STAPHYLOCOCCI

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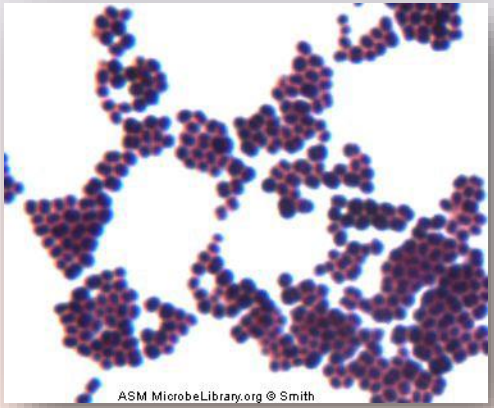
EUL Faculty of Medicine 2024-2025 Fall

General characteristics

- Gram-positive spherical cells arranged in irregular clusters
  - *staphylé*: a bunch of grapes
- May also appear as single cells, pairs or short chains

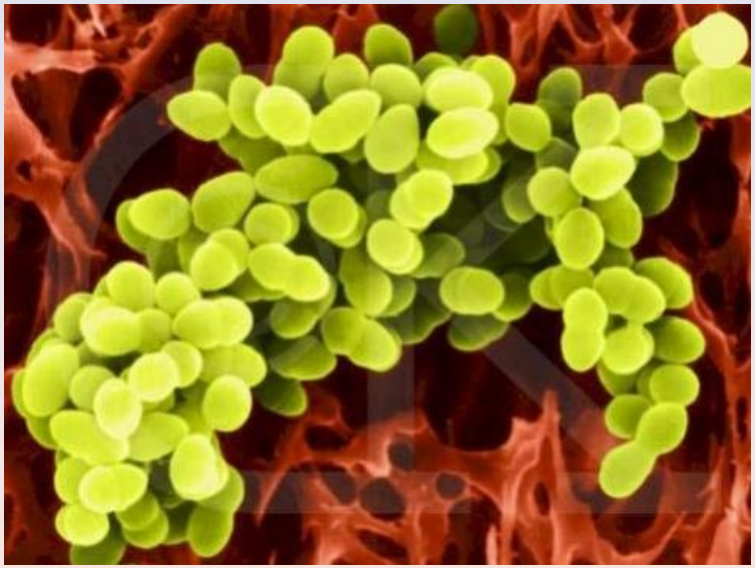


General characteristics

- Nonmotile
- Facultatively anaerobic
- Do not form spores
- Produce catalase
- Resistant to drying, heat and high concentration of salt
  - Can grow in media containing 10% of NaCl
  - Can grow at temperature of 18°C-40°C
- Produce pigments that vary from white to yellow
- Slowly ferment many carbohydrates; produce lactic acid
- Some are members of the normal flora

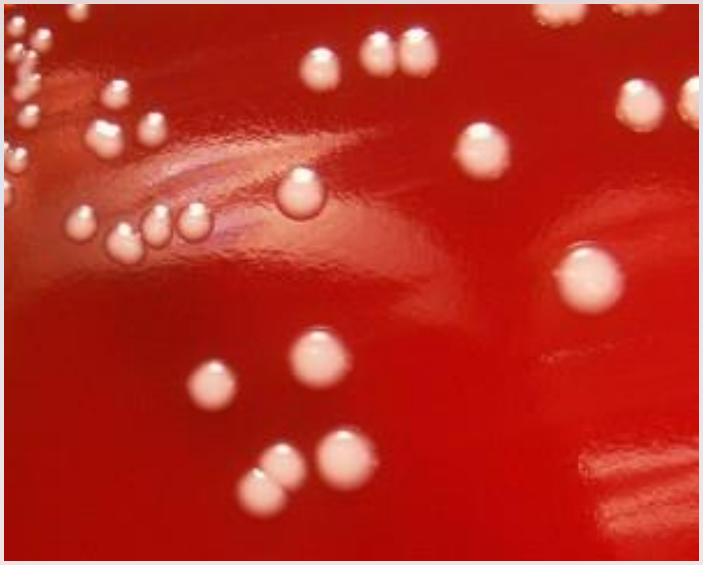
General characteristics

- The genus *Staphylococcus* has 45 species
- The species most commonly associated with human diseases:
  - *S. aureus*
  - *S. epidermidis*
  - *S. haemolyticus*
  - *S. lugdunensis*
  - *S. saprophyticus*



Morphological characteristics

- Grow readily on most bacteriologic media
- Grow most rapidly at 37°C but form pigment best at room temperature (20-25°C)
- Colonies are smooth, round, raised and glistening

