

MICROBIOLOGY: COMPREHENSIVE SYSTEMS-BASED REVIEW



An overview of general microbiology, immunology,
infection control, and major clinical infectious syndromes.



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Presentation Agenda:

From Foundational Principles to Clinical Syndromes



Part 1: Foundations of Microbiology

Cellular Structures: Prokaryotes vs. Eukaryotes

Visualization: Microscopy Techniques Bacterial Anatomy, Growth, and Genetics



Part 2: The Host Response & Control

Immunology: Innate and Adaptive Defenses

Infection Control: Hospital Protocols



Part 3: Clinical Syndromes: A Systems-Based Tou

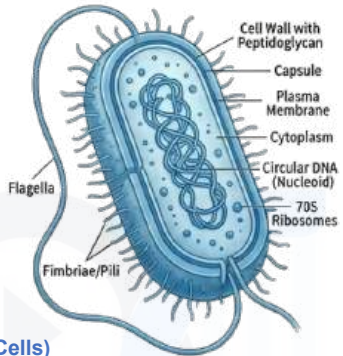
Coverage of major organ system infections from cardiovascular to the central nervous system.

Prokaryotic vs. Eukaryotic Cells:

Fundamental Differences in Structure

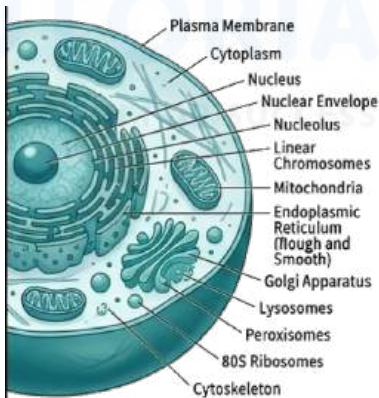
Prokaryotes (e.g., Bacteria)

- Genetic Material: Circular DNA in a non-enclosed nucleoid region.
- Organelles: Lack membrane bound organelles.
- Ribosomes: 70S size.
- Cell Wall: Contains peptidoglycan.
- Reproduction: Primarily via binary fission.



Eukaryotes (e.g., Fungi, Animal Cells)

- Genetic Material: Linear chromosomes within a true, membrane-bound nucleus.
- ↑Organelles: Possess mitochondria, endoplasmic reticulum, Golgi apparatus.
- Ribosomes: 80S size. Cell Wall: If present, composed of chitin (fungi) or cellulose (plants). Reproduction: Mitosis and/or meiosis.



Prokaryotic vs. Eukaryotic Cells: Fundamental Differences in Structure

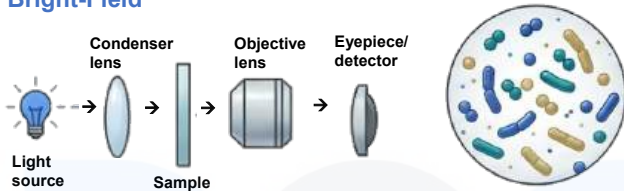
Feature	Prokaryotic Cell	Eukaryotic Cell
Nucleus	Absent (Nucleoid)	Present (True Nucleus)
DNA	Single, circular	Multiple, linear chromosomes
Organelles	Membrane-bound absent.	Membrane-bound present
Ribosomes	70S	80S
Cell Wall	Peptidoglycan (most)	Chitin/Cellulose (some)
Size	0.5-5 μm	10-100 μm

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Visualizing the Microbial World:

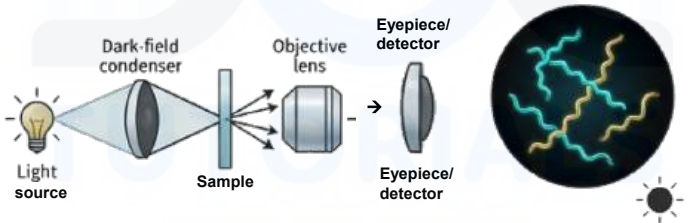
Four Key Microscopy Techniques

Bright-Field



Standard light microscopy using transmitted visible light. Best for stained specimens (e.g., Gram stains).
Low contrast for unstained, living organisms.

Dark-Field

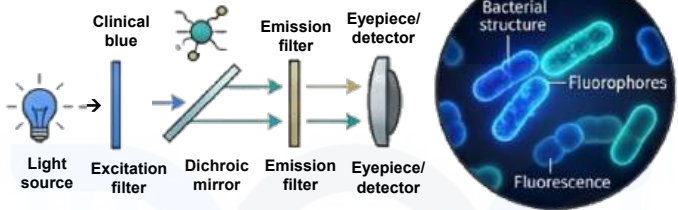


Specimen is brightly lit against a dark background, created by oblique lighting. Ideal for viewing live, unstained, or thin organisms like spirochetes (*Treponema pallidum*).

