DiagnosTechs™
CLINICAL & RESEARCH LABORATORY

Interpretive Guide - Bacterial Stool Culture

When we receive a stool sample at DiagnosTechs, we perform tests to rule out the presence of known enteric bacterial pathogens and opportunistic organisms that may cause acute or chronic disease. We also plate the stool sample on several types of aerobic culture media to assess the bacterial flora present in the patient's intestinal tract.

From bacterial growth on these aerobic culture plates, we report and quantify the mixed gram-positive and mixed gram-negative flora. The gram-positive and gram-negative flora include the various normal resident intestinal bacteria. We expect to find moderate to heavy growth of both mixed gram-negative and gram-positive bacteria from normal, healthy stool samples.

The **Bacterial Stool Culture (GP3)** reports the dominant organism(s) within the mixed flora. Up to three individual organisms are identified and quantified. This allows you to check for the prevalence of certain commensal and beneficial microorganisms and any opportunistic pathogens, as well as to compare the composition of the mixed flora to previous cultures sent to DiagnosTechs.

The **Expanded Bacterial Stool Culture (GP3x)** lists all bacterial species isolated and identified from the aerobic culture plates.

PLEASE NOTE: Case reports and research that a bacterium causes disease beyond the digestive tract (e.g., sepsis, meningitis, lung infections, etc.) does not mean that the same bacterium will cause problems when present in the gastrointestinal tract as found on stool culture. Also, strain differences in bacterial species can lead to significant differences in pathogenicity. Even with studies showing evidence that a specific bacterium may cause gastrointestinal disease, variations exist among bacteria such that not all members of the same genus and species will cause the same gastrointestinal problems.

Alphabetical Index of bacterial flora encountered on stool culture

Aeromonas spp.	*Corynebacterium* spp.	*Lactobacillus* spp.	*Rothia* spp.
Alloscardovia spp.	*Cronobacter* spp.	*Lactococcus* spp.	*Salmonella* spp.
Arcobacter spp.	*Enterobacter* spp.	*Leuconostoc* spp.	*Serratia* spp.
Bacillus spp.	*Enterococcus* spp.	*Lysinibacillus* spp.	*Shigella* spp.
Campylobacter spp.	*Escherichia* spp.	*Morganella* spp.	*Staphylococcus* spp.
Carnobacterium spp.	Shiga toxin-producing *Escherichia coli* (*E. coli*)	*Neisseria* spp.	*Stenotrophomonas* spp.
Citrobacter spp.	*Hafnia* spp.	*Proteus* spp.	*Streptococcus* spp.
Clostridioides spp.	*Herbaspirillum* spp.	*Providencia* spp.	*Vibrio* spp.
Clostridium spp.	*Klebsiella* spp.	*Pseudomonas* spp.	*Weissella* spp.
Comamonas spp.	*Kluyvera* spp.	*Raoultella* spp.	*Yersinia* spp.

***Aeromonas* spp.** (gram-negative and potentially pathogenic. The most common *Aeromonas* species implicated in enteric illness are *Aeromonas hydrophila*, *A. veronii*, and *A. caviae*.)

- *Aeromonas* species thrive in warm freshwater and case reports of infection are more common in the summer. The ability of these species to cause diarrheal disease is variable and may depend on strain characteristics and host susceptibility. Associated gastroenteritis may range from mild, self-limiting diarrhea to severe dysenteric illness producing loose stools containing blood and mucus, and colitis. Illness is thought to be caused by toxins and other virulence factors. *Aeromonas* infection is typically self-limiting but may alternately lead to chronic and recurring diarrhea. Treatment is generally supportive; however, more severe infections may benefit from antimicrobial therapy (Janda 2010).

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***Alloscardovia* spp.** (gram-positive rods related to *Bifidobacterium* species)

- *Alloscardovia omnicolens* was isolated and identified in 2007 (Huys 2007). Research information on the species is almost non-existent and it was initially thought to be a non-pathogenic part of normal flora in the oral cavity or gastrointestinal tract. Potential case reports have isolated the bacterium from the genitourinary tract related to urinary tract infections, raising some concerns that it may have some pathogenic potential (Mahlen 2009). The bacterium is difficult to differentiate from other potential pathogens, so our understanding of its role and potential pathogenicity in the gastrointestinal tract is limited.

***Arcobacter* spp.** (gram-negative spiral-shaped bacteria, with some strains being human pathogens; similar to *Campylobacter* and were originally classified as *Campylobacter* species*)*

- *Arcobacter butzleri* – a potential cause of enteritis, including diarrhea, abdominal pain, nausea, and fever. Length of infection can vary from days to months in duration (Vandenberg 2004). Transmission is fecal-oral, waterborne, animal food products, or exposure to animals.