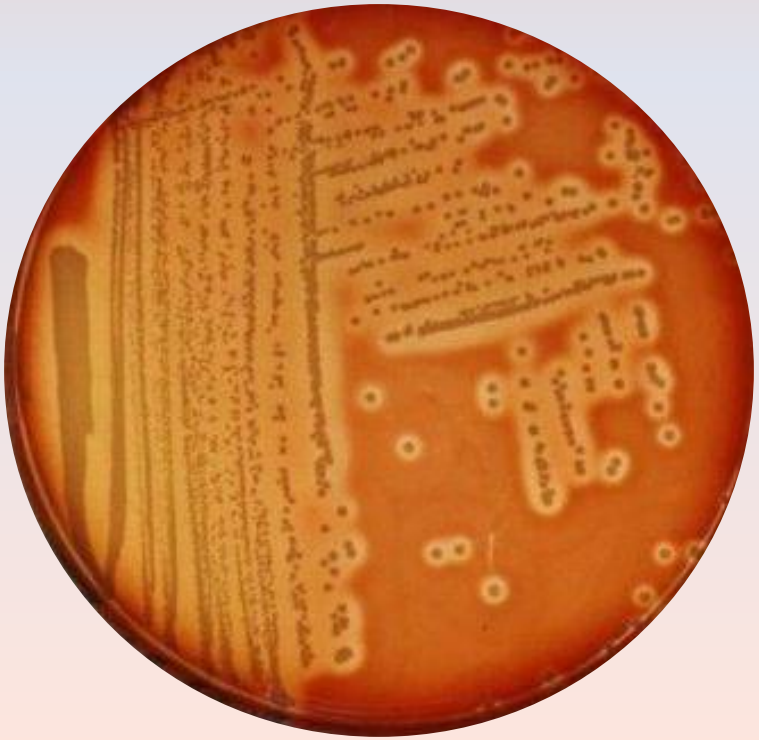


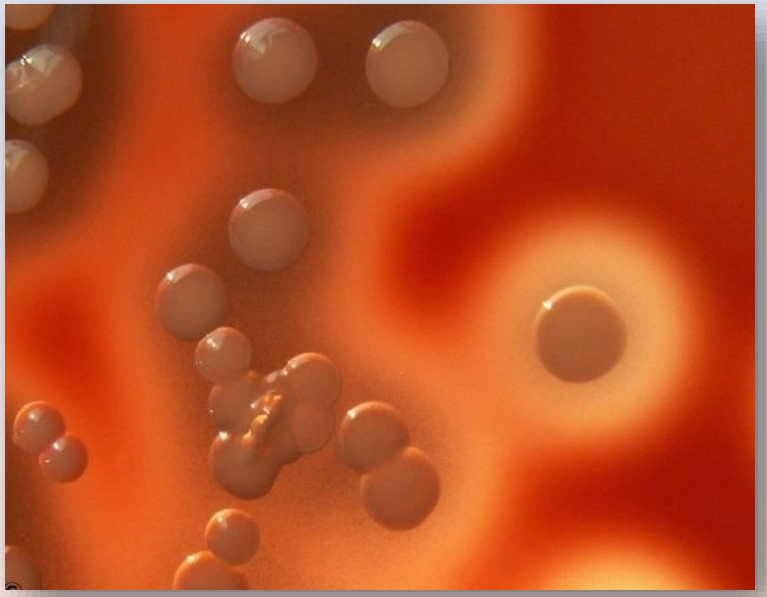
Morphological characteristics

- S. *aureus* usually form gray to deep golden yellow colonies
  - *aureus*: golden

Morphological characteristics

- *S. aureus* produces β-hemolysis when grown on 5% sheep blood agar





Staphylococcus aureus virulence factors

Structural components

- Capsule and slime layer
- Peptidoglycan
- Teichoic acids
- Protein A
- Clumping factor

Enzymes

- Catalase
- Coagulase
- Hyaluronidase
- Fibrinolysin
- Lipases
- Nuclease

Toxins

- Cytotoxins
- Exfoliative toxin
- Toxic shock syndrome toxin
- Enterotoxins

Structural components

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- Peptidoglycan
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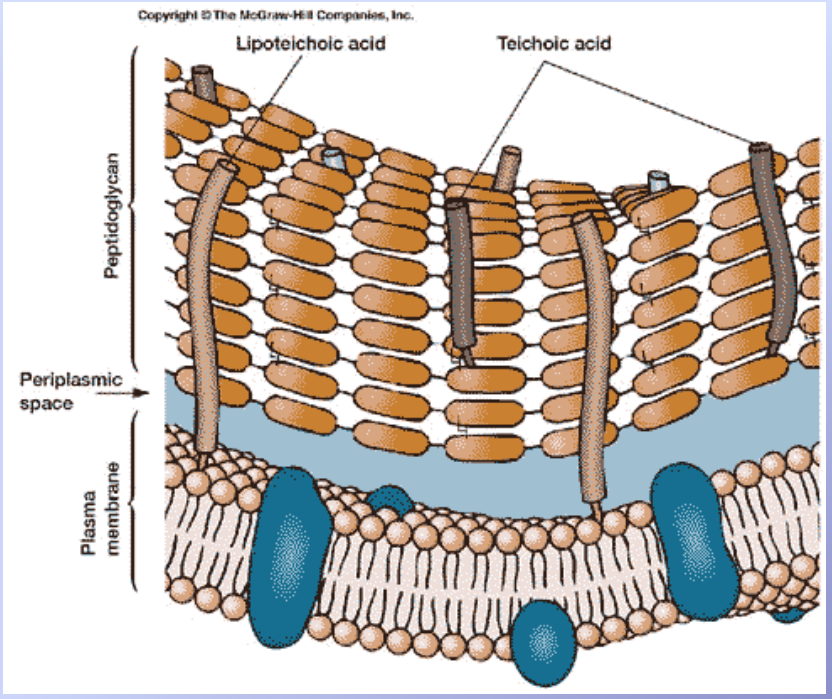
- Protein A
- Clumping factor

