies can be contracted from infected dead animals – take extreme caution in removing dead animals particularly if the brain is exposed (the rabies virus localizes in the brain). Any suspected cases of animal rabies are reported to local health departments and when confirmed are usually publicized in the local media. Take extra precautions when gardening, if a rabies alert has been issue for your area.

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100 Windsor, J.J. 2001 Br.J.Biomed.Sci. **58** 101-110

101 Lamps, L. W. & Scott, M. A. 2004 Am.J..Clin.Pathol. **121** Suppl. S71-80

102 Breitschwertdt, E.B. & Kordick, D.L. 2000 Clin.Microbiol.Rev. **13** 428-438

103 Comer, J.A. *et al.* 2001 Vector Borne Zoonotic Dis. **1** 91-115

104 Rabies Prevention and Control in Florida 2004 , Division of Environmental Health, Florida Department of Health

Guidelines to Reduce the Risk of Gardening Related Diseases

From a consideration of the information provided above, the following set of recommendations are presented for reducing the risk of infection from potential human pathogens that could be encountered whilst gardening. This encompasses the risk from time spent in the garden, as well as the subsequent consumption of garden produce. The resources listed at the end of the document should also be consulted for pertinent health related information and relevant safe horticultural procedures

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◆ **Never spread raw manure on the garden**.

◆ **Avoid the use of animal manure when composting, particularly in a small home garden compost pile, where the temperature is unlikely to be high enough to guarantee destruction of potential pathogens.**

◆**Restrict components of the compost pile, including any kitchen scraps used, to plant material.**

◆**If you must use animal manure as a source of compost, that from horses is the safest though not totally free of risk (possible source of *Giardia*).**

◆**If you must use animal manure, it is essential to exclude material from young animals such as calves.**

◆**If you must use animal manure, avoid contaminating finished compost with raw manure - have a separate set of tools to handle manure, and store compost well away from fresh manure.**

◆**Invest in a compost thermometer to ensure that the pile reaches the recommended temperature, and follow current procedures for turning the pile and keeping it aerated.**

◆**If the material to be composted is low in nitrogen rather than using manure, add a small amount of fertilizer or an organic source such as oil seed meal. Such materials are available commercially, specially formulated for use in small scale composting.**

◆**It is very important to exclude pest animals and insects from a**

compost pile that contains manure.

◆ Take precautions to prevent rain water run off from a compost pile from contaminating the garden site – this is essential if you insist on composting manure.

◆Scout the garden site for animal droppings, particularly if there are stray or feral animals in the area, or the garden site is frequented by rats or other wild animals such as raccoons. Promptly remove and dispose of such material in a plastic bag.

◆Before clearing or cultivating a previously undisturbed site for use as a garden, wet down any dry dusty areas.

◆Use an appropriate face mask when turning a compost pile, entering storage sheds (especially if dusty) and clearing out a new garden site, particularly if it is one where birds may have roosted. A face mask should also be worn on entering any previously abandoned structures that may be part of a new garden site, especially if there is evidence of a rat infestation, and when handling potting soil and organic fertilizers.

. **◆Wear appropriate clothing, including gardening gloves, a long sleeved shirt or blouse and sturdy foot wear. Never allow anybody, particularly children onto the garden site with bare feet.**

◆If children are involved in the garden they must be adequately supervised, with a designated person having the responsibility in a community garden. Keep them away from wildlife or stray animals, watch for signs of pica (eating dirt), and make sure that they do not consume any produce from the garden before it is thoroughly washed. Do not allow children to play in areas of standing water.

◆ If feasible try to level out the garden site to minimize pooling of water. Do not allow objects that could collect water to remain on site after you finish working in the garden.

◆Try to avoid gardening just before sunset and after sunrise (periods when mosquitoes are active,) during the summer rainy season, particularly following heavy rain that falls after a prolonged dry spell. If this is not possible, wear a long sleeved shirt/blouse and long pants and use an insect repellent containing at least 15% DEET (less for children). With cotton, nylon and wool based fabrics the product can be applied directly on clothing. The CDC now also recommends products containing

picaridin which is more acceptable for applying directly to areas of exposed skin, particularly on children.

◆All animal bites should be reported and receive prompt medical attention.

◆Before gardening, consult a health professional as to what precautions you should take if you believe you may suffer from any medical condition that could make you more susceptible to infection. Such conditions could include but are not limited to HIV/AIDS, cancer treatment, immunosuppressive drug therapy, previous splenectomy, pregnancy, diabetes, alcoholism or chronic liver or lung disease.

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Further Sources of Information

For relevant horticultural practices, including composting, as well as further information on the infectious agents described above, the following federal/state website resources should be consulted:

Centers for Communicable Diseases (CDC) – www.cdc.gov
Search the entire site for specific information, or consult the A-Z fact sheets on specific infectious diseases.

Florida Department of Health - www.doh.state.fl.us/
Information on Florida health concerns, with information sheets on infectious diseases of importance to Florida residents (go to Bureau of Epidemiology).

Miami-Dade County Health Department – www.dadehealth.org Information on local health related matters including disease statistics for Miami-Dade County. Also lists contacts for reporting any suspected disease outbreaks.

Center for Food Safety and Applied Nutrition, United States Food and Drug Administration – http://vm.cfsan.fda.gov . Extensive information on food safety issues.

National Center for Biotechnology Information http://www.ncbi.nlm.nih.gov
Select "PubMed" and search the National Library of Medicine's holdings of

biomedical journals and periodicals if you wish to access more in depth information on any of the pathogens listed above.

University of Florida Institute of Food and Agricultural Sciences – http://edis.ifas.ufl.edu Search this site for current information on both horticultural topics (e.g. composting), arthropod vectors of disease and zoonotic parasites.

Florida Medical Entomology Laboratory, University of Florida http://fmel.ifas.ufl.edu up to date information on disease vectors in Florida