

# Healthcare Associated Infection(HAI) Prevention

# Healthcare Associated Infections (HAI)

One in every 25 hospital patients has at least one HAI

HAI incidences raise patient healthcare costs and time

HAI can cause death to affected patients

HAI prevention in healthcare institutions includes:

- Sterilization of devices
- Disinfectant cleansing of hospital surfaces
- UV lamps in patient rooms
- Surface engineering of polymers
- Functionalizing polymers used in medical devices and substrates with an antimicrobial additive

# HAI Risk Factors

**Latrogenic** - Pathogens on the hands of medical personnel, invasive procedures ( intubation, and extended ventilation, indwelling vascular lines, urine catheterization), antibiotic use and prophylaxis

**Organizational** - Contaminated air-conditioning and water systems, staffing and physical layout of the facility (nurse to patient ratio, open beds close together)

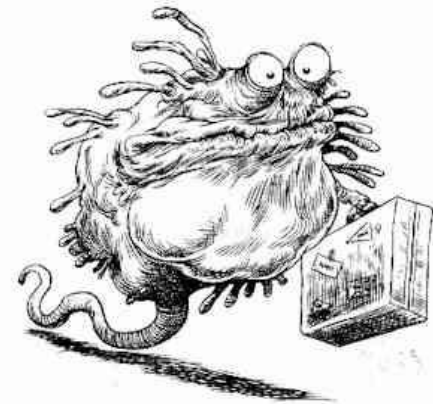
**Patient** - Severity of illness, underlying immunocompromised state, and length of stay

# Pathogen

Derived from Greek word “pathos” = suffering or passion

Infectious agents - also called microbe or microorganism

Can cause disease in an animal or plant host



# Types of Microorganisms

## Bacteria, Fungi/Mold, and Algae

Bacteria and Fungi/Mold feed off carbon found in polymers and causes degradation of polymer

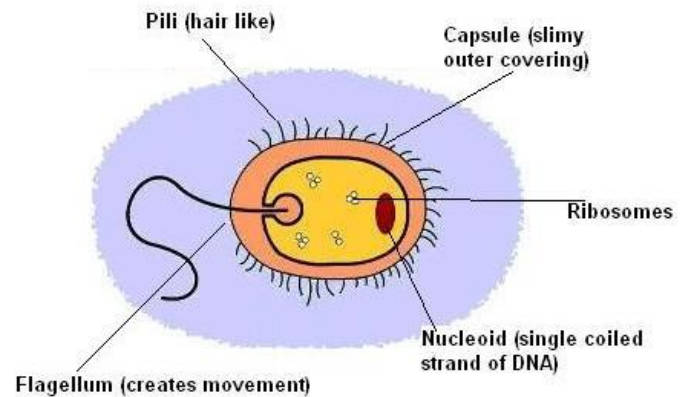
Algae doesn't harm polymer but traps water and is breeding ground for fungal growth

Bacteria is the biggest concern in medical plastics with fungi being a secondary concern

# Bacterial Resistance

Certain bacteria when attacked produce “spores” as a defensive mechanism

- Have thick walls
- Resistant to heat, humidity, and other difficult environmental conditions
- They can be hard to kill



# Biofilm Formation

Begins with attachment of free floating microorganisms to the plastic surface (weak Van der Waals forces)