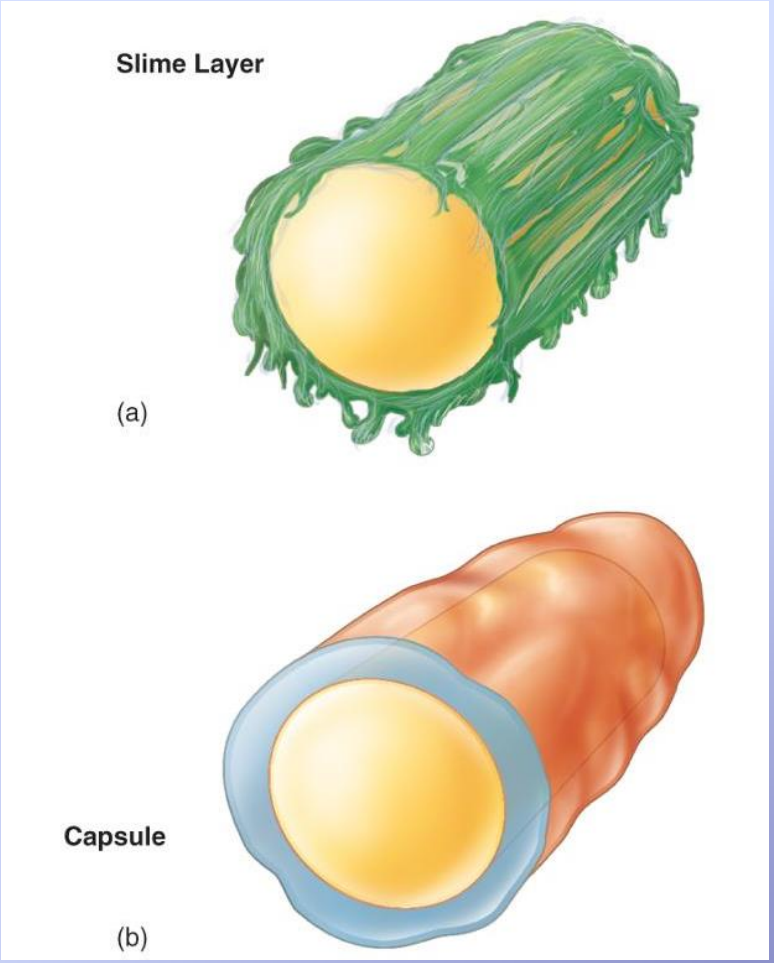


Structural components

Capsule and slime layer

Capsule:

- Polysaccharide capsule
- Inhibits phagocytosis by PMNs

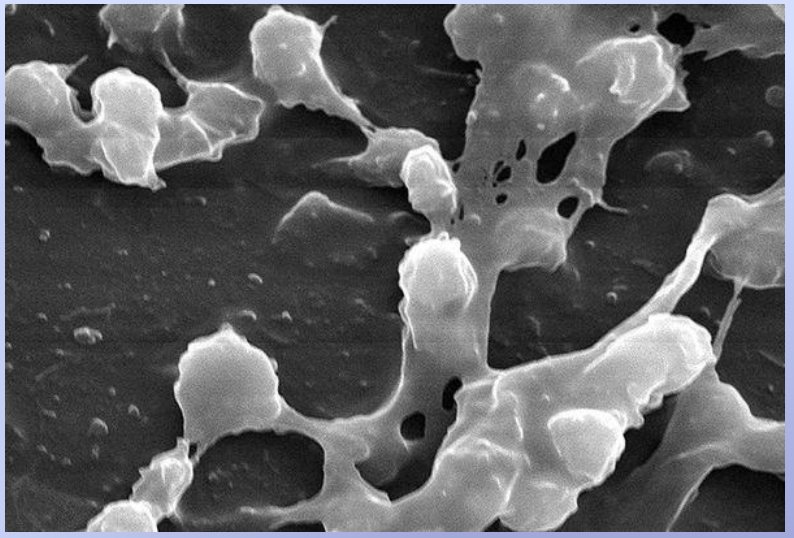


Structural components

Capsule and slime layer

Slime layer:

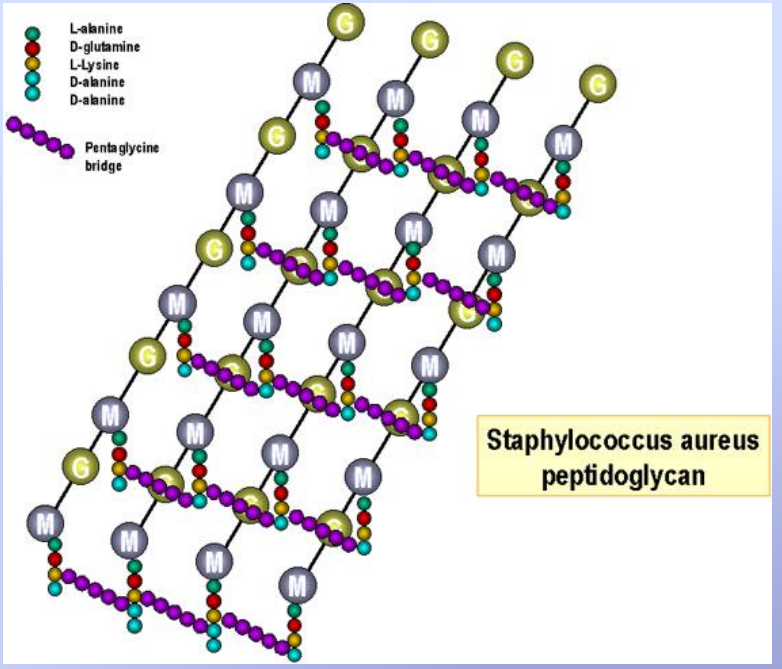
- Loose bound, water-soluble film
- Consists of monosaccharides, proteins and small peptides
- Binds bacteria to **tissues** and **foreign bodies** (catheters,and etc ...)



