Microorganisms and Human Disease  
(Chapters 21-26)  
Microbial Diseases of the  
Skin, Eyes, and  
Nervous, Cardiovascular, Lymphatic,  
Respiratory, Digestive, Urinary, and  
Reproductive Systems  

Lecture Materials  
for  
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Primary Source for figures and content:  
The Integumentary System

Epidermis: protective 1. Thick, multicellular layer, apical surface shed  
2. Keratinized cells, impenetrable  
3. Perspiration = salt & lysozyme  
4. Sebum = fatty acids

Dermis: blood supply

*Normal flora/microbiota must be salt and acid resistant.  
*To access to protected dermis, pathogens must penetrate epidermis through hair follicles, sweat glands,  
sebaceous glands, or damaged/broken epithelium

The Eyes: Conjunctiva (Mucous membrane)

Conjunctivitis = inflammation of the covering of the eye (“pink eye”), many infectious causes
The Nervous System

Peripheral Nervous System (PNS) = nerves, nervous tissue outside the CNS
- covered by meninges (connective tissue sheaths)
- surrounded by Cerebrospinal Fluid (CSF): contains no phagocytes, complement or antibodies
- protected by the blood brain barrier (but this also restricts access of leukocytes, complement and antibodies from the blood)
* No normal flora/microbiota
* Pathogens gain access to the CNS via trauma, travel along peripheral nerves, or by blood infection that causes inflammation to break down the blood-brain barrier
The Circulatory System:
The Cardiovascular System & The Lymphatic System

Cardiovascular System:
- Heart
- Arteries
- Veins
- Capillaries
- Blood & Blood cells

Lymphatic system:
- Lymphatic capillaries
- Lymphatic vessels
- Lymphoid follicles
  - MALT (Peyer’s Patches)
- Tonsils
- Lymphoid organs
- Lymph nodes
- Spleen
- Thymus
- Lymph & Lymphoid cells

*No normal flora/microbiota
*Infection in tissues easily gains access to lymphatic and blood vessels

Lymphangitis = inflammation of a lymph vessel due to microbe infection or toxins

Septicemia = proliferation of microbes in the blood

Septic shock = septicemia that leads to body-wide inflammation resulting in a drop in blood pressure that could be fatal

Endotoxic shock = septic shock caused by Gram negative organisms shedding LPS into the blood stream thus triggering body-wide inflammation
**The Respiratory System**

*Upper respiratory system colonized by many types of normal flora/microbiota*

*Lower respiratory system should be "clean": no normal flora/microbiota*

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**Pharyngitis** = inflammation of the mucosa of the pharynx (sore throat)

**Laryngitis** = inflammation of the laryngeal folds (vocal cords)

**Sinusitis** = inflammation of the mucosa of the sinuses

**Pneumonia** = inflammation of and fluid accumulation in the lungs
Accessory structures: teeth, tongue, salivary glands, liver, gallbladder, pancreas

Gastrointestinal Tract (G.I.): Mouth to anus

*Heavily colonized by normal flora/microbiota, most are located in the colon

Diseases:

1. Infection = colonization and growth of the microbe in the G.I. causes signs and symptoms of disease
2. Intoxication = ingestion of preformed bacterial toxin which causes signs and symptoms of disease (organism need not be present in the G.I.)

Both cause cramps, nausea, diarrhea and vomiting

Dysentery = diarrhea + blood + mucus

Gastroenteritis = inflammation of the mucosa of the stomach and intestine, fluid results in diarrhea
The Urinary System

* No normal flora/microbiota
* Opportunistic pathogens often originate from G.I.

  Cystitis = inflammation of the mucosa of the urinary bladder
  Pyelonephritis = inflammation of the kidney
The Reproductive System

Male

* No normal flora/microbiota
* Infections usually due to Sexually Transmitted Disease (STD) organisms

Female

* Vagina contains many normal flora/microbiota, mostly Lactobacillus
* Superior regions should be “clean”: infection by STDs can cause Pelvic Inflammatory Disease resulting in infertility
Bacterial Infections of the Skin

Staphylococci (*Staphylococcus aureus*): Gram + cocci
- coagulase: clot fibrin
- leukocidin: kill leukocytes

Scalded skin syndrome
- exfoliative toxin: peeling skin
- bacteremia → septicemia