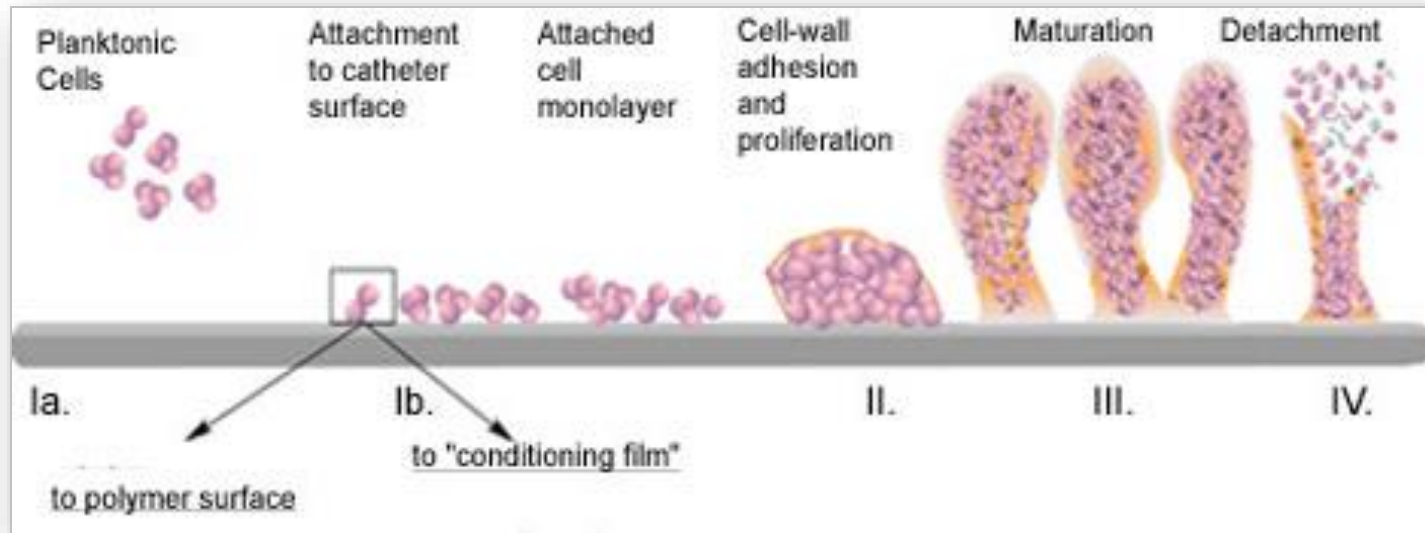
Colonies accumulate and grow (permanent anchorage to plastic surface)

Biofilm forms as colonies grow and mature (Cell division and recruitment)

Infection occurs when biofilm detaches from plastic substrate

Formed by gram positive or gram negative bacteria

# Biofilm Formation Diagram





# Infection Onset Risk

Device on threshold of entry in the body

Device left in place for **three or more days**

Handling and exposure of end of the device outside of body influence time of onset & severity of the infection

The longer the device is left in place, the greater the risk of infection

Infection occurs:

- At incision where device enters the body
- Bacteria detaches from device and travels into blood stream



Source: A.D.A.M. @ www.adam.com

# Antimicrobial

Destroying or suppressing the growth of microorganisms

Antimicrobial additives are used in medical plastics to destroy microorganism growth in order to prevent “biofilm” formation

# Types of Antimicrobial Effect

## Biocidal

- Killing the organism
- Inorganic additives



## Biostatic

- Preventing reproduction of the organism
- Organic and inorganic additives

# Antimicrobial Uses

Disinfect, sanitize, reduce, or mitigate growth or development of microbiological organisms.

Protect inanimate objects (for example floors and walls), industrial processes or systems, surfaces, water, or other chemical substances from contamination, fouling, or deterioration caused by bacteria, viruses, fungi, protozoa, algae, or slime.

# Antimicrobial Categories

**Non-public health products** - used to control growth of algae, odor-causing bacteria, bacteria which cause spoilage, deterioration or fouling of materials and microorganisms infectious only to animals.

**Public health products** - intended to control microorganisms infectious to humans in any inanimate environment.

# Generic Antimicrobials

**Sterilizers** - used to destroy or eliminate all forms of microbial life including fungi, viruses, and all forms of bacteria and their spores

**Disinfectants** (Hospitals) - used on hard inanimate surfaces and objects to destroy or irreversibly inactivate infectious fungi and bacteria but not necessarily their spores (completely destroys all specific test organisms in 10 minutes under conditions of the AOAC Use Dilution Test)

**Sanitizers** (Food Service) - used to reduce, but not necessarily eliminate, microorganisms from the inanimate environment to levels considered safe as determined by public health codes or regulations, including food contact and non-food contact products (destroys 99.999% of specified test bacteria in 30 seconds under conditions of the Official Detergent Sanitizer Test, also known as Weber & Black Test)

**Antiseptics and germicides** - used to prevent infection and decay by inhibiting the growth of microorganisms in living humans or animals; considered drugs and thus approved and regulated by the Food and Drug Administration (FDA).