Structural components

Peptidoglycan

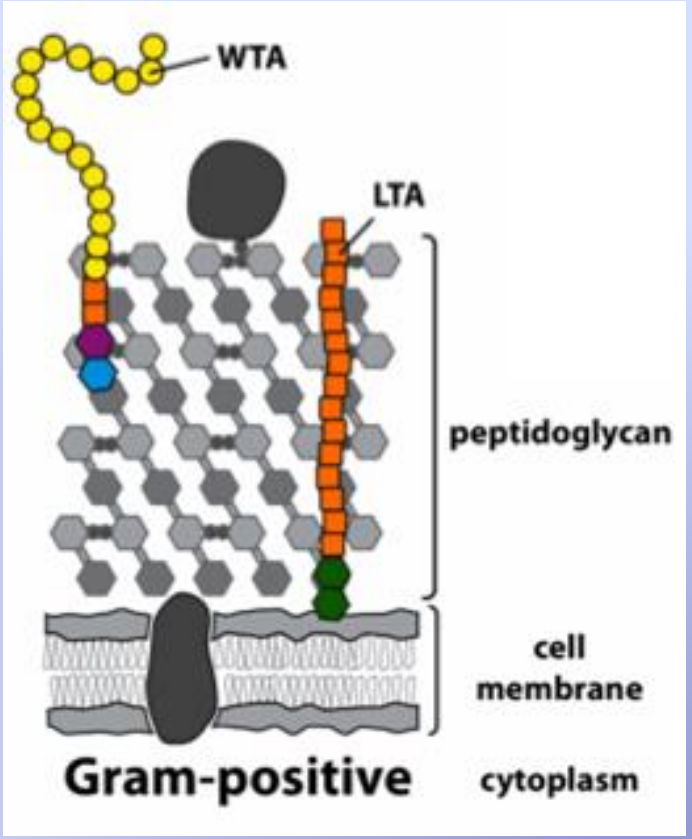
- Provides the rigid exoskeleton of the cell wall
- Stimulates;
  - Production of IL-1
  - Activation of complement
  - Aggregation of PMNs



Structural components

Teichoic acids

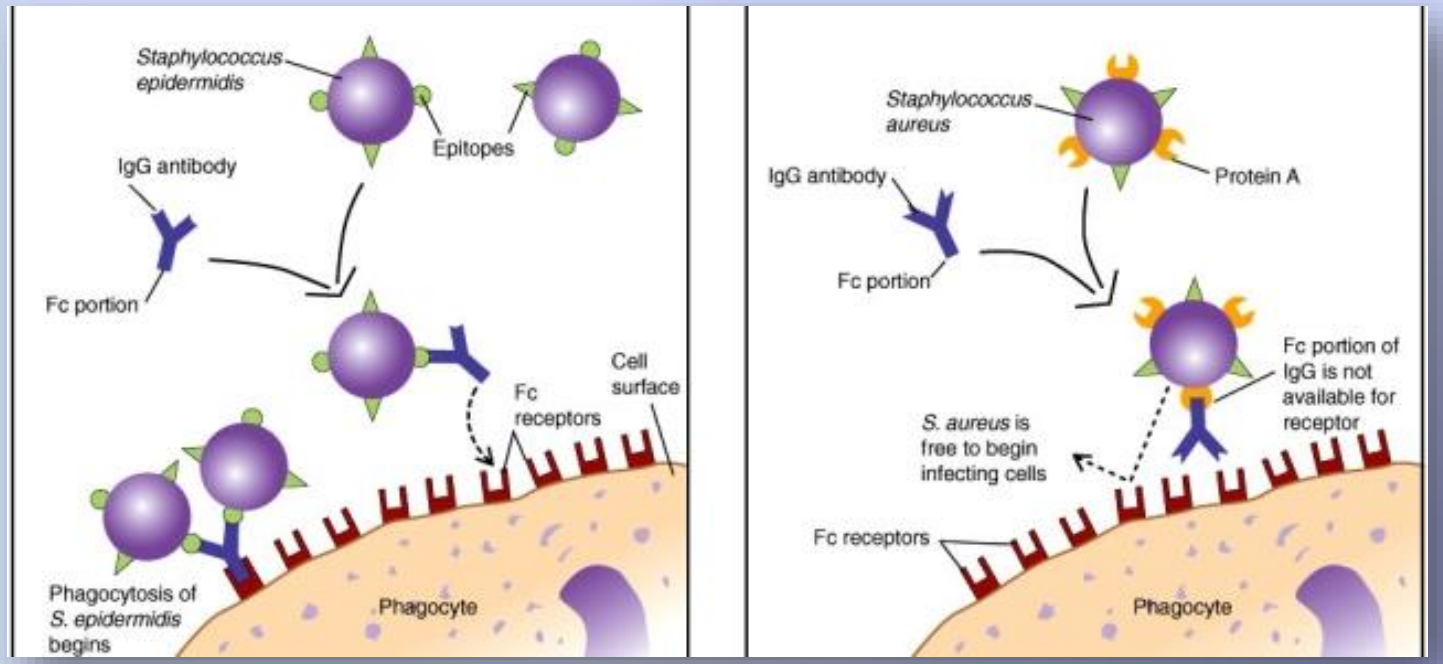
- Bound to peptidoglycan layer or cytoplasmic membrane (lipoteichoic acids)
- Species-specific
- Bind to fibronectin and mediate attachment to mucosal surfaces



