

Staphylococcal Infections

Pathogenesis · tissue morphology · clinicopathologic correlations

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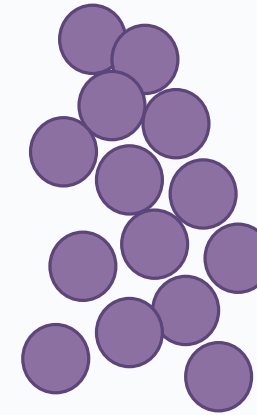
Learning objectives

- Distinguish *S. Aureus* from other clinically relevant staphylococci.
- Link surface factors and toxins to their specific tissue effects.
- Recognize the principal cutaneous and systemic disease patterns.
- Explain MRSA resistance in the context of altered penicillin-binding protein.

A pyogenic gram-positive coccus

- *S. Aureus* is a gram-positive coccus arranged in grape-like clusters.
- Its characteristic host response is suppurative, locally destructive inflammation.
- The same inflammatory signature appears across multiple organs.

Grape-like clusters of cocci



Gram-positive

Schematic · not a specimen

Clinical spectrum: Superficial to systemic

Skin and soft tissue

Impetigo; Furuncles; Carbuncles;
Abscesses

Deep invasive infection

Osteomyelitis; Pneumonia;
Endocarditis; Sepsis

Toxin-associated disease

Scalded-skin syndrome; Food
poisoning; Toxic shock

Nasal carriage is a reservoir

- Approximately 20% persistent nasal carriage of S. Aureus.
- Carriage is not equivalent to invasive disease.
- Colonization supplies a potential source for subsequent infection.

Population estimate as reported; Sampling period not specified.

Disease burden requires clinical context

>1 million

U.S. S. Aureus infections

~20,000

Attributable deaths / year

27%

3-month mortality in S. Aureus
bacteremia

Textbook-reported estimates; Underlying study periods are not supplied in the project excerpt.

Three clinically useful species profiles

Organism	Relevant pattern	Clinical setting
S. aureus	Pyogenic invasive and toxin-mediated diseases	Skin, blood, bone, lung, valves
S. epidermidis	Opportunistic device-associated infection	Catheters; prosthetic cardiac valves
S. saprophyticus	Urinary tract infection	Young females

Coagulase-negative staphylococci are opportunists

- S. Epidermidis represents the coagulase-negative group in this passage.
- Infection is particularly associated with catheters and prosthetic cardiac valves.
- Robbins also lists intravenous drug use as a relevant clinical context.

