Understanding the ANTIMICROBIAL PROCESS

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The increasing number of antibiotic resistant strains of bacteria and rising number of hospital acquired (nosocomial) infections continue to stress the importance of sterile technique. Approximately two million US patients each year in acute care facilities suffer from nosocomial infections, costing approximately $3.5 billion. According to the Centers for Disease Control's Hospital Infections Program approximately one-third of nosocomial infections can be prevented through the use of well-organized infection control programs, but only 6 percent to 9 percent are actually prevented.[1]

Patients acquire infections through airborne contaminants, ineffective hand-washing agents or technique, ineffective sterilization or disinfection procedures, length of hospital stay, and crowding in ICUs.[2,3] The patient's own suppressed immune system, malnutrition or history of illness may contribute to susceptibility, as well as the level of bacterial resistance to treatment.[3]

Surgical site infection (SSI) is the second most common nosocomial infection (behind urinary tract infections). The primary cause of SSI is the patient's own endogenous flora, but other sources include airborne contaminants or exogenous flora from the surgical team and contaminated or improperly sterilized instrumentation. Environmental sources—such as unsterile medications, contaminated antiseptic solutions or wound dressings, and improper cleaning/decontamination of anesthesia equipment, IV lines or fluids—also pose risks.[2]

The purpose of this article is to help the surgical technologist understand types of pathogenic microorganisms, the environment in which they thrive, and the mechanisms of antimicrobial agents upon those organisms. An understanding of which could lead to more careful practice of sterile technique and better protection for the patient and the surgical team.

Classifications of microorganisms

Microbial cells can best be understood by categorizing their cellular organization into specific biologic forms. These cells are divided into internal compartments by membrane systems. The compartments have specific activities for the maintenance of the functions of the cell. The nuclear compartment (nucleus) contains the cells' hereditary material (DNA). Outside the nuclear membrane, the organelles of the cell (eg, ribosomes, Golgi apparatus, lysosomes) within the cytoplasm are encased by the cell wall of the organism.[8]

There are three classifications of pathogenic microorganisms:

Type 1, Acellular, consists of prions, viroids, and viruses. These are the smallest organisms able to demonstrate pathogenic potential (Figure 1).[12] Viruses are obligated intracellular parasites that depend entirely upon the host cells' synthetic machinery for reproduction and energy production. They contain either DNA or RNA. DNA viruses frequently mature in the host cell's nucleus, while RNA viruses mature in the cytoplasm.

Type 2, Unicellular, are divided into prokaryotic cells (chlamydiae, mycoplasmas, bacteria) and eukaryotic cells (fungi, protozoa, algae, and plant, animal and human cells).[12] Prokaryotes lack a true cell nucleus (Figure 2). Instead, the genetic material of the cell lies within the cytoplasm. Unlike acellular organisms, unicellular forms contain both DNA and RNA and reproduce through binary fusion.

Eukaryotes are larger than bacteria and their genetic material is separated from the cell cytoplasm by a nuclear membrane. Many reproduce by budding (yeast) or grow in colonies (mold).

Type 3, Multicellular, consist of helminths (adult worms, larvae, and ova) and arthropods (lice, ticks, and fleas).[12] Infections within this category depend on specie, total number of helminths supported with the body of the host,

Do you know the difference?

Asepsis—the absence of pathogens in vivo
Antisepsis—the prevention of infection in vivo
Antiseptic—an agent or used to kill or remove microorganisms on living tissue
Bacteriostatic—an agent or method that inhibits metabolism or reproduction of bacteria
Bacteriocidal/bacteriocide—an agent or method that kills bacteria but not their spores
Disinfection—a process of killing or removing microorganisms from fomites through chemical or physical means
Disinfectant—an agent used to kill or remove microorganisms on fomites
Fungicide—an agent or process that kills fungi
Microbiocidal—an agent or process that kills microbes
Microbiostatic—an agent or process that inhibits growth or reproduction of microorganisms through drying, freezing, antibiotics, etc.
Sanitation—a method to reduce microorganisms to levels deemed safe by public health standards
Sterilization—complete destruction of all living organisms, including cells, spores, and viruses
Virucide—kills viruses