Structural components

Protein A

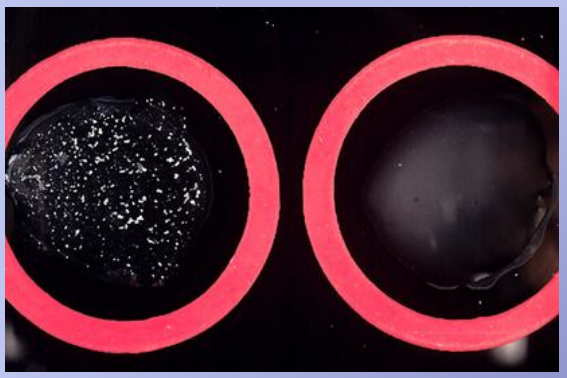
- Cell wall component of most S. *aureus* strains
- Binds to **Fc region** of IgG molecules
  - Prevents antibody-mediated immune clearance of the organism



Structural components

Clumping factor

- Outer surface of most strains of *S. aureus* contains clumping factor **(bound coagulase)**
- Fibrinogen ⟶ Fibrin
  - Staphylococci clump or aggregate
- Detection of this protein: Primary test for identifying *S. aureus*



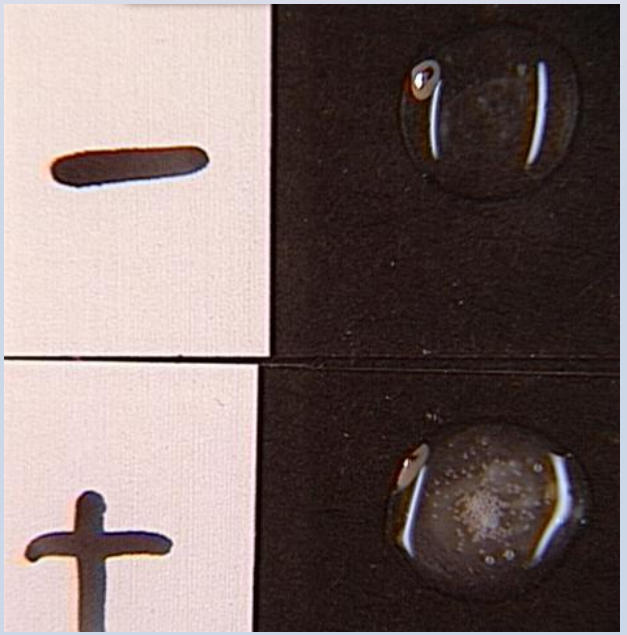
Slide coagulase test

Enzymes

- Catalase
- Coagulase
- Hyaluronidase
- Fibrinolysin (staphylokinase)
- Lipases
- Nuclease

Enzymes
Catalase

- Staphylococci produce catalase
  - Catalase converts hydrogen peroxide into water and oxygen
  - **Staphylococci: catalase (+)**
  - **Streptococci: catalase (-)**



Catalase test

$$2H_2O_2 \xrightarrow{\text{Catalase}} 2H_2O + O_2$$

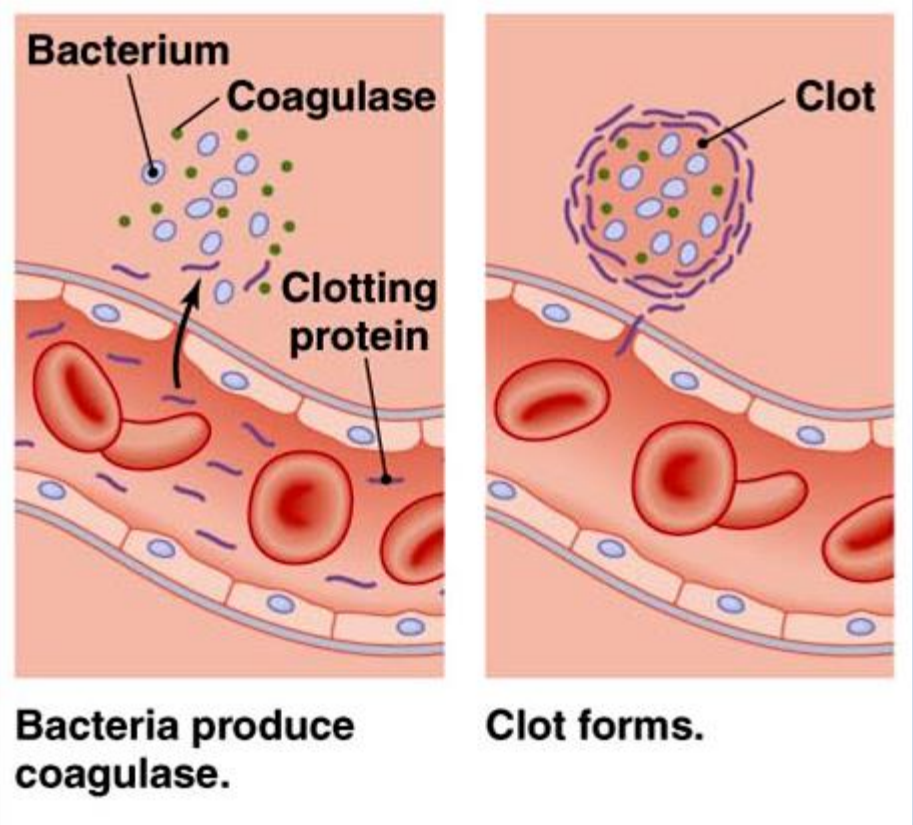
Hydrogen peroxide — Water — Oxygen

Enzymes
Coagulase

- *Only S. aureus*: Coagulase (+)
- Coagulase clots plasma
- Coagulase ⟶ deposit fibrin on the surface of staphylococci
  - Staphylococcal abscess ⟶ localizes the infection
  - Inhibits phagocytosis or destruction within phagocytic cells