Visualizing the Microbial World:

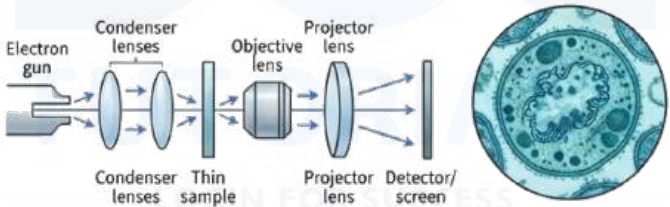
Four Key Microscopy Techniques

Fluorescence



Uses UV light to excite fluorophores that are attached to specific molecules. Provides high specificity and excellent contrast for targeting specific structures.

Electron (TEM)



Uses an electron beam instead of light for ultra-high resolution. Visualizes internal cellular ultrastructures but requires complex sample preparation (fixation, sectioning).

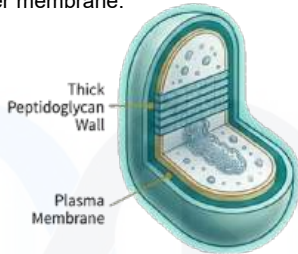


Bacterial Architecture:

The Gram-Positive vs. Gram-Negative Cell Envelope

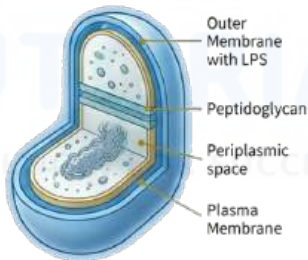
Gram -Positive Bacteria:

- Possess a thick, multi layered peptidoglycan cell wall.
- Lack an outer membrane.



Gram-Negative Bacteria

- Feature a thin peptidoglycan layer.
- Protected by an outer membrane containing lipopoly saccharide (LPS)

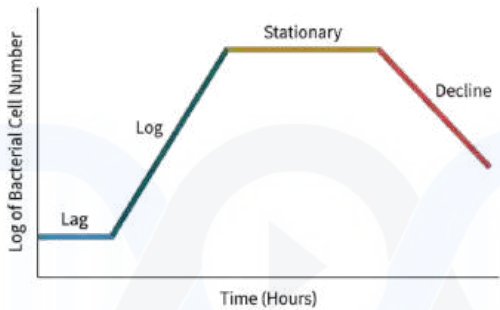


Common Surface Structures

- **Capsule:** Protective outer layer, aids in virulence
- **Flagella:** Provide motility.
- **Pili/Fimbriae:** Used for adherence and genetic exchange (conjugation)

Bacterial Growth Dynamics and the Diagnostic Workflow

Bacterial Growth Curve



- Lag Phase:**
Cells adapt; metabolic activity increases.
-
- Log (Exponential) Phase:** Rapid cell division at a constant rate.
-
- Stationary Phase:** Growth rate equals death rate.
-
- Decline (Death) Phase:** Cells die due to toxicity and nutrient depletion.

Laboratory Diagnosis Workflow

Step	Action	Key Consideration
1. Collection	Obtain specimen	Aseptic technique, site, optimal timing
2. Transport	Deliver to lab	Proper media, temperature control
3. Direct Tests	Initial analysis.	Gram stain, antigen
4. Inoculation	Plate specimen	Selective, enriched, or differential media
5. Incubation	Grow culture	Optimal temp/atmospheric conditions
6. Identification	Final analysis	Biochemical tests, MALDI-TOF, susceptibility

Mechanisms of Bacterial Genetic Exchange

Bacteria exchange genetic material to adapt, leading to phenomena like antibiotic resistance.



Transformation

The uptake of naked DNA fragments from the environment by a competent cell {e.g., *S. pneumoniae*}.



Transduction

DNA transfer mediated by a bacteriophage {a virus that infects bacteria}.



Conjugation

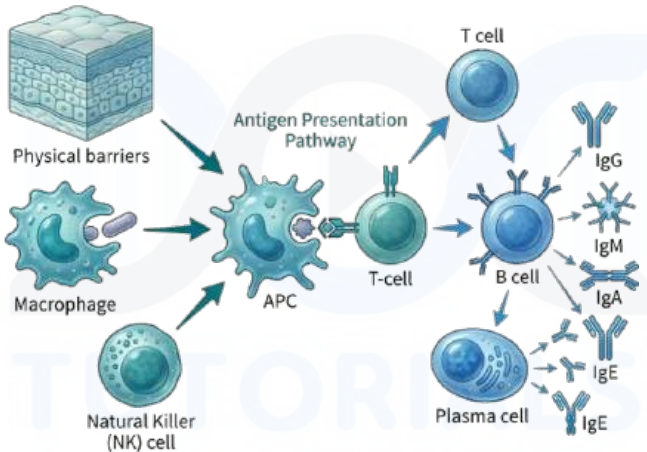
The direct cell-to-cell transfer of plasmid DNA {e.g., F-factor, R-factor plasmids) through a physical connection called a pilus.

