SECTION 1

Taxonomic Classification of Medically Important Microorganisms

Pocket Guide to Clinical Microbiology, Fifth Edition. Christopher D. Doern and Alexandra L. Bryson.

In order to remain true to the tradition set forth by the first four editions of this pocket guide, the first section will be devoted to describing the taxonomy of common (and some uncommon) organisms which are associated with humans and may be isolated by the clinical microbiology laboratory. The rate of taxonomic change continues to increase such that publishing a taxonomic list of organisms would quickly be out of date, rendering it obsolete. This is a product of ongoing proliferation of new species of organisms which are being identified by increasingly sophisticated genomic analyses. As such, the revised goal of this section will be to outline some high-level taxonomic groupings and provide the resources and references one would need to identify the most up-to-date taxonomic classifications.

The International Code of Nomenclature of Bacteria governs bacterial taxonomy, and all bacteria named after 1980 must be validly published in the International Journal of Systematic and Evolutionary Microbiology. A current listing of bacteria can be found at https://lpsn.dsmz.de. The International Committee on Taxonomy of Viruses (ICTV) governs viral taxonomy, and all currently recognized viruses can be found at https://ictv.global. The International Code of Nomenclature for algae, fungi, and plants governs fungal classification, and additional information can be found at https://www.iapt-taxon.org/nomen/main.php.

Taxonomic Classification of Bacteria

Classification and taxonomy of prokaryotes (bacteria) is complicated and is governed by the International Code of Nomenclature of Bacteria (ICNB)(last revised in 1990). By definition, each prokaryotic species must include a genus level name that is included within a hierarchy or ranks, which includes (from highest to lowest rank) domain (or empire), kingdom, phylum, class, order, family, genus, and species.

Most importantly, there is no such thing as an official classification of prokaryotes. This is because in contrast to eukaryotes, the prokaryotic designations are a matter of scientific judgment. Therefore, the closest things that we have to "official" taxonomic designations are those names that are generally accepted by the microbiology community. Despite this fact, microbiologists have achieved some amount of consensus by relying on resources such as the *International Journal of Systematic and Evolutionary Microbiology* and *Bergey's Manual of Systematics of Archaea and Bacteria,* which was last updated in 2012. In 2015 publication of this resource moved to continuous publication in an online format.

Initially bacteria were classified according to their phenotypic properties back in the 1920's. The product of these classification methods was published in *Bergey's Manual of Determinative Bacteriology*. Scientific methods for

classification have evolved and now include genetic analyses which provide a more objective and reproducible mechanism for differentiating organisms. A number of DNA-based methods can now be used for bacterial classification including small subunit ribosomal RNA (typically 16S), DNA-DNA hybridization, DNA G+C content, pulsed-field gel electrophoresis (PFGE), multilocus sequence typing (MLST), and lastly, whole genome-based analyses. Not only have these methods been instrumental in revolutionizing bacterial classification, but they have highlighted the enormous amount of microbial diversity that was being missed by culture-based methods.

The following is a consolidated taxonomic outline, which will focus on the taxonomic organization of those organisms that are most likely to be encountered in the clinical microbiology laboratory. This is not meant to be an exhaustive list of all bacteria. Rather, it is intended to provide some context to the relationships between some of the most commonly encountered organisms in human clinical specimens.

The taxonomy of bacterial classification is arranged in the following way. . .

Domain
Phylum
Class
Order
Family
Genera
Species

Domain: Bacteria

Family. *Acetobacteraceae*
Genus. *Roseomonas*
Family. *Actinomycetaceae*
Genus. *Actinobaculum*
Genus. *Actinomyces*
Genus. *Actinotignum*
Genus. *Arcanobacterium*
Genus. *Mobiluncus*
Genus. *Trueperella*
Family. *Aerococcaceae*
Genus. *Abiotrophia*
Genus. *Aerococcus*
Genus. *Dolosicoccus*
Genus. *Facklamia*
Genus. *Globicatella*
Family. *Aeromonadaceae*
Genus. *Aeromonas*

Family. *Alcaligenaceae*
Genus. *Achromobacter*
Genus. *Alcaligenes*
Genus. *Bordetella*
Genus. *Kerstersia*
Genus. *Oligella*
Family. *Atopobiaceae*
Genus. *Atopobium*
Family. *Azospirillaceae*
Genus. *Inquilinus*
Family. *Bacillaceae*
Genus. *Bacillus*
Family. *Bacteroidaceae*
Genus. *Bacteroides*
Family. *Bartonellaceae*
Genus. *Bartonella*
Family. *Bifidobacteriaceae*
Genus. *Alloscardovia*
Genus. *Bifidobacterium*
Genus. *Gardnerella*
Family. *Borreliaceae*
Genus. *Borrelia*
Family. *Brachyspiraceae*
Genus. *Brachyspira*
Family. *Brevibacteriaceae*
Genus. *Brevibacterium*
Family. *Brucellaceae*
Genus. *Brucella*
Genus. *Ochrobactrum*

NOTE: The taxonomy of these organisms is controversial. In 2020 taxonomists proposed that the genus *Ochrobactrum* be included within the genus *Brucella*. For the purposes of this text and the practice of clinical microbiology, we reject this proposal and will retain *Ochrobactrum* nomenclature. It is our contention that *Ochrobactrum* is a distinct genus which is not a cause of brucellosis, a severe form of human disease. Referring to *Ochrobactrum* as *Brucella* will present serious issues in interpreting the clinical significance of culture results. Readers are referred to Moreno E et al. 2023. *J Clin Microbiol* 61(8):e0043823 for a detailed discussion of the issue.

