

# Study Guide for Selected Bacterial Infections/Diseases/Intoxications and Etiological Agents

## Infections of the Integumentary system:

### 1. Staphylococcal infections (*Staphylococcus aureus*)

Bacteria identified as *Staphylococcus aureus* are Gram-positive, **pyogenic (puss-forming)** cocci capable of causing a variety of infections in any or all body tissues. These bacteria are commonly associated with **nosocomial infections** (those acquired within hospitals), and produce a variety of enzymes/toxins capable of causing damage to cells and tissues, e.g., coagulase, leukocidin, kinase and hemolysins. Specific conditions involving *Staphylococcus aureus* include:

- a) **Impetigo** – A superficial skin infection usually affecting small children.
- b) **Furuncles** (boils) – Tissue necrosis occurring after bacteria have established themselves within hair follicles or sebaceous glands.
- c) **Carbuncles** – Similar to furuncles, but occur in areas of thicker skin. The abscesses do not drain on their own, but tend to spread under the skin as collections of blood and puss.
- d) **Acute bacterial endocarditis** – Rapid spreading inflammation of the endocardium (heart lining) and damage to heart valves due to bacteria invading the bloodstream.
- e) **Toxic Shock Syndrome (TSS)** – Abrupt onset of high fever, vomiting, diarrhea, myalgia (muscle pain), a scarlatiniform rash, and hypotension followed by cardiac and renal failure in the most severe cases. Staphylococcal TSS is an **intoxication** and is due to Enterotoxin type B (a superantigen). Superantigens interact directly with MHC class II proteins, trigger massive T-cell responses and the release of excessive cytokine.

### 2. Streptococcal infections (*Streptococcus pyogenes*)

Bacteria identified as *Streptococcus pyogenes* are Gram-positive, pyogenic cocci sometimes called Group A,  $\beta$ -hemolytic *Streptococcus* (The group name is based on the Lancefield groups A-O of cell surface antigens, and  $\beta$ -hemolysis is complete hemolysis of RBCs). These organisms can invade a variety of tissues and are often secondary invaders following Staphylococcal infections.

- a) **Impetigo** – A superficial skin infection usually affecting small children; can involve both *Staphylococcus* and *Streptococcus* bacteria.
- b) **Erysipelas** – Sometimes called St. Anthony's fire, erysipelas is an acute and rapid-spreading infection often occurring as a complication of surgery or wound injury. Symptoms include high fevers, shaking, chills, fatigue, headaches, vomiting, and general illness within 48 hours of the initial infection. Skin involvement (a red, swollen, warm, hardened and painful rash) enlarges rapidly.
- c) **Scarlet fever** – Disease characterized by a skin rash, fever and sore throat, is caused by the the production of an erythrogenic toxin carried in the bloodstream from the site of primary infection (usually streptococcal infection of the throat).
- d) **Scarlatina** – A milder form of scarlet fever.

### 3. Anthrax (*Bacillus anthracis*)

Anthrax, also known as “Hoof and Mouth Disease”, is primarily a disease of sheep, cattle and horses, but can be transmitted to humans. It is usually acquired when exospores enter tissues through traumatized skin or mucous membranes, but spores may also be inhaled (wool sorters disease). If vegetative cells enter the bloodstream, septicemia develops and is usually fatal.

#### 4. *Pseudomonas* infections (*Pseudomonas aeruginosa*)

Bacteria identified as *Pseudomonas aeruginosa* are Gram-negative bacilli sometimes referred to as “quinessential opportunists” because they are ubiquitous, can readily invade tissues and are often resistant to multiple antimicrobial drugs. These bacteria are often associated with superficial wounds, abrasions and burns, but can also infect the eyes, ears, and respiratory system if the normal microbiota have been disturbed or resistance is down for other reasons. These organisms produce an exotoxin that inhibits protein synthesis, so limits healing, and a blue-green colored pigment called **pyocyanin** (often visible in puss, nasal discharge and in MHA). These bacteria can invade the bloodstream causing fatal sepsis and are often very difficult to eradicate.