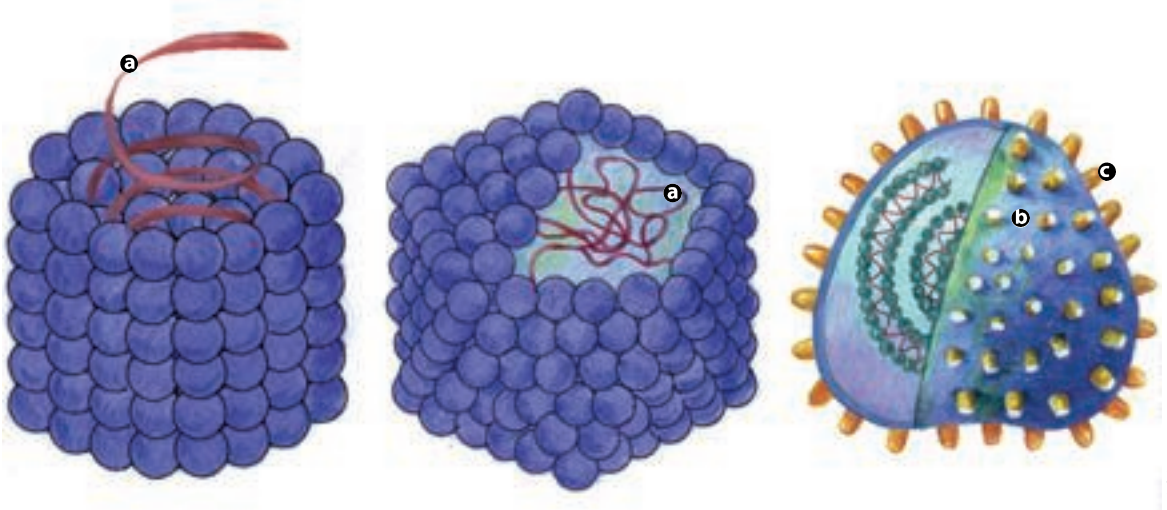


FIGURE 1

Types of viruses

ⓐ Nucleic Acid
ⓑ Envelope
ⓒ Spikes

and the host's defenses. The damage to the host varies from species to species. An example is the hookworm, which attaches directly to the intestinal mucosa and feeds on the blood often causing anemia within the host.

Arthropods are important medically because they infest the human skin or serve as vectors in transmission of other pathogens. Table 1 classifies common diseases by their type of pathogen.

Defense mechanisms of pathogens

• ***CAPSULE*** A few organisms, including a number of disease-producing bacteria, are able to manufacture a capsule that surrounds the entire exterior of the cell wall. The role of the capsule in the life of bacteria has yet to be discovered, but it does serve as a protective structure from phagocytosis.

• ***BACTERIAL CELL WALL*** The bacterial cell wall is rigid, provides protection, and gives shape to the cell. The most abundant substance of the cell wall is peptidoglycan, a complex of short peptides and sugars.[10]

Bacteria are divided into Gram-negative and Gram-positive groups based upon a reaction to a staining procedure, which is due to differences in their cell wall structures (Figure 3).[10] Gram-negative bacteria have a very thin peptidoglycan layer next to the cytoplasmic membrane.[10] The outer layer of these bacterial membranes is thicker and is composed of lipoprotein and lipopolysaccharide attached to the peptidoglycan layer. This outer membrane contains the somatic 0 antigens and the endotoxin characteristic of Gram-negative bacteria.[10]

Gram-positive bacteria have a heavy, rigid layer of peptidoglycan and teichoic acid that is thicker than that of Gram-negative cells. Gram-positive cells are most sensitive to the enzyme lysozyme, found in tears, saliva, and other body fluids, which hydrolyzes peptidoglycan.

• ***CYTOPLASM AND CYTOPLASMIC MEMBRANE*** Removal of the cytoplasmic membrane surrounding the entire cell will lead to bacterial lysis because the cell is unable to withstand the osmotic pressures found in nature.