***Bacillus* spp.** (gram-positive; they may be commensal organisms or opportunistic pathogens)

- *Bacillus altitudinis* – a potential opportunistic pathogen originally isolated from high altitude air samples (Nawar 2021).
- *Bacillus amyloliquefaciens* is used in agriculture to control bacterial and fungal plant root pathogens. It is closely related to *Bacillus subtilis*, and may be used as a bacterial starter culture in fermented soybean products (Compaoré 2013, Kimura 2019).
- *Bacillus cereus* is a common cause of food poisoning; cases are usually self-limited and involve either diarrhea or vomiting (Castiaux 2015, Kim 2015).
- *Bacillus coagulans* (formerly categorized as *Lactobacillus sporogenes*) is a lactic-acid-forming bacterial species that is used in probiotic formulations. It has been studied for the treatment of irritable bowel syndrome and antibiotic-associated diarrhea (Dolin 2009, Doron 2008).
- *Bacillus pumilus* may be associated with food poisoning and has shown some correlation with diarrheal illness in humans in one study (Samb-Ba 2014, From 2007). *Bacillus pumilus* has also been isolated as a normal constituent of kimchi, so not all strains of this bacterium are problematic (Yamanaka 2007).
- *Bacillus subtilis* is considered a normal gut commensal organism. *B. subtilis* is only known to cause disease in severely immunocompromised patients (Oggioni 1998). It has been used as a probiotic in healthy individuals and as a bacterial food culture in fermented bean products such as natto. The EPA evaluated the safety of *Bacillus subtilis* and considers it to have a low degree of virulence; it is not considered to be pathogenic or toxigenic (EPA 1997).

***Campylobacter* spp.** (gram-negative and potentially pathogenic)

Campylobacter species (*C. jejuni* and *C. coli*) cause self-limiting gastroenteritis. Autoimmune disorders are a long-term complication in about one in 2,000 cases. Occasionally, an infection may lead to Guillain-Barré syndrome, reactive arthritis, post-infectious irritable bowel syndrome, and possibly immuno-proliferative small intestinal disease. A small percentage of patients may develop complications such as meningitis, hepatitis, cholecystitis, and pancreatitis. Most cases of campylobacteriosis are self-limiting, and acute infections typically last from two to ten days. Fever, diarrhea (which may be bloody), abdominal cramps, and vomiting are the major symptoms.

Campylobacteriosis is the leading cause of food-borne gastroenteritis worldwide. Outbreaks have been associated with unpasteurized dairy products, contaminated water, poultry, and produce. Most cases are associated with eating raw or undercooked poultry or from cross-contamination of other foods. Animals can also be infected, and some people get infected from contact with the stool of an ill dog or cat. The organism may spread from one person to another (fecal-oral).

Because *Campylobacter* species are fastidious and quickly lose the ability to grow on bacterial stool culture plates, DiagnosTechs uses antigen testing to check for the presence of this organism in stool specimens.

***Carnobacterium* spp.** (gram-positive and non-pathogenic)

- *Carnobacterium divergens and C. maltaromaticum* may be found in food products. A specific strain of *C. maltaromaticum* is used as a food additive for packaged, ready-to-eat meat and other fresh processed meat. *Carnobacterium* spp. are not known to be pathogenic in humans but may cause disease in fish (Leisner 2007).

***Citrobacter* spp.** (gram-negative, opportunistic pathogens)

- *Citrobacter amalonaticus* – there is a published case study of enteric fever from this bacterium; (Suwansrinon 2005).
- *Citrobacter braakii* – an opportunistic pathogen; consider its role in relation to symptoms and other findings; may show resistance to antibiotics (Jeong 2011, Pepperell 2002).
- *Citrobacter farmeri* – a potential opportunistic pathogen, however, the research on this bacterium is limited. There is one case report of meningitis in an individual with a history of cancer, although the gastrointestinal tract was not considered as a potential source of the bacterium in this case (Tan 2010).
- *Citrobacter freundii* – an opportunistic pathogen and an established, but infrequent cause of diarrhea (Bai 2012); consider its role in relation to symptoms and other findings. Commonly confused with both *Salmonella* and *E. coli* and displays a wide range of pathogenic behaviors. Some strains may have antibiotic resistance (Samonis 2009, Delgado 2013, Pepperell 2002).
- *Citrobacter gillenii* – few publications exist on this strain of *Citrobacter*. May have similarities with other *Citrobacter species.* Potential opportunistic pathogen; consider in the context of symptoms.
- *Citrobacter koseri* – has been associated with a single outbreak of diarrheal illness at a university; consider in the context of symptoms (Rowe 1975).
- *Citrobacter murliniae* – few publications exist on this organism. May have similarities with other *Citrobacter* species. Potential opportunistic pathogen; consider in the context of symptoms.
- *Citrobacter sedlakii* – one case report of sepsis, meningitis, and brain abscess in a premature five-year-old (Dyer 1997). This bacterium is not well characterized in relation to gastrointestinal illness but may have similarities with other *Citrobacter* species.
- *Citrobacter youngae* – may cause intra-abdominal infections in immunosuppressed individuals (Chen 2013). This bacterium is an uncommon opportunistic pathogen.

***Clostridioides* spp. (including *C. difficile*)** (gram-positive and potentially pathogenic)

Clostridioides species include *Clostridioides difficile* (formerly *Clostridium difficile*). *C. difficile* is a gram-positive, spore-forming bacterium. It is the most common cause of hospital-acquired diarrhea, typically occurring after antibiotic use. It is also found in a growing number of outpatients related to the use of proton pump inhibitors and H2-blocking medications. *C. difficile* can produce toxins (A & B) that cause symptoms, including watery diarrhea, fever, loss of appetite, nausea, and abdominal pain or tenderness. As a complement to our bacterial stool culture, DiagnosTechs tests for the presence of *C. difficile* toxins in stool specimens.