#### 5. *Clostridium* infections (*Clostridium tetani*, *C. perfringens* and *C. botulinum*)

**Tetanus** is a disease caused by *Clostridium tetani*, Gram-positive, endospore-forming, anaerobic bacteria commonly associated with soil and the gastrointestinal tracts of animals worldwide. Spores are common in soil and often enter tissues by means of puncture wounds. The bacteria are not usually invasive, but produce a protein exotoxin called **tetanospasmin (tetanus toxin)**. The toxin enters the circulation, travels to neuromuscular junctions and then up axons (transported by dyneins). It blocks the release of inhibitory neurotransmitters [gamma-aminobutyric acid (GABA) and glycine], resulting in spastic and often sustained skeletal muscle contractions (**tetanus**). The resulting disease, also called “lock jaw”, is most often fatal without medical assistance. *Clostridium tetani* also produce a hemolysin called **tetanolysin**. Infection and disease are effectively prevented by administration of Tdap or DPT (a toxoid, vaccine combination).

**Gas gangrene** (myonecrosis) is most commonly (90%) caused by *Clostridium perfringens*, Gram-positive, endospore-forming, anaerobic bacteria associated with soil. Gas gangrene is most commonly caused by severe projectile wounds (acquired under combat conditions), but can also be associated with vascular blockage due to tumor growth, type II diabetes or thrombosis. Spores germinate in tissues, and the bacteria produce gasses that distend the tissues and interfere with normal circulation. They release alpha toxin and also produce enzymes (lecithinase, DNase, and hyaluronidase) that break down tissues and allow for the rapid advance of infection. Tissue necrosis with accompanying foul odor, fever, toxemia, shock and death were common prior to the availability of antibiotics, and amputation was the most usual method of control.

*Clostridium botulinum* is the causative agent of **botulism** (see G.I. tract infections) and is only rarely associated with wound infections.

#### **Infections and Diseases of the Gastrointestinal Tract:**

1. Many types of bacteria inhabit the human mouth and can under certain circumstances cause infection and/or disease. Some examples of conditions involving bacteria are listed below:
  - a) **Plaque** – Bacterial plaque is a sticky mixture of bacterial cells and salivary protein that builds up on the teeth providing an anaerobic environment. Facultatively anaerobic Streptococci are the primary contributors to plaque, and also produce lactic and other acids.
  - b) **Calculus** – Calculus forms when calcium salts are deposited in the plaque. Major contributors are the Gram variable Actinomycetes.
  - c) **Dental caries** – Dental caries develop due to the production of acids and endotoxins by various bacteria including Streptococci, Lactobacilli, and Bacteroides.
  - d) **Peridontal disease** - Peridontal disease is essentially inflammation and destruction of the soft tissues supporting the teeth, and has three forms;

- a) **Gingivitis** – Gingivitis is inflammation of the gingiva (gums).
  - b) **Peridontitis** – Peridontitis is destruction of deep tissue (bone) resulting in tooth loss.
  - c) **Acute necrotizing ulcerative gingivitis (ANUG)** – ANUG is an acute infection believed to be primarily due to stress.
2. Bacteria living in the mouth or within the gastrointestinal lumen can sometimes spread into other areas of the body causing bacteremia, appendicitis, and peritonitis:
- a) **Bacteremia** (bacteria in the bloodstream) can occur due to lesions in the mouth, stomach, intestines, etc.
  - b) **Appendicitis** (inflammation of the appendix) can involve a wide variety of gut bacteria.
  - c) **Peritonitis** (inflammation of the peritoneal cavity) can occur due to lesions in the intestinal wall allowing bacteria to enter the body cavity.
3. **Typhoid fever (*Salmonella enterica enterica*, serovar Typhi or *Salmonella Typhi*)**  
Typhoid fever or enteric fever is usually caused by *Salmonella Typhi*, Gram-negative, facultatively anaerobic bacilli, but similar symptoms may be caused by *S. paratyphi A* and *S. schottmulleri*. The infective organisms enter the host orally with contaminated food or drink, permeate the intestinal mucosa and are engulfed by phagocytes. They multiply within these cells, and are carried to various parts of the body. Prior to antibiotics, the chief complication of this disease was intestinal perforation and hemorrhage (mortality rate was 10 to 15%).
4. **Enterocolitis (*Salmonella enterica enterica*, serovar Typhimurium or *Salmonella Typhimurium*)**  
The most common manifestations of *Salmonella* infection begin 8-48 hours after ingestion, and include nausea, headache, vomiting, and profuse diarrhea. Toxic action is due to the presence of an endotoxin associated with the lipopolysaccharide layer of the cell wall.
5. **Dysentery (*Shigella dysenteriae*)**  
Gram-negative bacilli in the genus *Shigella* are recognized for their ability to cause dysentery. These bacteria are transmitted by "food, fingers, feces, and flies" and are highly communicable, with very low numbers of organisms (less than 200 cells) being required for infection. Cells invade the mucosa of the large intestine causing abscesses, ulcerations, and bleeding. Hosts suffer from abdominal pain, fever and watery diarrhea accompanied by mucous and blood.
6. **Diarrhea (*Escherichia coli*)**  
Gram-negative bacilli identified as *Escherichia coli* typically cause diarrhea in infants and adults (travelers diarrhea) by producing exotoxins or by invading the mucosa as do *Shigella*. Disease symptoms usually develop only when the organisms (part of the normal microbiota) become overgrown and the host defenses are low. See also "The Dark Side of *E. coli*" included in this syllabus.
7. **Cholera (*Vibrio cholerae*)**  
The cholera organisms (Gram-negative, comma-shaped bacteria) are non-invasive (stay within the epithelium) but produce an exotoxin (cholera toxin = Cholera toxin or CTX) that causes the hypersecretion of water and electrolytes (into the intestinal lumen). Victims suffer from serious dehydration, acidosis, shock, and sometimes death (mortality rate without treatment is between 25 and 50%). Cholera is endemic in India and South East Asia.