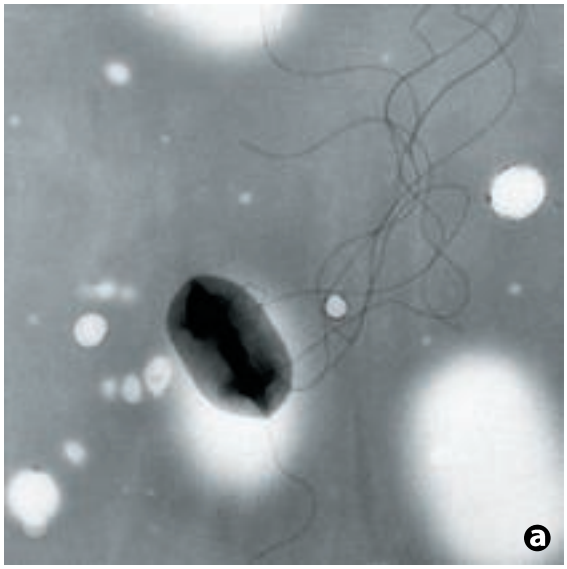
The cytoplasm contains ribosomes. Although the ribosomes function in a similar manner, it is possible to distinguish the ribosomes of prokaryotic cells from those of eukaryotic cells by their different sedimentation velocity in the ultra centrifuge. Bacterial ribosomes have a sedimentation value of 70s (svedberg units), whereas eukaryotic ribosomes are larger and heavier with a sedimentation value of 80s.[11]

• *SPORES* Approximately 150 types of bacteria produce spores. These bacteria form a tough shell within the cell during a resting stage. This

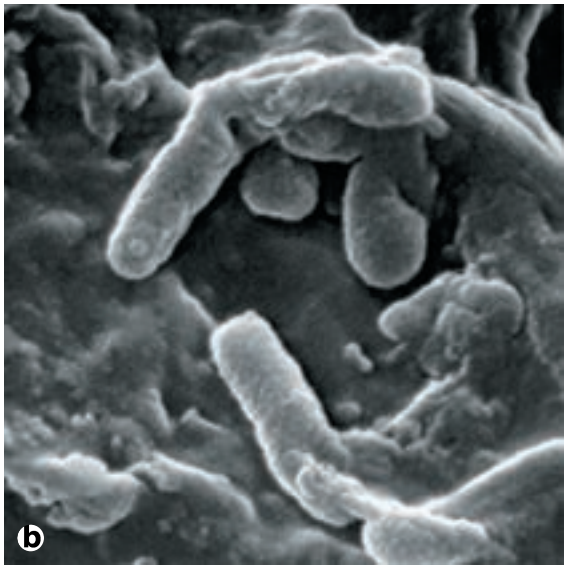
FIGURE 2

Examples of bacteria.

ⓐ *Escherichia coli* (transmission electron micrograph) with flagella, are Gram-negative intestinal bacterium that can cause diarrhea, urinary tract infection, and surgical site infection.
ⓑ *Pseudomonas aeruginosa* (scanning electron micrograph) are Gram-negative bacteria that are an opportunistic pathogen in hospitals and important in causing lower respiratory and urinary tract infections.
ⓒ *Streptococcus pneumoniae* (scanning electron micrograph) are Gram-positive bacteria and a common respiratory pathogen.
ⓓ *Bacillus anthracis* are rod-shaped, Gram-positive bacteria that cause anthrax.
ⓔ The *Enterococcus* species (scanning electron micrograph) was formerly in the *Streptococcus* family. This Gram-positive bacteria is a common cause of surgical site infections.
ⓕ *Legionella pneumophila* (transmission electron micrograph) is Gram-negative, rod-shaped bacteria that causes Legionnaires' disease



CDC/Elizabeth H White, MS, 1995



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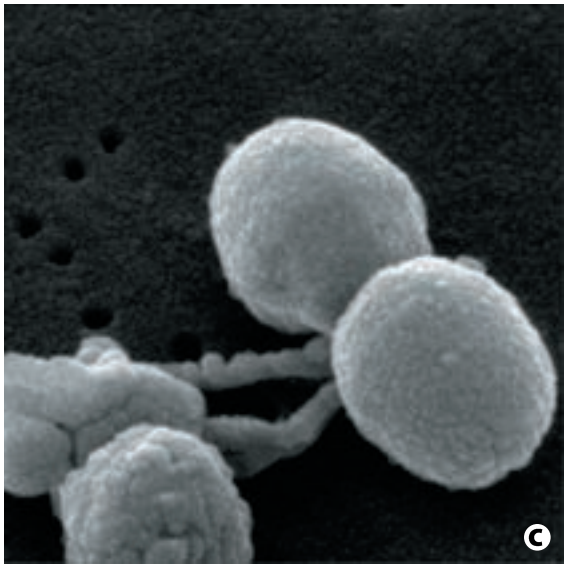