***Clostridium* spp.** (gram-positive and potentially pathogenic)

- *Clostridium difficile* has been reclassified to the genus *Clostridioides* (see above).
- *Clostridium halophilum* – few publications exist on this organism. May share characteristics with other *Clostridium* species. Potential opportunistic pathogen; consider in the context of symptoms.
- *Clostridium tertium* – Patients who develop infections with *C. tertium* are often neutropenic and in such instances, case reports of bacteremia and enterocolitis exist (Coleman 1993, Speirs 1988).

***Comamonas* spp.** (gram-negative, opportunistic pathogens)

- *Comamonas kerstersii* has been isolated from samples of individuals with diarrhea and is also associated with perforated appendix. In these cases, it is hypothesized that the bacterium translocated from the gastrointestinal tract (Biswas 2014).
- *Comamonas testosteroni* – typically found in polluted environmental samples, this bacterium utilizes steroids and aromatic compounds rather than carbohydrates as a carbon source (Liu 2015). It is typically considered to be of low virulence but has been occasionally associated with perforated appendix, although whether the bacterium originated from the gastrointestinal tract in these cases was unknown (Farshad 2012, Gul 2007).

***Corynebacterium* spp.** (gram-positive, may be commensal organisms or opportunistic pathogens)

- *Corynebacterium amycolatum* - not well-characterized bacteria that have been shown to cause vaginitis (Chen 2015), ear infections (Sengupta 2015), superficial wound infections, mastitis (Paviour 2002), endocarditis (Daniels 2003), and bacteremia (Oteo 2001). However, we found no case reports associated with overgrowth in the gastrointestinal tract.

- *Corynebacterium aurimucosum* – Typically considered part of the normal human microbial flora, although our understanding of this bacterium is limited. Opportunistic infections have been reported, but none involved the gastrointestinal tract. Some strains may exhibit antimicrobial (macrolide) resistance (Ortiz-Pérez 2010).
- *Corynebacterium minutissimum* - non-spore forming bacillus, a component of the normal skin flora, commonly associated with erythrasma - presents as macerated, scaly plaques between the toes or erythematous to brown patches or thin plaques in intertriginous areas.

Cronobacter spp. (gram-negative opportunistic pathogens)

- *Cronobacter sakazakii* – can cause meningitis, necroenterocolitis, and sepsis in infants. Animal studies demonstrate that some strains can cause diarrhea and possess significant virulence factors (Jaradat 2014).

Enterobacter spp. (gram-negative, opportunistic pathogens)

- *Enterobacter aerogenes* – case reports of diarrhea from this bacterium exist (Kiselev 1978) and it has been shown in some cases to cause diarrhea in children (Bondarenko 1986).
- *Enterobacter asburiae* – little is known about *E. asburiae*, although some concerns exist for *Enterobacter* spp. in general due to their antibiotic resistance (Mezzatesta 2012). We found no case reports of overgrowth of *E. asburiae* as a cause of gastrointestinal symptoms.
- *Enterobacter cloacae* – an opportunistic pathogen; outside of the digestive tract, it has been associated with urinary tract and respiratory tract infections. A member of the normal intestinal flora of many individuals, however, many strains exhibit virulence properties (Keller 1998), and research appears to indicate that some strains may cause gastrointestinal symptoms (Bondarenko 1986).
- *Enterobacter kobei* – one case report of this bacterium causing urosepsis exists, although its pathogenicity, in general, is not well-characterized. We found no case reports of overgrowth of *E. kobei* as a cause of gastrointestinal symptoms, although this species may behave similarly to other *Enterobacter* species (Hoffman 2005).
- *Enterobacter ludwigii* – little is known about *E. ludwigii*, although some concerns exist for *Enterobacter* spp. in general due to their antibiotic resistance (Mezzatesta 2012). We found no case reports of overgrowth of *E. ludwigii* as a cause of gastrointestinal symptoms, although this species may behave similarly to other *Enterobacter* species (Hoffman 2005).

Enterococcus spp. (gram-positive and may be commensal organisms or opportunistic pathogens)

- *Enterococcus avium* – found in birds, but still commonly found in mammals as well. Considered commensal but has been known to cause infections outside the gastrointestinal tract (Na 2012). Approximately 20% of humans carry *E. avium* in their digestive tract (Nowlan 1967).
- *Enterococcus casseliflavus* – appears to be commensal, commonly used in the production of cheese. It is known to cause infections outside the gastrointestinal tract. We found no case reports of gastrointestinal illness linked to this bacterium.
- *Enterococcus durans* – some strains have been shown to cause diarrheal illness in animals, although reports of human illness are few. Take in the context of symptoms and history (Devriese 2002).
- *Enterococcus faecalis* – typically considered commensal, although rare vancomycin-resistant strains may cause diarrhea and other problems in immune-compromised individuals; pathogenic strains typically are acquired in hospitals (Mutters 2013).
- *Enterococcus faecium* – typically considered commensal. Vancomycin-resistant strains, more common than vancomycin-resistant *E. faecalis*, occasionally cause diarrhea and other problems in immune-compromised individuals; typically acquired in hospitals (Mutters 2013).
- *Enterococcus gallinarum* – considered commensal yet has an inherent resistance to vancomycin and is known to cause infections outside the gastrointestinal tract. We found no case reports of gastrointestinal illness caused by this bacterium.
- *Enterococcus hirae* – a common cause of diarrheal illness in animals, although case reports of human illness do exist (Etheridge 1988).
- *Enterococcus mundtii* – little information exists on this species; however, a recent study examining its pathogenicity concluded that it has low virulence factors (Repizo 2014).
- *Enterococcus raffinosus* – little information exists on this species. It only rarely causes extraintestinal infections in humans (Mastroianni 2009); however, cases of antibiotic resistance have been noted (Savini 2008).

