The Mighty World of Microbes: An Overview

1

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The Microbial World On and Around Us

The world of microbes on our planet is vast and diverse. This includes the normal bacterial flora present on the skin and mucous membranes of humans. The human microbiome project (HMP) was launched by NIH in 2007 as a part of a road map for medical research. The HMP serves as a template for researchers who are studying more than 1,000 microbial genomes with a focus on their role in health and disease. The study samples have been derived from five human body regions that are known to be inhabited by microbial flora. These include the gastrointestinal tract, female urogenital tract, mouth, nose, and skin. The techniques being used include finger printing, sequencing, dynamic range, and comparison of multiple samples. It is now well accepted that there are more microbial cells than human cells in the human body. Just the gastrointestinal tract harbors more than tenfold microbial cells than the number of human cells in the entire body. The understanding of the relationship between microbes and humans is at best rudimentary at this point in time. Similarly, the relationship between humans and microbes in the environment and environmental surfaces is poorly understood except for a few pathogenic microbes.

The most well-studied host-associated microbes are those in the gastrointestinal tract. In the area of infectious diseases and infection control, we typically look at individual diseases caused by single organisms. Conventionally microbes are thought of as bad actors because the emphasis is on disease rather than interaction between human and microbial cells. The protective role of a large number of bacterial species that exist on and around us has largely been minimized. In fact, these bacteria should be referred to as "Nature's Bioshield." Their association with the areas they were put in by nature is strong and symbiotic. Since they are common to healthy individuals, their transmission from person to person is of no relevance. We know now that the disruption of this bioshield by physical injury and its alteration by the selection process from antibiotic use are the most significant risk factors for developing infectious diseases including those caused by multiple antibiotic-resistant bacteria and their transmission to others in the health-care as well as community settings.

The transmission from person to person was proven even before the germ theory of disease was proven. For example, in 1841, Ignaz Semmelweis,

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a Hungarian physician, attempted to mandate hand washing and change of coats used in autopsy rooms before examining patients or performing deliveries. He believed that invisible agents can be transferred particularly from autopsy room to delivery room thus infecting mothers during birthing. He built this belief from his observation that the death rates in the ward that was run by physicians were 18 % more than that in the ward run by midwives. He contributed that to the fact that physicians were working in autopsy rooms and the midwives were not. Also one of his colleagues died after he cut himself during an autopsy on a patient who had died from puerperal fever/sepsis. His colleagues did not accept the concept despite the fact that the death rate in the hospital dropped by 66 % after applying the two interventions. It is difficult to comprehend why Dr. Semmelweis faced opposition despite the success of his measures. The question was and remains today: Is it hard to apply these practices or are we not able to meaningfully convey the principles?

Historically, the concept of cleaning and sanitizing was practiced long before the germ theory was conceived, it is all about cleaning. Even the theories developed in the middle ages about cleaning said that diseases were caused by the presence of "miasma" in the air. Miasma is a poisonous vapor with a foul smell. This theory encouraged people to get rid of the foul smell by cleaning which helped decrease the rate of diseases by getting rid of what later was named as germs.

It was the effort of many scientists to develop and prove the germ theory. The first step was taken by Antoni Van Leeuwenhoek who saw tiny structures under the microscope in 1677 and called them "animalcules."

The germ theory of disease was well established in the early 1880s based on Robert Koch's published work on tubercle bacillus. In 1882, one of his assistants Friedrich Loeffler published the three postulates that need to be fulfilled to establish an association between a microbe and a disease process (Box 1.1). These postulates were formalized by Koch himself between 1884 and 1890. Concurrent with establishing the pathogenicity of the limited number of bacteria, the transmission pathways and their interruption were being conceived also. Joseph Lister and John Snow contributed significantly to the acceptance of germ theory.

Box 1.1

Loeffler's postulate	Koch's postulate
1. The organisms must be shown to be constantly present in characteristic form and arrangement in the disease tissue	1. The same organism must be present in every case of the disease
2. The organisms, which from their behavior appear to be responsible for the disease, must be isolated and cultivated in purity	2. The organism must be isolated from the diseased host and grown in pure culture
3. The pure cultures must be shown to include disease experimentally	3. The isolate must cause the disease, when inoculated into a healthy, susceptible animal
	4. The organism must be reisolated from the inoculated, diseased animal

A century and quarter later, everybody seems to agree with the importance of prevention and its application but the compliance is still an issue. Perhaps this is because the consequences of noncompliance are not obvious right away and it is hard to point to a single action that caused the incident. It is a fact that those we ask to comply with infection prevention practices do not have a clear understanding of the microbial world at large and therefore the principles. This has made it difficult and at times impossible to have an optimal adherence with these practices. We believe that it is absolutely necessary to convey to health-care providers of all levels the significance of the microbial flora on and around us, the factors that put them at risk for acquiring and subsequently transmitting disease-causing pathogens to patients at high risk of developing infectious processes due to multiple factors including age, immunocompromise, and comorbid conditions. With that in mind the rest of this chapter will provide an overview of bacteria, viruses,

prions, fungi, and parasites with focus on modes of transmission and therefore the modes of prevention of transmission. The details of the procedures to reduce transmission in the healthcare settings will be provided in the following chapters.

Pathogenic Bacteria and Their Modes of Transmission

Bacteria by definition lack membrane-enclosed nucleus and membrane-enclosed organelles like mitochondria and chloroplast. They have double-stranded DNA and a cell wall made of peptidoglycan. Based on the amount of the peptidoglycan in the cell wall, bacteria will retain crystal violet during the gram-staining process and not get decolorized which gives them a purple color and therefore are classified as gram-positive bacteria. In contrast, gram-negative bacteria have a thin layer of peptidoglycan, are decolorized after the initial staining by crystal violet, and take the counter stain safranin. These bacteria acquire pink in color and are classified as gram negative. The bacteria of clinical relevance are further classified based on their morphology that is spherical or cocci or rod shaped or bacilli. The cocci can be present in clusters such as staphylococci or in chains such as streptococci. The third level of classification is based on the growth under aerobic and anaerobic conditions. Most aerobic bacteria are able to also grow under anaerobic condition and are facultative anaerobes. Obligate anaerobes, on the other hand, grow only in the absence of oxygen. Further identification to the genus and the species level is determined by biochemical reactions (phenotypic characteristics) and/or molecular techniques (genotypic characteristics).

Gram-Positive Bacteria

Gram-positive aerobic cocci	Gram-positive anaerobic cocci	Gram-positive aerobic bacilli	Gram-positive anaerobic bacilli
Staphylococcus	*Peptostreptococcus*	*Bacillus*	*Clostridium*
Streptococcus	*Peptococcus*	*Corynebacterium*	*Actinomycete*
Enterococcus		*Listeria*	
		Nocardia	

Aerobic Gram-Positive Cocci

Staphylococci are aerobic/facultatively anaerobic gram-positive cocci that are not motile and do not form spores. Of the 31 species recognized, *Staphylococcus aureus* and *Staphylococcus intermedius* produce the enzyme coagulase which helps in their identification and is also a virulence factor.

S. aureus colonizes the skin and mucous membranes of 30–50 % of healthy adults and children, most commonly in the anterior nares, skin, vagina, and rectum [1]. In addition to coagulase, *S. aureus* has a number of virulence factors including exotoxins such as enterotoxin, exfoliative toxin, and toxic shock syndrome toxin 1. The primary sites of infections caused by *S. aureus* are the skin and soft tissue; however, infection can become disseminated, causing bloodstream infection and multiple organ involvement including endocarditis. The point of entry of *S. aureus* maybe obvious such as folliculitis or maybe related to skin disruption which is not obvious. In addition, *S. aureus* can colonize devices following transcutaneous insertion producing a biofilm on the device with subsequent potential for bloodstream infection and dissemination. The ingestion of food contaminated with *S. aureus* can cause food poisoning due to the presence of preformed enterotoxin.

Transmission of *S. aureus* occurs primarily by contact with the skin of colonized people and/or environmental surfaces which have been

contaminated by colonized people. Colonized personnel in the health-care setting serve as reservoir for *S. aureus* transmission to patients and to the surfaces. However, transmission is common even in the community setting. The best example is the recent significant increase in the community-associated skin and soft tissue infections caused by *S. aureus* clone 300. Food contaminated by dietary personnel has been implicated in staphylococcal food poisoning. Transmission of *S. aureus* can be reduced by hand hygiene and decontamination of environmental surfaces.

Coagulase-negative staphylococci (CNS) are present on the skin of all humans and are the most abundant constituent of the normal flora at this site [2]. If and when CNS enter the bloodstream, e.g., through insertion of medical devices, they can cause bloodstream infection, endocarditis in patients with prosthetic valves, infections of pacemakers and intravascular catheters, and other foreign bodies in place. *Staphylococcus* epidermidis accounts for about half of resident staphylococci and majority of the isolates in clinical blood specimens [3]. Other clinically significant species include *S. saprophyticus*, which causes urinary tract infection in young sexually active women, and *S. lugdunensis* which cause endocarditis, osteomyelitis, and septicemia. *S. hominis*, *S. haemolyticus*, *S. warneri,* and *S. simulans* are rarely isolated as pathogens. The most optimal way to prevent infections by CNS is hand hygiene, effective skin antisepsis, and barrier precautions during procedures outside the operating room.

Streptococci are facultatively anaerobic gram-positive cocci that form pairs or chains. Different species cause different infections, so it is important to know the classification. The classification does not depend on a single factor but rather it depends on different factors including hemolytic reaction on blood agar, serologic specificity of cell wall (Lancefield classification), and biochemical characteristics.

The serological classification (Lancefield classification) depends on the carbohydrate antigen in the cell wall based on which streptococci are classified into (A, B, C, etc.).

S. pyogenes, group A (GAS), β-hemolytic, is a common cause of pharyngitis and impetigo. *S. pyogenes* contains cell wall M protein which is an important virulent factor and induces cross-reactive antibodies leading to nonsuppurative complications of rheumatic fever and glomerulonephritis. It can occasionally colonize the respiratory tract and the skin. It can be transmitted from person to person through respiratory droplets to cause pharyngitis or through a break of the skin after direct contact to an infected person, fomite, or arthropod vector to cause skin infection. Nosocomial transmission of GAS to or by personnel can be prevented by hand hygiene and other practices including standard precautions that should be used for every patient contact. Other transmission-based precautions may be needed under special circumstances and outbreak situations.