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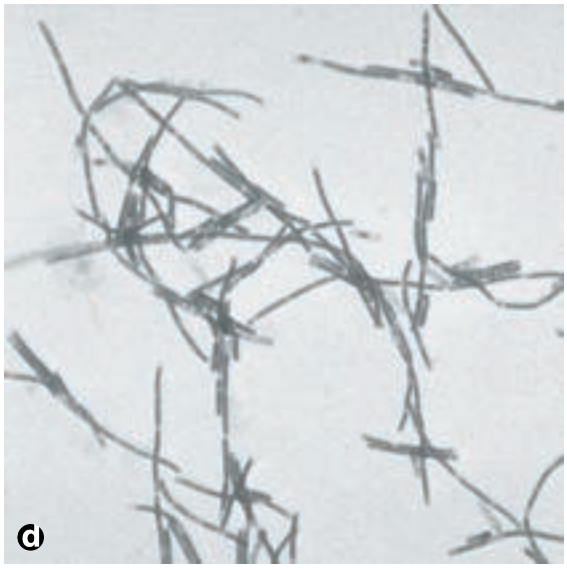

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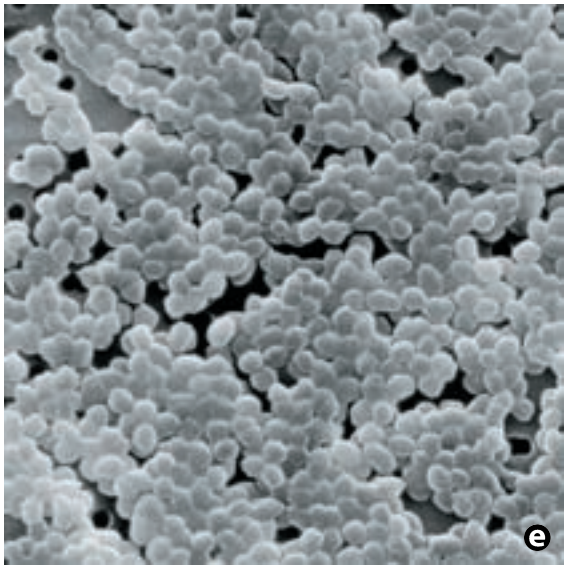

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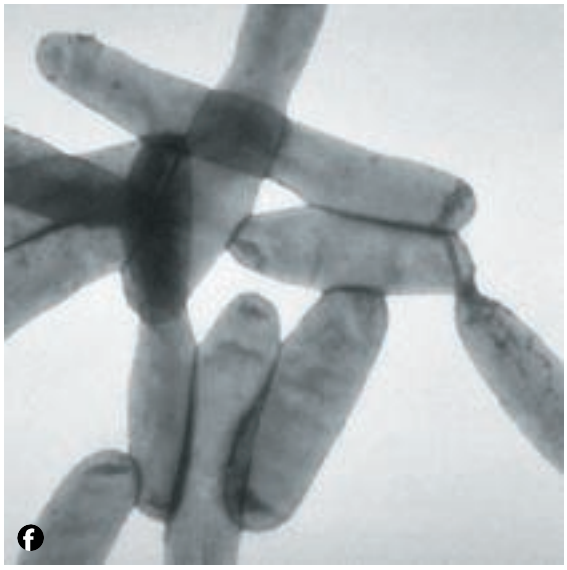

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shell protects the bacteria from changes in its environment. During this stage, it can survive without moisture or food, and even survive extreme hot or cold temperatures. When environmental conditions return to normal, the spore is able to grow and reproduce bacteria.[2]

• ***RESISTANCE*** Microorganisms have an incredible ability to adapt to their environment. They are able to mutate in several ways to avoid the negative effects of antimicrobial agents. They may change their cell membranes, receptor cites, or other aspects of their surfaces to keep the agent from binding with or entering the cell. Or, they may produce an enzyme that disables the antimicrobial agent. Over time, these organisms may become resistant to several agents typically used to kill them.[4] More about antimicrobial resistance was published in the June 1999 issue of *The Surgical Technologist.*

The antimicrobial process

Types of antimicrobial agents include antiseptic, disinfectant, sterilant and pharmaceutical. The use of these agents must be sufficient enough to achieve a therapeutic effect against the invading organisms. Knowledge of the biochemistry and mechanism of action of the specific agent is necessary when dealing with the surgical patient. By combining knowledge of the antimicrobial process with the structural function of the bacterial cell wall, cell lysis or destruction of the pathogen can be achieved effectively.