Enzymes

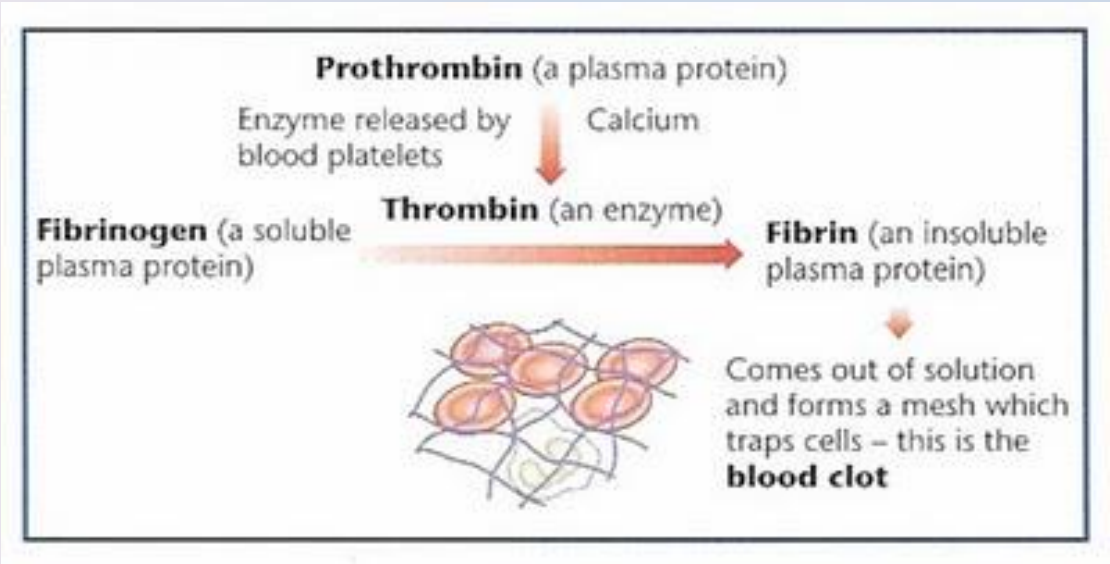
Coagulase



Tube coagulase test

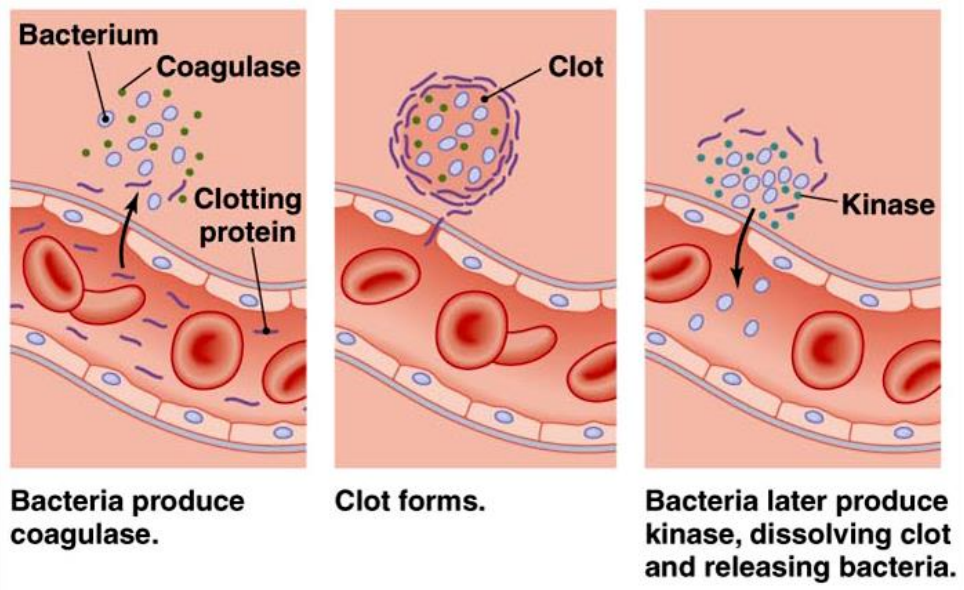
Enzymes
Coagulase

- Bound coagulase can directly convert fibrinogen to insoluble fibrin and cause clumping
- Extracellular coagulase first reacts with prothrombin, and conversion of fibrinogen to fibrin is catalysed



Enzymes
Spreading factors

- **Hyaluronidase:**
  - Hydrolizes hyaluronic acids (connective tissue)
- **Fibrinolysin (staphylokinase):**
  - Dissolves fibrin clots



Enzymes
Spreading factors

- **Lipases:**
  - Hydrolise lipids
  - Survival of staphylococci in the sebaceous areas of the body
- **Nuclease:**
  - Hydrolyze viscous DNA

Toxins

- Cytotoxins
  - Hemolysins
  - Panton-Valentine Leukocidine
- Exfoliative toxins
- Toxic shock syndrome toxin-1
- Enterotoxins

Toxins

Cytotoxins

- Hemolysins
  - Alpha (α)-toxin (α-hemolysin)
  - Beta (β)-toxin (sphingomyelinase C)
  - Delta (δ)-toxin
  - Gamma (γ)-toxin (γ-hemolysin)
- Panton-Valentine Leukocidin (PVL)

Toxins

Cytotoxins – Hemolysins

- Toxic to a variety of cells including leukocytes and erythrocytes
- **α-toxin:** important mediator of tissue damage in staphylococcal diseases
- The hemolysis on blood agar is particularly caused by **α-toxin**