## 8. Gastric Ulcers (*Helicobacter pylori*)

Gram-negative bacteria in the genus *Helicobacter* attach to the gastric mucosa, and stimulate inflammatory responses that can lead to tissue damage. Loss of protective mucous predisposes the stomach to peptic ulcer or gastritis. Transmission is probably from person to person.

## 9. Food intoxications: (non-infectious bacterial diseases)

a) **Staphylococcal food poisoning is caused by *Staphylococcus aureus*.** These bacteria produce a neurotoxin (enterotoxin) that stimulates the vomiting reflex 2-8 hours following ingestion. Vomiting is often accompanied by diarrhea.

b) **Botulism is caused by *Clostridium botulinum*,** a type of Gram-positive, anaerobic, spore-forming rod. *Clostridium botulinum* produce neurotoxins (7 different antigenic types) that are among the most toxic substances known to man (lethal dose for humans is about 1-2 micrograms). These protein exotoxins inhibit the release of the neurotransmitter **acetylcholine** and so cause flacid paralysis of skeletal muscles, resulting in respiratory failure and death. Symptoms begin 18-96 hours after ingestion. Infants may get botulism from organisms growing in their gut following the ingestion of honey – The California Honey Advisory Board recommendation is: **DO NOT FEED HONEY TO INFANTS** or children less than two years of age.

## Infections and Diseases of the Upper Respiratory Tract:

### 1. Strep throat (*Streptococcus pyogenes*)

Gram-positive cocci identified as *Streptococcus pyogenes* (Group A,  $\beta$ -hemolytic Streptococci) can infect the epithelium of the pharynx to cause streptococcal sore throat. This is the most common infection due to *S. pyogenes*. These organisms produce an erythrogenic toxin as well as two hemolysins, Streptolysin O and Streptolysin S. These materials enter the bloodstream to cause complications associated with streptococcal infections as listed below:

a) **Scarlet fever** – Streptococcal erythrogenic toxin causes fever, and skin rash.

b) **Rheumatic fever** – Hypersensitivity reactions result in inflammation of joints, skin, brain, and heart. Damage to heart valves may be severe.

c) **Acute Glomerulonephritis** – Hypersensitivity reactions cause damage to the kidney glomeruli and nephrons.

d) **Acute bacterial endocarditis** – Streptococci enter the bloodstream and cause endocarditis or inflammation of the endocardium (lining of the heart).

### 2. Diphtheria (*Corynebacterium diphtheriae*)

Gram-positive, irregular bacilli identified as *Corynebacterium diphtheriae* occur in the respiratory tract, on skin, and in wounds of infected individuals or carriers. The symptoms of diphtheria (fever, chills, fatigue, cyanosis, sore throat, hoarseness, cough, headache, difficulty or painful swallowing, difficulty breathing, foul-smelling bloodstained nasal discharge, swollen lymph nodes, and necrosis in various tissues) result from production of an exotoxin that inhibits protein synthesis within infected cells. The ability of the bacteria to produce toxin is gained from a bacteriophage through **lysogenic conversion**.