S. Saprophyticus: A distinct presentation

Species

S. Saprophyticus

Syndrome

Urinary tract infection

Population emphasis

Young females

Virulence is multimodal

Surface determinants

Adherence; Evasion of antibody-mediated killing

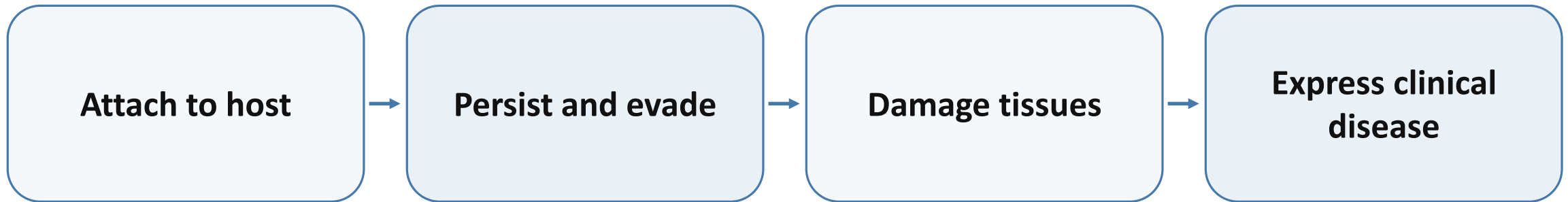
Secreted factors

Host-structure degradation and membrane injury

Resistance determinants

Reduced susceptibility to antibiotic classes

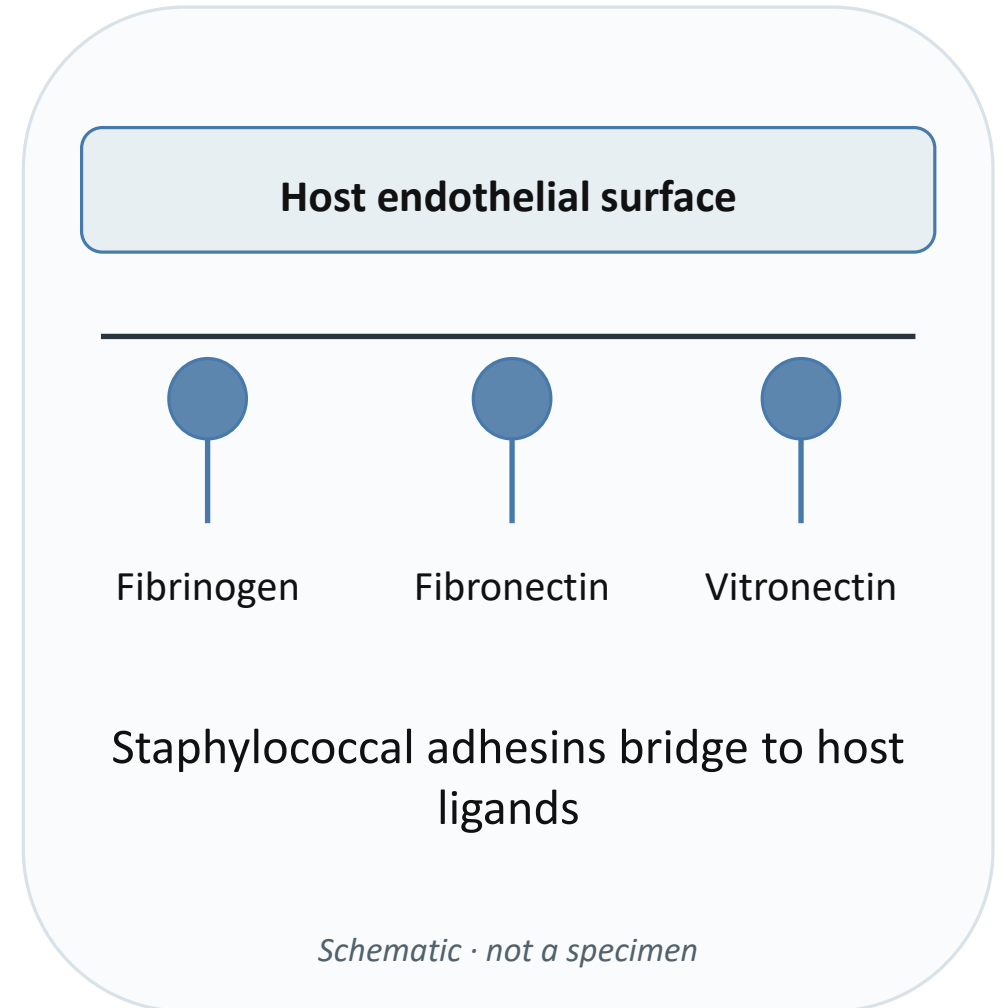
Pathogenesis: Four functional categories