Toxins

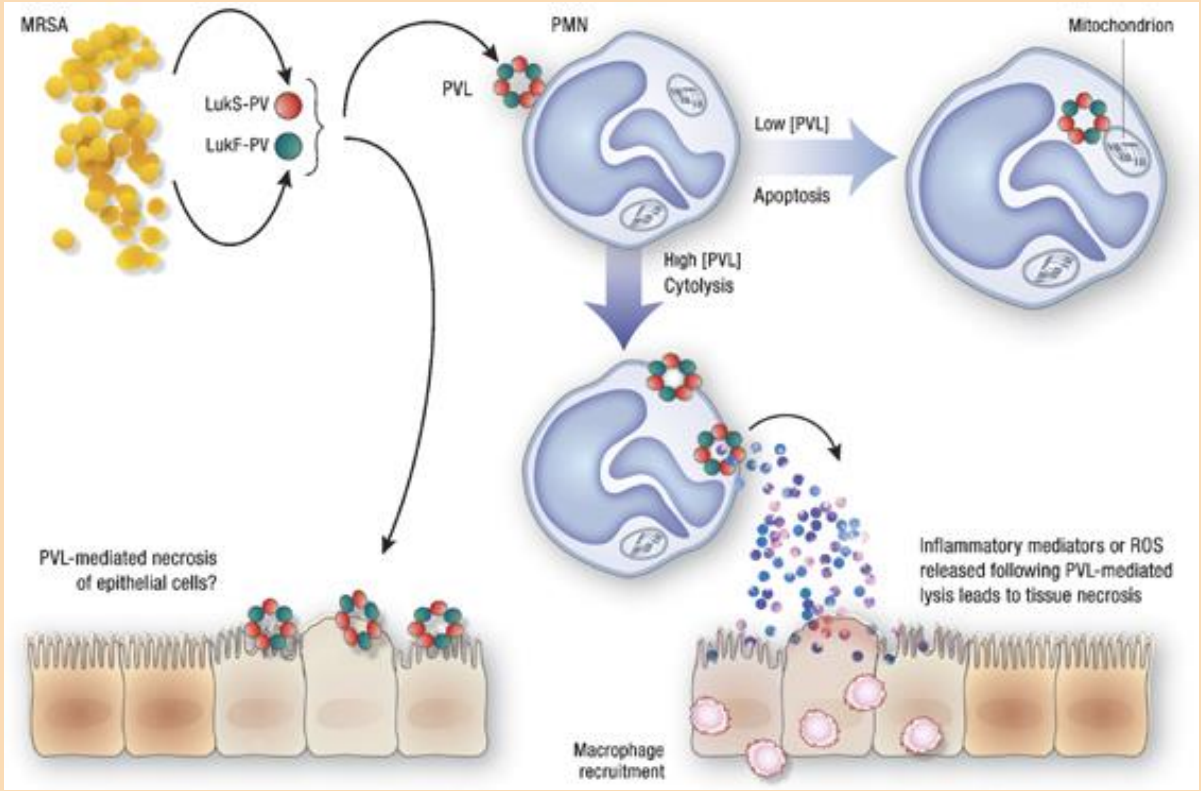
Cytotoxins – Panton-Valentine Leukocidin

- Leukotoxic but has **no hemolytic activity**
- Encoded on a mobile **phage**
- Majority of Community acquired – Methicillin resistant *Staphylococcus aureus* **(CA-MRSA)** strains: PVL (+)

Toxins

Cytotoxins – Panton-Valentine Leukocidin

- CA-MRSA is responsible for diseases including **necrotizing pneumonia**, severe sepsis and necrotizing faciitis
- PVL is related with **tissue necrosis**



Toxins

Exfoliative toxins

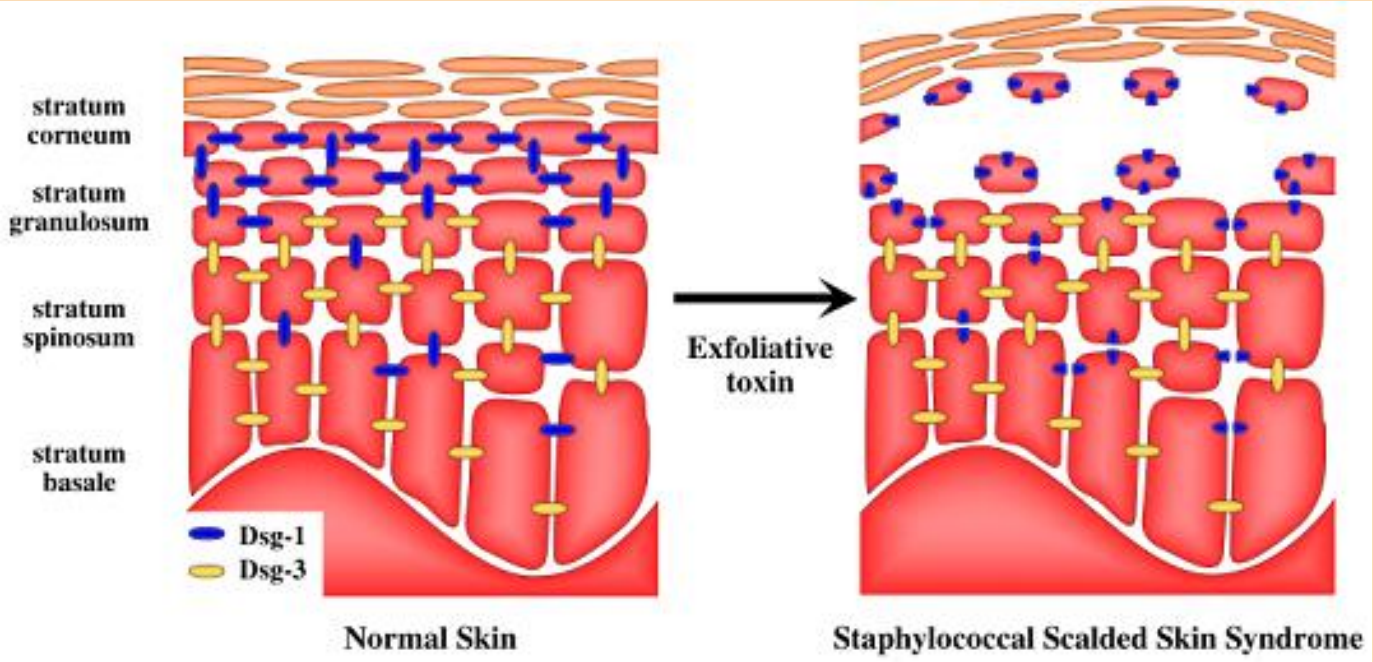
- **Superantigens**
- Epidermolytic toxins

