Other Microbiology / Parasitology

Background

Microbial pathogens include microscopic organisms such as bacteria, viruses, and protozoans, as well as multicellular organisms such as helminths (worms) and other parasites. Accurate microbial identification is critical for the optimal treatment of patients presenting with infection. Laboratory tests are often essential for guiding effective intervention. A wide range of testing options for infectious disease pathogens is available and varies by organism. These include in vitro detection of an antibody or antigen (serology), culture-based methods, and molecular assays that detect microbial DNA or RNA. The types of organisms likely to cause infection can vary significantly with geography. This section will address more prevalent microbial and parasitic infections.

Antibiotic Resistance and Bacterial Infections

In bacterial infection, both pathogen identity and resistance profiling are routinely used for therapy selection. Laboratories rely primarily on culture-based methodologies to perform bacterial identity and assess antibiotic resistance, although some molecular-based techniques, such as the polymerase chain reaction (PCR), are becoming available.

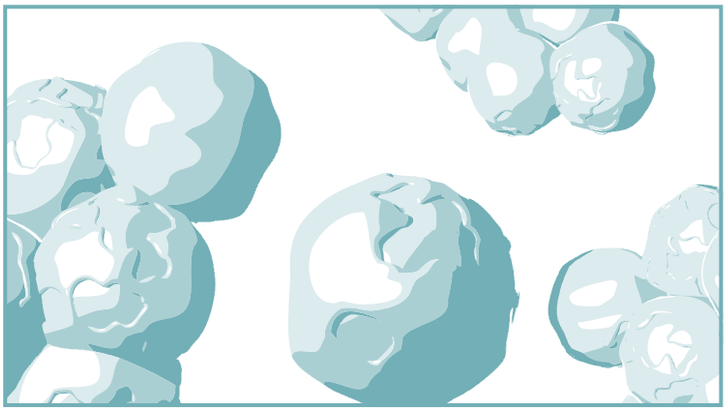
Antibiotic resistance in bacteria is of growing concern, with an increasing number of bacteria exhibiting resistance to one or more classes of drug (multi-drug-resistant organisms or MDROs*). MDROs include gram-positive organisms such as the ubiquitous *Staphylococcus aureus*, gram-negative organisms such as *Acinetobacter baumannii*, and acid-fast organisms such as *Mycobacterium tuberculosis*.[1] Some genera of bacteria have emerged, particularly in the hospital setting, that are susceptible to very few antibiotics.[2] Table 1 lists some of the more common bacteria that carry resistance to one or more antibiotics.[3]

Methicillin-resistant *S. aureus* (MRSA) and vancomycin-resistant enterococci (VRE) are growing in prevalence, and have important infection-control implications.[2] The increasing presence of several MDROs is of mounting concern in hospital-associated settings (including intensive care units and surgical suites), and nonhospital settings (dialysis centers, long-term care facilities). Infection can result in increased mortality (often from pneumonia or sepsis), and can cause significantly increased lengths of stay. Fortunately, most hospital-associated infections still demonstrate sensitivity to one or more classes of antibiotics. Identification of the resistance profile is often key to effective patient care.

*For epidemiologic purposes, MDROs are defined as microorganisms, predominantly bacteria, that are resistant to one or more classes of antimicrobial agents.

Table 1. Drug-resistant bacteria.[3]

Commonly Identified Resistant Bacteria
Methicillin-resistant *Staphylococcus aureus* (MRSA)
Vancomycin-resistant enterococci (VRE)
Extended spectrum beta-lactamase–producing (ESBL) bacteria • *Escherichia coli* • *Klebsiella pneumoniae*
Other gram-negative bacteria: • *Acinetobacter baumannii* • *Stenotrophomonas maltophilia* • *Burkholderia cepacia* • *Ralstonia pickettii*
Less Frequently Isolated but Highly Resistant Strains of *S. aureus*
Vancomycin-intermediate *S. aureus* (VISA)
Vancomycin-resistant *S. aureus* (VRSA)



Resistance Mechanisms

Multiple mechanisms of resistance are available to bacteria. Resistance occurs when bacteria acquire genetic information through mutations or acquisition of resistance genes. Mechanisms include modification or inactivation of the antibiotic and active efflux to remove antibiotic from the cell (Figure 1). *S. aureus* becomes MRSA via the acquisition of the mecA operon, which encodes an altered form of the penicillin-binding protein 2a (PBP2a). Expression of PBP2a reduces or eliminates the ability of antibiotics in the beta-lactam family (Table 2) to bind to the cell, conferring resistance. While MRSA is often sensitive to drugs outside of the beta-lactam classes, strains carrying additional resistance genes have been identified, particularly in hospital-associated MRSA. Vancomycin is still considered effective for most MRSA infections, although cases of both vancomycin-intermediate *S. aureus* (VISA) and vancomycin-resistant *S. aureus* (VRSA) have been reported. Acquisition of the vanA gene from VRE by MRSA is the suspected cause of resistance in VRSA.[4]

Figure 1. Common bacterial mechanisms of resistance.[5]

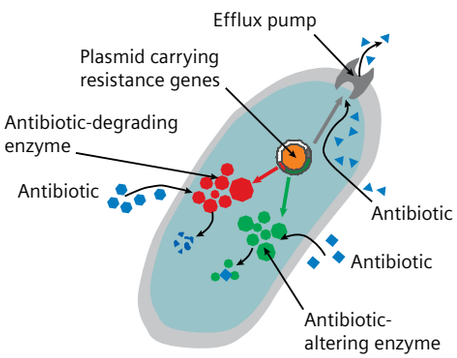


Table 2. Commonly-used beta-lactam antibiotics.