Escherichia spp. (gram-negative organisms; strains of *E. coli* and other *Escherichia* species may be commensal, opportunistic, or pathogenic.)

- *Escherichia coli* – a generally non-toxigenic and common bacterium in the digestive tract of mammals including humans. In most cases, *E. coli* is considered commensal (no discovered role in pathogenicity); however, some less common strains of *E. coli* may be more virulent and potentially associated with clinical symptoms. Research is ongoing on methods to identify these potentially more virulent strains properly.
- *Escherichia hermannii* – a rare bacterium that is believed to cause disease (Brenner 1982), including diarrheal illness (Chaudhury 1999).

Shiga toxin-producing *Escherichia coli* (*E. coli*) (gram-negative and potentially pathogenic)

Toxigenic strains of *E. coli* are biochemically identical to nontoxigenic *E. coli* except for the production of Shiga toxins. Shiga toxin-producing *E. coli* are transmitted through contaminated water or food, or contact with animals or infected persons. Infection with Shiga toxin-producing *E. coli* may cause acute symptoms ranging from mild diarrhea to severe acute abdominal cramping and bloody diarrhea. Severe infections associated with hemorrhagic colitis may progress to life-threatening complications including thrombocytopenia, hemolytic uremic syndrome, and kidney failure. *E. coli* O157 is the predominant disease-causing strain of this type and can be identified directly by culture.

All other Shiga toxin-producing *E. coli*, including the less virulent forms, are routinely identified by immunoassay testing to check for the presence of Shiga toxins.

In uncomplicated cases, the duration of symptoms is two to nine days, with an average of eight days. Antibiotic treatment is never indicated in this type of infection as it can increase the patient's likelihood of developing hemolytic uremic syndrome. Treatment is supportive and may require aggressive rehydration therapy.

Hafnia spp. (gram-negative opportunistic pathogens)

- *Hafnia alvei* – The most recent literature appears to reaffirm that *Hafnia alvei* may act as an enteric pathogen in humans (Donato 2008). Initially, research seemed to indicate that some strains of this species were associated with diarrheal illness; however, further testing suggested that the disease-causing organism was misidentified and should have been classified as enteropathogenic *E. coli* (Janda 1999). Additional studies reasserted the original conclusion that *Hafnia alvei* can cause gastrointestinal symptoms dependent on the strain. In one study ~70% of *Hafnia* spp. produced a cytolytic toxin (Abbott 2011). Case reports associate this bacterium with hemolytic uremic syndrome (Crandall 2006).
- *Hafnia paralvei* – like *Hafnia alvei*, *H. paralvei* can produce cytolytic toxins and may act as an enteric pathogen (Abbott 2011).

Herbaspirillum spp. (gram-negative opportunistic pathogens)

- *Herbaspirillum aquaticum* or *H. huttiense* – we found one case report of this organism as a cause of community-acquired pneumonia in an immunocompetent adult male (Regunath 2015).

Klebsiella spp. (gram-negative opportunistic pathogens)

- *Klebsiella oxytoca* – Can cause antibiotic-associated bloody diarrhea, which usually resolves with discontinuation of the antibiotic (Polage 2012). *Klebsiella oxytoca* has characteristics similar to *Klebsiella pneumoniae*.
- *Klebsiella pneumoniae* – an opportunistic pathogen that can cause pneumonia and urinary tract infections. Research indicates that *K. pneumoniae* is associated with antibiotic-associated diarrhea (Song 2008) and diarrheal disease in children (Niyogi 2000). *K. pneumoniae* is also a common etiological agent in SIBO (Pyleris 2012). Some strains are more virulent, and gastrointestinal carriage of these strains has been implicated as a risk factor in developing liver abscess especially in immunocompromised individuals (Fung 2012). *K pneumoniae* may be an initiating factor in some cases of inflammatory bowel disease and ankylosing spondylitis through molecular mimicry (Rashid 2011). Intestinal and systemic inflammation triggered by *K. pneumoniae* may also contribute to the pathogenesis of hypertension (Li 2017).
- *Klebsiella variicola* –initially considered commensal, recent studies show virulence comparable to *K. pneumoniae*, with this bacterium causing similar infections. Studies have found drug resistance genes similar to those identified in *K. pneumoniae* (Long 2017).

Kluyvera spp. (gram-negative opportunistic pathogens)

- *Kluyvera ascorbata* – has been shown to cause gastrointestinal infections with diarrhea and extraintestinal infections as well. This bacterium can be virulent, as seen in some case reports of infection in immunocompetent individuals; however, most cases with gastrointestinal involvement were in immunocompromised patients (Sarria 2001).
- *Kluyvera cryocrescens* – Less common as a human pathogen than *K. ascorbata*; it may share characteristics and cause diarrhea along with other extraintestinal infections, however current published data is limited (Sarria 2001, Fainstein 1982).