The action of these agents on microorganisms is more easily understood by analyzing the cellular components of microorganisms and the specific effects on the microbe by the agent of choice.[2,7] This action can be physical, chemical, or radiation.

Antiseptic agents

Antiseptic agents are chemicals used on tissue to either kill pathogenic organisms or inhibit their growth during contact between the agent and the organism.[7] Examples include hexachlorophene, iodophor, and benzalkonium (Zephiran chloride). Their effectiveness depends on both chemical and physical methods.

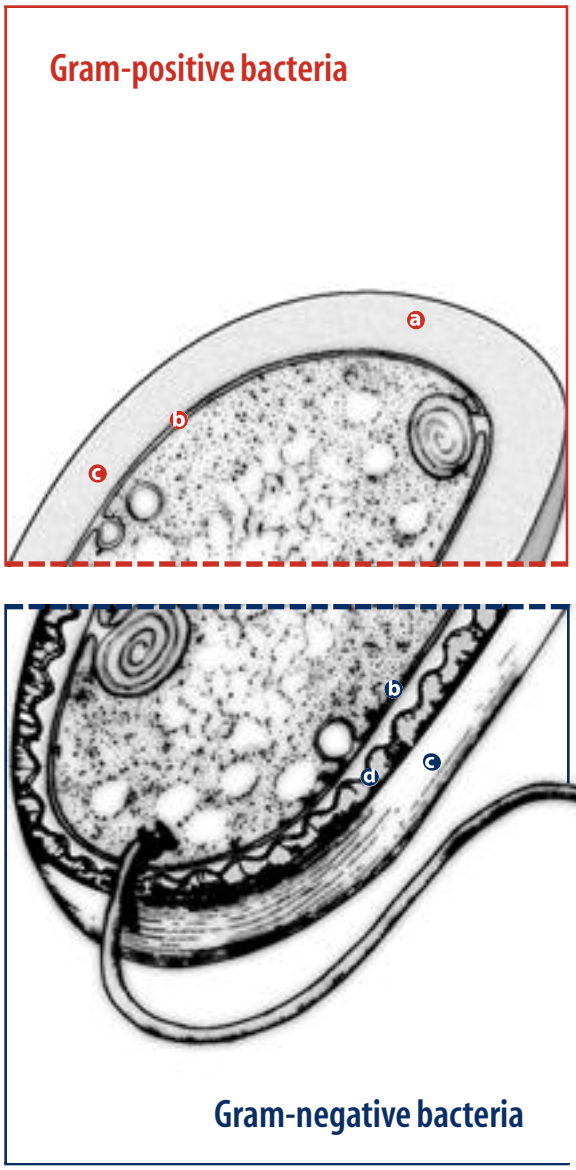
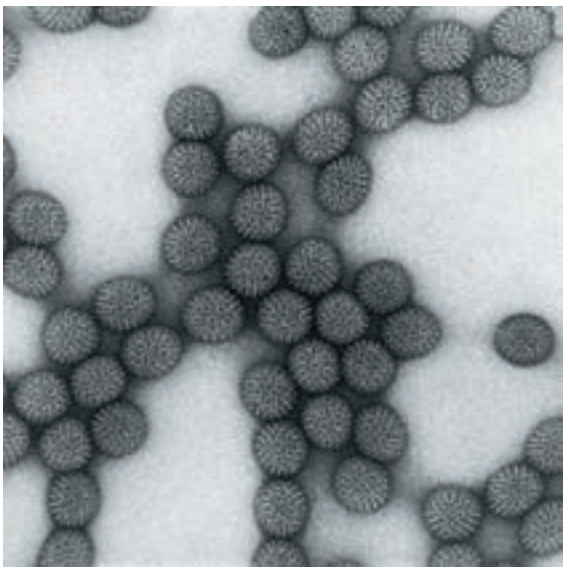


FIGURE 3

Differences in the cell walls of Gram-positive and Gram-negative bacteria

a Protein
Teichoic Acids
Peptidoglycan
b Cytoplasmic membrane
c Cell wall
d embrane
saccharide
ein



1978 CDC/ErskinePalmer

FIGURE 4

Transmission electron micrograph of rotavirus.