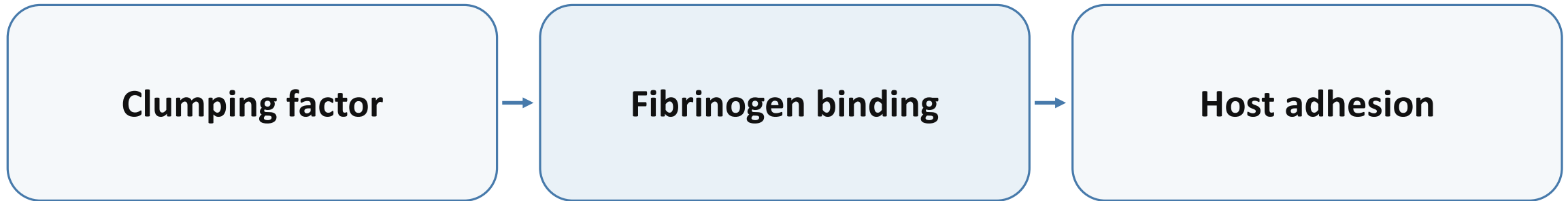
Integrated mechanism; The relative contribution of each factor varies by infection syndrome.

Endothelial adherence uses host proteins

- Surface receptors bind fibrinogen, fibronectin and vitronectin.
- Clumping factor is the staphylococcal receptor for fibrinogen.
- These interactions support bacterial attachment to host endothelial cells.



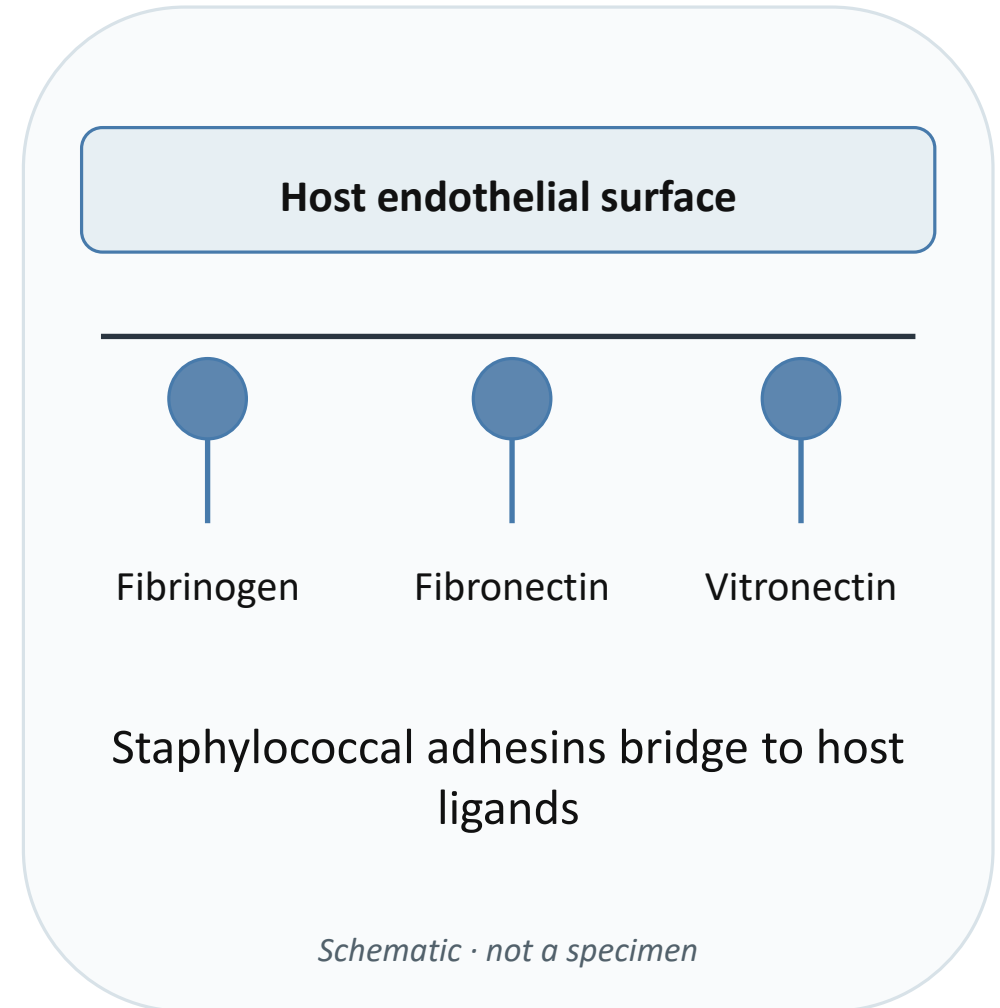
Clumping factor targets fibrinogen



*The term identifies a defined *S. Aureus* surface receptor, not a secreted toxin.*