Family. *Burkholderiaceae*
- Genus. *Burkholderia*
- Genus. *Cupriavidus*
- Genus. *Pandoraea*
- Genus. *Ralstonia*

Family. *Campylobacteraceae*
- Genus. *Campylobacter*

Family. *Cardiobacteriaceae*
- Genus. *Cardiobacterium*
- Genus. *Suttonella*

Family. *Carnobacteriaceae*
- Genus. *Alloiococcus*
- Genus. *Dolosigranulum*
- Genus. *Granulicatella*

Family. *Caulobacteraceae*
- Genus. *Brevundimonas*

Family. *Cellulomonadaceae*
- Genus. *Cellulomonas*

Family. *Chlamydiaceae*
- Genus. *Chlamydia*

Family. *Clostridiaceae*
- Genus. *Clostridium*
- Genus. *Sarcina*

Family. *Comamonadaceae*
- Genus. *Acidovorax*
- Genus. *Comamonas*
- Genus. *Delftia*

Family. *Corynebacteriaceae*
- Genus. *Corynebacterium*
- Genus. *Turicella*

Family. *Coxiellaceae*
- Genus. *Coxiella*

Family. *Dermabacteraceae*
- Genus. *Dermabacter*
- Genus. *Helcobacillus*

Family. *Dermacoccaceae*
- Genus. *Dermacoccus*

Family. *Dietziaceae*
- Genus. *Dietzia*

Family. *Eggerthellaceae*
- Genus. *Eggerthella*
- Genus. *Slackia*

Family. *Ehrlichiaceae*
- Genus. *Anaplasma*
- Genus. *Ehrlichia*
- Genus. *Wolbachia*

Family. *Enterobacteriaceae*
- Genus. *Cedecea*
- Genus. *Citrobacter*
- Genus. *Cronobacter*
- Genus. *Enterobacter*
- Genus. *Escherichia*
- Genus. *Klebsiella*
- Genus. *Kluyvera*
- Genus. *Leclercia*
- Genus. *Phytobacter*
- Genus. *Plesiomonas*
- Genus. *Salmonella*
- Genus. *Shigella*
- Genus. *Yokenella*

Family. *Enterococcaceae*
- Genus. *Enterococcus*
- Genus. *Vagococcus*

Family. *Erwiniaceae*
- Genus. *Erwinia*
- Genus. *Mixta*
- Genus. *Pantoea*

Family. *Erysipelotrichaceae*
- Genus. *Erysipelothrix*

Family. *Flavobacteriaceae*
- Genus. *Capnocytophaga*
- Genus. *Flavobacterium*

Family. *Francisellaceae*
- Genus. *Francisella*

Family. *Fusobacteriaceae*
- Genus. *Fusobacterium*

Family. *Gemellaceae*
- Genus. *Gemella*

Family. *Gordoniaceae*
- Genus. *Gordonia*

Family. *Hafniaceae*
- Genus. *Edwardsiella*
- Genus. *Hafnia*

Family. *Helicobacteraceae*
Genus. *Helicobacter*
Family. *Kytococcaceae*
Genus. *Kytococcus*
Family. *Lactobacillaceae*
Genus. *Lactobacillus*
Genus. *Pediococcus*
Family. *Legionellaceae*
Genus. *Legionella*
Family. *Leptospiraceae*
Genus. *Leptospira*
Family. *Leptotrichiaceae*
Genus. *Leptotrichia*
Genus. *Sneathia*
Genus. *Streptobacillus*
Family. *Leuconostocaceae*
Genus. *Leuconostoc*
Genus. *Weissella*
Family. *Listeriaceae*
Genus. *Listeria*
Family. *Microbacteriaceae*
Genus. *Leifsonia*
Genus. *Microbacterium*
Family. *Micrococcaceae*
Genus. *Arthrobacter*
Genus. *Kocuria*
Genus. *Micrococcus*
Genus. *Rothia*
Family. *Moraxellaceae*
Genus. *Acinetobacter*
Genus. *Moraxella* (formerly *Branhamella*)
Family. *Morganellaceae*
Genus. *Morganella*
Genus. *Proteus*
Genus. *Providencia*
Family. *Mycobacteriaceae*
Genus. *Mycobacterium*
Genus. *Mycobacteroides*
Genus. *Mycolicibacillus*
Genus. *Mycolicibacter*
Genus. *Mycolicibacterium*

Family. *Mycoplasmataceae*
Genus. *Mycoplasma*
Genus. *Ureaplasma*
Family. *Neisseriaceae*
Genus. *Eikenella*
Genus. *Kingella*
Genus. *Neisseria*
Family. *Nocardiaceae*
Genus. *Nocardia*
Genus. *Rhodococcus*
Family. *Nocardiopsidaceae*
Genus. *Nocardiopsis*
Family. *Oxalobacteraceae*
Genus. *Herbaspirillum*
Family. *Paenibacillaceae*
Genus. *Paenibacillus*
Family. *Paracoccaceae*
Genus. *Paracoccus*
Family. *Pasteurellaceae*
Genus. *Actinobacillus*
Genus. *Aggregatibacter*
Genus. *Haemophilus*
Genus. *Pasteurella*
Family. *Peptococcaceae*
Genus. *Peptococcus*
Family. *Peptoniphilaceae*
Genus. *Anaerococcus*
Genus. *Finegoldia*
Genus. *Helcococcus*
Genus. *Peptoniphilus*
Family. *Peptostreptococcaceae*
Genus. *Clostridioides*
Genus. *Peptostreptococcus*
Family. *Porphyromonadaceae*
Genus. *Microbacter*
Genus. *Porphyromonas*
Family. *Prevotellaceae*
Genus. *Prevotella*
Family: *Promicromonosporaceae*
Genus. *Oerskovia*

Family. *Propionibacteriaceae*
- Genus. *Cutibacterium*
- Genus. *Propionibacterium*