Lactobacillus spp. (gram-positive and may be commensal organisms)

- *Lactobacillus murinus* – a bacterium commonly found in the digestive tract of animals and researched for use as a probiotic, mostly in animals (Perelmuter 2008). We found no reports of this bacterium causing gastrointestinal illness in humans.
- *Lactobacillus rhamnosus* – a bacterium commonly used as a probiotic. We found no reports of this bacterium causing gastrointestinal illness in humans.

Lactococcus spp. (gram-positive and may be commensal organisms or opportunistic pathogens)

- *Lactococcus garvieae* – a rare opportunistic pathogen with low virulence; reported causative agent in several cases of endocarditis (Russo 2012). Not typically considered a gastrointestinal pathogen, but it may use gastrointestinal mucosal lesions to enter the body, which in rare cases may cause liver abscess, peritonitis, diverticulitis, and infective spondylodiscitis in association with endocarditis (Chan 2011). A well-known fish pathogen in cultured and freshwater species; also found as a contaminant in dairy products. The route of infection could be the ingestion of raw fish, grilled fish, or fresh dairy products.
- *Lactococcus lactis* – used in the dairy industry in making fermented cheeses. One case report related to endocarditis exists (Lin 2010). It has been used as a probiotic; some strains seem to decrease intestinal inflammation (Saraiva 2015).

Leuconostoc spp. (gram-positive organisms)

- *Leuconostoc lactis* is found on plants and to a lesser extent in milk and milk products. Also found as a component of cheese and butter starters. Non-pathogenic in both plants and animals.
- *Leuconostoc pseudomesenteroides* is a lactic acid-producing bacterium found in fermented food products such as kefir. Some strains of this organism have been shown to cause urinary tract infections, bacteremia, and meningitis, but case reports are uncommon (Cappelli 1999). We found no case reports of infections in the gastrointestinal tract. *L. pseudomesenteroides* is resistant to vancomycin.

Lysinibacillus spp. (gram-positive bacteria)

- *Lysinibacillus fusiformis* – pathogenicity is not well characterized, although some strains have been shown to produce toxins that could impact the gastrointestinal tract (From 2005). *L. fusiformis* was originally known as *Bacillus fusiformis*.

Morganella spp. (gram-negative opportunistic pathogens)

- *Morganella morganii* – Some strains can produce enterotoxins and could cause diarrheal illness (Ahrén 1990). Case reports also connect it with diarrhea and possibly inducing reactive arthropathy (Müller 1986, Cafferkey 1988).

Neisseria spp. (gram-negative bacteria)

- *Neisseria perflava* – Considered normal flora in the nasopharynx. Rarely, it may act as an opportunistic pathogen, however, there are no case reports of this bacterium causing gastrointestinal symptoms.

Proteus spp. (gram-negative opportunistic pathogens)

- *Proteus* spp. occur naturally in manure, soil, and polluted waters. *Proteus mirabilis, P. vulgaris, and P. penneri* are typically associated with urinary tract infections. Also, they may cause or contribute to rheumatoid arthritis through molecular mimicry (Ebringer 2014). Some research indicates that they may cause diarrhea, although this is disputed in the research literature as well (Ikeobi 1996, Müller 1986).

***Providencia* spp.** (gram-negative opportunistic pathogens)

- *Providencia rettgeri* – a potential cause of traveler's diarrhea, symptoms can include abdominal pain and vomiting (Yoh 2005).

***Pseudomonas* spp.** (gram-negative opportunistic pathogens)

- *Pseudomonas aeruginosa* is resistant to most antibiotics (Nathwani 2014). *P. aeruginosa* is known to cause diarrheal outbreaks in nurseries, and in children, some virulent strains may lead to diarrhea and sepsis, called Shanghai fever (Chuang 2014). Two studies appear to show an association between *P. aeruginosa* and irritable bowel syndrome, although more studies are needed to confirm a link (Kerckhoffs 2012, Shukla 2015).
- *Pseudomonas citronellolis* – a bacterium typically isolated from soil; its pathogenicity is mostly unknown. We found one case report of urosepsis in an individual shortly after a trans-rectal ultrasound-guided prostate biopsy. It is possible the patient's rectum may have become colonized with *P. citronellolis* from contact with soil, which then spread to the urinary tract and bloodstream due to the procedure (Williams 2019).
- *Pseudomonas fluorescens* – Preliminary research indicates that *P. fluorescens* may produce a compound that could act as a superantigen initiating Crohn's disease in some cases (Liu 2013).
- *Pseudomonas fragi* – commonly associated with meat, dairy, and other food spoilage; pathogenicity of this bacterium is not well characterized (Ternström 1993).
- *Pseudomonas lundensis* – commonly associated with meat, dairy, and other food spoilage; its pathogenicity is not well characterized (Ternström 1993).
- *Pseudomonas mendocina* – A common soil and waterborne bacterium that is a rare cause of illness in humans. We found no reports related to its presence in the digestive tract; most case reports are related to endocarditis (Mert 2007).
- *Pseudomonas monteilii* - It has been described as an environmental contaminant and potential pathogen. A case report identifies this bacterium as the cause of an exacerbation of bronchiectasis in an immunocompetent adult male. Though it is considered a colonizer and potential pathogen, its status as a human pathogen is unclear (Aditi 2017).
- *Pseudomonas nitroreducens* – a bacterium related to *P. aeruginosa*; its pathogenicity is unknown, and we found no case reports related to human disease in the medical literature (Anzai 2000).
- *Pseudomonas putida* – one case report associates this bacterium as a rare cause of acute gastroenteritis in a child (Bhattacharya 2015). There are strains of this bacterium that are considered non-pathogenic as well (Fernández 2015).
- *Pseudomonas rhodesiae* – has been isolated from soil; its pathogenicity is unknown, and we found no case reports related to human disease in the medical literature.