S. agalactiae, group B (GAS), β-hemolytic, can cause urinary tract infection, postpartum endometritis, and bacteremia in pregnant women and sepsis and meningitis in neonates. Recently it has been recognized as an important cause of sepsis in nonpregnant adults especially those with diabetes mellitus [4]. It can be a part of the flora of the upper respiratory tract and genitourinary tract. The transmission of GBS from the mother's vaginal flora to the newborn during delivery is clearly understood. This has lead to the practice of surveillance cultures for GBS in vaginal flora during antenatal care. There are clear guidelines to manage GBS colonization in pregnant women prior to and during delivery in order to prevent its transmission to the newborn.

Group C and group G (*S. dysgalactiae*) are β-hemolytic streptococci that can cause pharyngitis and cellulitis clinically indistinguishable from GAS disease although they are more commonly opportunistic and nosocomial pathogens. These similarities can be explained by the sharing of a number of virulence factors with GAS like streptolysin and antigens similar to M protein. They can be part of the normal human flora and the transmission is similar to that for GAS.

Viridans streptococci like *S. mitis*, *S. sanguis,* and *S. salivarius* are α-hemolytic and are members of the upper respiratory tract flora and can cause

transient bacteremia which makes them the principal cause of endocarditis on abnormal heart valves. *S. mutans* produces polysaccharide that contributes to the genesis of dental caries.

S. pneumoniae is α- or nonhemolytic which can cause pneumonia, meningitis, endocarditis, and disseminated infection. These bacteria are ubiquitous. Most infections are caused by spread from colonized nasopharynx or oropharynx to distal sites (lung, blood, meninges). Person-to-person spread through respiratory droplets is rare.

S. bovis (formerly called nonenterococcal group D streptococci) are nonhemolytic and can cause endocarditis and are commonly isolated in blood in patients with colon cancer. It can colonize the lower gastrointestinal tract and rarely the upper gastrointestinal tract.

Enterococci (formerly called group D streptococci) are gram-positive cocci of intestinal origin that usually form short chains. They are a part of the gastrointestinal flora which is the commonest source of infections caused by enterococci. Rarely person-to-person spread can occur. The infections caused by enterococci include endocarditis, urinary tract infection, wound infection, biliary tract infection, and bacteremia. *E. faecalis* in the most common species and causes 85–90 % of enterococcal infections, while *E. faecium* causes 5–10 %. Some of enterococci, especially *E. faecium*, are vancomycin resistant. In the United States, 80 % of *E. faecium* and 6.9 % of *E. faecalis* were resistant to vancomycin between 2006 and 2007 [5]. Vancomycin-resistant enterococci (VRE) are often multidrug-resistant bacteria, and contact precaution is applied in the hospital settings for prevention of transmission.

Anaerobic Gram-Positive Cocci

Peptococci are obligate anaerobic gram-positive cocci. These bacteria are part of the flora of the mouth, upper respiratory tract, and large intestine. They can cause soft tissue infection and bacteremia.

Peptostreptococci are obligate anaerobic gram-positive cocci that is α- or nonhemolytic. These bacteria are part of the normal flora on the skin and mucous membranes. They can cause abscesses mostly in association with other bacteria.

Aerobic Gram-Positive Bacilli

Bacillus species are aerobic spore-forming gram-positive rods occurring in chains. They are saprophytic organisms prevalent in soil, water, and air. The principle pathogens of this genus are *B. anthracis* and *B. cereus*. *B. anthracis* causes anthrax which occurs when the spores are introduced cutaneously or through inhalation. The inhalation form is more serious but both forms can be complicated by systemic disease and meningitis. In 2001, 22 cases occurred due to bioterrorist attacks through contaminated envelopes which brought awareness to this old pathogen since it was rarely seen in the United states from 1980 to 2000 [6]. *B. cereus* is known to cause food poisoning and occasionally can cause bacteremia. This is a challenging diagnosis as *Bacillus* species are common contaminants in blood cultures and only 5–10 % present bloodstream infection [7].

Corynebacterium: *C. diphtheria* is the most important member of the group and can cause respiratory and cutaneous disease. Asymptomatic carriers accounts for 5 % of the population and are important for the transmission of the disease [8]. It secretes a toxin that inhibits protein synthesis and has necrotizing and neurotoxic effect. Treatment of the carriers and isolation of infected patients are important measures for the prevention of transmission, but the toxoid-based vaccination is the key to the decrease in the incidence of diphtheria.

Listeria species are facultative, motile, nonspore-forming gram-positive rods. *L. monocytogenes* is the most common and can cause a wide spectrum of diseases. It enters through gastrointestinal tract and can cause food-borne infections (1 % of cases of food-borne infections [9]). It can cause septicemia, meningitis, or encephalitis especially in immunocompromised, pregnant women, elderly, and neonates.

Nocardia asteroides complex is the species that is responsible for the majority of the cases of nocardiosis. They are aerobic gram-positive rods but they are also weak acid-fast. Nocardia are found in soil and water and are not transmitted from person to person. Nocardiosis is an opportunistic infection associated with impaired cellular

immunity. It causes chronic pneumonia which can mimic tuberculosis and can spread from lung to brain and form abscesses. Disseminated form can spread to skin, kidney, bone, and other systems.

Anaerobic Gram-Positive Bacilli

Clostridium species are anaerobic spore-forming large gram-positive rods which are also saprophytic organisms found in the soil and the intestinal tract of animals and humans. Among the pathogens is *C. botulinum* that causes food poisoning mostly from the canned foods that leads to flaccid paralysis due to the blocking effect of the toxin on the acetylcholine release in the synapse of the neuromuscular junctions. *C. tetani* causes tetanus which is a tonic contraction of the muscles as the toxin blocks the release of the inhibitory mediators like gamma-aminobutyric acid. Both pathogens act through their toxins and are associated with high mortality. *C. botulinum* spores are highly resistant to heat and 20 min of boiling is needed to destroy these spores. For tetanus, the toxoid-based vaccination is the key for prevention.

C. perfringens can cause myonecrosis and gas gangrene when introduced into damaged tissue. The effect is through alpha and theta toxins which can cause rapid and significant damage to the muscles and soft tissues which can rapidly progress to shock and death. In the other hand, ingesting secreted enterotoxin can cause self-limited diarrhea.

C. difficile causes pseudomembranous colitis in patients with exposure to antibiotics. It secretes toxin A and toxin B which are responsible for the disease. Hand washing with soap and water is the only effective way to prevent transmission from patient to patient in the hospital setting. Alcohol-based hand hygiene products do not kill *C. difficile* spores.

Actinomyces are non-spore-forming branching anaerobic filamentous gram-positive bacilli that readily fragment into bacillary forms. They reproduce by binary fission, a feature that differentiates them from fungi [10]. Most are saprophytes and live in soil, but members of this group are responsible for actinomycosis.

Actinomyces israelii is responsible for most of the cases of actinomycosis. It is a part of the human oral flora. It causes chronic disease characterized by abscess formation, draining sinus tracts, fistulae, and tissue fibrosis. Cervicofacial form accounts for half of the cases and also can manifest as central nervous system, thoracic, abdominal, and pelvic infections [11].

Gram-Negative Bacteria

Gram-negative aerobic cocci	Gram-negative anaerobic cocci	Gram-negative aerobic bacilli	Gram-negative anaerobic bacilli
Neisseria	*Veillonella*	*Enterobacteriaceae*	*Bacteroides*
Moraxella		*Pseudomonas*	
		Haemophilus	
		Brucella	
		Bordetella	
		Legionella	
		Chlamydia	
		Mycoplasma	
		Rickettsia	

Aerobic Gram-Negative Cocci

Neisseria are aerobic or facultatively anaerobic gram-negative diplococci. *N. meningitidis* and *N. gonorrhoeae* are pathogenic for humans which are the only host and typically are found associated with or inside polymorphonuclear cells. Other *Neisseria* species are normal inhabitants of the upper respiratory tract; they are extracellular and rarely cause disease.

N. meningitidis can be subdivided into serogroups based on distinct capsular polysaccharides. Eight serogroups most commonly cause infections in humans (A, B, C, X, Y, Z, W135, and L). The organism is considered a respiratory pathogen and spread by the aerosol route. It is clear that the high attack rates seen in the less developed countries are in part due to poverty and a consequence of crowding, poor sanitation, and malnutrition. Infection can produce a variety of clinical manifestations, ranging from transient fever and bacteremia to meningitis and fulminant disease with death ensuing within hours of the onset of clinical symptoms.

CDC recommends two doses of MCV4 (the vaccine that covers serotypes A,C,Y, and W135) for adolescents aging from 11 to 18 years, the first dose at 11 years of age with a booster dose at age 16.

For chemoprophylaxis, CDC recommends for adults or children who within 7 days prior to the onset of meningococcal disease lived or slept in the same household as the patient, have been contacts in the day care center, or directly exposed to the patient's oral secretions (e.g., through kissing, mouth-to-mouth resuscitation, endotracheal intubation, or endotracheal tube management).

For health-care settings, patients infected with *N. meningitidis* are rendered noninfectious by 24 h of effective therapy. Personnel who care for patients with suspected *N. meningitidis* infection can decrease their risk of infection by adhering to droplet precautions. Postexposure prophylaxis is advised for persons who have had intensive, unprotected contact (i.e., without wearing a mask) with infected patients, e.g., mouth-to-mouth resuscitation, endotracheal intubation, endotracheal tube management, or close examination of the oropharynx of patients.

Moraxella catarrhalis is an aerobic gram-negative diplococcus that is an exclusive human pathogen involving the upper respiratory tract. Most children have upper respiratory tract colonization at some point in the first several years of life. Colonization is uncommon in healthy adults, occurring in approximately 1–5 % of individuals [12]. It is a common cause of otitis media in children and acute exacerbations in adults with chronic obstructive pulmonary disease.