Family. *Pseudomonadaceae*
- Genus. *Chryseomonas*
- Genus. *Pseudomonas*

Family. *Rhizobiaceae*
- Genus. *Agrobacterium*
- Genus. *Rhizobium*

Family. *Rickettsiaceae*
- Genus. *Orientia*
- Genus. *Rickettsia*

Family. *Shewanellaceae*
- Genus. *Shewanella*

Family. *Sphingobacteriaceae*
- Genus. *Sphingobacterium*

Family. *Sphingomonadaceae*
- Genus. *Sphingomonas*

Family. *Spirillaceae*
- Genus. *Spirillum*

Family. *Staphylococcaceae*
- Genus. *Staphylococcus*

Family. *Streptococcaceae*
- Genus. *Lactococcus*
- Genus. *Streptococcus*

Family. *Streptomycetaceae*
- Genus. *Streptomyces*

Family. *Tannerellaceae*
- Genus. *Parabacteroides*
- Genus. *Tannerella*

Family. *Treponemataceae*
- Genus. *Treponema*

Family. *Tropherymataceae*
- Genus. *Tropheryma*

Family. *Tsukamurellaceae*
- Genus. *Tsukamurella*

Family. *Veillonellaceae*
- Genus. *Veillonella*

Family. *Vibrionaceae*
- Genus. *Grimontia*
- Genus. *Photobacterium*
- Genus. *Vibrio*

Family. *Weeksellaceae*
Genus. *Bergeyella*
Genus. *Chryseobacterium*
Genus. *Elizabethkingia*
Genus. *Empedobacter*
Genus. *Weeksella*
Family. *Yersiniaceae*
Genus. *Ewingella*
Genus. *Serratia*
Genus. *Yersinia*

Recent Clinically Important Taxonomic Changes

There are ongoing taxonomic changes in the field of bacteriology, some of which have significant clinical implications. The following information will outline some of the recent changes that are relevant to the practicing clinical microbiologist.

Enterobacterales. In 2016 it was proposed that the family *Enterobacteriaceae* be revised based on recently published phylogenetic information. This proposal reclassifies a number of members into 6 other newly created families. In addition, order "*Enterobacteriales*" has been renamed "*Enterobacterales*."

Table 1.1 Reclassification of the Former Family *Enterobacteriaceae*

Order	Family	Select clinically relevant genera
Enterobacterales	*Enterobacteriaceae*	*Cedecea* *Citrobacter* *Enterobacter* *Escherichia* *Klebsiella* *Leclercia* *Salmonella* *Shigella* *Yokenella*
	Erwiniaceae	*Erwinia* *Mixta* *Pantoea*
	Hafniaceae	*Edwardsiella* *Hafnia*
	Morganellaceae	*Morganella* *Proteus* *Providencia*
	Yersiniaceae	*Serratia* *Yersinia*
	Budviciaceae	*No clinically relevant genera*
	Pectobacteriaceae	*No clinically relevant genera*

Consequently, it is no longer accurate to refer to this large group of organisms as "*Enterobacteriaceae,*" rather, they should be referred to as "*Enterobacterales.*" The table below summarizes the current taxonomy of select clinically relevant members of this new order (see also Janda JM, Abbott SL. 2021. *Clin Microbiol Rev* 34(2):e00174-20).

Mycobacterium. The genus *Mycobacterium* contains nearly 200 validly named species, the vast majority of which are environmental and not commonly encountered in the clinical laboratory. Historically, these organisms have been split into two groups based on growth rate: slow and rapidly growing mycobacteria. However, in 2018, the genus was divided into four new genera including *Mycolicibacterium, Mycolicibacter, Mycolicibacillus,* and *Mycobacteroides*. The table below outlines the newly assigned genera and their clinically relevant species.

Table 1.2 Newly Assigned Genera for Former *Mycobacterium*

Genera	Select clinically relevant species
Mycobacterium	*M. tuberculosis*
	M. bovis
	M. bovis BCG
	M. africanum
	M. caprae
	M. microti
	M. canettii
	M. pinnipedii
	M. avium
	M. bolletii
	M. chimaera
	M. gordonae
	M. haemophilum
	M. kansasii
	M. leprae
	M. simiae
	M. smegmatis
	M. szulgai
	M. ulcerans
	M. xenopi
Mycolicibacterium	*M. fortuitum*
	M. mageritense
	M. mucogenicum
	M. neoaurum
Mycolicibacter	*M. terrae*
Mycolicibacillus	*M. koreensis*
Mycobacteroides	*M. abscessus*
	M. chelonae
	M. immunogenum

Clinically Significant Bacterial Complexes and Groups

Matrix-assisted laser desorption ionization–time of flight mass spectrometry (MALDI-TOF MS) has given laboratories the ability to identify organisms to the subcomplex-level, something routine phenotypic methods were not reliably capable of. Because these subcomplex species have not historically been reported by clinical laboratories, clinicians are unlikely to understand that they are part of a complex and may not recognize their unique clinical significance. As such, it is recommended that organisms within certain complexes be reported as their higher-level complex names which have historically been used. In addition to facilitating provider understanding, in many cases it does appear as though there are clinically significant differences between the complex species. The following tables are intended to help laboratories understand which organisms fall within various clinically relevant complexes. Note, there is no unifying source that defines what is contained within a bacterial complex and these associations are continually being redefined as new information becomes available.