# Antimicrobial Options for Medical Devices

## Surface coating device component

- Finite duration of effectiveness
- Surface treatment can be wiped off

## Device polymer additive

- Melt blended into polymer before component mfg.
- Permanently bound in polymer matrix

# Criteria for Antimicrobial Additive Technologies for Plastics

Effectively kills microorganisms (e.g., bacteria, fungi/mold, algae)

Proven safe & effective

Works in a variety of plastics

Works in a variety of conditions and environments



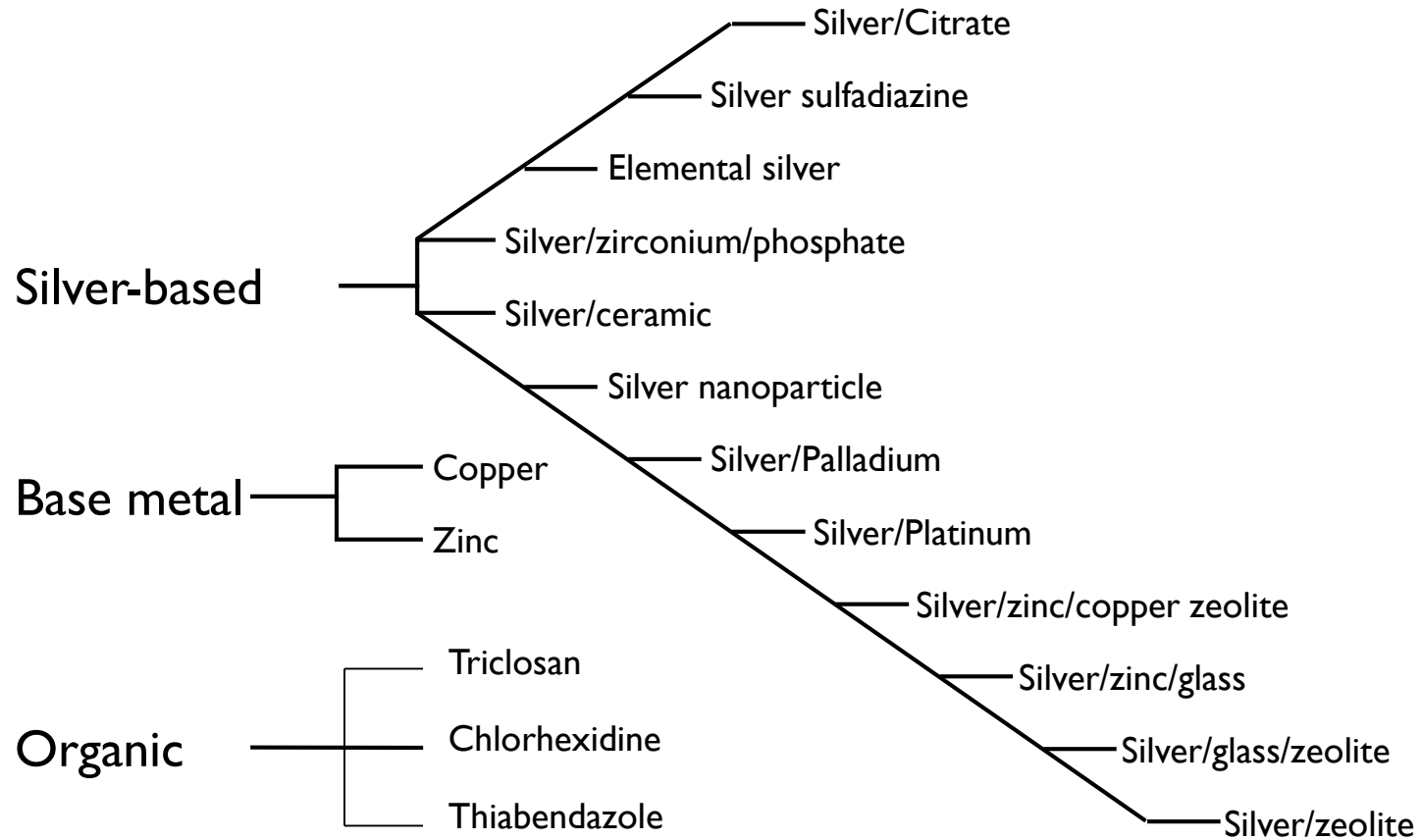
# Types of Antimicrobial Additives

**Organic** - Generally small molecules that are incompatible with the polymer matrix and diffuse to the surface of the polymer where they interact with microorganisms

**Inorganic** - Based on metal ions (e.g., silver) that are unreactive until released in association with another agent, such as moisture

*Antimicrobial additives remain stored in the polymer being released gradually to the surface, providing continual, long lasting activity*

# Antimicrobial Additives



Source: Wiktionary, Online Medical Dictionary