Anaerobic Gram-Negative Cocci

Veillonella are small anaerobic gram-negative cocci. They are part of the normal flora of the mouth, nasopharynx, and the intestine. Though occasionally isolated in polymicrobial anaerobic infections, they are rarely the sole cause of infection.

Aerobic Gram-Negative Bacilli

Enterobacteriaceae are aerobic (facultative anaerobic) non-spore-forming gram-negative bacilli. Some enteric organisms like *Escherichia coli* are part of the normal flora and incidentally cause disease, while others like Salmonellae and Shigellae are enteric pathogens for humans.

E. coli, *Proteus*, *Enterobacter*, *Klebsiella*, *Morganella*, *Providencia*, *Citrobacter*, and *Serratia* are members of the normal intestinal flora and can be a part of the normal flora of the upper respiratory and genital tracts. They can be recovered from the gastrointestinal tract of cattle and other mammals, soil, sewage, aquatic environment, contaminated food, water, and medical environment. They can be transient residents on the hands of health-care workers. They are transmitted by "food, fingers, feces, and flies" from person to person, and health-care workers play a significant role in the hospital setting.

They can cause hospital- and community-acquired infections, and some of them like Serratia and Enterobacter are considered opportunistic pathogens. They cause urinary tract infection, pneumonia, bacteremia, wound infections, and meningitis. Some E. coli strains can cause diarrheal diseases, e.g., enterotoxigenic *E. coli* that causes traveler's diarrhea due to exotoxins and enterotoxins and enterohemorrhagic *E. coli* that

causes hemorrhagic diarrhea due to the shiga-like toxin, among which the serotype O157:H7 can be associated with hemorrhagic uremic syndrome.

Association for Professionals in Infection Control and Epidemiology (APIC) recommends hand washing, alcohol-based hand hygiene, barrier protection, proper maintenance of equipment, and education as measures to prevent transmission.

CDC recommends personal hygiene including hand washing, cooking meat thoroughly, avoiding consuming raw milk and unpasteurized dairy products, and avoiding swallowing water during swimming.

In case of multiresistant bacteria contact, isolation should be performed to prevent transmission from one patient to another by applying hand hygiene and using gloves and gowns.

Shigellae are limited to the intestinal tract of humans and other primates. Infections are almost always limited to the gastrointestinal tract. The infective dose is low at 10–100 organisms, whereas it usually is 10^5–10^8 for Salmonella and Vibrio [13]. They are also transmitted by "food, fingers, feces, and flies" from person to person. Infections occurred most frequently among children in daycare centers.

Shigella causes diarrhea that is most of the times self-limited, and on recovery most persons shed the bacteria for a short period but few remain chronic intestinal carriers. *S. sonnei* commonly causes mild disease which may be limited to watery diarrhea, while *S. dysenteriae* or *S. flexneri* causes dysenteric symptoms (bloody diarrhea) [14].

CDC recommends hand washing after going to the bathroom, after changing diapers, and before preparing foods or beverages and supervising hand washing of toddlers and small children after they use the toilet. Keeping children with diarrhea out of child care settings and not to prepare food for others while ill with diarrhea are also recommended.

It is important to report the cases of shigellosis to the public health department. If many cases occur at the same time, it may mean that a restaurant or food or water supply has a problem that needs correction by the public health department.

Salmonella: Although there are many types of Salmonella, they can be divided into two broad categories: those that cause typhoid and enteric fever and those that primarily cause gastroenteritis. The typhoidal Salmonella, such as *S. typhi* and *S. paratyphi*, have a high host specificity for humans. Infection virtually always implies contact with an acutely infected individual, a chronic carrier, or contaminated food and water. In the United States, typhoid fever has become less prevalent and is now primarily a disease of travelers and immigrants. The much broader group of nontyphoidal Salmonella is a common cause of food-borne gastroenteritis worldwide, particularly in outbreak settings. Traditionally infection has been associated with raw meat or poultry products and improperly handled food that has been contaminated by animal or human fecal material or via the fecal-oral route, from other humans or farm or pet animals [15].

Enteric (typhoid) fever can be complicated with intestinal bleeding and perforation due to the ileocecal lymphatic hyperplasia. It is usually manifested by fever, bradycardia, abdominal pain, and faint rash. Symptoms gradually resolve over weeks to month.

CDC, besides hand hygiene, recommends that people should avoid eating raw or undercooked eggs, poultry, or meat. People who have salmonellosis should not prepare food for others until their diarrhea has resolved. Many health departments require that restaurant workers with *Salmonella* infection have a stool test showing that they are no longer carrying the *Salmonella* bacterium before they return to work. Reptiles and birds (especially baby chicks) are particularly likely to have *Salmonella*, and it can contaminate their skin. Everyone should immediately wash their hands after touching them, and they are not appropriate pets for small children and should not be in a house that has an infant.

Pseudomonas aeruginosa is a gram-negative aerobic bacillus. The organism is common in the environment, especially in water, even contaminating distilled water [16]. It is also the cause of infections associated with hot tubs and contaminated contact lens solutions. Considerable

attention is paid to *P. aeruginosa* as a potential pathogen in hospitals because reservoirs for infection can develop, especially in intensive care units. The organism is an opportunistic pathogen for immunocompromised hosts.

Historically, *P. aeruginosa* has been a major burn wound pathogen, an agent of bacteremia in neutropenic patients and the most important pathogen in cystic fibrosis patients. It can infect many organs; it is the second most common cause of nosocomial pneumonia (17 %), the third most common cause of urinary tract infection (7 %), the fourth most common cause of surgical site infection (8 %), the seventh most frequently isolated pathogen from the bloodstream (2 %), and the fifth most common isolate (9 %) overall from all sites [17].

CDC recommends contact precaution in addition to standard precaution if the organ is resistant to multiple antibiotic classes.

Multidrug-resistant ***Pseudomonas aeruginosa*** and ***Acinetobacter baumannii*** are becoming increasingly important nosocomial pathogens worldwide. To study the evolution of non-fermenters in a tertiary care hospital, a 10-year (1999–2008) retrospective trend analysis of antimicrobial consumption and resistance in non-fermenters causing bacteremia was undertaken. A significant increase in resistance in *A. baumannii* to fluoroquinolones ($r^2=0.63$, $P=0.006$), aminoglycosides ($r^2=0.63$, $P=0.011$), and carbapenems ($r^2=0.82$, $P=0.013$) and in *P. aeruginosa* to aminoglycosides ($r^2=0.59$, $P=0.01$) was observed. Carbapenem consumption was associated with the development of resistance in *A. baumannii* ($r=0.756$, $P=0.049$), whereas no such association was observed for other antimicrobials among non-fermenters [18].

Haemophilus is a facultative anaerobic pleomorphic gram-negative rod occurring in pairs or short chains. *H. influenzae type b* is an important human pathogen. *H. ducreyi*, a sexually transmitted pathogen, causes chancroid. Other species are among normal flora of mucous membranes and only occasionally cause disease. Humans are the only known reservoir.

H. influenzae is transmitted by respiratory droplet spread. It has encapsulated (serotypes a through f) and non-encapsulated forms (nontypeable). The most important serotype is *H. influenzae* serotype b (Hib), which was a frequent cause of bacteremia, meningitis, and other invasive infections prior to the routine use of Hib conjugate vaccines in children. Other capsular serotypes and unencapsulated *H. influenzae* strains can also cause disease, mainly mucosal infections (sinusitis, otitis, bronchitis) but occasionally cause more invasive infections.

Hib vaccine induces antibodies to the type b capsular polysaccharide; it is highly protective and is recommended by CDC for all children younger than 5 years old. It is usually given to infants starting at 2 months old.

Chemoprophylaxis is recommended for household contacts defined as persons residing with the index patient or nonresidents who cumulatively spent 4 or more hours with the index case for at least 5 of the 7 days prior to the day of hospital admission and there is a member of the contact's household who is younger than 4 years of age and is unimmunized or incompletely immunized or is an immunocompromised child, regardless of the child's immunization status.

Brucella are small, gram-negative, nonmotile, facultative, intracellular aerobic rods. Brucellosis is a zoonotic infection transmitted to humans by contact with fluids from infected animals (sheep, cattle, goats, pigs, or other animals) or through food products such as unpasteurized milk and cheese. It is one of the most widespread zoonosis worldwide [19]. Clinical manifestations of brucellosis include fever, night sweats, malaise, anorexia, arthralgias, fatigue, weight loss, and depression. It can become chronic and is characterized by localized infections like spondylitis, osteomyelitis, tissue abscesses, and uveitis.

Bordetella pertussis causes pertussis, also known as "whooping cough" which is a highly contagious, acute respiratory illness. In the prevaccine era, the disease predominantly affected children less than 10 years of age and usually manifested as a prolonged cough illness with one or more of the classical symptoms, including inspiratory whoop, paroxysmal cough, and post-tussive emesis [20]. Since the introduction of pertussis

vaccines, the epidemiology of reported pertussis infections has changed; in the United States in the 1990s, more than one-half of cases occurred in adolescents and adults [21]. Routine childhood vaccination in the United States is performed with the DTaP vaccine (acellular pertussis vaccine combined with tetanus and diphtheria toxoids) and the vaccine efficacy is 92 % [22]. Postexposure antibiotic prophylaxis is warranted for individuals with close contact to a person with pertussis. A close contact is defined as a person who has had face-to-face exposure within 3 ft of a symptomatic patient. Individuals with direct contact with respiratory, nasal, or oral secretions may also be considered close contacts.

Legionellas are aerobic, gram-negative bacilli. *L. pneumophila* is the most common species, which causes at least 80 % of human infections. It can cause community-acquired and hospital-acquired pneumonia. Legionellosis refers to the two clinical syndromes, Legionnaires' disease which is the more common syndrome of pneumonia caused by *Legionella* species and Pontiac fever which is an acute, febrile, self-limited illness with minimal if nay respiratory symptoms. Transmission in facilities has been linked to potable water distribution systems. CDC recommends culturing of the water at sites the patient was exposed to in case of nosocomial legionnaire's disease.