### 3. Otitis media - middle ear infection (various bacteria)

Various types of bacteria can infect the middle ear by moving up the eustachian tubes from the pharynx. Typical infective agents include *Streptococcus pneumoniae*, *Haemophilus influenzae*, *Streptococcus pyogenes*, *Staphylococcus aureus*, *Pseudomonas aeruginosa* and others.

## Infections and Diseases of the Lower Respiratory Tract:

### 1. Whooping cough (*Bordetella pertussis*)

Small, Gram-negative bacilli identified as *Bordetella pertussis* are the etiological agents of whooping cough. These bacteria adhere to the epithelial surfaces of the trachea and bronchi, where they multiply rapidly and interfere with the action of cilia. A cough develops from mild to explosive with a characteristic "whoop" and leads to rapid exhaustion. Secondary infection with other organisms is common, often resulting in pneumonia. Whooping cough is readily prevented through immunization (Tdap or DPT).

### 2. Epiglottitis or croup (*Haemophilus influenzae*)

Gram-negative, facultatively anaerobic bacteria identified as *Haemophilus influenzae* are the most common causative agents associated with croup or epiglottitis; causing cough and respiratory distress. These organisms were named in 1918 due to their association with an influenza outbreak, but they do not cause influenza. *Haemophilus influenzae* can also cause pneumonia, otitis media, bacteremia, infectious arthritis, and meningitis (in infants and newborns).

### 3. Pneumonia (*Streptococcus pneumoniae*)

Pneumonia is an inflammatory condition of the lung affecting primarily the alveoli. It is characterized by cough, chest pain, fever, and difficulty breathing due to fluid accumulation within the lungs. Pneumonia affects around 450 million people per year (globally), and results in about 4 million deaths. Approximately 60-80% of all bacterial pneumonias are caused by *Streptococcus pneumoniae* (Gram-positive pneumococci). Only capsule-forming strains are virulent.

#### Other organisms associated with bacterial pneumonia include:

*Haemophilus influenzae* (small Gram-negative rods);

*Klebsiella pneumoniae* (cause pneumonia associated with alcoholics and diabetics);

*Mycoplasma pneumoniae* (cause acute "non-bacterial" pneumonitis);

*Pseudomonas aeruginosa* (cause pneumonia in children with cystic fibrosis).

### 4. Legionnaire's disease (*Legionella pneumophila*)

Small, Gram-negative bacteria identified as *Legionella pneumophila* were recognized as the causative agents of an outbreak of respiratory illness associated with the American Legion Convention in Philadelphia in 1976. Symptoms included high fever, cough, chills, and decreased respiratory function. The bacteria are common inhabitants of water and tend to cause sporadic epidemics with mortality rates of between 10 and 20%.

### 5. Tuberculosis (*Mycobacterium tuberculosis*)

Bacteria identified as *Mycobacterium tuberculosis* have Gram-positive type cell walls, but do not stain well with traditional Gram stain methods because they are **acid fast**. Tuberculosis, or consumption as it was previously called, is a chronic progressive disease of the lower respiratory tract, but contact with the disease agents does not necessarily result in disease. *M. tuberculosis* organisms inhaled in droplet nuclei reproduce within phagocytic cells and enter the lymphatics. Lesions develop that may be 1) Exudative; in which case acute inflammation is followed either by massive tissue necrosis or gradual healing, or 2) Productive; in which case there is chronic granuloma development. Exudative lesions initiate cell-mediated immune (CMI) responses and lead to development of a positive tuberculin test. Lesions that do not heal become productive. Productive lesions contain giant multinucleated cells containing tubercle bacilli, epithelial cells, and a peripheral zone of fibrous tissue. When the fibrous tissue walls off the interior, necrosis occurs, and the lesion is then called a tubercle. Within the tubercles the bacteria do poorly, but remain viable, and can reactivate later on (**the disease is latent**). The development and healing or progression of lesions is

determined chiefly by 1) the number of mycobacteria entering the host, and 2) host resistance and hypersensitivity.