Penicillins	Penicillinase-Stable Penicillins	β-lactam / β-lactamase Inhibitor Combinations	Cephalosporin	Cephamycins	Monobactams	Penems
Penicillin	Methicillin	Amoxicillin-clavulanic acid	Cefaclor Cephalexin	Cefotetan	Aztreonam	Imipenem
Amoxicillin	Nafcillin	Ticarcillin-clavulanic acid	Cephalothin Cefazolin	Cefoxitin		Meropenem
Ampicillin	Dicloxacillin	Piperacillin-tazobactam	Cefuroxime			Ertapenem
Mezlocillin	Oxacillin	Ampicillin-sulbactam	Cefotaxime			Doripenem
Piperacillin			Ceftazidime			Faropenem
Ticarcillin			Ceftriaxone Cefepime Ceftobiprole			

Other Microbiology / Parasitology
(continued)

MRSA in the Hospital and in the Community

Although only one of many resistant organisms, much attention has been given to MRSA due to its growing prevalence in healthcare settings as well as emergence of MRSA strains in the community.[6–8] MRSA was first recognized in 1961, shortly after the introduction of methicillin, but remained primarily confined to hospital settings for many years. Prevalence of MRSA has grown steadily, and it is now one of the most commonly identified antibiotic-resistant pathogens in many parts of the world (Figure 2).[6] In the US, the proportion of MRSA isolates in intensive care units (ICUs) may exceed 60%.[6,7] In Europe, MRSA prevalence varies widely, from less than 1% in northern Europe to more than 40% in southern and western Europe.[8] Rates of colonization and infection with MRSA continue to increase, prompting initiatives such as hand hygiene to help limit transmission in the healthcare arenas.[3]

In an effort to control rising rates of transmission, some countries have enacted legislation for mandatory reporting of MRSA infections. Routine infection-control measures have been implemented in many hospitals, with varying rates of success. While the introduction of hand hygiene procedures and other infection-control initiatives can reduce infection rates, healthcare facilities can struggle with compliance, and may not achieve a significant and sustained reduction. Some hospitals have initiated active surveillance for MRSA in an attempt to control transmission by identifying colonized patients.

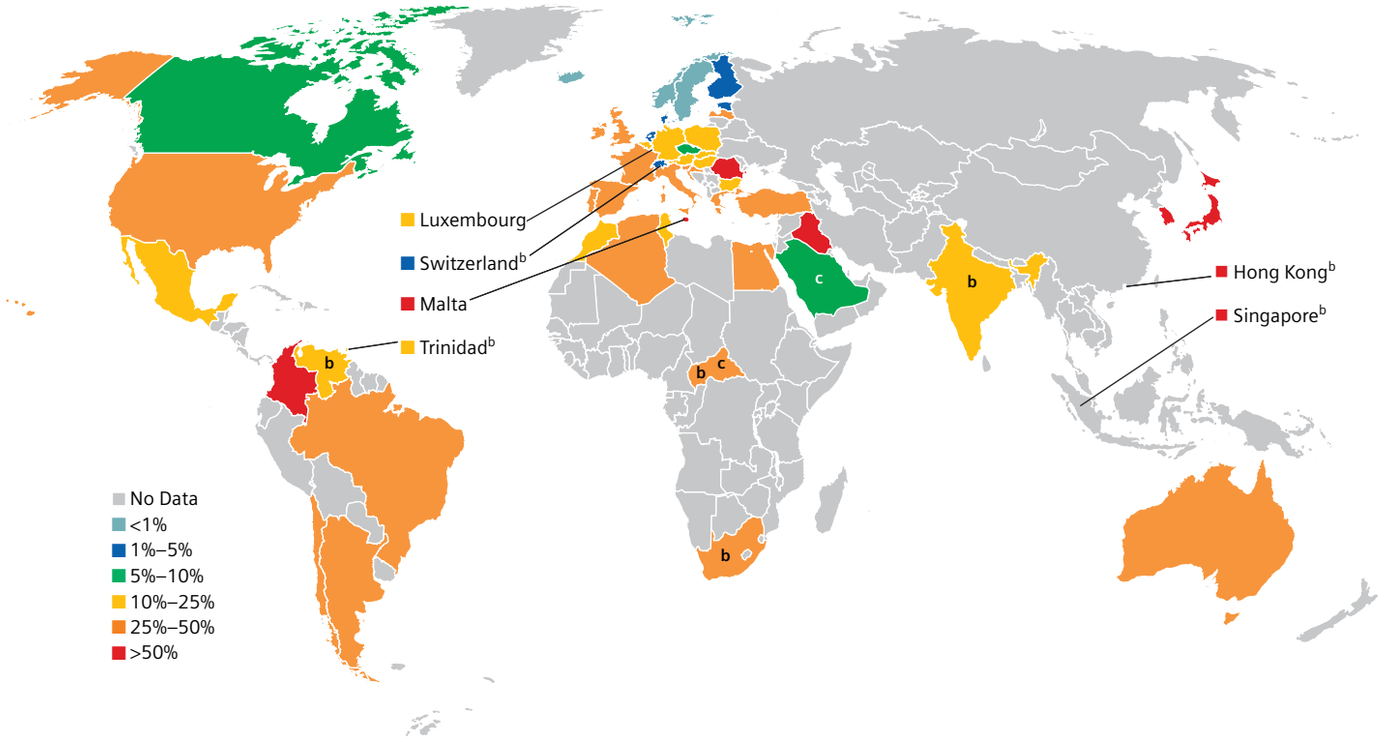
More recently, MRSA infections have been identified at increasing rates outside of the traditional healthcare setting.[9] These strains, known as community-associated MRSA (CA-MRSA), are genetically different from strains of hospital-associated MRSA (HA-MRSA). CA-MRSA frequently presents as skin abscesses, boils, or other lesions (often mistaken for a spider or bug bite), although sepsis and pneumonia can occur. CA-MRSA often occurs in otherwise healthy people who lack known risk factors for HA-MRSA (Table 3). MRSA can be distinguished from susceptible strains of *S. aureus* only by isolating a sample from the infected site for laboratory analysis. CA-MRSA typically harbors less resistance than HA-MRSA, although both are associated with beta-lactam resistance.