FIGURE 5

Transmission electron micrograph of influenza A virus.

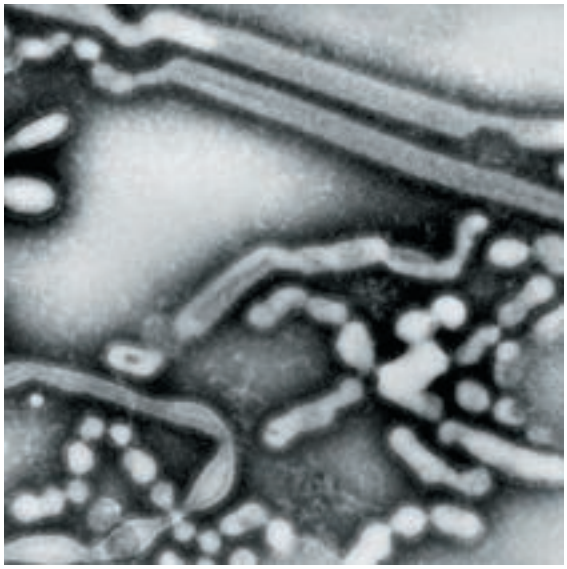


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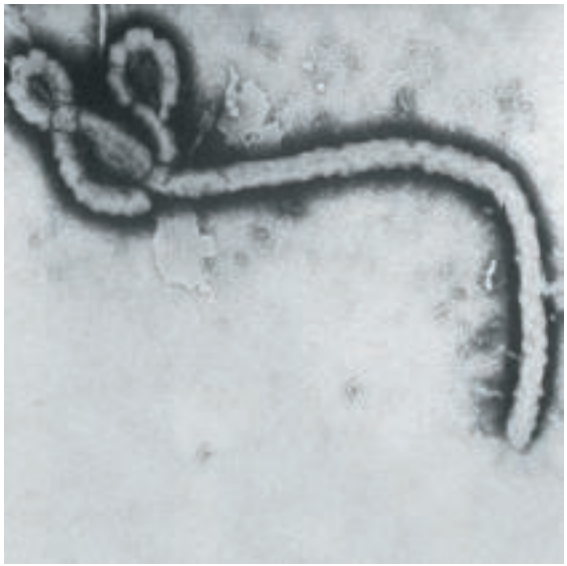
FIGURE 6

Transmission electron micrograph of Ebola virus.



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The physical action of rinsing and scrubbing is important in ridding the area of bacteria and other debris. Chemical agents, such as antiseptics, then affect pathogenic cells through disruption of the cell membrane, inactivation of enzymes or damage to the genetic material. The effectiveness of the chemical in killing pathogens depends on the following factors: exposure, time, concentration, pH or acidity of the solution, temperature, and bioburden.[2,4]

Pharmaceutical agents

Pharmaceutical agents are chemicals used on living tissue to destroy the microbe while preserving the tissue. These agents can be antibacterial (antibiotics), antifungal, antiviral or antipara-

TABLE 1 Diseases by type of pathogen[4,6]

Disease	Virus (acellular)
Bronchitis	Parainfluenza, RSV
Chickenpox	Varicella-zoster
HIV/AIDS	Human immunodeficiency (HIV)
Mononucleosis	Epstein-Bar, cytomegalovirus
Measles	Parainfluenza
Meningitis	Coxsackieviruses, echoviruses, mumps, herpes simplex
Mumps	parainfluenza
Pneumonia	Influenza, adenovirus, rhinovirus, coronavirus, parainfluenza

Disease	Bacteria (unicellular)
Anthrax	*Bacillus anthracis*
Cholera	*Vibrio cholerae*
Diphtheria	*Corynebacterium diphtheriae*
Meningitis	*Haemophilus influenzae*, *Neisseria meningitidis*
Pneumonia	*Haemophilus influenzae, Klebsiella pneumoniae, Staphylococcus aureus, Streptococcus pneumoniae*
Strep Throat	*Streptococcus pyogenes*
Syphilis	*Treponema pallidum*
Tetanus	*Clostridium tetani*
Typhoid fever	*Salmonella typhi*