Toxic shock syndrome
- bacteremia → septicemia

Streptococci (Group A β-hemolytic e.g. *Streptococcus pyogenes*): Gram + cocci
- >80 types classified by M-protein: antiphagocytic, aids adherence to mucosa
- hemolysins: RBC lysis
- streptokinases: fibrinolysis
- hyaluronidase: dissolve hyaluronic acid
- deoxyribonucleases: hydrolyze DNA
- proteases: hydrolyze proteins

Skin infections: folliculitis
- sty
- abscess

Menigitis
Pneumonia
Pharyngitis
Heart infections
Dental cavities
Ear aches
Impetigo
Necrotizing fasciitis
- exotoxin A: superantigen

*Pseudomonas* species: Gram – bacilli
- Skin infections
- Rash
- Ear infections
*Propionibacterium acnes*: Gram + bacilli

Acne: in sebaceous glands, sebum → free fatty acids, elicit neutrophil attack

**Viral Infections of the Skin**

**Warts** – Papilloma virus (HPV)

- infects & integrates in skin cells → proliferation

**Small pox** – Variola virus

- Variola major: 20% mortality
- Variola minor: < 1% mortality
- respiratory route transmission → organ infection, lesions
- no animal reservoir
- vaccination: last case 1977

**Chicken pox** – Varicella-Zoster Herpes Virus

- respiratory route transmission → skin, pus-filled vesicles
- low mortality
- latent in nerve ganglia
  - reactivation = Shingles
    - blindness, paralysis

**Herpes**

- Herpes Simplex Virus 1 (HSV1): oral lesions (cold sore, fever blister)
  - oral & respiratory route transmission
  - trigeminal nerve ganglia latency
- Herpes Simplex Virus 2 (HSV2): genital lesions
  - sexual transmission
  - sacral nerve ganglia latency

**Measles** – Rubeola virus

- respiratory route transmission → respiratory infection → rash & Koplik’s spots
- can be fatal in infants & elderly
- no animal reservoir
- vaccination
Fungal Infections of the Skin

Candidiasis – *Candida* species, *C. albicans*: dimorphic fungi

- Oral thrush
- Vaginitis
  (commensal of GI → opportunistic systemic mycosis in immunocompromised host)

Ring worm – Various fungi genera/species

- Mycosis of hair follicles, nails, epidermis

Bacterial Infections of the Eyes

- Neonatal gonorrheal ophthalmia – *Neisseria gonorrhoeae*: Gram – cocci
  - corneal scarring → blindness
- Trachoma – *Chlamydia trachomatis*: Gram – pleomorphic cocci
  - corneal scarring → blindness
  - greatest cause in infectious blindness worldwide

Viral Infections of the Eyes

- Herpetic keratitis – HSV1
  - corneal ulcers → blindness

Protozoan Infections of the Eyes

- Acanthamoeba keratitis – Amoebozoa protozoan
  - corneal digestion → blindness

Bacterial Infections of the Nervous System

Bacterial Meningitis

- *Streptococcus pneumoniae*: Gram + diplococci
- *Haemophilus influenzae*: Gram – bacilli
- *Neisseria meningitidis*: Gram – cocci
- transmitted via nasal secretions
- nasal & pharyngeal mucosa → throat infection → bacteremia → menigitis → shock
- 40% mortality
Tetanus – *Clostridium tetani*: Gram + bacilli, obligate anaerobe, endospore forming
soil → puncture wound → anaerobic infection → toxemia
tetanospasmin: neurotoxic to motor neurons = spastic paralysis
100% mortality untreated, treatment with tetanus immunoglobulin 25% mortality
toxoid vaccine

Botulism – *Clostridium botulinum*: Gram + bacilli, obligate anaerobe, endospore forming
soil & water → growth in anaerobic food → ingestion → toxemia
botulinum toxin: blocks Acetylcholine release at neuromuscular junction = flaccid paralysis
70% mortality
Botox

Leprocy – *Mycobacterium leprae*: acid-fast bacilli
generation time 12 d, optimal temp 30°C
inhalation → neuron infection, peripheral regions →
Tuberculoid leprocy: numbness and nodules on skin patches, spontaneous recovery or
Lepromatous leprocy: infection & necrosis of skin cells (poor cell mediated immunity)

**Viral Infections of the Nervous System**

Poliomyelitis – Poliovirus
replicates in GI, transmission via oral fecal route → tonsil infection → viremia → CNS motor nerve infection → necrosis → paralysis
no animal reservoir
vaccines

Rabies – Rabies virus
transmission via bite or saliva → muscle & CT (30-50 d) → nerves → CNS: fatal encephalitis:
paralysis & death
encephalitis causes agitation
vaccination effective after exposure
Fungal Infections of the Nervous System