S. aureus can acquire the mecA gene from the staphylococcal chromosomal cassette (SCCmec), commonly found in five forms (SCCmec I–V).[10] SCCmec I to III tend to carry more genetic information and are more often associated with hospital-acquired infections that display a higher level of resistance. SCCmec IV and V carry smaller amounts of genetic material, and are associated with community-acquired infections that show increased antibiotic susceptibility. However, CA-MRSA appears to be encroaching on the healthcare setting and may be gaining more resistance. In addition, CA-MRSA is more frequently associated with pathogenic elements such as the Panton-Valentine leukocidin (PVL) gene, which may enhance virulence.[10]

Table 3. American Medical Association (AMA) definitions: epidemiologic classification of invasive MRSA infections.[9]

Classification	Definition
Healthcare-associated	
Community-onset	Cases with at least one of the following healthcare risk factors: • Presence of an invasive device at the time of admission • History of MRSA infection or colonization • History of surgery, hospitalization, dialysis, or residence in a long-term care facility in previous 12 months preceding culture
Hospital-onset	Cases with positive blood culture result from a normally sterile site obtained more than 48 hours after hospital admission. These cases may also have one or more of the community-onset factors.
Community-associated	Cases with no documented community-onset healthcare risk factors

Figure 2. Worldwide evidence of MRSA prevalence.[6,a] Reprinted with permission from Elsevier.



[a]All presented MRSA proportions are from peer-reviewed studies undertaken since 1998. Prevalence estimates for Morocco, Algeria, Tunisia, Egypt, Jordan, Lebanon, and Turkey are from the antimicrobial resistance in the Mediterranean region (www.slh.gov.mt/armed/earss.asp). Studies providing the most recent estimates of the MRSA proportion have been taken into account. If more than one study reported over the same period, the study including different types of clinical isolates was preferred over studies including only one specific type of specimen.
[b]Prevalence estimates are based on a study that included only one hospital.
[c]Prevalence estimates are based on studies between 1993 and 1997.

Other Microbiology / Parasitology
(continued)

Serology and Bacterial Infection

While much of bacteriology relies on culture-based technology to both identify bacteria and determine resistance, serology continues to play a key part in clinical assessment. Table 4 lists some of the more common bacteria for which serologic testing can be useful for diagnosis and patient care. Diagnosis of many bacterial infections can often be difficult, requiring laboratory tests for accurate assessment. Lyme disease and syphilis are often either misdiagnosed or remain undiagnosed, as both can present with varied medical signs and symptoms. With these two pathogens, serological tests often provide the information necessary for an accurate diagnosis.

Lyme Disease

The causative agent of Lyme disease is the spirochete *Borrelia*. The disease is transmitted through the bite of an infected tick.[11] Lyme disease is found throughout the United States and in many countries in Europe. Early symptoms are often vague, making diagnosis a challenge. The characteristic presentation of Lyme disease includes a circular skin rash (erythema migrans) that often presents as a bull's eye one day to one month after the tick bite (usually appearing within 7 days). Other symptoms include fatigue, muscle and joint pain, chills, fever, lymphadenopathy, and headaches. Misdiagnosis is common in the absence of the rash.

The disease process has been divided into three stages based on signs and symptoms: early localized, early disseminated, and late persistent.[12] Common primary symptoms of each stage are shown in Table 5.[13] Disease manifestations can vary between the US and Europe; this may be related to the strain of *Borrelia*.

Tests for antibodies can be useful for facilitating an accurate diagnosis of Lyme disease. A positive IgM test is indicative of an early infection. Effective treatment with antibiotics is available, and greater success is associated with earlier treatment.[14]

Syphilis

Syphilis is a chronic disease caused by *Treponema pallidum*. It has been called "the great imitator," as many of its signs and symptoms are indistinguishable from other types of infections. Syphilis is acquired by direct contact, usually sexual, with active primary or secondary lesions. Studies have shown that approximately 16% to 30% of individuals who had sexual contact with a syphilis-infected person become infected.[15] Infection is also transmitted vertically since the bacteria can cross the placenta and infect the fetus. Fetal infection can result in spontaneous abortion, stillbirth, death of the neonate, or congenital disease.

Syphilis is a reemerging disease; increased rates have been seen in many countries.[15,16] Of particular importance is the fact that syphilis infection greatly increases the transmission and acquisition of HIV infection. The worldwide burden of syphilis is enormous, with an estimated 12 million new cases each year.[15]

Table 4. Serologic detection of bacterial infections.