Disease	Fungi (unicellular)
Athlete's foot	*Trichophyton, Epidermophyton, Microsporum*
Meningitis	*Cryptococcus neoformans*
Pneumonia	*Aspergillus fumigatus, Aspergillus favus, Aspergillus niger*
Systemic mycosis	*Blastomyces, Histoplasma, Cryptococcus, Coccidioides, Candida*
Ringworm infections	*Trichophyton, Epidermophyton, Microsporum*
Vaginal candidiasis	*Candida*

Disease	Protozoa (multicellular)
Gum Disease	*Entamoeba gingivalis*
Malaria	*Plasmodium falciparum, Plasmodium ovale, Plasmodium ovale, Plasmodium vivax, Plasmodium malariae*
Pinworm	*Enterobius vermicularis*
Pneumonia	*Pneumocystis carinii*

sitic. Examples of pharmaceutical agents include penicillin, aminoglycoside and miconazole (Monistat).[5]

Antibiotics can be classified on the basis of their action on the microbial cell:

1. Inhibition of cell wall synthesis occurs with penicillins, cephalosporins, bacitracin, and vancomycin. The mode of action is to inhibit peptidoglycan synthesis.[11]
2. Action against the cell membranes occurs with polymyxin, nystatin, amphotericin B, and imidazoles. These agents inhibit normal function of the bacterial cell membrane.[11]
3. Inhibitors of protein synthesis include aminoglycoside, tetracycline, chloramphenicol, erythromycin, and lincomycin. These antimicrobials bind to a subunit of the bacterial ribosome causing a blockage of the initiation complex, meaning they cannot form peptide bonds, through interference with attachment of tRNA to the ribosomes' mRNA complex and production of faulty proteins through distortion of the mRNA code.[11]
4. Inhibition of transcription and nucleic acid synthesis causing potent inhibition of bacterial DNA-dependent RNA polymerase occurs with rifamycin, chloroquine, sulfonamides, and trimethoprim.[11]

In the hospital setting, most infections are caused by bacteria and viruses (Figures 4, 5, and 6), although fungi and parasites occasionally are involved. Because viruses are particles that live inside the host's cells, antiviral agents have been difficult to find. Cells that are infected with a virus have some characteristics that differ from healthy cells. The action of pharmaceutical antiviral agents is based on inhibiting division of infected cells without affecting normal cells. Antiviral treatments for HIV, AIDS, herpes, influenza, even viral pneumonia are currently on the market.[2,5]

Antifungal agents can also be difficult to create because fungal cells are similar enough to human cells that the drugs used to treat their overgrowth can be toxic to humans. Fungi often live in the natural flora of the human body, but can become pathogenic, and sometimes life threatening, when the immune system is impaired, such as with AIDS (Figures 7 and 8).[5] Antifungal agents such as Amphotericin B and the azoles cause damage to the cell membranes of fungi, changing their permeability. 5-Fluorocytosine kills fungi by interfering with nucleic acid synthesis.[6]

Disinfectants and sterilants

Disinfectants and sterilants are chemical agents used on fomites and are categorized by levels of sterilization (Table 2). At the disinfectant level, the agents are effective on all microorganisms except spores, killing bacteria, fungi, viruses, etc.[2] At higher levels, disinfectants may also be used as sterilants to kill all organisms including spores. Varying the time of exposure or concentration