Cryptococcosis – *Cryptococcus neoformans*: thick capsule yeast
inhalation of pigeon droppings → lung infection → blood → CNS: chronic meningitis
30% mortality

Other Infections of the Nervous System

Transmissible spongiform encephalopathies – prion
prion = infectious protein, misfolded, directs misfolding of other proteins
transmitted by ingestion or direct contact → CNS: progressive spongiform degeneration of neurons
Creutzfeldt-Jakob disease: source? genetic?
Kuru: cannibals of New Guinea

Bacterial Infections of the Cardiovascular System

Puerperal sepsis/Childbirth fever – *Streptococcus pyogenes*: Gram + cocci
uterus → abdominal cavity → blood → septicemia

Bacterial endocarditis – α-hemolytic Streptococci, *Staphylococcus aureus*: Gram + cocci
mouth (tooth extraction) → blood → heart valves: destruction

Rheumatic fever – *Streptococcus pyogenes*: Gram + cocci
pharyngitis →
autoimmune disorder: reaction to M protein → cross react with CT (joints & heart valves):
progressive destruction

Tularemia – *Francisella tularensis*: Gram – pleomorphic bacilli
rabbits & squirrels contact, or deerflies, ticks, lice bites → ulcer → lymph nodes →
septicemia → body-wide abscesses & organ infection
highly transmittable: 10 bacteria = full infection
survives in phagocytes
Brucellosis – *Brucella* species: Gram – bacilli
mucous membrane → uterus → chills, fever, malaise, abortion
grows on fetal carbohydrate
transmitted in milk
reproduces in macrophages

Anthrax – *Bacillus anthracis*: Gram + bacilli, endospore forming
soil → spore inhalation → multiply in macrophages → fatal septicemic shock
capsule does not elicit protective immune response
high mortality unless very early treatment

Gangrene – *Clostridium* species: Gram + bacilli, anaerobic, endospore forming
ischemic wound → necrotic tissue → anaerobic infection = gangrene
toxins promote necrosis of live tissue
enzymes digest into deeper tissues
*Clostridium perfringens*: soil & GI
treatment: amputation, hyperbaric chambers

Bubonic plague – *Yersinia pestis*: Gram – bacilli
mild infection in rodents
flea bite → blood & lymph → proliferates in phagocytic cells → buboes → fever & hemorrhages →
septicemic plaque → septic shock
pneumonic plague → death, 100% mortality in 3 days
(542-767 AD 25% of pop. of Europe died of plague)

Lyme disease – *Borrelia burgdorferi*: spirochaete
mild infection in mice
deer tick bite → rash → flu-like → body wide organ & tissue infections →
heart damage, facial paralysis, arthritis

Typhus – *Rickettsia* species
obligate intracellular parasite
endothelial cells → vessel hemorrhaging → “spotted” fever
Epidemic Typhus – *Rickettsia prowazekii*: Gram – pleomorphic bacilli
  human body lice feces → fever & hemorrhaging
  high mortality
Endemic murine typhus – *Rickettsia typhi*: Gram – pleomorphic bacilli
  rat flea → mild disease
Rocky Mountain Spotted Fever – *Rickettsia rickettsii*: Gram – pleomorphic bacilli
  tick (parasite of tick) → rash, headache, fever → kidney & heart failure

**Viral Infections of the Cardiovascular System**

Infectious Mononucleosis – Epstein Bar Virus (EBV)
  saliva → incubation 4-6 w → B cells → lymphocyte proliferation → fever, sore throat,
  swollen lymph nodes, weakness → latent B cell infection
Burkitts Lymphoma – EBV
  EBV + malaria concurrent → jaw tumor

**Viral Hemorrhagic Fevers**
  zoonotic diseases: animal host no illness
  transmission to human → internal organ hemorrhage
  vector borne: (mosquito)
    Yellow fever: monkey
    Dengue fever: unknown
  body fluid transmission:
    Ebola: unknown
    Lassa fever: rodents
    Hantavirus pulmonary syndrome: rodents

**Protozoan Infections of the Cardiovascular System**

Toxoplasmosis – *Toxoplasma gondii*: Apicomplexa protozoan
  rodent & cat feces → blood cells → brain damage or death to fetus (& immunocompromised)
Malaria – *Plasmodium* species: Apicomplexa protozoan

- Anopheles mosquito $\rightarrow$ RBC lysis $\rightarrow$ capillary blockage: kidney & liver failure, brain damage
- sexual cycle in mosquito, proliferation in human