Fibronectin and vitronectin aid attachment

- *S. Aureus* displays receptors for both extracellular host proteins.
- Binding provides molecular connections at the host interface.
- Adherence is an early step in tissue-associated infection.



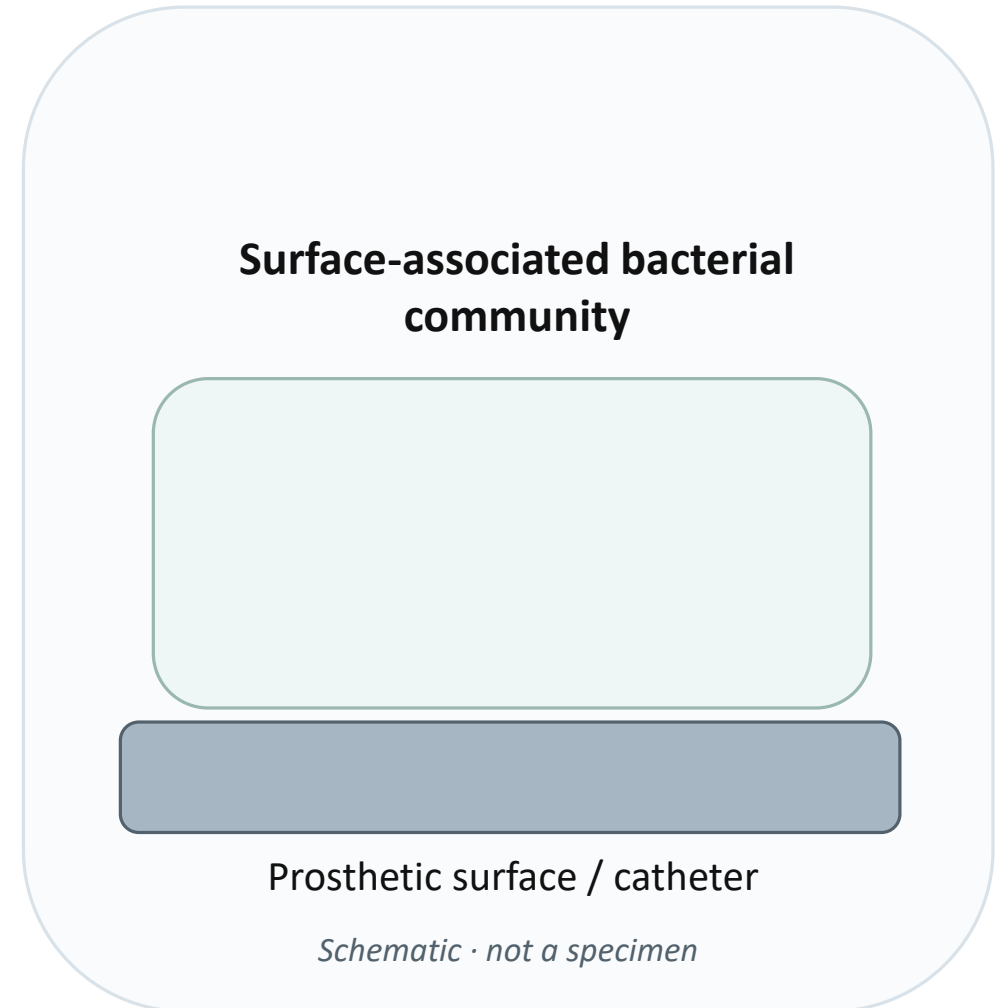
The capsule supports persistence



The capsule with biofilm formation on prosthetic material and resistance to host phagocytosis.