Table 1.3 *Enterobacter cloacae* Complex Organisms

***Enterobacter cloacae* complex**
E. asburiae
E. carcinogenus
E. cloacae
E. mori
E. hormaechei
E. kobei
E. nimipressuralis
E. ludwigii

Table 1.4 *Klebsiella oxytoca* Complex Organisms

***Klebsiella oxytoca* complex**
K. spallanzanii
K. huaxiensis
K. oxytoca
K. michiganensis
K. pasteurii
K. grimontii

Table 1.5 Taxonomy of *Citrobacter freundii* Complex

***Citrobacter freundii* complex**
C. braakii
C. freundii
C. gillenii
C. murliniae
C. rodentium
C. sedlakii
C. werkmanii
C. youngae
C. portucalensis

Table 1.6 Taxonomy of *Pseudomonas fluorescens* Group Organisms

***Pseudomonas fluorescens* group**
P. fluorescens
P. koreensis

Table 1.7 Taxonomy of *Pseudomonas putida* Group Organisms

***Pseudomonas putida* group**
P. cremoricolorata
P. fulva
P. monteilii
P. mosselii
P. parafulva
P. plecoglossicida
P. putida

Table 1.8 Taxonomy of *Pseudomonas aeruginosa* Group Organisms

***Pseudomonas aeruginosa* group**
P. aeruginosa
P. alcaligenes
P. citronellolis
P. indica
P. jinjuensis
P. knackmussii
P. nitroreducens
P. otitidis
P. panipatensis
P. resinovorans
P. thermotolerans
P. anguilliseptica
P. flavescens
P. mendocina
P. oleovorans

Table 1.9 Taxonomy of *Acinetobacter calcoaceticus-baumannii* Complex

***Acinetobacter baumannii* complex**
A. baumannii
A. calcoaceticus
A. nosocomialis (former genospecies 13 TU)
A. pittii (former genospecies 3)
A. oleivorans
A. lactucae
A. seifertii

Table 1.10 Taxonomy of *Burkholderia cepacia* Complex

***Burkholderia cepacia* complex**
B. ambifaria
B. anthina
B. arboris
B. cenocepacia
B. cepacia
B. contaminans
B. diffusa
B. dolosa
B. lata
B. latens
B. metallica
B. multivorans
B. pyrrocinia
B. seminalis
B. stabilis
B. vietnamiensis
B. pseudomultivorans

Table 1.11 Taxonomy of Mycobacteria

Acid-fast bacilli	Newly proposed genera
***M. abscessus-chelonae* complex**	
M. chelonae	
M. stephanolepidis	
M. salmoniphilum	
M. saopaulensis	*Mycobacteroides*
M. franklinii	
M. immunogenum	
M. abscessus subsp. *massiliense*	
M. abscessus subsp. *abscessus*	
M. abscessus subsp. *bolletii*	
***M. fortuitum-smegmatis* group**	
M. porcinum	
M. neworleansense	
M. septicum	
M. farcinogenes	
M. coneptionense	
M. senegalenses	
M. fortuitum	
M. peregrinum	*Mycolicibacterium*
M. setense	
M. houstonense	
M. aquaticum	
M. brisbanense	
M. margaritense	
M. wolinskyi	
M. goodii	
M. smegmatis	
***M. terrae* complex**	
M. nonchromogenicum	
M. herakilonense	
M. longobardum	
M. hiberniae	
M. engbaekii	*Mycolicibacter*
M. minnesotense	
M. arupense	
M. terrae	
M. kumamotonense	
M. senusense	
M. algericum	

Acid-fast bacilli	Newly proposed genera
***M. avium* complex**	
M. vulneris	
M. colombiense	
M. mantenii	
M. arosiense	
M. timonense	
M. bouchedurhonense	
M. avium	
M. marseillense	
M. paraintracellulare	
M. intracellulare	
M. youngonense	
M. chimaera	
***M. xenopi* group**	
M. noviomagense	
M. xenopi	
M. heckeshornense	
Selected unaffiliated pathogens	
M. ulcerans	
M. marinum	*Mycobacterium*
M. gordonae[a]	
M. szulgai	
M. kansasii	
M. lepromatosis	
M. leprae	
M. haemophilum	
***M. tuberculosis* complex**	
M. tuberculosis	
M. bovis	
M. bovis bacillus Calmette-Guerin (BCG)	
M. caprae	
M. africanum	
M. pinnipedii	
M. microti	
M. canettii	
M. mungi	
M. orygis	
Dassie bacillus	
Chimpanzee bacillus	
M. suricattae	

[a] *M. gordonae* is commonly isolated from clinical specimens but not considered to be a pathogen.

Table 1.12 Taxonomy of the *Staphylococcus aureus* Complex

***Staphylococcus aureus* complex**
S. aureus
S. argenteus
S. schweitzeri
S. singaporensis

Table 1.13 Taxonomy of the *Staphylococcus intermedius* Group

***Staphylococcus intermedius* group**
S. intermedius
S. pseudintermedius
S. delphini
S. cornubiensis
S. ursi

Table 1.14 Taxonomy of the Viridans Group Streptococci

Viridans group streptococci	
***Streptococcus bovis/equinus* complex**	*S. macacae*
S. gallolyticus subspecies *gallolyticus*	*S. ferus*
S. luteciae	*S. merionis*
S. gallolyticus subspecies *macedonicus*	*S. pluranimalium*
S. gallolyticus subspecies *pasteurianus*	*S. caballi*
S. infantarius subspecies *infantarius*	*S. henryi*
S. equinus	*S. orisratti*
S. alactolyticus	***Streptococcus salivarius* group**
S. lutetiensis	*S. salivarius*
***Streptococcus anginosus* group**	*S. thermophilus*
S. anginosus	*S. vestibularis*
S. constellatus	***Streptococcus mitis* group**
S. intermedius	*S. mitis*
***Streptococcus mutans* group**	*S. massiliensis*
S. mutans	*S. cristatus*
S. sobrinus	*S. oligofermentans*
S. ratti	*S. infantis*
S. hyovaginalis	*S. peroris*
S. thoraltensis	*S. australias*
S. dentapri	*S. sinensis*
S. downei	*S. pseudopneumoniae*
S. dentirousetti	*S. pneumoniae*
S. criceti	*S. oralis*
S. orisuis	***Streptococcus sanguinis* group**
S. merionis	*S. sanguinis*
S. ursoris	*S. parasanguinis*
S. devriesei	*S. gordonii*

Taxonomic Classification of Human Viruses

The taxonomy of viral classification is arranged in the following way. . .