**Bacterial Infections of the Respiratory System**

Streptococcal Pharyngitis (Strep throat) – *Streptococcus pyogenes*: Gram + cocci

- streptokinases: fibrinolysis
- streptolysins: host cell lysis
- resistant to phagocytosis

Scarlet fever – *Streptococcus pyogenes*: Gram + cocci

- erythrogenic toxin $\rightarrow$ pink skin rash
- high fever

Diptheria – *Cornebacterium diptheriae*: Gram + pleomorphic bacilli

- phage lysogeny = toxin production $\rightarrow$ inhibit protein synthesis
- airborne transmission $\rightarrow$ throat infection: sore throat, fever, neck swelling; gray membrane of fibrin, necrotic tissue & bacteria $\rightarrow$ suffocation
- toxoid vaccine

Pertussis/Whooping Cough – *Bordetella pertussis*: Gram – cocobacilli

- capsule inhibits phagocytosis
- throat infection $\rightarrow$ tracheal cytotoxin produced $\rightarrow$ ciliated cells destroyed: violent coughing, suffocation

Tuberculosis – *Mycobacterium tuberculosis*: acid-fast bacilli

- generation time 20 h
- replicates in macrophages
- high resistance
- inhalation $\rightarrow$ lung tubercles $\rightarrow$ Ghon complexes $\rightarrow$ septicemia
- weigh loss, coughing, with blood in sputum, fatigue
- 3 million die annually
Bacterial Pneumonia

*Streptococcus pneumoniae*: Gram + cocci
*Haemophilus influenzae*: Gram – bacilli
*Mycoplasma pneumoniae*: tiny, no cell wall

Lung inflammation → suffocation

Legionnaires disease – *Legionella pneumophila*: Gram – bacilli

Fresh water amoeba → inhalation → macrophages → pneumonia → death

No person to person transmission

**Viral Infections of the Respiratory System**

Common Cold – Rhinovirus

Respiratory mucosa → sneezing, coughing, nasal secretion, congestion

Self limiting, non fatal

Influenza – Influenza virus, enveloped with spikes

Chills, fever, headache, malaise, cold-like symptoms → secondary infections → death

Antigenic shift of spikes

Recombination between animal and human flu results in deadly strains

**Fungal Infections of the Respiratory System**

Histoplasmosis – *Histoplasma capsulatum*: dimorphic fungi

Inhalation of spores: bat feces → lung infection → blood & lymph → body-wide lesions

Mississippi & Ohio River valleys

Coccidiomycosis – *Coccidioides immitis*: dimorphic fungi

Inhalation of spores: dust storm → tuberculosis like respiratory illness

California & Arizona
Bacterial Infections of the Digestive System

Staphylococcal Food Poisoning – *Staphylococcus aureus*: Gram + cocci
resistant: heat, drying, salt, radiation, osmotic pressure
grows in food at room temp, produces enterotoxin (stable through 30 min boiling)
nose → food: enterotoxin (super antigen) → vomiting & diarrhea
quick onset, no mortality

Shigellosis – *Shigella* species: Gram – bacilli
survives stomach, replicates inside intestinal epithelial cells
shiga toxin: inhibits protein synthesis, causes necrosis of cells
human/primate feces → intestinal epithelium → shiga toxin → dysentery
some mortality
infectious with low dose exposure

Salmonellosis – *Salmonella enterica, S. typhimurium*: Gram – bacilli
pathogen of animals and humans
transmitted on contaminated eggs, meat, contact with reptiles
animal feces → intestinal mucosa, multiplies in cells → diarrhea → blood & lymph → organ infections → septic shock,
requires high dose to be infectious
mortality 1% due to shock

Typhoid fever – *Salmonella typhi*: Gram – bacilli
oral fecal route of transmission
carriers: organism in gallbladder, shed to intestine, no symptoms

  Typhoid Mary
human feces → ulceration of intestine → bacteremia → death
  fever, headache, diarrhea

20% mortality
vaccine poorly effective
Cholera – *Vibrio cholerae*: Gram – vibrio, polar flagellum
oral fecal route of transmission from fecal contaminated water
phage conversion → cholera toxin: fluid & electrolyte loss from human cell
water → small intestine → cholera toxin → electrolyte & water loss → shock → death
vaccine poorly effective, many strains