***Raoultella* spp.** (gram-negative opportunistic pathogens, formerly designated *Klebsiella*)

- *Raoultella ornithinolytica* – found in aquatic environments, fish, and insects. A rare opportunistic pathogen in the respiratory tract, urinary tract, stool, and blood. It has been associated with enteric fever-like syndrome (Morais 2009). Although uncommon, *R. ornithinolytica* bacteremia may occur more often in patients with underlying malignancies (Chun 2015).
- *Raoultella planticola* – also found in aquatic environments, soil, and on some plants. Case reports include enteric fever-like syndrome, pancreatitis, and cholangitis (Puerta-Fernandez 2013). Gastrointestinal carriage is thought to be one of the sources of infection with this bacterium as it has been found in neonates as well as adult stool samples.

***Rothia* spp.** (gram-positive commensal organisms or lower virulence opportunistic pathogens)

- *Rothia mucilaginosa* – an emerging opportunistic pathogen, commonly shown to cause blood, pulmonary, and other infections in immunocompromised individuals, but case reports do exist of infections in immunocompetent patients (Baeza Martínez 2014). It is hypothesized that extraintestinal infections of *R. mucilaginosa* may originate from the gastrointestinal tract or other sources (Ramanan 2014). We found no case reports of this bacterium causing gastrointestinal pathology, although our understanding of the pathogenic potential of *R. mucilaginosa* is limited.

***Salmonella* spp.** (gram-negative and potentially pathogenic)

Salmonella species (nontyphoidal) can lead to gastroenteritis via the ingestion of contaminated meat, poultry, eggs, and dairy products. The most common animal hosts of *Salmonella* are birds and reptiles. Symptoms usually begin between 6 and 48 hours after exposure and consist of nausea, vomiting, and diarrhea. Patients may also develop fever, headache, and myalgias. The illness is normally self-limiting and resolves within a few days. Antibiotics are generally not recommended in most cases because they do not shorten the course of the illness and can make transmission to others more likely by prolonging the length of time the bacterium remains in the stool. In rare cases, *Salmonella* infection may cause reactive arthritis or in other cases, it can lead to infections beyond the gastrointestinal tract that may require antibiotic treatment.

***Serratia* spp.** (gram-negative bacteria)

- *Serratia liquefaciens* – a bacterium that has been shown to cause diarrheal illness in children (Brooks 1988). Strains have also been shown to cause infective ulcerations of the skin (Lazaro Diez 2015).
- *Serratia marcescens* - an opportunistic pathogen whose clinical significance has emerged as an important nosocomial healthcare-associated pathogen and a frequent source of outbreaks of hospital infection (Merkier, 2003) in both adult (Yoon, 2005) and pediatric patients.

***Shigella* spp.** (gram-negative and potentially pathogenic)

Shigella species cause shigellosis, in which diarrhea may range from watery stool to severe, life-threatening dysentery. All *Shigella* species can cause acute, bloody diarrhea.

Shigella can spread rapidly through a population, particularly in crowded and unsanitary conditions. It is commonly transmitted in foods consumed raw, such as salads, dips, and dairy products. Episodes of shigellosis appear to follow seasonal variations. In developed countries, the highest incidence generally occurs during the warmer months and can be particularly severe in children one to four years old, the elderly, and immunocompromised individuals.

In otherwise healthy people, the disease is usually self-limiting and will resolve in five to seven days. *Shigella* infection may be reduced in duration and severity with antibiotic treatment, which also reduces the shedding of infectious organisms, although some concerns exist about inducing antibiotic resistance.

***Stenotrophomonas* spp.** (gram-negative opportunistic pathogens)

- *Stenotrophomonas maltophilia* – This bacterium may cause significant infections in the gastrointestinal tract, although case reports are quite rare. There is a case report of life-threatening malabsorption and weight loss due to colonization in the small intestine in a young individual due to this bacterium (Hellmig 2005). It has also been researched as a possible agent involved in diarrhea in oncology patients, the only significant finding is that colonization was associated with the use of antimicrobial medications (Apisarnthanarak 2003). More studies are needed to draw firm conclusions.