Order
Family
Subfamily
Genus
Species

Practically speaking, most clinical microbiologists organize viruses in terms of genome structure, family, and genus, and only rarely are the subfamily or species designations utilized. As such, the following taxonomic structure is presented in terms of what would be most useful to the practicing clinical microbiologist.

Single-stranded, nonenveloped DNA viruses
Family. *Parvoviridae*
Genus. *Erythroparvovirus*
Species. Human parvovirus B19

Double-stranded, nonenveloped DNA viruses
Family. *Adenoviridae*
Genus. *Mastadenovirus*
Species. Human adenoviruses (species A to G)
Family. *Papillomaviridae*
Genus. *Alpha papillomavirus*
Species. Alpha 1-14
Genus. *Beta papillomavirus*
Species. Beta 1- 6
Genus. *Gamma papillomavirus*
Species. Gamma 1 – 27
Genus. *Mu papillomavirus*
Species. Mu 1-3
Genus. *Nu papillomavirus*
Species. Nu 1
Family. *Polyomaviridae*
Genus. *Betapolyomavirus*
Species. JC polyomavirus, BK polyomavirus

Double-stranded, enveloped DNA viruses
Family. *Hepadnaviridae*
Genus. *Orthohepadnavirus*
Species. Hepatitis B virus

Family. *Orthoherpesviridae*
Genus. *Simplexvirus*
Species. Human herpesvirus 1 (herpes simplex virus type 1; HHV-1), human herpesvirus 2 (herpes simplex virus type 2; HHV-2)
Genus. *Varicellovirus*
Species. Human herpesvirus 3 (varicella-zoster virus [VZV]; HHV-3) Genus. *Lymphocryptovirus*
Species. Human herpesvirus 4 (Epstein-Barr virus [EBV]; HHV-4)
Genus. *Cytomegalovirus*
Species. Human herpesvirus 5 (CMV; HHV-5)
Genus. *Roseolovirus*
Species. Human herpesvirus 6 (roseola virus; HHV-6), human herpesvirus 7 (HHV-7)
Genus. *Rhadinovirus*
Species. Human herpesvirus 8 (HHV-8)
Family. *Poxviridae*
Genus. *Orthopoxvirus*
Species. Vaccinia virus, variola virus smallpox virus, cowpox virus, monkeypox virus
Genus. *Molluscipoxvirus*
Species. Molluscum contagiosum virus
Genus. *Parapoxvirus*
Species. Orf virus

Single-stranded, positive-sense, nonenveloped RNA viruses
Family. *Astroviridae*
Genus. *Mamastrovirus*
Species. Human astrovirus
Family. *Caliciviridae*
Genus. *Norovirus*
Species. Norwalk virus
Genus. *Sapovirus*
Species. Sapporo virus
Family. *Picornaviridae*
Genus. *Enterovirus*
Species. Enterovirus A (human coxsackievirus A2, human enterovirus 71) Enterovirus B (human coxsackievirus B1, human echovirus), Enterovirus C (human poliovirus 1 to 3, human coxsackievirus A1), Enterovirus D (human enterovirus 68, 70, and 94), Rhinovirus A, B, and C.
Genus. *Aphthovirus*
Species. Foot-and-mouth disease virus

Genus. *Hepatovirus*
Species. Human hepatitis A virus (HHAV)

Single-stranded, positive-sense, enveloped RNA viruses
Family. *Coronaviridae*
Genus. *Betacoronavirus*
Species. Human coronavirus, Severe acute respiratory syndrome (SARS) virus, Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) Middle East respiratory syndrome (MERS) virus, hCoV HKU1
Genus. *Alphacoronavirus*
Species. Human coronaviruses (hCoV) 229E, hCoV NL63
Family. *Flaviviridae*
Genus. *Orthoflavivirus*
Species. Yellow fever virus, West Nile virus, St. Louis encephalitis (SLE) virus, Japanese encephalitis (JE) virus, Dengue virus (types 1 through 4), Zika virus, Powassan virus, many other viruses
Genus. *Hepacivirus*
Species. Hepatitis C virus (HCV)
Family. *Matonaviridae*
Genus. *Rubivirus*
Species. Rubella virus
Family. *Togaviridae*
Genus. *Alphavirus*
Species. Sindbis virus, Eastern equine encephalitis (EEE) virus, Western equine encephalitis (WEE) virus, Venezuelan equine encephalitis (VEE) virus, Chikungunya virus, many other viruses

Single-stranded, negative-sense, enveloped RNA viruses
Family. *Arenaviridae*
Genus. *Mammarenavirus*
Species. Lymphocytic choriomeningitis (LCM) virus, Lassa virus, Junin virus, Machupo virus, Sabia virus, other viruses
Family. *Filoviridae*
Genus. *Marburgvirus*
Species. Marburg virus
Genus. *Ebolavirus*
Species. Ebola virus
Family. *Hantaviridae*
Genus. *Orthohantavirus*
Species. Hantaan virus, Sin Nombre virus, other viruses

Family. *Nairoviridae*
Genus. *Orthonairovirus*
Species. Crimean-Congo hemorrhagic fever virus (CCFV), other viruses
Family. *Orthomyxoviridae*
Genus. *Alphainfluenzavirus*
Species. Influenza A virus
Genus. *Betainfluenzavirus*
Species. Influenza B virus
Genus. *Gammainfluenzavirus*
Species. Influenza C virus
Family. *Paramyxoviridae*
Genus. *Respirovirus*
Species. Sendai virus, Human parainfluenza virus (types 1 and 3)
Genus. *Orthorubulavirus*
Species. Mumps virus, Human parainfluenza virus (types 2 and 4)
Genus. *Morbillivirus*
Species. Measles virus
Genus. *Henipavirus*
Species. Hendra virus, Nipah virus
Family. *Peribunyaviridae*
Genus. *Orthobunyavirus*
Species. Bunyamwera virus, California encephalitis virus, La Crosse virus, many other viruses
Family. *Phenuiviridae*
Genus. *Phlebovirus*
Species. Rift Valley fever virus, Heartland virus other viruses
Family. *Pneumoviridae*
Genus. *Orthopneumovirus*
Species. Human respiratory syncytial virus (RSV)
Genus. *Metapneumovirus*
Species. Human metapneumovirus
Family. *Rhabdoviridae*
Genus. *Lyssavirus*
Species. Rabies virus