Pathogen	Related Disease	Antibody Class Detected			
		Ig Total	IgG	IgM	IgA
Borrelia species	Borreliosis (Lyme disease)	•	•	•	
Bordetella pertussis	Whooping cough		•	•	•
Brucella abortus	Brucellosis		•	•	
Chlamydia pneumoniae	Pneumonia		•	•	•
Chlamydia trachomatis	Sexually transmitted disease (STD)		•	•	•
Corynebacterium diphtheriae	Diphtheria		•		
Helicobacter pylori	Peptic ulcers		•		•
Mycoplasma pneumoniae	Pneumonia		•	•	
Treponema pallidum	Syphilis	•			
Clostridium tetani	Tetanus		•		

Table 5. Stages of Lyme disease.[13]

Stage	Possible Symptoms
1: Early localized (7–10 days)	Erythema migrans, flulike symptoms
2: Early disseminated (weeks to months)	Intermittent arthritis, cranial nerve palsies, AV nodal block, severe malaise, peripheral neuropathy
3: Late persistent (months to years)	Chronic asymmetric monoarticular or oligoarticular arthritis, encephalitis, myelitis, paresthesias, severe fatigue

Syphilis is a multistage disease with diverse manifestations (Table 6). It is important that diagnosis always be supported by appropriate laboratory tests because syphilis can mimic other diseases, resulting in a missed or delayed diagnosis.[15,17]

Laboratory diagnosis relies on microscopy, and treponemal and nontreponemal serologic tests.[15–18] Primary and secondary syphilis can be diagnosed through microscopy (if lesions are present) and serologic tests. Latent syphilis is primarily diagnosed by serologic tests. The sensitivities of diagnostic tests depend on the stage of disease (Table 7).[15,17]

In many countries, perinatal screening is standard. A common approach to screening is to use a nontreponemal test initially; patients who test positive are then assessed using a treponemal test.[17]

Antibiotic treatment, usually penicillin, is very effective, although penicillin-resistant forms have been identified. Nontreponemal tests are typically used for monitoring treatment response.

Table 6. Stages of syphilis.[15,17,18]

Progression	Stage	Symptoms
1	Infection	Replication at the site of infection; dissemination to other tissues, including the central nervous system (CNS)
2	Primary syphilis	Chancre at site of infection, regional lymphadenopathy
3	Secondary syphilis	Disseminated rash, generalized lymphadenopathy
4	Latent syphilis	Recurrence of secondary syphilis; symptoms in up to 25% of individuals
5	Tertiary syphilis (includes neurosyphilis)	Gumma; cardiovascular and late neurological complications

Table 7. The application and limitations of diagnostic tests in different stages of syphilis.[17] Originally published in English in The Canadian Journal of Infectious Diseases & Medical Microbiology. The publisher of this journal does not assume responsibility for errors or discrepancies that may occur during translation.

Stage	Recommended Tests	Comments
Primary syphilis	Direct examination, nontreponemal tests, treponemal tests	Detection of *T. pallidum* in lesions is definitive evidence of syphilis, but a negative result does not rule out syphilis. PCR-based tests have a high reliability. In the first 2 to 3 weeks, serology may not be positive in most cases; and, in early primary syphilis, treponemal tests are recommended. The presence of a genital ulcer and a positive nontreponemal test may not indicate primary syphilis. Repeat serology over a 2- to 12-week period to rule out syphilis.
Secondary syphilis	Direct examination, nontreponemal tests, treponemal tests	*T. pallidum* can be detected in skin and mucosal lesions, and PCR-based tests may be useful in atypical lesions. Serological tests have nearly 100% sensitivity. In persons with a history of syphilis, a fourfold increase in titer provides presumptive diagnosis of secondary syphilis.
Latent syphilis	Nontreponemal tests, treponemal tests	Nontreponemal tests are reactive in early latent syphilis, but the sensitivity declines over time. In low prevalence populations, false-positive results are common with both types of tests. Reactive treponemal tests in the absence of a reactive nontreponemal test require confirmation.
Tertiary syphilis	Nontreponemal tests, treponemal tests	Up to 30% of *T. pallidum* may not be reactive in nontreponemal tests, whereas treponemal tests are almost always reactive. Therefore, treponemal tests should always be considered. Lesions are not suitable for direct microscopic examination.
Neurosyphilis	Nontreponemal tests, treponemal tests	Diagnosis requires a combination of tests. VDRL-CSF, the standard serological test for CSF, is highly specific but insensitive. Therefore, a negative VDRL-CSF result does not rule out neurosyphilis. In addition to a reactive VDRL-CSF, diagnosis depends on reactive serological tests and CSF abnormalities. FTA-ABS is more sensitive than VDRL-CSF but less specific. Therefore, the CSF FTA-ABS test may be useful to exclude neurosyphilis. PCR-based tests have a high reliability.
Congenital syphilis	Direct examination, nontreponemal tests	Diagnosis requires a combination of tests. Venous blood from both the mother and the child should be tested. Serological tests on infant serum can be nonreactive if the mother has a low titer or was infected late in pregnancy. IgM-specific tests are useful for neonatal serum, but negative results may not rule out congenital syphilis. *T. pallidum* can be detected by direct examination of a variety of specimens from the neonate, and PCR-based tests have a high reliability. Asymptomatic congenital syphilis requires a comprehensive approach.