***Staphylococcus* spp.** (gram-positive bacteria)

- *Staphylococcus aureus* – Methicillin-resistant *Staphylococcus aureus* (MRSA) has been shown in rare cases to cause infectious colitis (Kalakonda 2015). There is also a case series on children under five having sporadic diarrhea related to enterotoxigenic *S. aureus* (Efuntoye 2003).
- *Staphylococcus condimenti* – initially discovered in fermented soy sauce, there is little published information on this species. One case report associates it with catheter-induced bacteremia (Misawa 2014).
- *Staphylococcus epidermidis* – isolated from a small number of children under five struggling with sporadic diarrhea, although the significance of this finding is unclear as the study does not elucidate if the strains were enterotoxigenic (Efuntove 2003). Animal studies suggest that this bacterium might cause diarrhea in children (Thelen1978).
- *Staphylococcus simulans* – a bacteria that can act as an opportunistic pathogen, some strains have significant antimicrobial resistance and can present similarly to MRSA (Barnham 1996). One case report of oral colonization in Crohn's disease with potentially related oral lesions has been reported although this does not prove causation for Crohn's (Ficarra 1993).

Streptococcus spp. (gram-positive commensal organisms or opportunistic pathogens)

- *Streptococcus agalactiae* – originally discovered as a cause of bovine mastitis, this organism is part of the normal bacteria colonizing the gastrointestinal tract and genitourinary tract of a significant proportion of the human population. In colonized women, this bacterium becomes a risk factor for pregnancy and after birth as a common cause of neonatal sepsis. Its presence in the gastrointestinal tract does not appear correlated with specific gastrointestinal symptoms, with no reports related to diarrheal illness. The bacterium can carry some significant virulence factors (Emaneini 2016).
- *Streptococcus anginosus* – part of the normal bacterial flora (oral, intestinal, and vaginal); outside thegastrointestinal tract it may infect the brain and liver and is known for causing abscesses (Doern 2010). Other common sites of infection include the abdomen and skin. Its presence or overgrowth in the gastrointestinal tract is not well characterized, and we found no reports of this bacterium related to diarrheal illness. This bacterium does carry virulence factors and due to its commensal nature, may be under-recognized as a pathogen (Asam 2014).
- *Streptococcus canis* – Also known as Group G streptococci, this bacterium is typically carried by dogs. Reports of endocarditis, skin and soft tissue infections, sepsis, pharyngitis, and arthritis exist for Group G (Lam 2007), however, no case reports of gastrointestinal illness in humans related to the carriage of this bacterium were found. The organism is beta-hemolytic, which may increase its potential virulence.
- *Streptococcus constellatus* – Very similar to *Streptococcus anginosus*, this bacterium may be under-regarded as a cause of problems due to its commensal nature (Asam 2014). It does possess some virulence factors; however, we could not find any reports linking it to gastrointestinal pathology from its presence in the GI tract.
- *Streptococcus cristatus* – part of the normal oral bacterial flora. One study shows an antagonistic relationship between *Streptococcus cristatus* and *Porphyromonas gingivalis*, a primary cause of adult periodontitis. (Ho, 2017)
- *Streptococcus dysgalactiae* – One case report associates rare strains of this bacterium with bloody diarrhea and hemolytic uremic syndrome (Galán-Sánchez 2013). *S. dysgalactiae* does commonly carry genes for significant virulence factors (Lo 2015).
- *Streptococcus equi* – a disease-causing pathogen in horses, it causes a condition called strangles that can suffocate a horse due to lymph node swelling in the neck. There are strains of *S. equi* considered to be pathogenic in humans that can cause severe illness including glomerulonephritis, rheumatic fever, meningitis, and infectious arthritis (Pelkonen 2013). We found no case reports of gastrointestinal disease related to its presence in the gastrointestinal tract.
- *Streptococcus equinus* – a commensal organism in horses and ruminant animals, less common in humans. Sometimes referred to as *S. bovis*, although *S. equinus* is the preferred species name. Rarely this bacterium may cause bacteremia and infective endocarditis in humans. It is closely related to *S. gallolyticus* (Jans 2015).
- *Streptococcus gallolyticus* (*Streptococcus bovis* biotype I) is found in the intestinal flora in 2.5-15% of individuals (Abdulamir 2011), and when present with endocarditis and bacteremia is strongly linked to colorectal cancer. Questions remain about whether it causes colorectal cancer or is merely correlated with its presence. This bacterium has also been linked to diarrhea in children (Jin 2013).
- *Streptococcus gordonii* – an oral commensal bacterium, it can cause endocarditis and occasionally septic arthritis after oral trauma that allows the bacterium to enter the bloodstream (Yombi 2012). Preliminary in-vitro research suggests that *S. gordonii* biofilms may increase the virulence of *Candida* infections in the upper gastrointestinal tract (Diaz 2012).
- *Streptococcus infantarius* (*Streptococcus bovis* biotype II) is closely related to *Streptococcus gallolyticus*; systemic infection with this bacterium is associated with increased risk of digestive system cancers (Corredoira 2008)
- *Streptococcus lutetiensis* – has been associated with diarrhea in children and appears to have some pathogenic and virulence factors associated with it (Jin 2013).
- *Streptococcus mitis* – implicated in some cases of oral and respiratory infection along with sepsis. This bacterium is similar to *S. pneumoniae*, and a recent study showed a correlation with diarrhea in young children in low-income countries (Pop 2014). Interpret in the context of symptoms and our limited understanding.
- *Streptococcus oralis* – commensal bacterium in the oral cavity; it can in rare cases cause extraintestinal meningitis and other opportunistic infections. *S. oralis* is used as a dental probiotic along with *S. rattus* and *S. uberis* (Zahradnik 2009). Preliminary in-vitro research suggests that *S. oralis* biofilms may increase the virulence of *Candida* infections in the upper gastrointestinal tract (Diaz 2012).
- *Streptococcus parasanguinis* – considered an oral commensal organism, *S. parasanguinis* is one of the early colonizers of dental surfaces in the human oral cavity (Peng 2008). The presence of *S. parasanguinis* in the oral cavity is associated with a healthy microflora (Corby 2005). Its presence or overgrowth in the gastrointestinal tract has not been correlated with any gastrointestinal pathology.
- *Streptococcus peroris* – part of the *Streptococcus mitis* group, commonly found in the oral cavity, little published information exists on this species, consider similar to *S. mitis* (Kawamura 1998).