Double-stranded, enveloped RNA viruses
Family. *Retroviridae*
Genus. *Deltaretrovirus*
Species. Human T-lymphotropic virus type 1 (HTLV-1), human T-lymphotropic virus type 2 (HTLV-2)

Genus. *Lentivirus*
Species. Human immunodeficiency virus type 1 (HIV-1), human immunodeficiency virus type 2 (HIV-2)
Family. *Sedoreoviridae*
Genus. *Rotavirus*
Species. Rotavirus (types A, B, and C)
Family. *Spinareoviridae*
Genus. *Coltivirus*
Species. Colorado tick fever virus

Taxonomic Classification of Fungi

The taxonomic classification of fungal organisms has always been complicated by the different methods that have been used to classify them. Their nomenclature is further complicated by the convention of employing multiple names for the various propagative states of fungi (teleomorph [sexual] and anamorph [asexual]). In January of 2013 the Amsterdam Declaration on Fungal Nomenclature went into effect, indicating that a single naming convention would be adopted to address this problem and working groups were established to resolve the many discrepancies that existed in fungal nomenclature. These groups would propose lists of names that are accepted and names that are no longer valid. For new names to be accepted the International Code of Nomenclature for algae, fungi, and plants (ICN) requires that taxa be registered in a recognized online resource such as MycoBank (https://www.mycobank.org/) and Index Fungorum (http://www.indexfungorum.org).

Though fungal taxonomy is in a state of flux and the information published here risks quickly becoming obsolete, the following section will endeavor to summarize the old and newly proposed names for some clinically relevant fungi in an effort to provide some clarity to this issue.

Fungi are divided into four divisions (phylum or subphylum): Mucoromycotina, Entomophthoromycotina, Ascomycota, and Basidiomycota. The Protozoa and Chromista kingdoms include some members that possess a fungus-like appearance and are clinically relevant, such as *Rhinosporidium* and *Pythium*.

The taxonomy of fungal classification is arranged in the following way. . .

Phylum
Subphylum
Class
Order
Family
Genus
Species

The following table will provide the old and new name for select fungi that have recently undergone nomenclature changes. This list is not meant to be exhaustive but to include those fungi which are commonly found in clinical specimens.

Table 1.15 Revised Species Names of Selected Clinically Relevant Fungi[a]

Previous species name	Revised species name	Category
Emmonsia "species 3"	*Blastomyces percursus*	Dimorphics
Emmonsia "species 5"	*Emergomyces africanus*	
Emmonsia crescens	*Emergomyces crescens*	
Emmonsia helica	*Blastomyces helicus*	
Emmonsia parva	*Blastomyces parvus*	
Emmonsia pasteuriana	*Emergomyces pasteurianus*	
Emmonsia soli	*Emergomyces soli*	
Histoplasma capsulatum var *capsulatum*	*Histoplasma capsulatum sensu stricto*	
Histoplasma capsulatum var *capsulatum*	*Histoplasma mississippiense*	
Histoplasma capsulatum var *capsulatum*	*Histoplasma ohiense*	
Histoplasma capsulatum var *capsulatum*	*Histoplasma suramericanum*	
Lacazia loboi	*Paracoccidioides loboi*	
Paracoccidioides brasiliensis	*Paracoccidioides brasiliensis sensu stricto*	
Paracoccidioides brasiliensis	*Paracoccidioides americana*	
Paracoccidioides brasiliensis	*Paracoccidioides lutzii*	
Paracoccidioides brasiliensis	*Paracoccidioides restrepoana*	
Paracoccidioides brasiliensis	*Paracoccidioides venezuelensis*	
Penicillium marneffei	*Talaromyces marneffei*	
Sporothrix schenckii	*Sporothrix schenckii sensu stricto*	
Sporothrix schenckii	*Sporothrix brasiliensis*	
Sporothrix schenckii	*Sporothrix globosa*	
Sporothrix schenckii	*Sporothrix luriei*	
Acremonium kiliense	*Sarocladium kiliense*	Hyaline hyphomycetes
Acremonium roseogriseum	*Gliomastix roseogrisea*	
Acremonium strictum	*Sarocladium strictum*	
Chaetomium atrobrunneum	*Amesia atrobrunnea*	
Fusarium dimerum	*Bisifusarium dimerum*	
Fusarium falciforme	*Neocosmospora falciformis*	
Fusarium keratoplasticum	*Neocosmospora keratoplastica*	