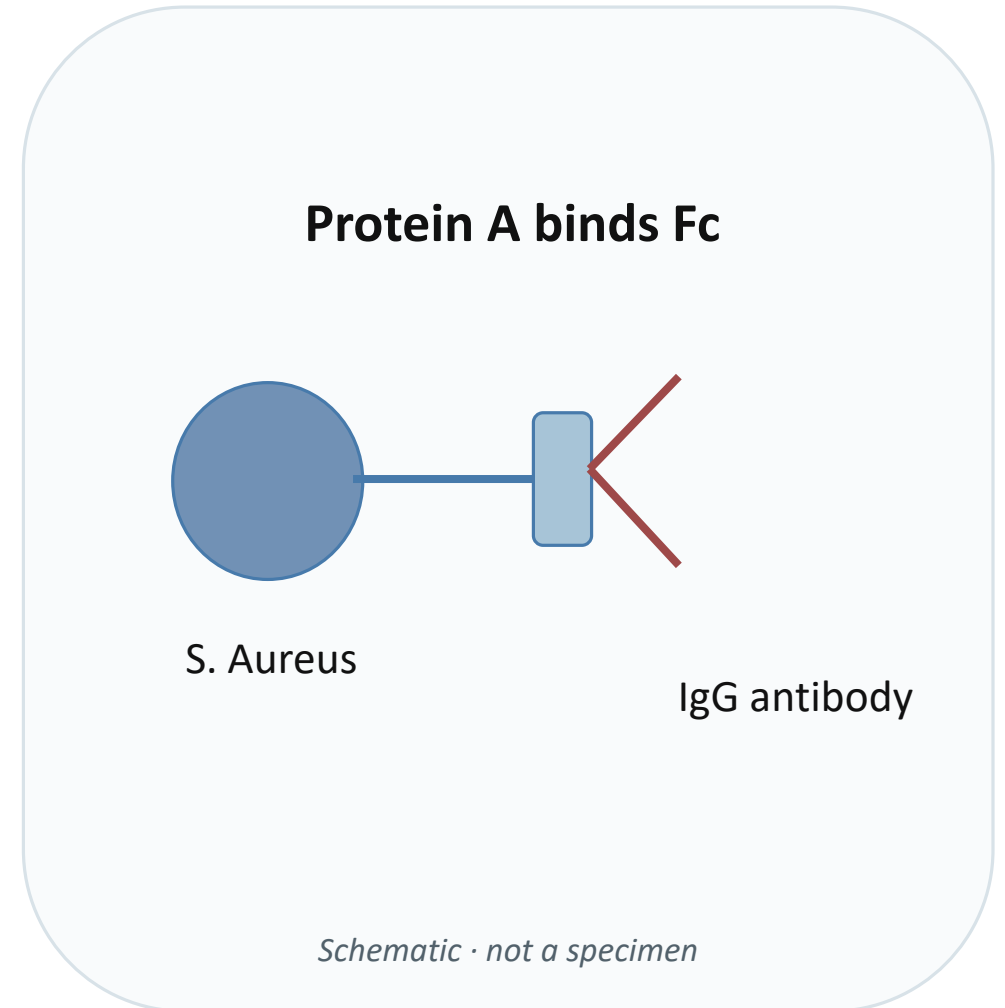
Biofilm alters the prosthetic interface

- Bacteria adhere to artificial surfaces such as prosthetic valves and catheters.
- The resulting surface-associated community is termed a biofilm.
- Such infections are difficult for the host to eradicate.



Protein A interferes with antibody action

- Protein A binds the Fc portion of immunoglobulins.
- This alters the normal interaction between antibody and host effector mechanisms.
- The functional outcome is escape from antibody-mediated killing.