- *Streptococcus pneumoniae* – outside of the gastrointestinal tract, *S. pneumoniae* is a major cause of pneumonia, meningitis, and septicemia worldwide (Watkins 2015). In rare cases, it has been associated with gastroenteritis as well (Soman 2009).
- *Streptococcus pyogenes* – A cause of skin infections and pharyngitis; rare case reports of hemolytic uremic syndrome with and without bloody diarrhea (Yildiz 2004, Shimizu 2012). This bacterium has been associated with severe fatal disease including nausea, diarrhea, and vomiting (Ekelund 2004). Infections can be serious and life-threatening.
- *Streptococcus salivarius* – in development for use in dental probiotics due to its production of a bacteriocin (an antibiotic) that inhibits closely related species such as *Streptococcus pyogenes*. People with naturally occurring *S. salivarius* on their tongue have been shown to have fewer strep throat infections (Wescombe 2009). Recent research has shown a positive correlation between fecal levels of this bacterium and bloody diarrhea in children in low-income countries (Pop 2014). *S. salivarius* is a diverse species with a large set of response regulators that are likely involved in host-bacterial interactions (Delorme 2015).
- *Streptococcus sanguinis* – commensal bacterium in the oral cavity; preliminary in-vitro research suggests that *S. sanguinis* biofilms may increase the virulence of *Candida* infections in the upper gastrointestinal tract (Diaz 2012).
- *Streptococcus vestibularis* – a rare cause of endocarditis and bacteremia usually in immunocompromised individuals (Tufan 2010). We found no cases reported of gastrointestinal illness related to its presence in the gastrointestinal tract.

***Vibrio* spp.** (gram-negative and potentially pathogenic)

Vibrio species include the causative agent for cholera, *Vibrio cholerae*, as well as other species that can cause gastroenteritis including *V. parahaemolyticus* and *V. vulnificus*.

Pathogenicity is strain-specific, and not all strains of these *Vibrio* species cause gastrointestinal illness. *Vibrio* species are frequently isolated from estuarine and marine environments. The gastroenteritis associated with these organisms is typically mild or moderate self-limiting diarrhea but may progress and lead to severe complications in immunocompromised patients. Symptoms include diarrhea, abdominal cramps, nausea, vomiting, fever, and bloody stool. This pathogen is most often linked to contaminated fish and shellfish, with most cases resulting from the consumption of contaminated oysters. Symptoms usually last from two to six days. Treatment is supportive although severe infections may benefit from antibiotic therapy.

***Weissella* spp.** are gram-positive, opportunistic pathogens.

Weissella species are non-spore forming, catalase-negative, gram-positive coccobacilli. They are often misidentified by traditional and commercial phenotypic identification methods as *Lactobacillus* spp. or *Lactobacillus*-like organisms. Nineteen species have been identified to date. *W. confusa*, *W. cibaria*, and *W. viridescens* are the only species isolated from humans. The true prevalence of *Weissella* spp. continues to be probably underestimated. *Weissella* spp. have been isolated from a wide range of habitats including raw milk, feces, fermented cereals, and vegetables. *Weissella* is believed to be a rare cause of usually nonfatal infections in humans and is often considered a contaminant. However, in recent years, *Weissella* spp. have been implicated in bacteremia, abscesses, prosthetic joint infections, and infective endocarditis. *Weissella* spp. are inherently resistant to vancomycin (Kamboj 2015).

- *Weissella confusa* - The literature contains 18 case reports implicating *W. confusa* as the causal agent of abscess, bacteremia, and endocarditis. In most of these cases, the patients had a chronic illness with either immunosuppression or long-standing antibiotic therapy, which can lead to selection of micro-organisms (Kumar 2011).

***Yersinia* spp.** (gram-negative and potentially pathogenic)

- *Yersinia enterocolitica* infection manifests as nonspecific, self-limiting diarrhea, which in rare cases can lead to autoimmune complications. Most symptomatic infections occur in children younger than five years old.

Yersiniosis is frequently characterized as gastroenteritis with diarrhea and/or vomiting; however, fever and abdominal pain are the hallmark symptoms. *Yersinia* infections can mimic appendicitis and mesenteric lymphadenitis. The duration of illness is generally short, yet sometimes *Yersinia* infection can become chronic and recurrent. Foods associated with outbreaks of this organism include undercooked pork, unpasteurized milk, and oysters. Untreated water can also be a source of infection. Treatment of *Yersinia* enteritis is supportive, and patients do not generally benefit from the use of antibiotics, although more disseminated *Yersinia* infections may require antibiotic treatment (Sabina 2011).

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