A positive tuberculin test indicates a hypersensitivity reaction to the bacteria or their products. Persons that have experienced a positive reaction with a skin test should not repeat the procedure since a second or subsequent reaction may be much worse (due to cytotoxic T-cell activity).

### **Infections and diseases of the Urinary Tract:**

#### **1. Cystitis or bladder infection (*Escherichia coli*)**

Gram-negative bacilli identified as *Escherichia coli* are the most common causative agents of cystitis or bladder infection. Symptoms occur much more commonly in females than in males due to anatomical differences and improper hygiene.

#### **2. Pyelonephritis (*Escherichia coli*)**

When infection in the urinary bladder spreads up the ureter to the pelvis and kidneys, the result is pyelonephritis (inflammation in the kidneys and pelvis). This type of infection is characterized by fever, severe back pain and damage to kidney tissues. If left untreated it can result in renal failure.

#### **3. Glomerulonephritis (various bacterial agents)**

Antibody-antigen reactions may be involved with various bacteria, see *Streptococcus pyogenes* and strep throat.

#### **4. Gonorrhea (*Neisseria gonorrhoeae*)**

Fastidious, Gram-negative diplococci identified as *Neisseria gonorrhoeae* are the etiological agents of gonorrhea, one of the most common sexually transmitted diseases in the world. Pathogenicity is the result of pili production due to **lysogenic conversion**. Gonorrhea in males causes a painful burning sensation upon urination, but may go unnoticed in females. Neonatal gonorrhea was once the major cause of infant blindness and was prevented by drops of silver nitrate in the eyes of newborn infants.

#### **5. Syphilis (*Treponema pallidum*)**

Gram-negative spirochetes identified as *Treponema pallidum* are the etiological agents of syphilis. Natural infection is limited to the human host, and is usually transmitted by sexual contact. In about 10% of cases, the primary lesion is extragenital, often oral, and the spirochetes may even enter through a break in the epidermis caused by unrelated injury.

#### **Stages of syphilis occur as follows:**

**Primary stage** involves local multiplication of the spirochetes at the site of entry and development of a painless "hard chancre" in about 2-10 weeks. This lesion heals spontaneously, but the organisms persist in the body.

**Secondary stage** occurs when the spirochetes are spread throughout the body. There may be fever, sore throat, and a rash. Any skin lesions that develop during either this or the primary stage are highly infectious.

**Tertiary stage** develops in about 30% of cases and involves a hypersensitivity reaction. Severe damage to cardiovascular and nervous tissue, and ulcerations on various organs are typical.

**Congenital syphilis** results in severe damage to the fetus and may be fatal.

#### **6. Non-gonococcal urethritis (*Chlamydia trachomatis*)**

Obligate intracellular parasites (hypotrophs) identified as *Chlamydia trachomatis* commonly cause disease symptoms similar to gonorrhea. These bacteria may be sexually transmitted or passed to neonates at birth. They can also cause an eye disease called trachoma that can lead to blindness.

**Sexually transmitted diseases (Gonorrhea, syphilis and *Chlamydia* infection) are much more hazardous for females than they are for males because:**

- a) Infections in females are often asymptomatic, so can go unnoticed for extended periods of time.
- b) The bacteria involved can move up the fallopian tubes into the pelvic cavity causing pelvic inflammatory disease (essentially peritonitis).
- c) Bacteria can cause lesions within the female reproductive system making infected individuals much more susceptible to infection with HIV (a potentially deadly human retrovirus).
- d) The bacteria can cross the placenta in pregnant individuals, causing congenital infection of the fetus resulting in blindness, deafness, anatomical abnormalities, miscarriages, premature births, stillbirths, or death in neonates.

### **Infections and Diseases of the Nervous System:**

#### **1. Meningitis (*Neisseria meningitidis*)**

Fastidious, Gram-negative diplococci identified as *Neisseria meningitidis* are the most common etiological agents of meningitis. The organisms colonize the nasopharynx and then spread to the bloodstream if host resistance is down. In the blood they cause bacteremia (meningococemia) that can proceed to meningitis very quickly. Severe headache, stiff neck, vomiting, and PMNs in the CSF occurs, progressing to coma and sometimes death within a few hours. People may become asymptomatic carriers of the *Neisseria*.