The Immune System:

Innate and Adaptive Defenses

Innate Immunity

- The non-specific, first line of defense.
- Components: Physical barriers (skin), phagocytes (macrophages), and Natural Killer (NK) cells.



Adaptive Immunity

- A highly specific, antigen-driven response that generates memory.
- Mediated by T cells and B cells.
- Antigen Presenting Cells (APCs) bridge the innate and adaptive systems.
- B cells mature to produce antibodies (immunoglobulins). The five main classes are IgG, IgM, IgA, and IgE, each with specific roles.

Understanding Hypersensitivity:

The ACID Classification

Hypersensitivity refers to an exaggerated or inappropriate immune response to an antigen, leading to tissue damage.

Type	Mnemonic Name	Mediator	Onset	Mechanism & examples
Type 1	Anaphylactic (#2688D2 Clinical Blue)	 IgE	Minutes	Mast cell degranulation upon antigen cross-linking IgE. Ex: Anaphylaxis, allergies, asthma.
Type 2	Cytotoxic (#006A71 Scientific Teal)	 IgG, IgM	Hours	Antibody-directed cell lysis via complement or ADCC. Ex: Hemolytic anemia, Good pasture's syndrome.
Type 3	Immune Complex (#B58900 Muted Gold)	 Ag-Ab Complexes	Hours-Days	Deposition of soluble antigen antibody complexes in tissues, activating complement. Ex: SLE, Serum sickness.
Type 4	Delayed (#DC322F Warning Red)	 T-Cells	24-72 hrs	Sensitized T-cells release cytokines, activating macrophages. Ex: TB skin test, contact dermatitis.

Hospital Infection Control:

Core Pillars of Prevention

Standardized protocols are essential to prevent nosocomial (hospital-acquired) infections.

Hand Hygiene:

The cornerstone (WHO 5 Moments).

Personal Protective Equipment (PPE):

Correct donning/doffing for contact, droplet, & airborne precautions.



Sterilization & Disinfection:

Spaulding classification for medical instruments.

Device-Associated Infection Prevention:

Use of "bundles" to prevent CAUTI, CLABSI, and VAP.

Waste Management: Proper segregation and disposal of biomedical waste.

Clinical Syndromes I:

Cardiovascular, GI & Hepatobiliary Infections

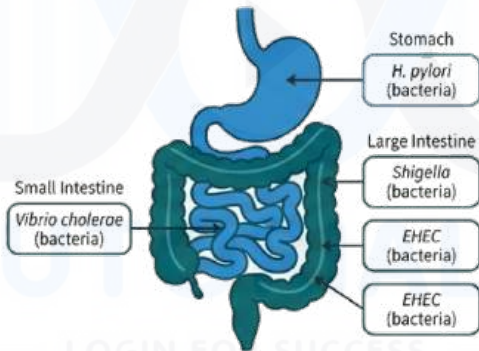
Bloodstream/Cardiovascular



Bacteremia: Presence of bacteria in the blood, which can progress to sepsis.

Infective Endocarditis: Infection of the heart's inner lining, typically the valves. Diagnosed using the Modified Duke criteria.

Gastrointestinal



Pathogens often localize to specific regions: *H. pylori* (stomach), *Vibrio cholerae* (small intestine), *Shigella* and *EHEC* (large intestine).

Hepatobiliary



Viral Hepatitis: Types A, B, C, D, and E differ in transmission routes and their potential to cause chronic infection.

Bacterial Syndromes: Include pyogenic liver abscess and cholangitis (infection of the bile ducts).

Clinical Syndromes II:

Skin, Soft Tissue & Respiratory Infections

Skin & Musculoskeletal

- **Bacterial:** Staphylococcus aureus (abscesses, impetigo), Streptococcus pyogenes (cellulitis, necrotizing fasciitis).
- **Fungal:** Dermatophytes cause tinea infections ("ringworm").

Respiratory Tract

- **Pneumonia:** Clinically differentiated into Typical & Atypical presentations



Feature	Typical Pneumonia	Atypical Pneumonia
Onset	Rapid, acute	Gradual, insidious
X-ray Pattern	Lobar consolidation	Patchy, diffuse infiltrates
Pathogens	S. pneumoniae, H. influenzae.	M. pneumoniae, C. pneumoniae, Viruses

Clinical Syndromes III: CNS & Urogenital Tract Infections

Central Nervous System (CNS)



- **Meningitis:** Inflammation of the meninges, which can be bacterial, viral, or fungal.
- **Encephalitis:** Inflammation of the brain parenchyma, most often viral in origin.
- **Neurotoxin-mediated diseases:** Tetanus (tetanospasmin) and Botulism cause severe neurological symptoms via potent bacterial toxins.