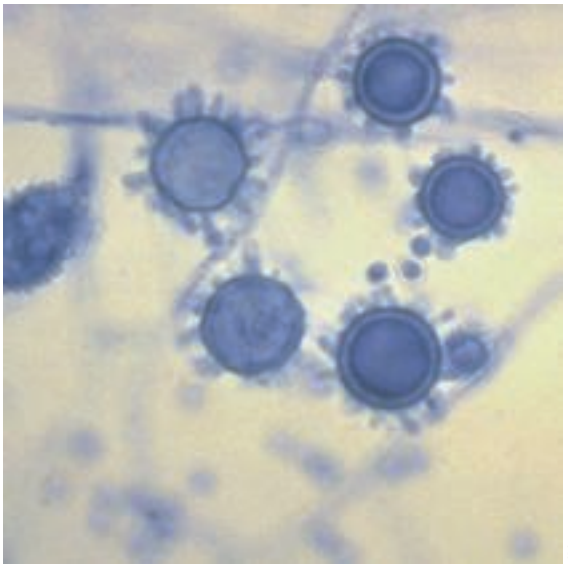

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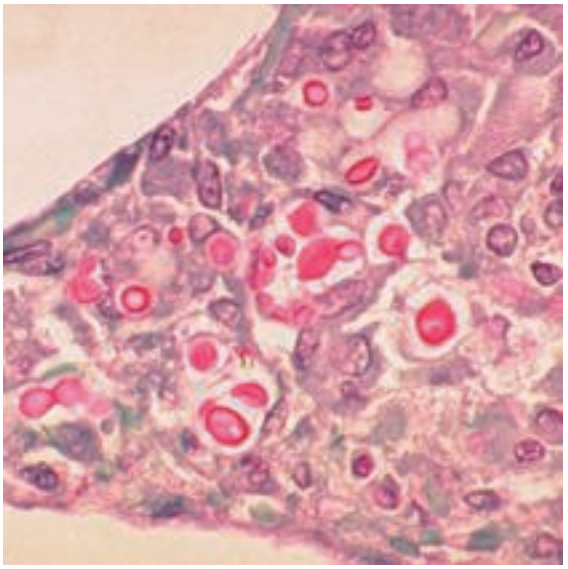
FIGURE 7

Asexual spores of *Histoplasma capsulatum*. Microconidia are also present.



1984 CDC/Edwin P. Ewing Jr.

FIGURE 8

Cryptococcosis of lung in a patient with AIDS.

Histopathology of lung shows widened alveolar septum containing a few inflammatory cells and numerous yeasts of *Cryptococcus neoformans*. The inner layer of the yeast capsule stains red.

TABLE 2 Disinfectant classification and use

Level	Effective against	Ineffective against	Use on	Examples
High Glutaraldehyde (Soacide or Cidex) Hydrogen peroxide solutions Paracytic Acid Chlorine compounds (Chlorine dioxide and chlorous acid)	All microorganisms except spores	Spores	Critical Items - items used in sterile tissue or body cavity	Surgical instruments, implants, hypodermic needles
Intermediate Phenolic compounds Iodophors, 450 ppm Isopropyl and ethyl alcohols	Fungi, bacteria, hydrophilic viruses, *M tuberculosis,* and HBV	Spores	Semicritical Items - items that come into contact with mucous membranes or non-intact skin but not used in sterile tissue or body cavity	Cystoscopes, colonoscopes, laryngoscopes
Low Chloride compounds Iodophors, 100 ppm Quaternary ammonium compounds (Quats)	Fungi, bacteria, hydrophilic viruses	Some viruses such as *M tuberculosis* and spores	Noncritical items - Items that contact only environmental surfaces and unbroken skin	Blood pressure cuff, OR furniture, OR tables

Adapted from Surgical Technology for the Surgical Technologist: A Positive Approach to Education.

of the solution based on the type of fomite is necessary to achieve complete sterilization. Problems with the strength, use, or contamination of disinfectants or sterilants used in the OR could compromise the infection control process.[2,4]

Chemical agents, such as iodophor and hexachlorophene, concentrate on the cell surface altering the physical and chemical properties of the pathogen's cell membrane. This prevents normal cellular function and either destroys or inhibits the pathogen. Alcohol and phenol are examples of chemicals that inactivate the pathogen's enzymes. Chemicals, such as formalin and Pyridium, damage the cells' genetic material (DNA and nucleic acids respectively), killing the microbials.[4]

Many chemical agents are hazardous to human skin or corrosive to equipment. When choosing a chemical agent, the surgical technologist should take into consideration the type of pathogens present, the toxicity to humans and the properties of the objects needing disinfection.[2]

Physical methods of sterilization effectively disable or kill pathogens by physically altering their environment. Temperature can affect a microbe's ability to reproduce and to metabolize nutrients. The temperature at which an organism thrives differs, but for many, normal body temperature is optimum. Thermal steril-