Previous species name	Revised species name	Category
Fusarium lichenicola	*Neocosmospora lichenicola*	
Fusarium petroliphilum	*Neocosmospora petroliphila*	
Fusarium solani	*Neocosmospora solani*	
Fusarium solani species complex 20	*Neocosmospora suttoniana*	
Fusarium solani species complex 43	*Neocosmospora catenate*	
Fusarium solani species complex 6	*Fusarium metavorans*	
Fusarium solani species complex 7	*Neocosmospora gamsii*	
Fusarium solani species complex 9	*Neocosmospora tonkinensis*	
Gibberella fujikuroi	*Fusarium fujikuroi*	
Microsporum cookei	*Paraphyton cookei*	
Microsporum fulvum	*Nannizzia fulva*	
Microsporum gallinae	*Lophophyton gallinae*	
Microsporum gypseum	*Nannizzia gypsea*	
Microsporum nanum	*Nannizzia nana*	
Microsporum persicolor	*Nannizzia persicolor*	
Neosartorya udagawae	*Aspergillus udagawae*	
Paecilomyces lilacinus	*Purpureocillium lilacinum*	
Paecilomyces marquandii	*Marquandomyces marquandii*	
Penicillium argillaceum	*Rasamsonia argillacea*	
Trichophyton ajelloi	*Arthroderm uncinatum*	
Trichophyton terrestre	*Arthoderma terrestre*	
Candida glabrata	*Nakaseomyces glabrata*	Yeast and yeast-like organisms
Candida guilliermondii	*Meyerozyma guilliermondii*	
Candida kefyr	*Kluyveromyces marxianus*	
Candida krusei	*Pichia kudriavzevii*	
Candida lipolytica	*Yarrowia lipolytica*	
Candida lusitaniae	*Clavispora lusitaniae*	
Geotrichum capitum	*Magnusiomyces capitatus*	
Geotrichum clavatum	*Magnusiomyces clavatus*	
Rhodotorula minuta	*Cystobasidium minutum*	
Scedosporium prolificans	*Lomentospora prolificans*	
Trichosporon cutaneum	*Cutaneotrichosporon cutaneum*	
Trichosporon loubieri	*Apiotrichum loubieri*	
Trichosporon mycotoxinivorans	*Apiotrichum mycotoxinivorans*	

(continued)

Table 1.15 Revised Species Names of Selected Clinically Relevant Fungi (*continued*)

Previous species name	Revised species name	Category
Bipolaris australiensis	*Curvularia australiensis*	Dematiaceous hyphomycetes
Bipolaris hawaiiensis	*Curvularia hawaiiensis*	
Bipolaris spicifera	*Curvularia spicifera*	
Ochroconis gallopava	*Verruconis gallopava*	
Phialophora richardsiae	*Pleurostoma richardsiae*	
Pseudallescheria boydii	*Scedosporium boydii*	
Ramichloridium mackenziei	*Rhinocladiella mackenziei*	
Ramichloridium schulzeri	*Myrmecridium schulzeri*	
Scedosporium prolificans	*Lomentospora prolificans*	
Hendersonula toruloidea	*Nattrassia mangiferae*	Coelomycetes
Leptosphaeria senegalensis	*Falciformispora senegalensis*	
Leptosphaeria tompkinsii	*Falciformispora tompkinsii*	
Madurella grisea	*Trematospheria grisea*	
Pyrenochaeta mackinnonii	*Nigrograna mackinnonii*	
Pyrenochaeta romeroi	*Medicopsis romeroi*	
Scytalidium dimidiatum	*Neoscytalidium dimidiatum*	
Scytalidium hyalinum	*Neoscytalidium dimidiatum*	
Absidia corymbifera	*Lichtheimia corymbifera*	Mucoromycotina
Mycocladus corymbifera	*Lichtheimia corymbifera*	
Rhizomucor variabilis	*Mucor irregularis*	
Rhizopus azygosporus	*Rhizopus microsporus*	
Rhizopus delemar	*Rhizopus arrhizus* var *delemar*	
Rhizopus microsporus	*Rhizopus microsporus*	
Rhizopus microsporus var chinensis	Variant no longer recognized	
Rhizopus microsporus var *oligosporus*	Variant no longer recognized	
Rhizopus microsporus var *rhizopodiformis*	Variant no longer recognized	
Rhizopus oryzae	*Rhizopus arrhizus*	
Saksenaea vasiformis	*Saksenaea vasiformis sensu stricto*	
Saksenaea vasiformis	*Saksenaea erythrospora*	
Saksenaea vasiformis	*Saksenaea oblongispora*	

[a] Data from Kidd SE, Abdolrasouli A, Hagen F. 2023. *Open Forum Infect Dis* 10(1):ofac559 and de Hoog S et al. 2023. *J Clin Microbiol* 61(11):e0087323.

Taxonomic Classification of Parasites[a]

The term "parasite" refers to a group of eukaryotic organisms, about 200 of which are medically relevant helminths, and 80 of which are medically relevant protozoan species. Within this subset of nearly 300 parasites, about 100 species are commonly found in humans, and an even smaller number within that cause a disproportionate number of important diseases.

Since the last edition of this Pocket Guide significant taxonomic changes have occurred, with eukaryotes now organized into supergroups based on monophyletic lineages. Eukaryotic parasites can be found within four of the five following supergroups: Amoebozoa, Archaeplastida, Excavata, Opisthokonta, and SAR. Another major change, specific to the protists, is that the traditional nomenclature of kingdom, phylum, class, and order has largely been replaced by clades. Presented in the following table are the taxonomic classifications of some of the most important human parasites.

Human Parasite Taxonomy[a]
Protistan parasites

Supergroup. Amoebozoa
- Clades. Archamoebae: Entamoebida
  - Genus. *Entamoeba coli*
  - Genus. *Entamoeba dispar*
  - Genus. *Entamoeba gingivalis*
  - Genus. *Entamoeba hartmanni*
  - Genus. *Entamoeba histolytica*
  - Genus. *Endolimax nana*
  - Genus. *Entamoeba polecki*
  - Genus. *Iodamoeba buetschlii*
- Clades. Discosea: Longamoebia: Centramoebida
  - Genus. *Acanthamoeba* genotypes
  - Genus. *Balamuthia mandrillaris*

Supergroup. Excavata
- Clades. Discicristata: Euglenozoa: Kinetoplastea
  - Genus. *Leishmania amazonensis*
  - Genus. *Leishmania braziliensis*
  - Genus. *Leishmania donovani*
  - Genus. *Leishmania infantum*
  - Genus. *Leishmania major*
  - Genus. *Leishmania mexicana*
  - Genus. *Leishmania tropica*
  - Genus. *Trypanosoma brucei gambiense*