Urogenital Tract



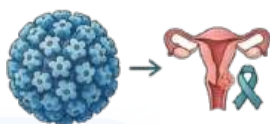
- **Urinary Tract Infection (UTI):** Most commonly caused by *E.coli* (~80%). Can be localized as cystitis (bladder) or ascend to become pyelonephritis (kidney).
- **Sexually Transmitted Infections (STIs):** Can present as urethritis/vaginitis (e.g., Gonorrhea, Chlamydia) or as genito-ulcerative diseases (e.g., Syphilis, Genital Herpes).

Special Topics:

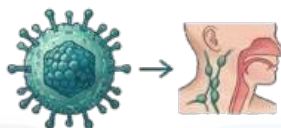
Oncogenic Viruses & Emerging Pathogens

Oncogenic Viruses

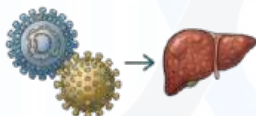
Viruses with established causal links to human cancers..



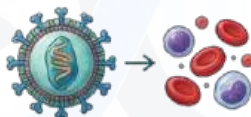
HPV: Cervical Cancer



EBV: Lymphoma,
Nasopharyngeal Carcinoma



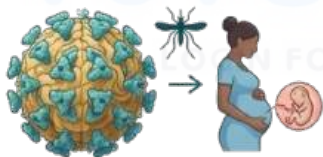
HBV/HCV: Hepatocellular
Carcinoma



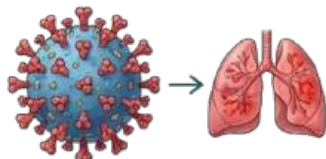
HTLV-1: Adult T-cell
leukemia/lymphoma

Emerging Viruses

Pathogens of recent global significance.



Zika Virus: Transmitted by Aedes mosquitoes; notable for causing congenital microcephaly.



SARS-CoV-2 (COVID-19):
Pandemic coronavirus transmitted by respiratory droplets, causing a spectrum of illness from asymptomatic to severe ARDS.

Core Principles & Conclusion



Structure Determines Function: Understanding bacterial cell wall differences (Gram+/-) is fundamental for diagnostics & antibiotic selection.



Prevention is Paramount: Hand hygiene, PPE, and vaccination are the most effective strategies against infectious disease transmission.



Rapid Diagnostics Save Lives: Modern molecular techniques (e.g., NAAT) enable faster pathogen identification and targeted therapy.

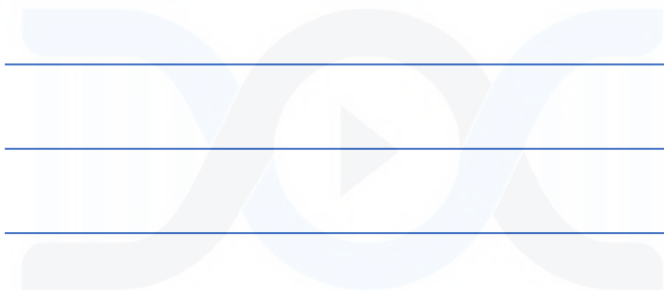


Antimicrobial Stewardship: Judicious use of antibiotics based on culture and susceptibility data is crucial to combat resistance.



A Systems-Based Approach is Key: Understanding infection by body system facilitates accurate clinical correlation and differential diagnosis.

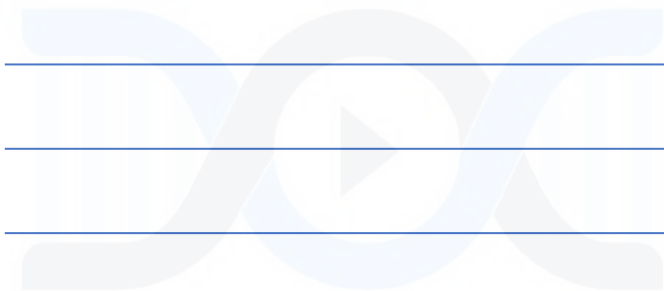
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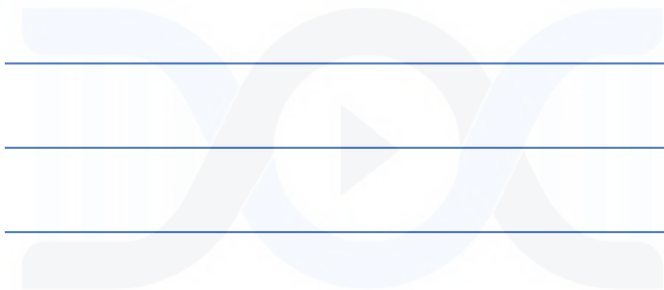
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