Meningitis may also be caused by *Streptococcus pneumoniae*, *Haemophilus influenzae*, *Escherichia coli* (in neonates), *Listeria monocytogenes*, and *Pseudomonas aeruginosa*, as well as various other bacteria not listed. 30-40% of meningitis cases are virally caused. Viral infections are less severe and are of shorter duration than bacterial meningitis.

#### **2. Leprosy or Hansen's Disease (*Mycobacterium leprae*)**

Leprosy, also known as Hansen's Disease, is an insidious disease caused by acid-fast bacteria identified as *Mycobacterium leprae*. Infections typically begin with involvement of the "cooler" regions of the body; skin, superficial nerves, nose, pharynx, eyes, and testicles. Two forms occur depending on the host resistance and cell-mediated immune responses.

**Tuberculoid leprosy** involves localized infection, the host CMI response being able to prevent spread. **Lepromatous leprosy** occurs when the host CMI response is inadequate, and involves multiple lesions throughout the body, with progressive deterioration.

Leprosy is communicable, with transmission most likely to occur when small children are exposed for prolonged periods to heavily infected individuals. Nasal secretions are the most likely infectious materials.

### **Infections and Diseases of the Circulatory System:**

#### **1. Acute bacterial endocarditis (*Staphylococcus aureus* and/or *Streptococcus pyogenes*)**

#### **2. Subacute bacterial endocarditis (*Staphylococcus epidermidis* or *Micrococcus luteus*) other agents may be involved.**

#### **3. Bacteremia and/or septicemia (various organisms may be involved)**

**4. Relapsing fever (*Borrelia recurrentis*)**

Spirochetes identified as *Borrelia recurrentis* are the etiological agents of relapsing fever, a zoonosis endemic in many parts of the world. The infective agents are transmitted by ticks. Onset of disease is sudden following incubation of 3-10 days and includes chills, and an abrupt rise in temperature. This is followed by a period of 4-10 days during which there are no symptoms, and then a second attack of chills, fever, and malaise. There are from 3-10 recurrences of fever during which time the organisms are present in the bloodstream. Mortality rate during epidemics may reach 30%.

**5. Lyme Disease (*Borrelia burgdorferi*)**

Spirochetes identified as *Borrelia burgdorferi* are recognized as the etiological agents of Lyme disease (named after Lyme, Connecticut). The bacteria are transmitted by small ixodid ticks (genus *Ixodes*) and so infection is typically contracted during the spring and summer months when ticks are active. At the onset, disease is characterized by an expanding annular skin lesion at the bite site. This is eventually accompanied by headache, stiff neck, and fever. Treatment with antibiotics during the acute stages of infection typically result in prompt recovery, and are highly recommended to prevent secondary complications. Persistent infection can result in arthritis and neurological symptoms including blindness, memory loss and severe muscle pain.

**6. Plague (*Yersinia pestis*)**

Gram-negative bacteria identified as *Yersinia pestis* are the etiological agents of plague, a disease endemic to rodent populations throughout the world. Plague is directly transmitted from one rodent to another via the bite of fleas who have become infected by sucking the blood of other infected individuals. The bacilli essentially plug up the fleas intestinal tract so that no blood can get through. The hungry fleas bite repeatedly spreading bacilli with each bite. Humans acquire plague from flea bites as well, but the disease is not usually spread from person to person via fleas. When human infection develops into pneumonia, droplet nuclei are produced and the disease becomes highly contagious. Plague organisms enter the lymphatics and cause inflammation with greatly enlarged lymph nodes "bubos" which may become necrotic. Organisms may enter the bloodstream and spread to various parts of the body causing severe damage and ultimately death.

**7. Tularemia "deer-fly or rabbit fever" (*Francisella tularensis*)**

Gram-negative bacilli identified as *Francisella tularensis* are the etiological agents of Tularemia. The bacteria are essentially parasites of rodents that are adapted to transmission by biting flies, ticks, and a rabbit louse; all of which keep the infection endemic among animal populations. Handling, skinning, or eating infected animals, or drinking contaminated water may result in human infection. The bacteria enter the bloodstream and travel to various organs. Pneumonia and fatal septicemia may develop without treatment. The species name comes from Tulare county, California, where the disease was first discovered.