Chlamydias are gram-negative or variable obligate intracellular bacteria. The species that most commonly affect humans are *C. trachomatis*, *C. pneumoniae,* and *C psittaci*. *C. trachomatis* causes sexually transmitted disease that is often asymptomatic but can cause cervicitis in women and urethritis in men. The most serious complication in women is pelvic inflammatory disease that can occur in asymptomatic patients also and can lead to infertility. *C. pneumoniae* and *C. psittaci* cause pneumonia and the transmission of the organism is thought to be person to person.

Mycoplasma pneumoniae is a facultative anaerobic rod that is not visible on gram staining due to the absence of cell wall. It is transmitted from person to person by respiratory droplets during close contact [23]. Patients with respiratory infection caused by *M. pneumoniae* may have cough, pharyngitis, rhinorrhea, and ear pain; only 10 % of patients develop pneumonia. Extrapulmonary manifestations are hemolysis, skin rash, and rarely central nervous system complications.

Rickettsia: Rocky Mountain spotted fever (RMSF) is a potentially lethal but usually curable tick-borne disease. The etiologic agent, *Rickettsia rickettsii*, is a gram-negative, obligate intracellular bacterium. The clinical spectrum of human infection with *R. rickettsii* ranges from mild to fulminant. In the early phases of illness, most patients have nonspecific signs and symptoms such as fever, headache, malaise, myalgias, and nausea. Rash appears between the third and fifth days of illness. RMSF occurs throughout the United States, in Canada, Mexico, Central America, and in parts of South America. In the United States, it is most prevalent in the southeastern and south central states. RMSF is usually transmitted via a tick bite. Tick bites are painless and up to one-third of patients with proven RMSF do not recall a recent tick bite.

Scrub typhus is a rickettsial disease caused by the organism *Orientia tsutsugamushi* and is transmitted to humans by the bite of a larval-stage trombiculid mite or chigger. Scrub typhus is widespread in the so-called tsutsugamushi triangle which includes Japan, Taiwan, China, and South Korea on the north, India and Nepal on the west, and Australia and Indonesia on the south. Epidemics of scrub typhus have been reported from various parts of the Indian subcontinent [24–27].

It presents as either a nonspecific febrile illness with constitutional symptoms such as fever, rash, myalgias, and headache or with organ dysfunctions involving organs such as kidney (acute renal failure, ARF), liver (hepatitis), lungs (acute respiratory distress syndrome, ARDS), central nervous system (meningitis), or with circulatory collapse with hemorrhagic features. Scrub typhus is one of the differential diagnoses (in addition to leptospirosis, malaria, or dengue fever) in patients with hemorrhagic fever especially if associated with jaundice and/or renal failure.

Anaerobic Gram-Negative Bacilli

Bacteroides are anaerobic gram-negative bacilli and are normal inhabitants of the bowel. They can cause intra-abdominal abscess and peritonitis after bowel injury, most of the times in association with other bacteria.

Spirochetes

Treponema pallidum organisms are slender spirals that are actively motile as seen on dark field microscopy. It causes syphilis which is a chronic infection. The initial clinical manifestations of primary syphilis consist of a painless chancre at the site of inoculation, which usually heals within a few weeks. Few months later, approximately 25 % of individuals with untreated primary infection develop secondary syphilis characterized by systemic symptoms including fever, rash, headache, malaise, anorexia, and diffuse lymphadenopathy. Asymptomatic patients who have *Treponema pallidum* infection by serologic testing alone have "latent syphilis." Patients in the early latent period (within 1 year of primary infection) are believed to be potentially infectious in contrast to late latency when transmission is no longer likely. When patients are untreated during the earlier stages of syphilis, they are at risk for major complications involving the central nervous system or cardiovascular structures or granulomatous disease of the skin or bones. Syphilis is sexually transmitted, except for cases resulting from vertical transmission (i.e., infection acquired in utero or during delivery). Syphilis is transmissible during early disease (primary and secondary syphilis) and early latent disease.

Borrelia burgdorferi causes Lyme disease which is a tick-borne illness. It is responsible of all cases in the United States. In Europe, *B. afzelii* and *B. garinii* are additional responsible species. Borrelia is a spirochete; it is motile, spiral, and cannot be seen by standard light microscopy because of its small size. Lyme disease has three phases; early localized disease manifests as erythema migrans (EM) and nonspecific findings that resemble a viral syndrome, usually occurring within 1 month of the tick bite. Early disseminated disease manifests as acute neurologic or cardiac involvement, usually occurring several weeks to several months after the tick bite. Late disseminated disease manifests as arthritis and neurological manifestations, and in Europe skin manifestations occur months to a few years after the onset of infection. It is transmitted by small ticks called Ixodes. Deer and mice constitute the main animal reservoir. It is endemic in the northeastern and Midwestern parts of the United States, parts of Asia, and parts of Europe.

Leptospira are spiral-shaped aerobic spirochetes; they tend to stain poorly with common laboratory stains and are best visualized by dark field microscopy. The majority of leptospirosis cases occur in the tropics, although cases are also observed in temperate regions. The natural hosts for the organism are various mammals; man is only incidentally infected. The disease leptospirosis (Weil's disease) is associated with a variable clinical course. The disease may manifest as a subclinical illness followed by seroconversion, a self-limited systemic infection, or a severe, potentially fatal illness accompanied by multiorgan failure. Humans most often become infected after exposure to environmental sources, such as animal urine, contaminated water, or soil or infected animal tissue through cuts or abraded skin, mucous membranes, or conjunctiva. Vaccination of domestic animals against leptospirosis provides substantial protection. The major control measure available for humans is to avoid potential sources of infection such as stagnant water, rodent control, and protection of food from animal contamination. No vaccine is available for humans.

Mycobacteria

Mycobacteria are rod-shaped, aerobic bacteria that do not stain readily but when stained they resist decolorization by alcohol or acid leading to the popular reference of acid-fast bacteria. *M. tuberculosis* causes tuberculosis, *M. leprae* causes leprosy, and *M. avium complex* and other atypical mycobacteria are opportunistic infections

that occasionally cause disease in immunocompetent patients.

Tuberculosis (TB) is the second most common infectious cause of death in adults worldwide (HIV is the most common). It can affect every organ system. The clinical manifestations are fatigue, weight loss, and fever. Pulmonary involvement causes chronic cough and hemoptysis can be seen in advanced stage. Bloodstream dissemination leads to miliary tuberculosis with lesions in many organs. Latent tuberculosis occurs when the bacteria are present but not manifested by clinical disease and it might become active years later. The people with latent tuberculosis have a 10 % chance to have active tuberculosis in their life, while HIV patients with latent tuberculosis can have active disease more frequently, as high as 5–10 % a year. The human host is the natural reservoir for *M. tuberculosis*. Person-to-person transmission occurs via inhalation of droplet nuclei [28]. Close household contact with an individual with smear-positive pulmonary TB is the most important risk factor for TB. The effective way to prevent tuberculosis is by diagnosing and treating active and latent diseases. Airborne precautions are applied in health-care setting for suspected and confirmed cases of tuberculosis. BCG, a live vaccine for tuberculosis, is an attenuated stain of *M. bovis*. Studies have shown a wide range of effectiveness, from 0 % to 80 %. It is used in endemic area and result in a positive PPD test which wanes with time. The recommendation is to interpret the PPD test without considering the history of BBG vaccine as the chance of having latent tuberculosis with positive PPD is much higher than the chance to have positive test due to BCG vaccine.

Leprosy (*Hansen's disease*) caused by *M. leprae* involves the skin and peripheral nerves. It is an important global health concern. Early diagnosis and a full course of treatment are critical for preventing lifelong neuropathy and disability. Although the mode of transmission of Hansen's disease remains uncertain, most investigators think that *M. leprae* is usually spread from person to person in respiratory droplets. In the United States, contact with armadillos (handling, killing, or eating) has been reported as a mode of transmission in some cases [29]. BCG vaccine can be used for leprosy in addition to tuberculosis; a single dose appears to be 50 % protective, and two doses further increase protection. Development of an improved BCG vaccine, BCG booster, or alternate vaccine strain is an important research goal that could benefit control of both tuberculosis and leprosy [30].

Pathogenic Viruses and Their Modes of Transmission

Viruses can be transmitted by different modes, the common ones being sexual contact, blood products, respiratory droplets, and direct contact.

Herpes virus family includes herpes simplex virus type 1 (HSV1), herpes simplex virus type 2 (HSV2), varicella-zoster virus, cytomegalovirus, Epstein-Barr virus, and human herpes viruses 6, 7, and 8. Once a patient has become infected by a herpes virus, the infection remains for life. The initial infection may be followed by latency with subsequent reactivation. Each has double-stranded DNA. The viral membrane is quite fragile and a virus with a damaged envelope is not infectious which means that the virus can only be acquired by direct contact with mucosal surfaces or secretions of an infected person.

HSV1 and HSV2: The virus is found in the lesions on the skin and mucous membranes but can also be present in a variety of body fluids including saliva and vaginal secretions. Both types of HSV can infect oral or genital mucosa depending on the regions of contact. HSV1 is usually spread mouth to mouth (kissing or the use of utensils contaminated with saliva) or by transfer of infectious virus to the hands, after which the virus may enter the body via any wound or through the eyes. HSV2 is more commonly spread through sexual contact.

In primary herpetic gingivostomatitis, the typical clear lesions first develop followed by ulcers that have a white appearance. The infection, often initially on the lips spreads to all parts of the mouth and pharynx. Reactivation from the trigeminal ganglia can result in what are known as "cold sores."

Genital herpes is usually caused by HSV2 with about 10 % of cases being the result of HSV1 infection. Primary infection is often asymptomatic but many painful lesions can develop on the glans or shaft of the penis in men and on the vulva, vagina, cervix, and perianal region in women.

Secondary episodes of genital herpes, which occur as a result of reactivation of the virus in the sacral ganglion, are less severe and last a shorter time than the first episode. Recurrent episodes usually follow a primary HSV2 infection. Patients who are about to experience a recurrence usually experience a prodrome in which there is a burning sensation in the area that is about to erupt. Whether there is an active disease or not, an infected patient remains infectious even without overt symptoms. Clearly, these persons are a significant reservoir in the spread of genital herpes virus infection.