CSF: cerebrospinal fluid; **FTA-ABS**: fluorescent treponemal antibody absorption; **PCR**: polymerase chain reaction; **VDRL**: Venereal Disease Research Laboratory.

Other Microbiology / Parasitology
(continued)

Serology and Viral Infections

Testing for human immunodeficiency virus (HIV) and hepatitis viruses is routinely done for blood donors, and for screening, diagnostic, and management purposes. These pathogens are discussed in previous sections of this educational guide. Serologic tests play an important role in the diagnosis of a number of viral infections (Table 8) including dengue fever, Epstein–Barr virus, and tick-borne encephalitis. These three viral diseases are discussed in more detail below.

Table 8. Common viruses and associated diseases.

Virus	Disease
Adenovirus	Colds
Dengue virus	Dengue (hemorrhagic fever)
Epstein–Barr virus	Infectious mononucleosis
Influenza A, B virus	Flu
Measles virus	Measles
Parainfluenza 1–3	Flu
Parotitis virus	Parotitis
Parvovirus B 19	Fifth disease
Respiratory syncytial virus	Respiratory infection
Tick-borne encephalitis virus	Tick-borne encephalitis
Varicella zoster virus	Chicken pox, shingles
Herpes simplex 1 and 2 virus	Oral (HSV-1) and genital (HSV-2) herpes

Dengue Fever

Dengue fever is a mosquito-borne (*Aedes aegypti*) viral infection that is primarily endemic in tropical and subtropical areas, including Africa, Southeast Asia, and South America. Dengue is the most widespread vector-borne viral disease in humans. It is currently estimated that there are 50 to 100 million cases of dengue fever per year, worldwide. About 500,000 cases of dengue fever result in the severe forms of the disease, dengue hemorrhagic fever (DHF) and dengue shock syndrome (DSS). These forms can be fatal.[19] Since 2000, rates have been steadily increasing, claiming more victims in more countries (Figure 3).[20]

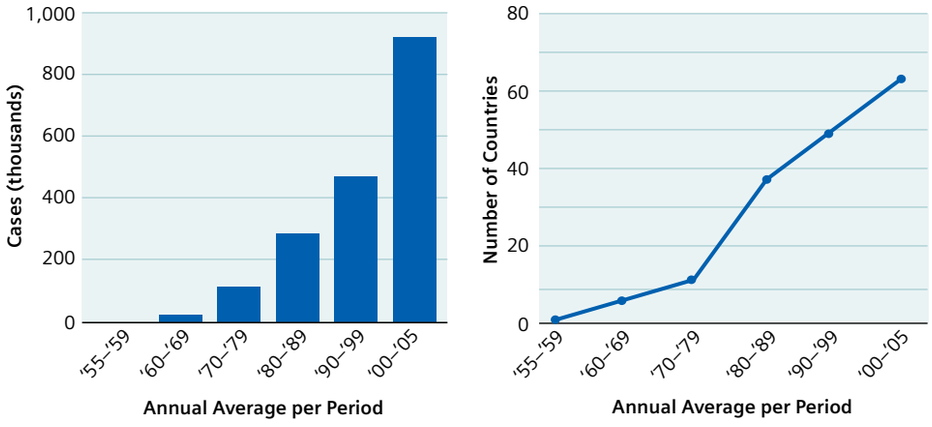
Dengue fever is caused by any of four closely related viral serotypes (DEN-1, DEN-2, DEN-3, and DEN-4) of the genus *Flavivirus*. Infection with one of these serotypes provides lifelong immunity to the infecting serotype only. Therefore, infection with a different serotype is possible in a previously infected individual. Individuals with second infections are at greater risk for DHF. The disease usually presents as an acute febrile illness, historically known as "break-bone fever." While painful, nearly all patients recover from this form of dengue fever.[21]

Serologic tests can aid in diagnosis; a positive IgM result for dengue is suggestive of an acute infection. Treatment is symptomatic. Since there is no vaccine, fumigation and educational campaigns are currently the primary means of preventing infection.

Epstein–Barr Virus

Epstein–Barr virus (EBV) is a member of the herpesvirus family. EBV occurs worldwide and is a common human pathogen, infecting greater than 90% of the world's adult population.[22] EBV is generally transmitted by saliva. Many healthy people harbor the virus in their saliva, making transmission difficult to prevent.

Figure 3. The increasing rates of dengue fever.[20] Reprinted with permission from the World Health Organization.



EBV typically establishes a lifelong infection. In industrialized countries, initial infection frequently occurs during adolescence or young adulthood, and presents as infectious mononucleosis 35% to 50% of the time.[23] Infectious mononucleosis is rare outside of industrialized countries.[22] Symptoms of infectious mononucleosis include fever, sore throat, and lymphadenopathy, and may last as long as 4 months. No specific antiviral treatment is available, so treatment is usually limited to symptom management. EBV has also been associated with the development of Burkitt's lymphoma, nasopharyngeal carcinoma, and other lymphoproliferative conditions.[22]

Typically, EBV does not pose a fetal risk; however, studies have shown that reactivation during pregnancy is associated with shorter duration of pregnancy, lighter babies, and in rare cases damage to the fetal heart and liver.[23,24] EBV has also been implicated as a causative agent in placental infection.[24]

Typical testing options for EBV include white blood cell count, antibody to the viral capsid antigen (IgM and IgG), and antibody to the nuclear antigen (IgG). The diagnosis of EBV is summarized in Table 9, although interpretation of tests must be done with caution.