Adherence and immune evasion are distinct

Factor	Primary interaction	Pathogenic effect
Clumping factor	Fibrinogen	Adherence
Fibronectin / vitronectin receptors	Host ligands	Adherence
Capsule	Artificial material / host phagocytes	Biofilm; reduced phagocytosis
Protein A	Antibody Fc region	Immune evasion

Staphylococcal toxins: Major groups

Membrane-damaging

α , β , δ , γ toxins; Leukocidin

Exfoliative

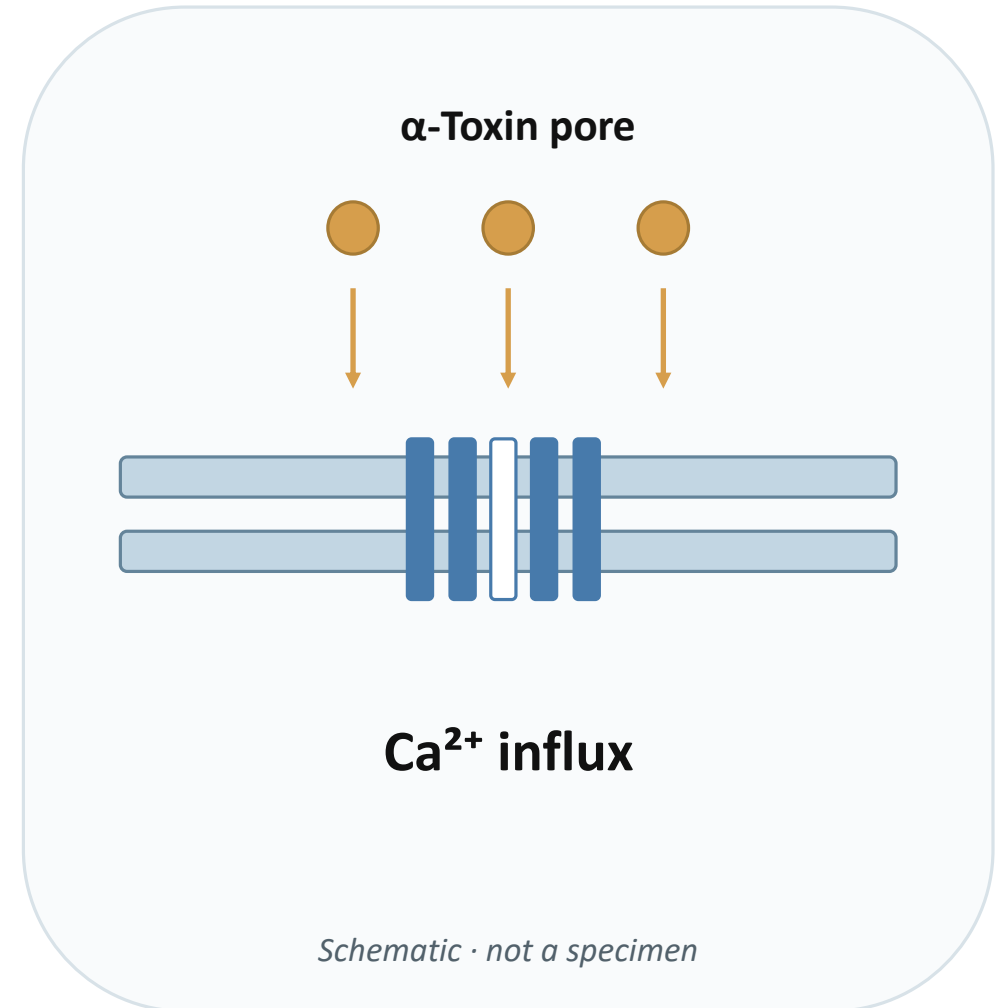
Exfoliative toxins A and B

Superantigen activity

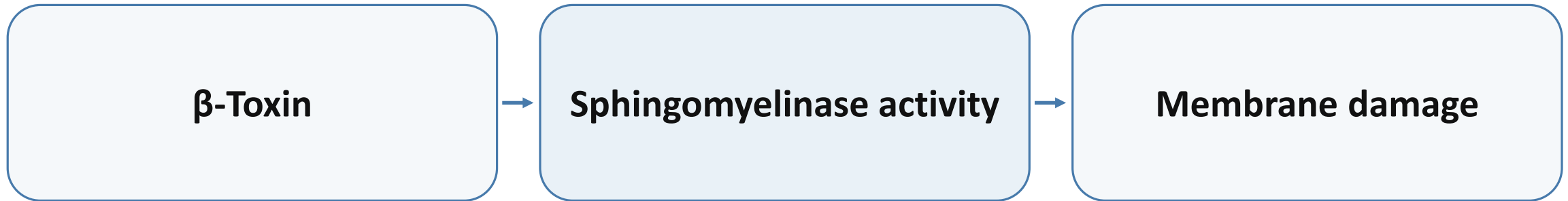
Toxic shock; Food poisoning

α -Toxin disrupts the plasma membrane

- α -Toxin inserts into host-cell plasma membranes.
- Pore formation permits injurious calcium entry.
- Loss of membrane integrity contributes to cell damage.