Varicella-Zoster virus: This virus causes two major diseases, chicken pox (varicella) usually in childhood and shingles (zoster) later in life. Shingles is a reactivation of an earlier varicella infection.

This virus is highly infectious and more than 90 % of the population of the United States has antibodies against varicella proteins including those with no history of chicken pox. In the household of an infected patient, 90 % of contacts who have not had the disease will get it (unless vaccinated). Spreading of the infection can be from virus in the respiratory tract (by a cough) or from contact with ruptured vesicles on the skin containing infectious virus. Thus, the contagious period can be up to 12–14 days after the initial infection. The disease is more severe in older children and adults. This is particularly the case in immunocompromised patients (AIDS, transplantation, etc.) where the disease may last for several weeks and the fever may be more pronounced. The spread of the virus may lead to infections in the lungs, liver, and in the meninges with mortality up to 20 %.

Shingles: After the infectious period, the virus may migrate to the ganglia where the virus will be dormant. The virus may then be reactivated under stress or with immune suppression. This usually occurs later in life. Lesions occur in restricted areas (dermatomes) that are innervated by a single ganglion. Reactivation can lead to chronic burning or itching pain called postherpetic neuralgia which is seen primarily in the elderly.

Congenital varicella syndrome is caused by infection in utero during the first trimester. It leads to scarring of the skin of the limbs; damage to the lens, retina, and brain; and microphthalmia.

Epstein-Barr virus is the causative agent of Burkitt's lymphoma in Africa and infectious mononucleosis in the west. The primary infection is often asymptomatic but the patient may shed virus for many years. Some patients develop infectious mononucleosis after 1–2 months of infection. The disease is characterized by malaise, lymphadenopathy, tonsillitis, enlarged spleen and liver, and fever. A large proportion of the population (90–95 %) is infected with Epstein-Barr virus and, although usually asymptomatic, will shed the virus from time to time throughout life. The virus is spread by close contact (kissing disease).

Cytomegalovirus: The virus is spread in most secretions, particularly saliva, urine, vaginal secretions, and semen (which shows the highest titer of any body fluid). *Cytomegalovirus* infection is therefore sexually transmitted. It can also spread to a fetus in a pregnant woman and to the newborn via lactation, though there is some doubt about the importance of milk transmission. In the hospital, the virus can also be spread via blood transfusions and transplants. In third world countries with more crowded conditions, the virus is found in a much higher proportion of the population than in western countries.

During a primary infection of the mother, the virus can spread via the placenta to the fetus and congenital abnormalities can occur. In patients who have received an organ transplant or have an immunosuppressive disease (e.g., AIDS), cytomegalovirus can be a major problem. Particularly important is cytomegalovirus retinitis which occurs in up to 15 % of all AIDS patients. In addition, interstitial pneumonia, colitis, esophagitis, and encephalitis can occur.

Human herpes viruses 6 and 7: These viruses can be isolated from saliva of the majority of adults. They cause exanthem subitum, otherwise known as roseola infantum.

Human herpes virus 8: This was formerly known as Kaposi's sarcoma associated herpes virus and is found in the saliva of many patients with HIV infection/AIDS.

Herpes B virus: This is a simian virus found in old-world monkeys such as macaques, but it can be a human pathogen in people who handle monkeys (monkey bites are the route of transmission). In humans, the disease is much more severe than it is in its natural host. About 75 % of human cases result in death with serious neurological problems (encephalitis) in many survivors. There is some evidence that the disease can be transmitted from a monkey-infected human to another human.

Rubella begins with a prodrome consisting of headache, malaise, fever, and lymphadenopathy followed by the maculopapular rash that lasts for 3 days. The patient is contagious 1 week before and 1–2 weeks after the onset of the rash. Not all patients will have classical symptoms and sometimes symptoms are very mild. The virus can cause congenital rubella if it occurs in the first trimester; it can manifests as fetal death, premature delivery, and congenital rubella syndrome with hearing loss, developmental delay, growth retardation, and cardiac and ophthalmic defects. The virus is shed in respiratory secretions and transmitted through contact or droplet transmission and the humans are the only natural host. Prior to the vaccine, outbreaks of rubella occurred variably every few years. It is rare since the use of routine vaccination (MMR) that is given in two doses at 12–15 months and at 6 years. The rate of immunization is about 100 % in the developed countries but in developing countries still less than 50 % [31].

Measles is characterized by the prodrome phase of fever, malaise, and anorexia followed by conjunctivitis, coryza, cough, and then the rash. The humans are the only host for this virus and the patient is considered contagious 4 days before and 4 days after the rash. Measles can be severe especially in immunocompromised patient and it is the most highly contagious diseases known. The vaccine is very effective and is part of MMR vaccine. Measles virus replicates in the nose, mouth, and throat of the infected person and is dispersed into the air when the ill person coughs, sneezes, or talks. The virus remains viable and contagious for up to 2 h in the air or on surfaces; therefore, transmission can occur without face-to-face contact. Those who are not immune may become infected by inhaling the virus, having contact with droplets containing the virus, or by touching a contaminated surface and then touching the mouth or nose. CDC strategies to prevent nosocomial transmission of measles include documentation of measles immunity in health-care personnel, prompt identification and isolation of persons with fever and rash, and adherence to airborne precautions for suspected and proven cases of measles.

Mumps infection is frequently accompanied by a nonspecific prodrome consisting of low-grade fever, malaise, headache, myalgia, and anorexia followed within 48 h by the development of parotitis. The possible complications of mumps are meningitis, encephalitis, and orchitis. Symptomatic infection in adults is usually more severe than in children. The humans are the only host and the patient is contagious 2 days before and 9 days after the parotitis. The virus is typically transmitted by respiratory droplets or direct contact [32]. Vaccination is effective and is a part of MMR vaccine.

Influenza occurs in outbreaks of varying extent every year. This epidemiologic pattern reflects the changing nature of the antigenic properties of influenza viruses. Influenza begins with the abrupt onset of fever, headache, and myalgia accompanied by manifestations of respiratory tract illness such as nonproductive cough, sore throat, and nasal discharge. The major complication of influenza is pneumonia, which occurs most frequently at the extreme of age and in patients with underlying chronic illnesses. People with Influenza can spread it to others up to 6 ft away. It is spread mainly by droplets directly and indirectly by touching a surface or object that has the virus on it and then touching one's own mouth or nose. There are two main types of flu virus,

types A and B. In addition to humans, animals like ducks, chickens, pigs, whales, horses, and seals can also be the host for type A virus, while the humans are the only hosts for type B. Patients are contagious one day before symptoms develop and up to 5–7 days after. In 2010, the Advisory Committee on Immunization Practices (ACIP) for the first time recommended annual influenza vaccination for all persons aged ≥6 months in the United States. Although vaccination is the primary mode of prevention in the community, patients with Influenza should be under droplet precautions while in the hospital.

Although avian influenza A viruses usually do not infect humans, rare cases of human infection with avian influenza A viruses have been reported. Most human infections with avian influenza A viruses have occurred following direct or close contact with infected poultry.

Swine influenza viruses do not normally infect humans. However, sporadic human infections with swine influenza viruses have occurred. Most commonly, human infections with swine viruses occur in people with exposure to infected pigs but there have been documented cases of limited spread of swine influenza viruses from person to person.

Respiratory syncytial virus (RSV) causes seasonal outbreaks of respiratory tract illness throughout the world, usually during the winter season. Almost all children are infected by 2 years of age but it is common among adults also. The infection starts as upper respiratory tract infection with sneezing, rhinorrhea, cough, and sometimes fever and can spread to lower respiratory tract, especially in young children, the elderly, and patients with cardiopulmonary diseases. Direct contact is the most common route of transmission, but large aerosol droplets also have been implicated [3]. Hand washing and contact precautions are used to prevent nosocomial spread. Immunoprophylaxis is available to prevent severe RSV illness in certain infants and children who are at high risk. Researchers are working to develop RSV vaccines, but none is available yet.

Parvovirus (B19): The majority of infected individuals will either be asymptomatic or have nonspecific flu-like symptoms of malaise, muscle pain, and fever. The others will present with the classic symptoms of B19 infection including rash (erythema infectiosum) and arthralgia (fifth disease). It can cause transient aplastic crisis in those with chronic hemolytic disorders and chronic pure red blood cell aplasia in immunocompromised individuals. The only known host for B19 is humans. The respiratory tract secretions are likely to be an important source of infectious virus and virus gain entry through the respiratory tract. Transmission occurs by large droplets through close contact with the infected person and fomites. The other modes of transmission are vertical transmission during pregnancy and hematogenous transmission through blood products. Infection during pregnancy can result in fetal complications including miscarriage and nonimmune hydrops fetalis. Until a vaccine becomes available, good hygienic practices should be the focus of prevention strategies as it has been shown that hand washing and not sharing food or drinks can at least partially prevent the spread of the virus.

Rhinovirus is one of the most common etiologic agents of the common cold and may play a role in asthma exacerbations. The nasopharynx is the initial site of infection and the virus remains in the nasal secretions for 5–7 days and can be transmitted through small-particle and large-particle aerosol.

Adenovirus: Most adenoviral diseases are self-limited, although fatal infections can occur in immunocompromised hosts and occasionally in healthy children and adults [33]. Most commonly, it causes upper respiratory tract syndromes, but it can also cause pneumonia, gastrointestinal, and ophthalmologic symptoms. Transmission can occur via aerosol droplets, the fecal-oral route, and by contact with contaminated fomites. Adenoviruses can cause significant nosocomial infections. Prolonged infection control measures may be necessary to ensure elimination of adenovirus following a nosocomial outbreak. Oral adenovirus vaccine is approved for use in US military personnel aged 17 through 50 years [34].

Enteroviruses include polioviruses, groups A and B coxsackieviruses, echoviruses, and enteroviruses.