Tick-borne Encephalitis

Tick-borne encephalitis (TBE) of viral origin is caused by a *Flavivirus* (species: tick-borne meningoencephalitis virus). It is an important infectious disease in many parts of Europe, Russia, and Asia. Prevalence corresponds with the geographic distribution of the ixodid tick (the tick acts both as a vector and a reservoir).[26] Humans are commonly infected through tick bites, but infection can occur with the consumption of raw milk from goats, sheep, or cows.

TBE generally occurs as a biphasic illness.[27] The initial incubation period of 7 to 14 days is asymptomatic. The first phase (viremic) often presents with nonspecific symptoms that may include fever, myalgias, headache, and nausea that lasts 2 to 4 days. The second phase (neurologic) occurs in 20% to 30% of patients following about 8 days of remission. The disease may present as meningitis (fever, headache, and a stiff neck), as well as encephalitis (drowsiness, confusion, and sensory disturbances). Mortality occurs in 1% to 2% of infections, usually within 5 to 7 days of the onset of neurologic symptoms.[26]

There is no specific therapy for TBE. Hospitalization with intubation and ventilatory support may be needed in patients experiencing the second (neurologic) phase.

A diagnosis of TBE typically requires detection of TBE IgM antibody in either blood or cerebrospinal fluid.[27] Patients are generally in the neurologic phase before the IgM antibody test is positive. A vaccine is available (although not currently FDA approved in the US).

Table 9. Interpretation of Epstein–Barr virus (EBV) test results.[25]

Stage	Test Results[a]
Primary infection	IgM to capsid antigen positive and antibody to nuclear antigen negative
Past infection (4–6 months to years earlier)	Antibodies to both capsid antigen and nuclear antigen are positive[b]
Reactivation	An elevation of antibodies to nuclear antigen suggests reactivation[c]
Chronic EBV infection	Reliable evidence of chronic EBV infection is seldom found in patients that are symptomatic for more than 4 months. If illness lasts for more than 6 months, other sources of chronic illness should be considered.

[a]Interpretation of EBV test results can be complicated. Consultation with an infectious disease specialist may be useful.
[b]A majority of adults (up to 95%) have been infected with EBV and will have a positive antibody test. High levels may be present for years and are not diagnostic for a recent infection.
[c]An elevated antibody test does not automatically indicate that the patient's condition results from EBV reactivation. Reactivation is frequently subclinical.

Other Microbiology / Parasitology
(continued)

Serology and Nonworm-Parasitic Infections

Parasitic infections result in a substantial disease burden globally. Common nonworm-parasitic infections are listed in Table 10. Diagnosis often involves serologic and other laboratory tests. Leishmaniasis and amebiasis can be serious, particularly if dissemination and organ involvement occurs.

Table 10. Common nonworm-parasitic infections.

Organism	Disease	Serologic Detection
Trypanosoma cruzi	Chagas disease	IgG
Entamoeba histolytica	Amebiasis	IgG
Leishmania infantum	Leishmaniasis	IgG
Plasmodium species	Malaria	IgG

Leishmaniasis

Leishmaniasis is caused by protozoa of the *Leishmania* species. Transmission occurs via the bite of some types of phlebotomine sandflies. Leishmaniasis is found in 88 countries of Central America, South America, Africa, India, the Middle East, Asia, southern Europe, and the Mediterranean.[28] Approximately 12 million people worldwide have leishmaniasis, and 50,000 die each year.[29] Incidence is highest in tropical and subtropical regions. Clinical classification of leishmaniasis is usually in one of four categories (Table 11).[30] The CDC estimates that approximately 1.5 million cases of cutaneous leishmaniasis and 500,000 cases of visceral leishmaniasis occur each year.[29]

Table 11. Clinical classification of leishmaniasis.[30]

Type	Presentation and Prognosis
Cutaneous	Skin ulcers on exposed areas such as face, arms, legs. Ulcers usually heal in 2–10 months; scarring is common. Left untreated, cutaneous can progress to disseminated mucocutaneous
Diffuse cutaneous	Disseminated and often chronic skin lesions; difficult to treat
Mucocutaneous	Without treatment, lesions can partially or totally destroy membrane tissue in the nose, mouth, throat, and surrounding tissue
Visceral leishmaniasis (kala azar)	Characterized by high fever, weight loss, swelling of the spleen and liver, and anemia; mortality rate of 75%–100% within 2 years if left untreated

Serologic testing can be useful, particularly for cases of visceral leishmaniasis.[29,31] Coinfection with HIV is also an emerging problem. Treatment can vary with the type of disease, as well as with the species of *Leishmania*. Moreover, some *Leishmania* species have already acquired resistance to antimonial drugs, the first line of treatment in many countries.[29]