β -Toxin is a sphingomyelinase



Mechanistic label from the supplied Robbins excerpt.

δ -Toxin acts like a detergent



Distinguish detergent-like action from the α -toxin pore mechanism.

γ -Toxin and leukocidin affect different cells

γ -Toxin

- Red-cell lysis.
- Part of the membrane-damaging toxin group.

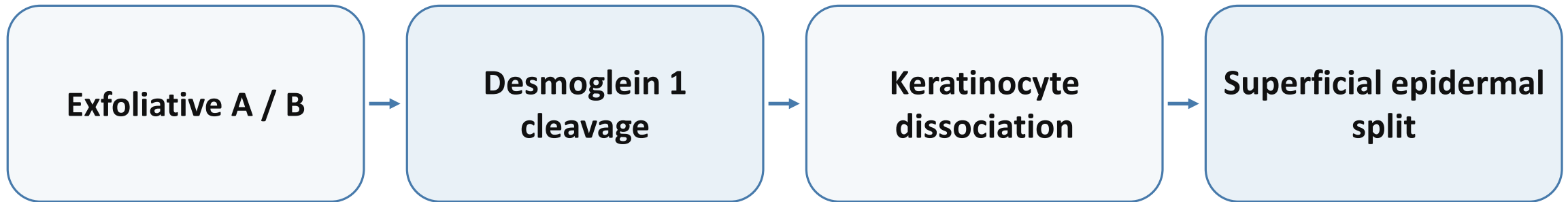
Leukocidin

- Causes lysis of phagocytes.
- Targets a major cellular host defense.

Toxin-mediated damage is not a single process

Toxin	Stated mechanism / target	Consequence
α	Pores in plasma membrane	Calcium influx; injury
β	Sphingomyelinase	Membrane damage
δ	Detergent-like action	Membrane damage
γ	Red blood cells	Cell lysis
Leukocidin	Phagocytes	Cell lysis