Most of the cases are asymptomatic or result in an undifferentiated febrile illness. Other clinical manifestations of disease include exanthems, enanthems, myopericarditis, and meningitis. Paralytic poliomyelitis which is a known complication of infection due to polioviruses has been eradicated in the United States and other developed countries due to successful vaccination strategies. Poliomyelitis is targeted for worldwide eradication. These viruses are ubiquitous throughout the world and are transmitted from person to person through fecal-oral contact. Simple hygienic measures, such as hand washing, are important to prevent the spread.

Human papillomavirus (HPV): There are more than 100 types of HPV. Some infect skin causing warts (like HPV types 1, 2, and 4), some infect mucous membranes causing genital warts or condyloma acuminatum (like HPV types 6 and 11 that account together for 90 % of genital warts), and some cause intraepithelial neoplasm in the genital area and cervical cancer (like HPV types 16 and 18 that account together for 70 % of all cervical cancer). HPV genotypes can be broadly split into high risk and low risk based upon their association with the development of cervical cancer. HPV only infects humans. Close personal contact is assumed to be of importance for the transmission of cutaneous warts, while anogenital and cervical infection are primarily transmitted through sexual contact. Vaccine plays an important role in prevention. Two vaccines are available. The quadrivalent vaccine (Gardasil) includes HPV types 6, 11, 16, and 18 and prevents genital warts and intraepithelial neoplasia. The bivalent vaccine (Cervarix™) includes HPV types 16 and 18 and prevents intraepithelial neoplasia. Routine immunization should be offered to girls and boys 11–12 years of age but can be administered as early as 9 years. Catch-up vaccination should be offered for females aged 13–26 years and males aged 13–21.

The human immunodeficiency virus (HIV) is a retrovirus, which infects humans when it comes in contact with tissues such as those that line the vagina, anal area, mouth, and eyes or through a break in the skin. Three stages of HIV infection have been described. The initial stage of infection (primary infection), which occurs within weeks of acquiring the virus, is characterized by a flu- or mono-like illness that is seen in about half of the patients and generally resolves within weeks. In this stage there is a rapid increase in plasma viremia, with high viral titers and widespread dissemination targeting lymphoid organs especially the GART. The patients are highly contagious in this stage. This phase is followed by a marked reduction in the virus to steady-state levels probably because of vigorous antivirus cellular responses. The immune response probably accounts for the mono-like or flu-like acute retroviral syndrome. The second stage, a chronic asymptomatic infection lasts an average of 8–10 years. The third stage is the acquired immune deficiency syndrome stage in which the patient is at high risk for opportunistic infections, cancers, severe weight loss, and dementia. The most common modes of infection are sexual transmission at the genital or colonic mucosa, exposure to other infected fluids such as blood or blood products, transmission from mother to infant, and, occasionally, accidental occupational exposure. Due to rapid genetic changes in the virus, there is as yet no vaccine against this infection. Post exposure prophylaxis is used for occupational and nonoccupational exposure and most experts recommend three antiretroviral drugs for 4 weeks.

Hepatitis B: The spectrum of clinical manifestations of hepatitis B virus (HBV) infection varies in both acute and chronic diseases. During the acute phase, manifestations range from subclinical or anicteric hepatitis (70 %) to icteric hepatitis (30 %) and, in some cases, fulminant hepatitis (0.1–0.5 %). During the chronic phase, manifestations range from an asymptomatic carrier state to chronic hepatitis, cirrhosis, and hepatocellular carcinoma. When symptomatic, a patient with acute infection may have anorexia, nausea, jaundice, and right upper quadrant discomfort that lasts from 1 to 3 months, and 5 % of adults will develop chronic disease compared to 90 % if infected at birth [35]. The method of acquiring HBV infection varies geographically. Perinatal transmission is most common in high prevalence areas such as

the southeast Asia and China, while sexual contact and percutaneous transmission (e.g., intravenous drug use) are most common in the United States, Canada, and western Europe. Vaccination is highly effective (90 % effectiveness in immunocompetent) and it can be given safely to pregnant women. The Advisory Committee on Immunization Practices (ACIP) recommends that all children receive their first dose of hepatitis B vaccine at birth and complete the vaccine series by age 6–18 months. Older children and adolescents who did not previously receive the hepatitis B vaccine should also be vaccinated. After exposure to hepatitis B virus (HBV), whether it is occupational or nonoccupational, appropriate and timely prophylaxis can prevent HBV infection and subsequent development of chronic infection or liver disease. People who completed hepatitis B vaccine series and did not receive post-vaccination testing should receive a single booster vaccine dose, while unvaccinated persons should receive both hepatitis B immune globulin and hepatitis B vaccine as soon as possible after exposure (preferably within 24 h). The same approach is used for children born to infected mothers. Hepatitis B vaccine may be administered simultaneously with HBIG through a separate injection site.

Hepatitis C: Most acutely infected patients are asymptomatic or have a clinically mild course; jaundice is present in fewer than 25 %. Acute HCV infection typically leads to chronic infection in 60–80 % of cases. Percutaneous transmission (e.g., intravenous drug use) is the most common mode of transmission. Perinatal transmission and sexual contact are also possible modes of transmission. Most scientific evidence demonstrates that although HCV can be transmitted sexually, such transmission happens rarely, so patients with one long-term, steady sex partner do not need to change their sexual practices. However, heterosexual and homosexual persons with concurrent HIV infection or with more than one partner are at risk and should use condoms. Women do not need to avoid pregnancy or breast-feeding, but patients should be advised that approximately six of every 100 infants born to HCV-infected woman become HCV infected. HCV has not been shown to be transmitted through breast-feeding. Testing to determine whether HCV infection has developed is recommended for health-care workers after percutaneous or per mucosal exposures to HCV-positive blood. Children born to HCV-positive women also should be tested as prompt identification of acute infection is important, because outcomes are improved when treatment is initiated earlier in the course of illness. No postexposure prophylaxis has been demonstrated to be effective against HCV. Immune globulin has no role in prevention and no vaccine for hepatitis C is available.

Rabies viruses: Rabies is virtually always fatal, but disease can be prevented with proper wound care and post exposure prophylaxis. The first symptoms of rabies may be very similar to those of the influenza including general weakness, discomfort, fever, and headache. These symptoms may last for days before progressing to symptoms of cerebral dysfunction, anxiety, confusion, agitation, delirium, hydrophobia, and insomnia. The rabies virus is transmitted through saliva or brain/nervous system tissue.

Transmission of rabies virus usually begins when infected saliva of a host is passed to an uninfected animal. The most common mode of rabies virus transmission is through the bite and virus-containing saliva of an infected host. Transmission has been rarely documented via other routes such as contamination of mucous membranes (i.e., eyes, nose, mouth), aerosol transmission, and corneal and organ transplantations. All species of mammals are susceptible to rabies virus infection but only a few species are important as reservoirs for the disease. In the United States, distinct strains of rabies virus have been identified in raccoons, skunks, foxes, coyotes, and bats which play an important role in transmission. In developing countries dogs are the primary source. Postexposure prophylaxis consists of a regimen of one dose of immune globulin and four doses of rabies vaccine over a 14-day period. Preexposure prophylaxis should be targeted to persons in high-risk groups, including veterinarians, laboratory workers, and international travelers.

Yellow fever virus causes yellow fever which has a high case fatality rate. It starts with nonspecific symptoms and signs including fever, malaise, headache, and joint pains followed by a period of remission lasting up to 48 h followed by a systemic illness which is characterized by hepatic dysfunction, renal failure, coagulopathy, and shock. CDC recommends immunization for travelers to yellow fever endemic areas of Africa and South America and for residents of those areas.

West Nile virus causes West Nile fever characterized by fever, headache, malaise, back pain, anorexia, and a maculopapular rash that appears in approximately one-half of patients. It can present as encephalitis, meningitis, or an acute asymmetric flaccid paralysis. It is found in the Americas, southern Europe, western parts of Asia, Russia, Australia, and Africa. Wild birds serve as hosts but generally remain asymptomatic. No human vaccine is yet available.

St. Louis encephalitis virus: Infection with SLE virus only rarely results in clinical illness but encephalitis can occur especially in elderly patients. The virus is widely distributed in the Americas.

Japanese encephalitis virus: The most common presentation of JEV infection is acute encephalitis but it can manifest as aseptic meningitis or a nonspecific febrile illness with headache. Pigs and wading birds are considered amplifying hosts. Humans are incidental and dead-end hosts for JEV as they do not develop sufficiently high viremia to infect feeding mosquitoes.

Dengue: The clinical manifestations of dengue range from self-limited dengue fever to dengue hemorrhagic fever with shock syndrome which is more common than the self-limited form. Dengue viruses are endemic in every continent except Europe and Antarctica. To date, there is no licensed vaccine available for preventing dengue.

Yellow fever virus, West Nile virus, St. Louis encephalitis virus, Japanese encephalitis viruses, and dengue virus are members of the family Flaviviridae and are transmitted by mosquito. Personal protection measures include the use of mosquito repellents and mosquito nets.

Prions and Their Mode of Transmission

Prions are small infectious pathogens containing protein but lack nucleic acid. Prion diseases are neurodegenerative diseases that have long incubation periods and progress rapidly once clinical symptoms appear. Five human prion diseases are currently recognized: kuru, Creutzfeldt-Jakob disease (CJD), variant Creutzfeldt-Jakob disease (vCJD), Gerstmann-Straüssler-Scheinker syndrome (GSS), and fatal familial insomnia (FFI). Bovine spongiform encephalopathy (BSE), one of a number of prion infections affecting animals, was responsible for bringing these agents to more widespread public attention because of its link to vCJD. Prion diseases appear to result from neurotoxic accumulation of abnormal isoforms of the prion protein. The gene encoding the prion protein in humans is located on the short arm of chromosome 20. A strong link was established between mutations in this gene and forms of prion disease with a familial predisposition (familial Creutzfeldt-Jakob disease, Gerstmann-Straüssler-Scheinker syndrome, and fatal familial insomnia). The two diseases that are thought to be due to transmission of prions are kuru and vCJD. In kuru, symptoms begin with tremors, ataxia, and postural instability followed by loss of ambulation and involuntary movements. Dementia progresses in the late stages of the disease, with death typically occurring within 9–24 months from the onset. It is felt to be transmitted from person to person. Cannibalism which was common in New Guinea in the past could be the reason why it was endemic there. Now as this practice has been stopped, kuru has become rare. vCJD presents with a progressive course of cognitive decline with prominent neuropsychiatric features often accompanied by sensory symptoms and leads to death after an average of 14 months. Transmission to humans occurs through ingestion of infected bovine meat products. There is no person-to-person transmission, but it can occur during invasive medical interventions. One of the characteristic features of prions is their resistance to a number of usual decontaminating

procedures. Private room and other measures are not required for infection control. But for surgical procedures on any person with confirmed or suspected prion diseases, every effort should be made to plan carefully not only the procedure but also the infection prevention practices surrounding the procedure, e.g., instrument handling, storage, cleaning and decontamination, or disposal. Written protocols are essential.