Genus. *Trypanosoma brucei rhodesiense*
Genus. *Trypanosoma cruzi*
Genus. *Trypanosoma rangeli*
Clades. Discicristata: Heterolobosea: Tetramitia
Genus. *Naegleria fowleri*
Clades. Metamonada: Fornicata: Diplomonadida
Genus. *Giardia duodenalis* (syn. *G. intestinalis, G. lamblia*)
Clades. Metamonada: Fornicata: Retortamonadida
Genus. Chilomastix mesnili
Genus. *Retortamonas intestinalis*
Clades. Metamonada: Parabasalia:Trichomonadea
Genus. *Trichomonas vaginalis*
Clades. Metamonada: Parabasalia: Tritrichomonadea
Genus. *Dientamoeba fragilis*

Supergroup. SAR
Clades: Apicomplexa: Aconoidasida: Haemospororida
Genus. *Plasmodium falciparum*
Genus. *Plasmodium knowlesi*
Genus. *Plasmodium malariae*
Genus. *Plasmodium ovale*
Genus. *Plasmodium vivax*
Clades: Apicomplexa: Aconoidasida: Piroplasmorida
Genus. *Babesia divergens*
Genus. *Babesia duncani*
Genus. *Babesia microti*
Clades. Apicomplexa: Conoidasida: Coccidia
Genus. *Cyclospora cayetanensis*
Genus. *Cystoisospora (*formerly *Isospora) belli*
Genus. *Sarcocystis hominis*
Genus. *Toxoplasma gondii*
Clades. Apicomplexa: Conoidasida: Cryptosporidium
Genus. *Cryptosporidium hominis*
Genus. *Cryptosporidium parvum*
Clades. Ciliophora: Litostomatea: Trichostomatia
Genus. *Balantioides* (formerly *Balantidium* and *Neobalantidium*) *coli*
Clades. Stramenopiles: Blastocystis
Genus. *Blastocystis* spp.

Helminths (worms)
- Supergroup. Opisthokonta
  - Phylum. Nematoda (Nematodes, Roundworms)
    - Order. Ascaridida
      - Family: Anisakidae
        - Genus. *Anisakis* spp.
        - Genus. *Pseudoterranova* spp.
      - Family. Ascarididae
        - Genus. *Ascaris lumbricoides*
        - Genus. *Bayliascaris procyonis*
        - Genus. *Toxocara canis*
        - Genus. *Toxocara cati*
    - Order. Camallanida
      - Family. Dracunculidae
        - Genus. *Dracunculus medinensis*
    - Order. Oxyurida
      - Family. Oxyuridae
        - Genus. *Enterobius vermicularis*
    - Order (suborder). Rhabditida (Strongylida)
      - Family. Ancylostomatidae
        - Genus. *Ancylostoma ceylanicum*
        - Genus. *Ancylostoma duodenale*
        - Genus. *Necator americanus*
      - Family. Angiostrongylidae
        - Genus. *Angiostrongylus cantonensis*
        - Genus. *Angiostrongylus costaricensis*
      - Family. Strongyloididae
        - Genus. *Strongyloides fuelleborni*
        - Genus. *Strongyloides stercoralis*
    - Order. Spirurida
      - Family. Gnathostomatidae
        - Genus. *Gnathostoma* spp.
      - Family. Onchocercidae
        - Genus. *Brugia malayi*
        - Genus. *Brugia timori*
        - Genus. *Dirofilaria immitis*
        - Genus. *Loa loa*
        - Genus. *Mansonella ozzardi*
        - Genus. *Mansonella perstans*
        - Genus. *Onchocerca volvulus*
        - Genus. *Wuchereria bancrofti*

Order. Trichinellida
Family. Capillariidae
Genus. *Calodium hepaticum* (formerly *Capillaria hepatica*)
Family. Trichinellidae
Genus. *Trichinella nativa*
Genus. *Trichinella pseudospiralis*
Genus. *Trichinella spiralis*
Family: Trichuridae
Genus. *Trichuris trichiura*

Phylum. Platyhelminthes
Class. Cestoda (tapeworms)
Order. Cyclophyllidea
Family. Dipylidiidae
Genus. *Dipylidium caninum*
Family. Hymenolepididae
Genus. *Hymenolepis diminuta*
Genus. *Rodentolepis* nana (formerly *Hymenolepis nana)*
Family. Taeniidae
Genus. *Echinococcus granulosus*
Genus. *Echinococcus multilocularis*
Genus. *Taenia saginata*
Genus. *Taenia solium*
Order. Pseudophyllidea
Family. Diphyllobothriidae
Genus. *Adenocephalus pacificus*
Genus. *Dibothriocephalus latus* (*Diphyllobothrium latum)*
Genus. *Dibothriocephalus nihonkaiensis*
Class. Trematoda (flukes, flatworms)
Order. Diplostomida
Family. Schistosomatidae
Genus. *Schistosoma haematobium*
Genus. *Schistosoma intercalatum*
Genus. *Schistosoma japonicum*
Genus. *Schistosoma mansoni*
Genus. *Schistosoma mekongi*
Order. Plagiorchiida
Family. Dicrocoeliidae
Genus. *Dicrocoelium dendriticum*

Family. Fasciolidae
- Genus. *Fasciola gigantica*
- Genus. *Fasciola hepatica*
- Genus. *Fasciolopsis buski*

Family. Heterophyidae
- Genus. *Heterophyes heterophyes*

Family. Opisthorchidae
- Genus. *Clonorchis sinensis*
- Genus. *Opisthorchis felineus*
- Genus. *Opisthorchis viverrini*

Family. Paragonimidae
- Genus. *Paragonimus heterotremus*
- Genus. *Paragonimus kellicotti*
- Genus. *Paragonimus westermani*

[a] Adapted from Adl SM, Mathison BA. 2023. Taxonomy and Classification of Human Eukaryotic Parasites. *In* Carroll KC, Pfaller MA, Karlowsky JA, Landry ML, McAdam AJ, Patel R, Pritt BS (ed). *Manual of Clinical Microbiology*, 13th Edition. ASM Press, Washington, DC.