Amebiasis

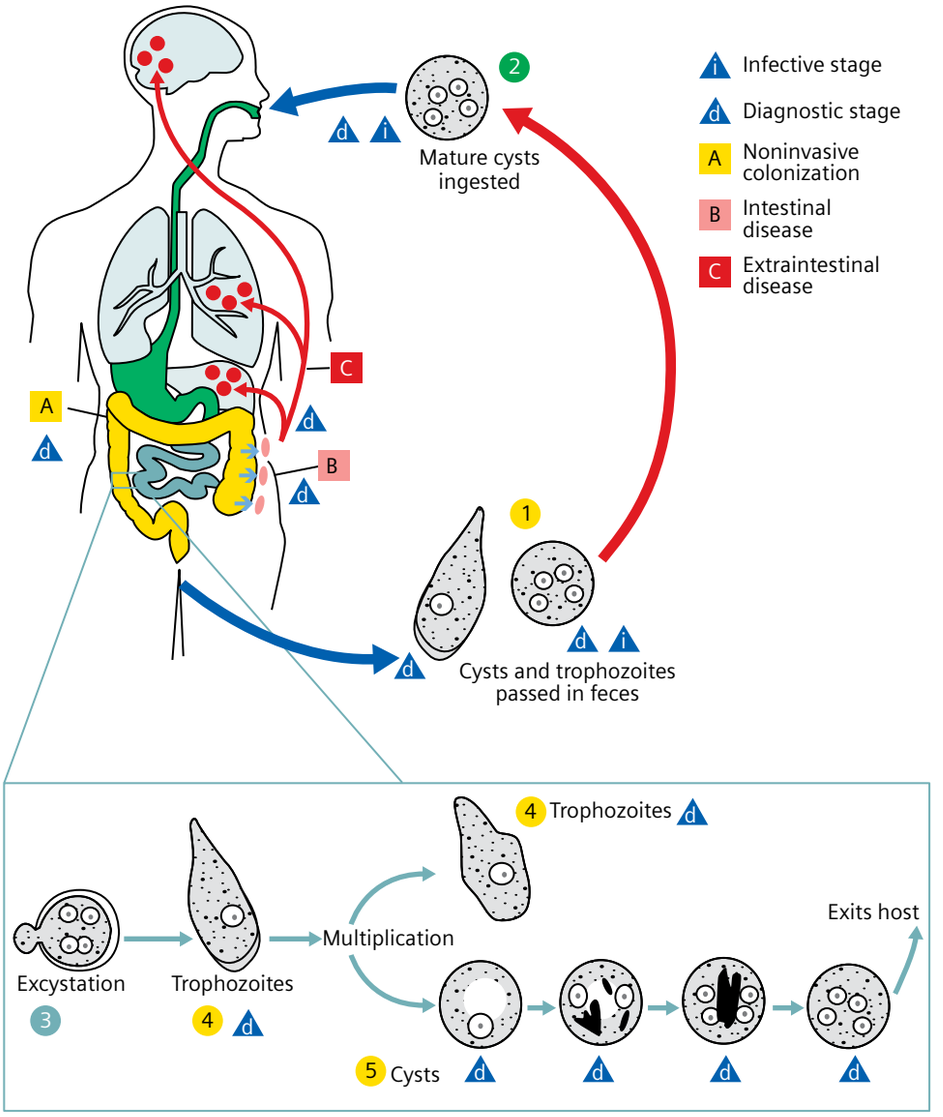
Entamoeba histolytica is a parasitic protozoan. Approximately 50 million people are thought to be infected worldwide.[32] As with many parasites, *E. histolytica* has a complex life cycle (Figure 4).[33] Cysts and trophozoites are passed in feces. Infection usually occurs by ingestion of the cyst form (which can survive for several days outside of the host) in contaminated food or water. Exposure to fecal material during sexual contact is also a risk factor.

While infection may be asymptomatic, symptomatic presentation may include invasive intestinal amebiasis (dysentery, colitis, appendicitis) and invasive extraintestinal amebiasis (liver abscess, peritonitis, and pleuropulmonary abscess).

Microscopic examination of the stool for cysts and trophozoites is a common diagnostic approach. Antibody detection can be useful for diagnosis of patients with extraintestinal disease since organisms may not be present in the stool.[32,34]

Treatment options vary with disease severity (asymptomatic, mild to moderate intestinal disease, or severe intestinal and extraintestinal disease), and patient age.[35]

Figure 4. The life cycle of *E. histolytica*.[33]



Serology and Worm Infections

Helminth infections present an important public health challenge. As much as 10% of the developing world is infected with intestinal worms.[36] Common worm infections are listed in Table 12. Infection with schistosomes, and possibly other worms, may increase risk of infection with HIV, a particular problem in areas highly endemic for both types of pathogens. Infections are often transmitted through contaminated water, food, or soil. Serologic tests to detect worm infections can be useful in diagnosis. Ascariasis and toxocariasis are two of the more common diseases associated with worm infections.

Table 12. Common worm infections.

Worm	Disease
Ascaris lumbricoides	Ascariasis
Taenia solium	Cysticercosis
Toxocara canis	Toxocariasis
Trichinella spiralis	Trichinosis
Schistosoma species	Schistosomiasis
Echinococcus	Echinococcosis, Hydatidosis

Other Microbiology / Parasitology
(continued)

Ascariasis

Ascariasis is caused by *Ascaris lumbricoides*, an intestinal nematode that is the most common human worm infection.[37] *Ascaris lumbricoides* is the largest roundworm (up to 35 cm in length) that causes parasitic intestinal infections. Present worldwide, prevalence rates for *Ascaris* are highest in the tropics and subtropics, and regions with poor sanitation.