Pathogenic Fungi and Their Modes of Transmission

Candida is a yeast that causes candidiasis. There are over 20 species of *Candida* that can cause infection in humans, the most common of which is *Candida albicans*. *Candida* can present on the skin and mucous membranes of humans without causing infection and is considered normal flora. However, overgrowth of these organisms is seen as collateral damage to the normal flora by antibiotic use or compromise of the immunity due to hematological malignancies, steroid use, and HIV infection. Symptoms range from local mucous membrane infections to widespread dissemination with multisystem organ failure.

Aspergillus is a mold. It is ubiquitous in nature and can exist in indoor and outdoor environments. Most people breathe in *Aspergillus* spores every day without being affected. The spectrum of illness includes allergic reactions, lung infections, and extrapulmonary dissemination. People who are at risk are patients with severe and prolonged neutropenia, receipt of high doses of glucocorticoids and other drugs, or conditions that lead to chronically impaired cellular immune responses.

Cryptococcus is yeast that can be found in soil throughout the world. People can inhale the yeast with no symptoms or mild pneumonia in immunocompetent patients. It is a common cause of meningoencephalitis in patients with HIV. Despite the finding of this fungus in pigeon guano, direct transmission from pigeons to humans has not been reported, neither has person-to-person transmission. Soil is the documented source of infection.

Endemic mycoses: Each of the four endemic mycoses, blastomycosis, histoplasmosis, coccidioidomycosis, and paracoccidioidomycosis, is geographically restricted to a specific area of the world. The fungi that cause coccidioidomycosis and histoplasmosis exist in the soil, while the fungi that cause blastomycosis and paracoccidioidomycosis are presumed to reside in nature, but their habitat has not been clearly identified. Each of these mycoses is caused by a thermally dimorphic fungus, and most infections are initiated in the lungs following inhalation of the conidia. Only few infections lead to disease which can be acute or chronic pneumonia or extra pulmonary. These mycoses are not transmissible among humans or other animals.

Tinea versicolor is a common superficial fungal infection caused by Malassezia which is a dimorphic fungus. Patients with this disorder often present with hypopigmented, hyperpigmented, or erythematous macules on the trunk and proximal upper extremities. Malassezia is a component of normal skin flora; transformation of Malassezia from yeast cells to a pathogenic mycelial form is associated with the development of clinical disease. External factors suspected of contributing to this conversion include exposure to hot and humid weather, hyperhidrosis, and the use of topical skin oils. Tinea versicolor is not transmitted from person to person and is not related to poor hygiene.

Cutaneous mycoses (ringworm or tinea) are caused by fungi that infect only the superficial keratinized tissue of the skin, hair, and nail. Three types of dermatophytes account for the majority of infections: *Epidermophyton*, *Trichophyton*, and *Microsporum*. Dermatophytoses have varied presentations and are named by the location involved, tinea capitis, tinea pedis, tinea corporis, and tinea cruris. Dermatophytes are classified as geophilic, zoophilic, or anthropophilic depending on whether their usual habitant is soil, animals, or humans. Dermatophytes are acquired by contact with contaminated soil or with infected humans or animals.

Sporotrichosis is a subacute to chronic infection caused by the dimorphic fungus Sporothrix schenckii. Infection usually involves cutaneous

and subcutaneous tissues but can occasionally occur in other sites like lungs, meninges, and other viscera especially in individuals with underlying illnesses including alcoholism, diabetes mellitus, and AIDS. Days to weeks after cutaneous inoculation of the fungus, a papule develops at the site of inoculation. This primary lesion usually ulcerates, then similar lesions occur along lymphatic channels proximal to the original lesion. S. schenckii exists in wood, hay, and soil. Inhalation of S. schenckii from soil is the presumed route of transmission for pulmonary sporotrichosis. Zoonotic transmission is uncommon but has been traced back to a variety of animals, cats being the most common.

Pathogenic Parasites and Their Modes of Transmission

Parasites of medical importance come under the kingdom called Protista and Animalia. Protista includes the microscopic single-celled eukaryotes known as protozoa. In contrast, helminths are macroscopic, multicellular worms possessing well-differentiated tissues and complex organs and belong to the kingdom Animalia. Parasites are transmitted to humans through arthropod vector like plasmodia, babesia, *Trypanosoma,* and *Leishmania,* through the gastrointestinal tract like Giardia, Entamoeba histolytica, Isospora, Cyclospora, Toxoplasma, Cryptosporidium, Microsporidia, and Balantidium which typically will affect the gastrointestinal tract but can affect other organs as well. Some parasites are sexually transmitted like Trichomonas.

Protozoa

Plasmodium There are four species that normally infect humans, namely, *Plasmodium falciparum, Plasmodium vivax, Plasmodium ovale,* and *Plasmodium malariae.* Malaria is the most important parasitic disease of humans, with transmission in over 100 countries affecting close to three billion people and causing one to two million deaths each year [36]. The initial symptoms and signs are nonspecific and may include tachycardia, tachypnea, chills, malaise, fatigue, diaphoresis, headache, cough, anorexia, nausea, vomiting, and diarrhea. Then periodic attacks of fever occur 48–72. Complications are due to severe anemia and capillary plugging from an adhesion of infected red blood cells with each other and endothelial lining of capillaries resulting in hypoxic injury to the brain and kidney. This occurs especially in *P. falciparum* infection where the parasitemia is more severe compared to the other species. Malaria is transmitted via the bite of a female Anopheles mosquito, which occurs mainly between dusk and dawn. Other comparatively rare mechanisms for transmission include congenitally acquired disease, blood transfusion, sharing of contaminated needles, and organ transplantation. In areas where malaria is endemic, the groups at high risk for severe malaria and its consequences include young children (6–36 months) and pregnant women. Older children and adults develop partial immunity after repeated infections and are at relatively low risk for severe disease. As disease incidence wanes, older age groups will become more susceptible due to decreasing immunity. Travelers to areas where malaria is endemic generally have no previous exposure to malaria parasites and are at very high risk for severe disease if infected. Modes of preventions include chemoprophylaxis and protection from mosquito bite by netting, protective clothing, and insect repellents which are also effective. Prompt diagnosis and treatment including "self-treatment" prevents complications.

Giardia lamblia has a worldwide distribution, particularly common in the tropics and subtropics. It can be asymptomatic but symptomatic giardiasis ranges from mild diarrhea to severe malabsorption syndrome. Usually, the onset of the disease is sudden and consists of foul smelling, watery diarrhea, abdominal cramps, flatulence, and steatorrhea. The life cycle consists of two stages, the trophozoite and the cyst. Transmission occurs by ingestion of the infective cyst. It is acquired through the consumption of inadequately treated contaminated water, ingestion of contaminated uncooked vegetables or fruits,

and person-to-person spread by the fecal-oral route. The cyst stage is resistant to chlorine in concentrations used in most water treatment facilities. For prevention of transmission, asymptomatic reservoirs of infection should be identified and treated, contaminated food and water should be avoided, and drinking water from wells, lakes, and streams should be boiled, filtered, or iodine treated.

Entamoeba histolytica has a worldwide distribution. Although it is found in cold areas, the incidence is highest in tropical and subtropical regions that have poor sanitation and contaminated water. About 90 % of infections are asymptomatic, and the remaining produce a spectrum of clinical syndrome. Intestinal form causes diarrhea, flatulence, and cramping. In extraintestinal amebiasis, amebic abscesses are formed and the most common site is the liver. The main source of infection is water and food contamination. Symptomatic amebiasis is usually sporadic. The epidemic form is a result of direct person-to-person fecal-oral spread under conditions of poor personal hygiene. The essential measures for prevention are introduction of adequate sanitation measures, education about the routes of transmission, and avoidance in eating raw vegetables grown by sewage irrigation.

Other Protozoa

Protozoa/disease	Epidemiology and modes of transmission	Clinical manifestations	Prevention
Leishmania donovani/ Visceral leishmaniasis or kala-azar	Kala-azar occurs in three distinct epidemiologic patterns: 1. In the Mediterranean basin and parts of China and Russia, the reservoir hosts are primarily dogs and foxes. 2. In sub-Saharan Africa, rats and small carnivores are believed to be the main reservoirs. 3. In India and the neighboring countries (and Kenya), it is an anthroponosis (there is no other mammalian reservoir host other than human)	Symptoms begin with intermittent fever, weakness, diarrhea, and chills and sweating that may resemble malaria symptoms early in the infection. The organisms proliferate and invade cells of the liver, spleen, and bone marrow causing hepatosplenomegaly, weight loss, and anemia	Prompt treatment of human infections and control of reservoir hosts
	The vector is the sand fly		Protection from sand flies by screening and insect repellents
L. tropica complex, L. aethiopica/old world cutaneous leishmaniasis	*L. tropica* complex is present in many parts of Asia, Africa, and Europe	The first sign, a red papule, appears at the site of the fly's bite. This lesion becomes irritated with intense itching then enlarges and ulcerates	Prompt treatment and eradication of ulcers
	The urban form is thought to be an anthroponosis, while the rural form is zoonosis with human infections occurring only sporadically. The reservoir hosts are rodents	Gradually the ulcer becomes hard and crusted and exudes a thin, serous material	Control of sand flies and reservoir hosts
	L. aethiopica is endemic in Ethiopia and Kenya. The disease is a zoonosis with hyraxes serving as reservoir hosts		
	The vector is the sand fly		