- Lead to generalized desquamation of the **staphylococcal scalded skin syndrome (SSSS)**
  - Dissolve mucopolysaccharide matrix of epidermis

Toxins

Exfoliative toxins

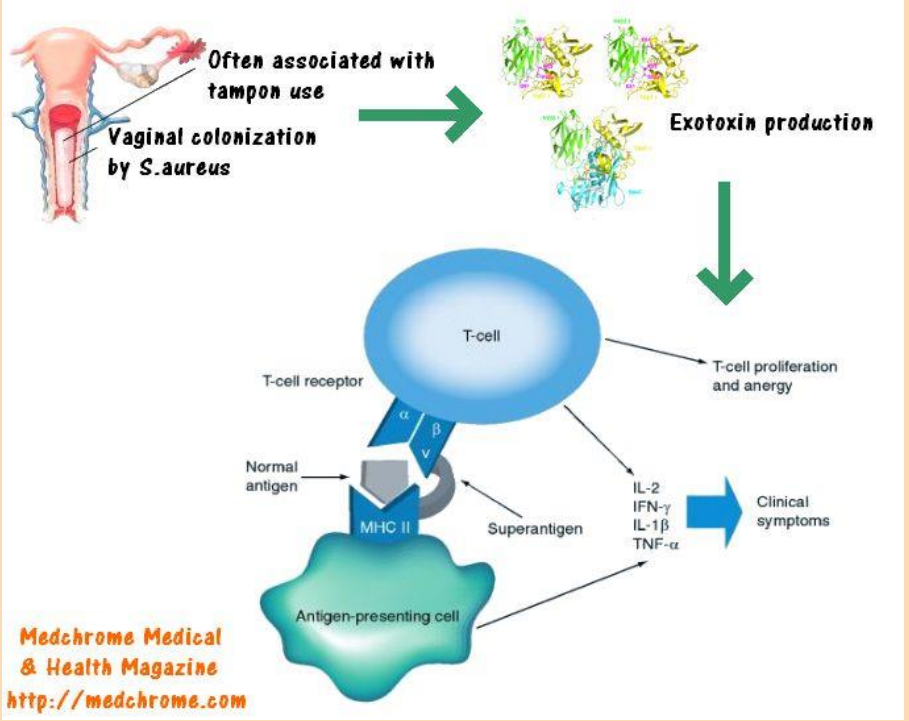
- Toxins lead to splitting of desmosomes in the stratum granulosum



Toxins

Toxic shock syndrome toxin-1 (TSST-1)

- **Superantigens**
- Heat- and proteolysis-resistant
- Causes **toxic shock syndrome (TSS)**
  - Associated with fever, shock and multisystem involvement, including desquamative skin rash



Toxins

Toxic shock syndrome toxin-1 (TSST-1)

- Toxic shock syndrome:
  - Menstruation-associated TSS – tampon use
  - Nonmenstruation-associated TSS – antibiotic treatment, hospital exposure
- For production of TSST-1
  - Low level of glucose
  - Temperature of 37-40°C
  - pH of 6.5-8
  - **Oxygen**
    - Tampon use
    - Proteolytic cleavage of menstrual blood (without tampon use)

Present in menstruation without tampon use

Toxins

Enterotoxins

- **Superantigens**
- Important cause of **food poisoning**
- Staphylococcal enterotoxins A to R
- Enterotoxin A: most commonly associated with food poisoning
- **Heat-stabile** and **resistant to hydrolysis** by gastric and jejunal enzymes

Toxins

Enterotoxins

- Produced when *S. aureus* grows in carbohydrate and protein foods
- The toxins cause nonspecific activation of T cells and cytokine release
  - Release of inflammatory mediators from mast cells
  - Increase in intestinal peristalsis and fluid loss
  - Nausea and vomiting

Staphylococcal diseases

Staphylococcus aureus

- **Toxin-mediated diseases**
  - Scalded skin syndrome
  - Food poisoning
  - Toxic shock syndrome
- **Suppurative infections**
  - Impetigo
  - Folliculitis
  - Furuncles or boils
  - Carbuncles
  - Bacteremia, meningitis and endocarditis
  - Pneumonia and empyema
  - Osteomyelitis
  - Septic arthritis

Treatment, Prevention and Control