*Escherichia coli* Gastroenteritis: Gram – bacilli
usually common harmless flora
pathogenic stains: altered fimbrae & toxin production
Traveler’s diarrhea strains: adhesive fimbrae & toxins: self limiting gastroenteritis
Enterohemorrhagic strains: adhesive fimbrae & shiga toxin → colon hemorrhage → blood →
organ infection → death
Cows & deer unaffected by shiga toxin

Peptic ulcer disease – *Helicobacter pylori*: spirilium
urease: urea → ammonia (buffer) for stomach colonization → ulcer, self destruction via acid
environmental source unknown

**Viral Infections of the Digestive System**

Mumps – Mumps virus
transmitted in saliva and respiratory secretions
saliva → respiratory tract → lymph nodes → viremia → salivary glands
can also infect testes & ovaries, cause meningitis, pancreatitis
vaccine effective
Hepatitis = viral infection and inflammation of the liver

Hepatitis A – Hepatitis A virus (HAV)
   fecal/oral → intestinal epithelium → viremia → liver, kidney, spleen
   anorexia, nausea, diarrhea, fever, chills, jaundice
   self limiting
   effective vaccine

Hepatitis B – Hepatitis B virus (HBV)
   blood & body fluids → liver: chronic = cirrhosis → cancer
   anorexia, nausea, diarrhea, fever, chills, joint pain, jaundice
   some mortality
   effective vaccine

Hepatitis C – Hepatitis C virus (HCV)
   blood & sexual contact → liver: asymptomatic 20 years + → cirrhosis → cancer →
   death
   high mortality
   no vaccine

Hepatitis D – Hepatitis D virus (HDV)
   coinfect with HBV → chronic liver infection → progressive damage → death
   (requires HBV envelope)

Hepatitis E – Hepatitis E virus (HEV)
   fecal/oral → (see Hep A) → mortality in pregnant females

Viral Gastroenteritis – Rotavirus
   fecal/oral transmission → fever, diarrhea, vomiting
   low mortality

Protozoan Infections of the Digestive System

Giardiasis – *Giardia lamblia*: Archaezoa protozoan
   fecal contaminated water, fecal/oral route
   water: cysts → intestine colonization → malaise, nausea, flatulence, weight loss, diarrhea
   interferes with nutrient absorption
   low mortality
Cryptosporidiosis – *Cryptosporidium parvum*: Apicomplexa protozoan
  fecal contaminated water, fecal/oral route
  water: oocysts → intestinal epithelium → diarrhea
  some mortality

Amoebic dysentery – *Entamoeba histolytica*: Amoebozoa protozoan
  fecal contaminated water, fecal/oral route
  water: cysts → trophozoites digest intestinal epithelium → dysentery

**Bacterial Infections of the Urinary and Reproductive System**

Gonorrhea – *Neisseria gonorrhoeae*: Gram – diplococci
  fimbriae for attachment
  infect between mucosal epithelial cells
  STD → mucosa infection → inflammation → scarring & infertility
  pus in males
  initially asymptomatic in female → pelvic inflammatory disease
  transmission to eyes of new born → blindness
  does not survive outside the body: human to human transmission only

Nongonococcal Urethritis (NGU) – *Chlamydia trachomatis* and others: Gram – pleomorphic cocci
  STD → mucosa infection → inflammation → scarring & infertility
  (see Gonorrhea)
  *C. trachomatis* is most common STD

Syphilis – *Treponema pallidium*: spirochete, obligate pathogen
  Stages:
    Primary: chancre → blood
    Secondary: rashes & lesions (contagious), hair loss, malaise, fever → latent →
    transmission to fetus → brain damage or still birth
    Tertiary: immune reaction to latent infection → lesions in organs
    paralysis, blindness, seizures, heart problems
Viral Infections of the Urinary and Reproductive System

Acquired Immune Deficiency Syndrome (AIDS) – Human Immunodeficiency Virus (HIV)

mutated monkey virus, entered human population in Africa ~1930
transmitted in blood or sexual body fluids
STD & blood → infects T Helper cells (CD4 cells) → integrates (reverse transcription) →
latent or replicating, death of CD4 cells → immunocompromised → death by secondary infections
rapid antigenic variation: high mutation rate
single patient can have > 100 million variants

stages (10 year progression):
Category A: asymptomatic, swollen lymph nodes
Category B: Candidiasis of mouth, throat, vagina
Shingles, diarrhea, fever, cancers
Category C: AIDS (CD4 cells <200)
severely immunocompromised
Candidiasis of bronchi & lungs
Tuberculosis, Pneumonia,
Toxoplasmosis of the brain,
Kaposi’s sarcoma (HSV8): cancer of CT