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Protozoa/disease	Epidemiology and modes of transmission	Clinical manifestations	Prevention
L. Mexican, L. braziliensis/New World cutaneous and mucocutaneous leishmaniasis	Occurs in South and Central America, especially in the Amazon basin	The types of lesions range from oriental sore to disseminated cutaneous leishmaniasis	Avoiding endemic areas
	Rodents, monkeys, raccoons, and domesticated dogs serve as reservoirs		Prompt treatment of infected individuals
	The vector is the sand fly		Control of sand flies and reservoir hosts
Trypanosoma brucei complex/African trypanosomiasis (sleeping sickness)	*T. brucei gambiense* is limited to tropical west and Central Africa	Sleeping sickness starts with an ulcer at the site of the fly bite. The disease progresses causing lethargy, tremors, and mental retardation. In the final stage the patient develop convulsions, and hemiplegia prior to death	Control of breeding sites of tsetse flies and use of insecticides
	An animal reservoir has not been proven for this infection		Treatment of human cases
	T. brucei rhodesiense is found primarily in East Africa, especially the cattle-raising countries		Avoiding insect bite by wearing protective clothing and using insect repellants
	Domestic animal hosts (cattle and sheep) and wild animals act as reservoir hosts		
	The vector is the tsetse fly		
Trypanosoma cruzi/American trypanosomiasis (Chagas' disease)	Found in South and Central America, wild animals are the reservoir hosts	May be asymptomatic. One of the earliest signs is development of erythematous and indurated area at the site of the insect bite	Insect control, eradication of nests
	The vector is the blood-sucking triatomine insects or kissing bugs	Accompanied with fever, myalgia, and fatigue	Treating infected person and exclusion of donors by screening blood
		The chronic disease is characterized by hepatosplenomegaly, myocarditis, and achalasia	
Balantidium coli/balantidiasis	*B. coli* is distributed worldwide	Mostly asymptomatic	Following good hygiene practices including washing all fruits and vegetables with clean water when preparing or eating them
	Swine and monkeys are the most important reservoirs	Symptomatic disease is characterized by abdominal pain, tenesmus, nausea, anorexia, and watery stools with blood and pus	
	Infections are transmitted by the fecal-oral route; outbreaks are associated with contamination of water supplies with pig feces	Extraintestinal invasion of organs is extremely rare in balantidiasis	
	Person-to-person spread has been implicated		

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Protozoa/disease	Epidemiology and modes of transmission	Clinical manifestations	Prevention
Toxoplasma gondii/ toxoplasmosis	The definitive host is the domestic cat and other felines. Humans and other mammals are intermediate hosts. *T. gondii* is usually acquired by ingestion. Transplacental transmission from an infected mother to the fetus can occur. Human-to-human transmission, other than transplacental transmission, does not occur	After infecting the intestinal epithelium, the organisms spread to other organs especially the brain, lungs, liver, and eyes Most primary infections in immunocompetent adults are asymptomatic. Encephalitis is the most common presentation of toxoplasmosis among AIDS patients. Congenital infection can result in abortion, stillbirth, or neonatal disease with encephalitis, chorioretinitis, and hepatosplenomegaly	Cooking food to safe temperature and avoiding drinking untreated water. Pregnant or immunocompromised. Avoid changing cat litter or wear disposable gloves and wash hands afterwards
Cyclospora cayetanensis/ cyclosporiasis	Infection occurs worldwide It is acquired by fecal-oral transmission, especially via contaminated water supplies. There is no evidence for an animal reservoir	An intestinal protozoan that causes watery diarrhea in both immunocompetent and immunocompromised individuals. The diarrhea can be prolonged and relapsing in immunocompromised patients	Avoiding food or water that may have been contaminated with feces Chlorine or iodine is unlikely to kill *Cyclospora* oocysts
Isospora belli/isosporiasis	The organism is acquired by fecal-oral transmission of oocysts from either human or animal sources	An intestinal protozoan that causes diarrhea, especially in AIDS patients	Avoiding food or water that may have been contaminated with feces Chlorine or iodine is unlikely to kill *Cyclospora* oocysts
Cryptosporidium parvum/ cryptosporidiosis	The organism is acquired by fecal-oral transmission of oocysts from either human or animal sources Water (drinking water and recreational water) is the most common method of transmission	The main symptom is diarrhea. It is most severe in AIDS patients	Practicing good hygiene Avoid swimming if you are experiencing diarrhea and If infected, do not swim for at least 2 weeks after diarrhea stops
Microsporidia/ microsporidiosis	The organisms are transmitted by fecal-oral route. It is uncertain whether an animal reservoir exists	Causes severe, persistent, watery diarrhea in AIDS patients	Practicing good hygiene
Trichomonas vaginalis/ trichomoniasis	This parasite has worldwide distribution, and sexual intercourse is the primary mode of transmission. Occasionally, infections can be transmitted by fomites (toilet articles and clothing) Rarely infants may be infected by passage through the mother's infected birth canal	In women it can cause vaginitis with vaginal discharge and dysuria In men it is mostly asymptomatic and very rarely may cause urethritis	Both male and female sex partners must be treated to avoid reinfection Good personal hygiene, avoidance of shared toilet articles and clothing Safe sexual practice

Helminths

Helminths are multicellular organisms that cause morbidity and mortality worldwide. They cause different diseases in humans, but few helminthic infections cause life-threatening diseases. They enter the body through different routes including the mouth, skin, and the respiratory tract.

The helminths are classified into three major groups. These are as follows:

1. Trematodes (flukes)
2. Nematodes (round worms)
3. Cestodes (tapeworms)

Medically Important Trematodes (Flukes)

They are found in a wide range of habitats. The great majority inhabit the alimentary canal, liver, bile duct, ureter, and bladder of vertebrate animals.

Helminth/disease	Location in host	Epidemiology	Mode of transmission
Schistosoma haematobium/ schistosomiasis	The veins of the bladder of humans	Africa and the Middle East	Larva penetrates skin from snail-infected water
Schistosoma mansoni/ schistosomiasis	The veins of the intestine	Africa, South America, and the Middle East	Larva penetrates skin from snail-infected water
Fasciola hepatica/fascioliasis	Liver and bile duct	Worldwide	Aquatic vegetation
Paragonimus westermani/paragonimiasis	Lungs, brain, and other sites	Asia (China, India, Indonesia, Malaya, etc.) and some African countries	Raw crabs and other freshwater crustaceans

Medically Important Nematodes (Round Worms)

These helminths have a tough protective covering or cuticle. They have a complete digestive tract with both oral and anal openings. They are free-living (majority) or parasites of humans, plants, or animals. Their life cycle includes egg, larvae, and adult.

Helminth/disease	Location in host	Epidemiology	Mode of transmission
Ascaris lumbricoides/ ascariasis	Small intestine, larvae through lungs	Infecting more than 700 million people worldwide	Contaminated food and water
Ancylostoma duodenale/ hookworm infection	Small intestine, larvae through lungs	Temperate zones	From infected soils through skin
Necator americanus/ hookworm infection	Small intestine, larvae through lungs	Worldwide tropics and North America	From infected soils through skin
Ancylostoma braziliense/cutaneous larva migrans	Subcutaneous migratory larvae	Worldwide	Contact with soils contaminated by dog or cat feces
Toxocara canis and *Toxocara cati*/visceral larva migrans	Cerebral, myocardial, and pulmonary migratory larva	Worldwide	Ingesting soil contaminated by dog or cat feces
Strongyloides stercoralis/ strongyloidiasis	Duodenum, jejunum, and larva through skin and lungs	Worldwide	From infected soil through skin
Enterobius vermicularis (pin worm)/enterobiasis	Cecum, colon	Worldwide	Direct infection from a patient (fecal-oral route), self contamination

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Helminth/disease	Location in host	Epidemiology	Mode of transmission
Trichuris trichiura (whipworm)/trichuriasis	Cecum, colon	Worldwide	Ingesting contaminated soils
Wuchereria bancroftil/ filariasis	Lymph nodes and the lymphatic vessels, microfilariae through the bloodstream	Infecting over 100 million people worldwide	Mosquito is the vector
Onchocerca volvulus/onchocerciasis	Skin, lymphatic vessels, and cornea; microfilariae through the subcutaneous tissue fluids	Africa and South America	Black fly is the vector
Loa loa/loiasis	Conjunctiva, microfilariae through the bloodstream	Western and Central Africa	Mango fly and deerfly are the vectors
Dracunculus medinensis/ dracunculiasis	Subcutaneous, usually leg and foot	India, Nile Valley, and Central, western, and equatorial Africa	Drinking contaminated water with
Trichinella spiralis/trichinellosis	Larvae in striated muscle	Worldwide, more than 100 different animal species can be infected But the main reservoir host for humans is swine	Consumption of undercooked pork

Medically Important Cestodes (Tapeworms)

They require an intermediate host. Adult tapeworms inhabit the small intestine, where they live attached to the mucosa. Tapeworms do not have a digestive system. Their food is absorbed from the host's intestine.

Helminth	Location in host	Epidemiology	Mode of transmission
Hymenolepis nana (dwarf tapeworm)/hymenolepiasis	Small intestine	Worldwide	Consumption of contaminated raw vegetables, direct infection from a patient (fecal-oral route), and self contamination
Hymenolepis diminuta (rat tapeworm)/hymenolepiasis	Small intestine	Worldwide, humans and rats are the reservoir	Ingestion of food contaminated by rat flea
Echinococcus granulosus (dog tapeworm)/ echinococcosis (hydatidosis)	Larvae in the liver, lung, brain, peritoneum, long bone, and kidney	Worldwide, definitive hosts are dogs where worms live in small intestine. Humans are intermediate host carrying the hydatid cyst (larva)	Ingestion of food contaminated by feces of dogs, handling or caressing infected dogs
Taenia saginata (beef tapeworm)/taeniasis	Small intestine	Worldwide	Undercooked beef
Taenia solium (pork tapeworm)/taeniasis	Small intestine	Worldwide	Undercooked pork
Diphyllobothrium latum (broad or fish tapeworm)/ diphyllobothriasis	Small intestine	Worldwide	Undercooked freshwater fish

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