# Inorganic Antimicrobials

Based on metal ions (**e.g., silver**) - unreactive until released in association with another agent, such as moisture

Remain stored in the polymer being released gradually to the surface, providing continual, long lasting activity

Biocidal and biostatic effect

Bound within a delivery system such as ceramic glass, doped titanium dioxides, zeolites

Density of metal ions and delivery system regulate how quickly ions are released and the duration of the action

Less sensitive to temperature

# Ionic Silver Antimicrobial Additive

Silver metal, in itself, is not antimicrobial

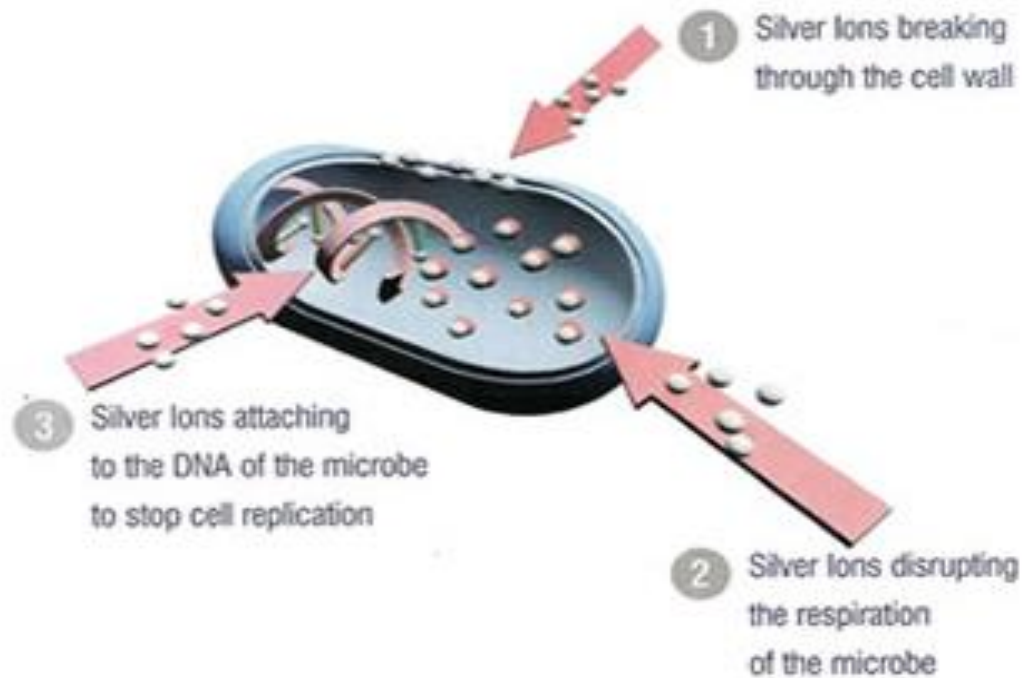
Silver ions, a by-product of oxidation, have excellent antimicrobial properties

Release rate is critical: too slow is ineffective; too fast not suitable for long term dwelling catheter

Release depends on amount & particle size of carbon and metal powders (also depends on permeability of the polymer composition)

# Ionic Silver Action

They inhibit the reproduction of the microbe by:



# Organic Antimicrobials

Generally small molecules that are incompatible with the polymer matrix and diffuse to the surface of the polymer where they interact with microorganisms

Biostatic effect

Reacts quickly to microorganism

Leaches out over time

Sensitive to high processing temperatures

Cost advantage

Used in disposable products

# Silane based Antimicrobial

- Organo-silane based antimicrobial
- Works against bacteria, fungi and algae
- Faster antimicrobial action than silver
- Effective against bacteria, fungi, algae
- Available in liquid, powder, other forms
- Works well in TPU's, nylon's, LDPE, silicone
- Does not discolor
- Does not work well with PC and PP
- Low loadings to achieve results
- EPA registered

# Other Antimicrobial Technologies

## Thiabendazole

- Organic
- Effective against fungi
- Film preservative
- Can be transparent

## Isothiazolinone

- Organic
- Effective against some bacteria, fungi, some algae
- Migratory

## Triclosan

- Synthetic organic chemical
- Many brands
- Commonly used in soaps, toothpaste, clothing, fibers, etc.
- Very potent
- Concern is that bacteria will become more resistant over time
- While questions persist, triclosan appears to be safe
- Not commonly used in medical devices

## OBPA

- Organometallic base
- Arsenic is an active ingredient
- Used in flexible PVC and polyurethane
- Effective against fungi
- Migratory
- Popular trade name is Vinyzene™

## Zinc Pyrithione

- Organic
- Effective against fungi, bacteria
- Used in cosmetics, paints, sealants
- Migratory
- Supplied as a powder



# Antimicrobial Additive Considerations for Medical Plastics

Addition level to achieve kill

Particle form and size

In-process stability with plastic

Migration characteristics

Ultraviolet light exposure

Heat stability of the antimicrobial

Chemistry of the polymer

Amount of active ingredient in the antimicrobial additive

Stability in water

# Antimicrobial Testing

Many tests for antimicrobial effectiveness

No internationally recognized standard methods for determining the efficacy of anti-bacterial plastics

Claims should not be misleading

# Antimicrobial Tests

USP 51 – antimicrobial effectiveness tests

USP 1227 – Neutralization validation

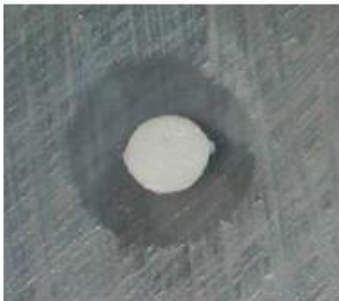
ASTM tests (E1153; E-2149; E2180; G21)

AATCC Methods (30, Part 3; 100; 147; 174, Parts 1 and 3)

Zone of inhibition

Soil burial

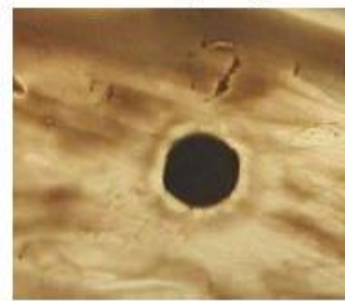
*Bacillus cereus*  
ATCC 14579



*Paenibacillus dendritiformis* C168



*Escherichia coli*  
MM294(pBS42)



*Pseudomonas putida*  
NRLL-B-14688



# Antimicrobial Efficacy Measurement

“Time-Kill” curves used to measure efficacy

Provides data in terms of “log-kill”

Log kill = ‘killing power.’

- One log is 90% kill,
- Two logs are 99% kill,
- Three logs are 99.9% kill
- Each log represents an additional 9

# Regulatory – United States

Antimicrobials/biocides are considered pesticides

Regulated by Environmental Protection Agency (EPA)

- Under Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
- Antimicrobial products must be registered with EPA before they are sold

# Regulatory - Europe

Antimicrobials/biocides are regulated by Biocidal Products Directive 98/8/EC adopted in 1998

Directs member states to have common procedures for evaluating and approving biocidal substances before 2008

Formulators and manufacturers must apply for authorization

- Assessment studies required
- Approval in one member state results in approval in all member states