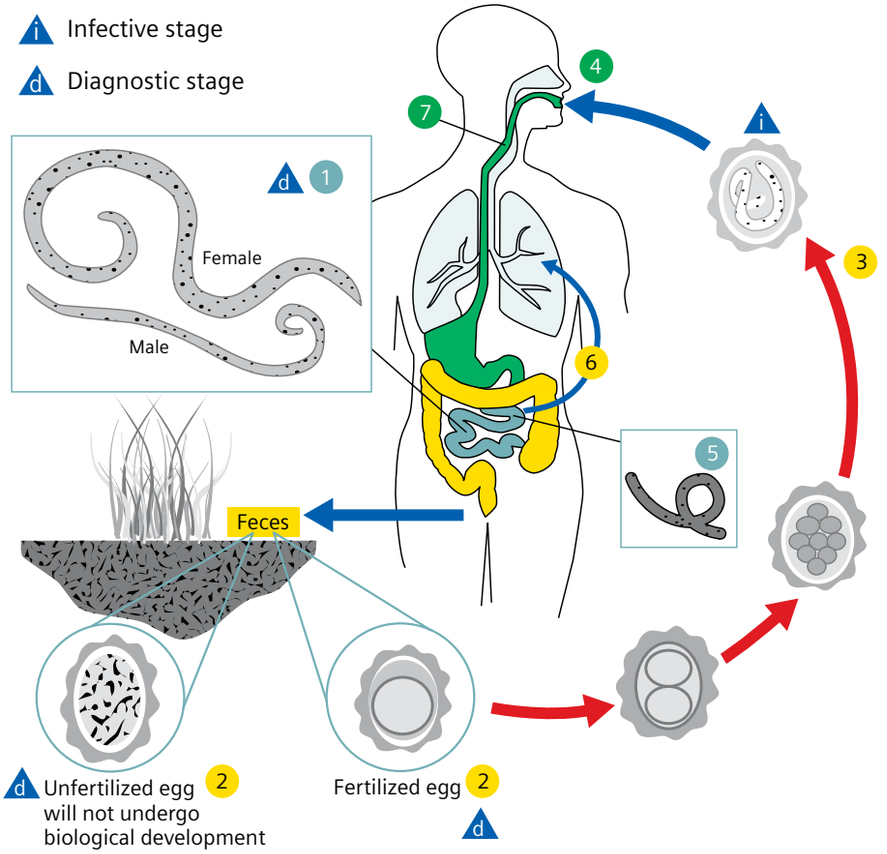
Infection may be asymptomatic or present with abdominal pain. Immature worms can migrate to the lungs, causing dyspnea. Intestinal blockage may occur in patients with high worm burdens. The infection cycle is depicted in Figure 5.[38] For diagnosis, microscopic examination of the stool for eggs is common. A serologic test for detection of antibody to *Ascaris lumbricoides* can also be used to assess infection. Treatment is available and is usually effective.[39]

Toxocariasis

Toxocariasis is a worldwide human infection caused by *Toxocara canis* (a dog roundworm), or *Toxocara cati* (a cat roundworm). Prevalence rates vary, but are generally much higher in tropical countries.[40] Children between the ages of 2 to 7 years are most likely to experience infection. Eggs from *Toxocara* are common in soil, primarily due to the shedding of eggs in dog and cat feces.[41] Eggs can survive for weeks or even years in the environment. Once ingested, the eggs decorticate in the human intestine, releasing larvae. The larvae can penetrate the intestinal wall and migrate to the muscles, liver, and lung, or more rarely, to the eye and brain.

Toxocara infection is commonly recognized as one of three syndromes associated with differing symptoms and pathology (Table 13). Although clinical symptoms vary, chronic eosinophilia is a frequent finding (although it may be absent in ocular or covert toxocariasis).

Figure 5. The life cycle of *Ascaris lumbricoides*.[38]*



*Ascaris eggs can be found in human feces; contamination of soil can result in accidental ingestion. Immature worms hatch from the eggs in the stomach, migrate through the lungs, up to the throat where they are swallowed. The larvae then travel to the intestines where the adult worms mature. Females lay eggs that are passed in the feces, allowing the cycle to repeat.[38]

Table 13. Clinical presentation of *Toxocara* infections.[40]

Type	Clinical Presentation
Covert toxocariasis	Most common in children. Often presents as a mild, febrile illness that may be subclinical. Symptoms can include cough, difficulty sleeping, abdominal pain, headaches, and behavioral problems.
Visceral larva migrans	Caused by migration of larvae to internal organs and the resulting inflammation. Symptoms can vary with the organ affected but include fatigue, anorexia, weight loss, pneumonia, fever, cough, abdominal pain, and headaches. Severe cases can lead to myocarditis or respiratory failure.
Ocular larva migrans	Caused by migration of larvae to the eye, and found more often in older children and adults. Symptoms can include decreased vision, red eye, or leukocoria. Granulomas and chorioretinitis can sometimes be observed in the retina. This form is associated with low or absent serum antibodies to *Toxocara*.

The disease is usually self-limiting, although neurologic or ocular involvement can increase the risk of morbidity and mortality. The diagnosis of toxocariasis usually depends on a high index of suspicion and positive serologic findings (antibody to the organism). Treatment can vary with the organs impacted, but often includes chemotherapy in patients with liver, lung, or eye involvement. Prognosis, particularly with treatment, is generally good.

Conclusion

Despite advances in modern medicine and the evolution of antimicrobial and antiparasitic therapies, microbial and parasitic diseases continue to present clinical challenges. The growing prevalence of drug-resistant organisms is a source of great concern since they can limit therapeutic options. Laboratory testing will continue to play a critical role in the diagnosis and management of microbial and parasitic disease by providing clinicians with information such as organism identity, infection stage, and resistance.

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