**8. Rocky Mountain Spotted Fever (*Rickettsia rickettsii*)**

Hypotrophs identified as *Rickettsia rickettsia* are the causative agents of Rocky Mountain Spotted fever. The bacteria are transmitted by ticks, and disease symptoms include a high fever, muscle pain, and a characteristic rash on wrists and ankles. The mortality rate is 20% if left untreated.

**9. Epidemic Typhus (*Rickettsia prowazekii*)**

Hypotrophs identified as *Rickettsia prowazekii* are the etiological agents of epidemic typhus, a disease common during World War I (more people died of typhus than died of gunshot wounds). The bacteria are transmitted by human body lice (*Pediculus humanus corporis*), and the disease is characterized by high fever, headache, and rash followed by kidney, heart, and neurological involvement.



## 10. Scrub Typhus (*Orientia tsutsugamushi*)

The etiological agents of scrub typhus were previously identified as *Rickettsia*, but are now identified as *Orientia tsutsugamushi*. The bacteria are transmitted by mites and cause a disease characterized by fever, headache and skin rash. Scrub typhus has a high mortality rate.

### The "Dark Side" of *E. coli*

Bacteria identified as *Escherichia coli* (*E. coli*) are Gram-negative, facultatively anaerobic coliforms long-recognized as being a part of the **normal microbiota** within the human G.I. tract. These bacteria form protective bacteriocins, help us digest food and produce vitamins. They are well known in microbiology laboratories as research tools and as hosts for the production of recombinant proteins. *E. coli* are also a potential pathogens, and some of the more virulent strains are indicated here.

- 1. Enterotoxigenic *E. coli* (ETEC)** - The enterotoxigenic strains of *E. coli* produce protein exotoxins that act as enterotoxins (affect the G.I. tract). When the bacteria bind to host cells, their toxins are released at the cell surface. Some bind outside, others enter the cell. They cause increased production of cyclic AMP or cyclic GMP which changes the cell's membrane function. The epithelial cells secrete chloride ions and close their sodium gates so that excess electrolytes accumulate outside the cell. Water leaves via osmosis, and the result is diarrhea. In infants, this loss of fluid and electrolytes can be fatal.
- 2. Enteropathogenic *E. coli* (EPEC)** - The enteropathogenic strains of *E. coli* do not produce exotoxins, but bind to their host cells (via a protein called intimin) and cause them to lose their microvilli. This causes characteristic lesions on the surfaces of villi. The cells also experience an increase in intracellular calcium and a derangement of their cytoskeleton. Some cells take the bacteria into endocytic vesicles. The overall effect is to cause cells to secrete excess chloride and stop the influx of sodium. Again, the result is severe diarrhea and fluid loss.
- 3. Enterohemorrhagic *E. coli* (EHEC)** - The enterohemorrhagic *E. coli* cause only a few of the over 20,000 cases of *E. coli* associated diarrhea in the United States each year, and occur in sporadic outbreaks. The most common serotype involved is O157:H7. These bacteria cause lesions in the intestine similar to the EPEC. They also produce large quantities of a toxin known as **verotoxin** or **shiga-like (Shigella-like) toxin**. This toxin inhibits protein synthesis and causes the death of endothelial cells lining the blood vessels within villi. The result is dysentery with hemorrhage into the intestinal lumen. It also causes hemolytic uremic syndrome, when the endothelium is damaged in both the gut and the kidney. The roughened endothelium causes fibrin to form which slices RBCs as they pass. Normal clotting mechanisms may be damaged as well, resulting in widespread internal hemorrhaging. Death may occur due to hemorrhage or kidney failure.
- 4. Enteroinvasive *E. coli* (EIEC)** - The enteroinvasive *E. coli* cause dysentery symptoms essentially like those of *Shigella* sp. though they do not produce shiga-like toxins. These strains actively invade cells of the colon and spread laterally to infect other cells.

*Escherichia coli* in the bloodstream can cause a rapidly fatal form of septicemia due to the effects of the lipopolysaccharide (LPS) portion of their Gram-negative cell walls. The LPS triggers factors that can cause fever, abnormal blood clotting and circulatory shock.

The *E. coli* that live as "normal microbiota" within your intestinal tract may be pathogenic to someone else, so please keep them to yourself.