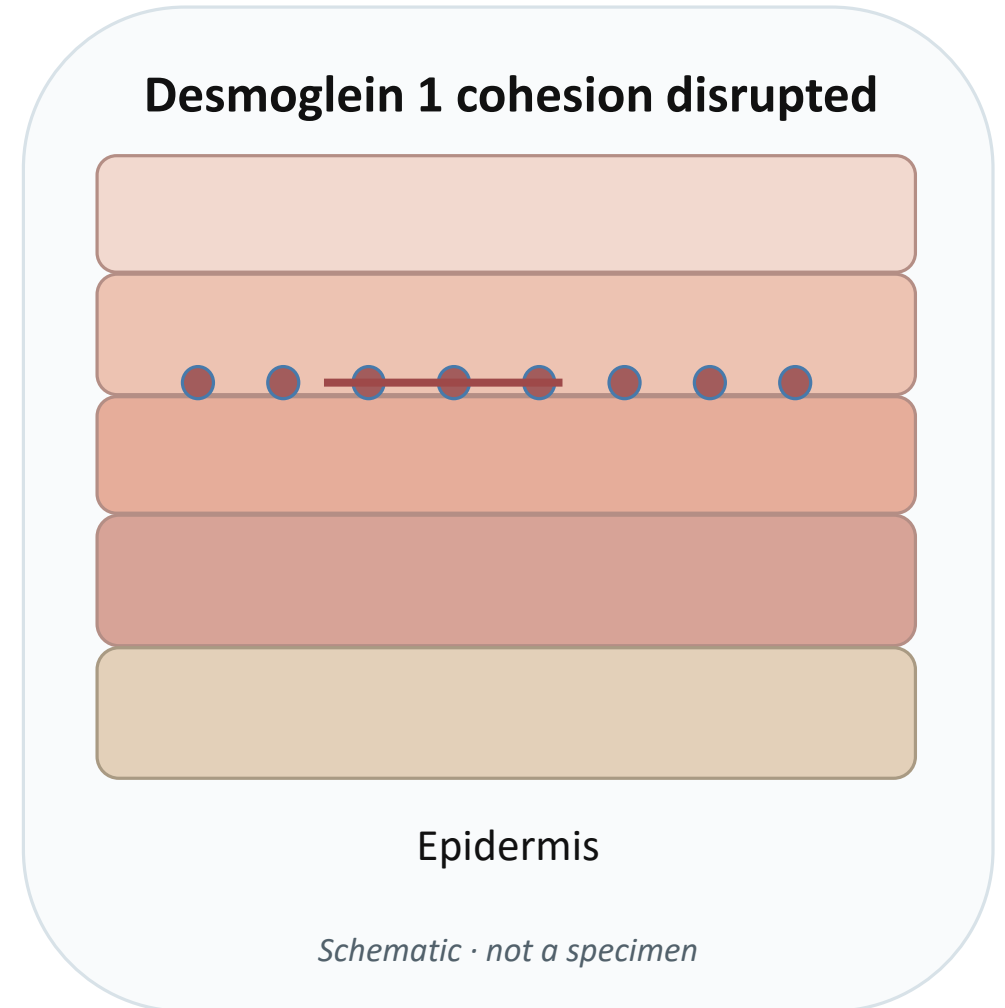
Exfoliative toxins attack cell adhesion



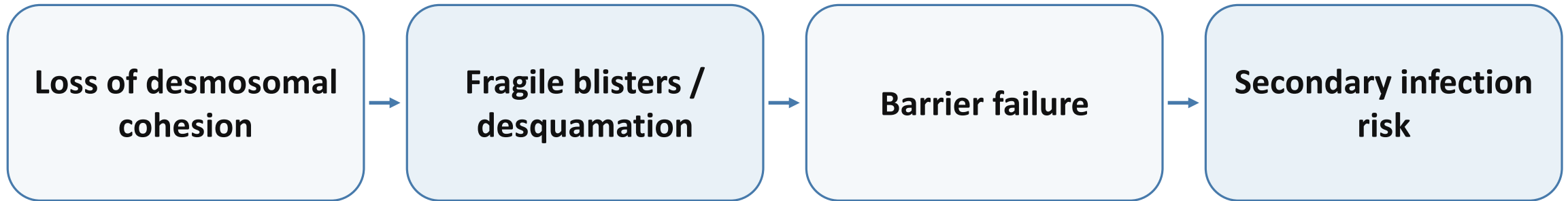
Original sequence derived from the source; “Keratinocyte” refers to keratinocyte.

Desmoglein 1 holds epidermal cells together

- Desmoglein 1 is a desmosomal adhesion protein.
- Exfoliative toxins A/B are serine proteases that cleave it.
- Loss of superficial epidermal cohesion promotes blister formation.



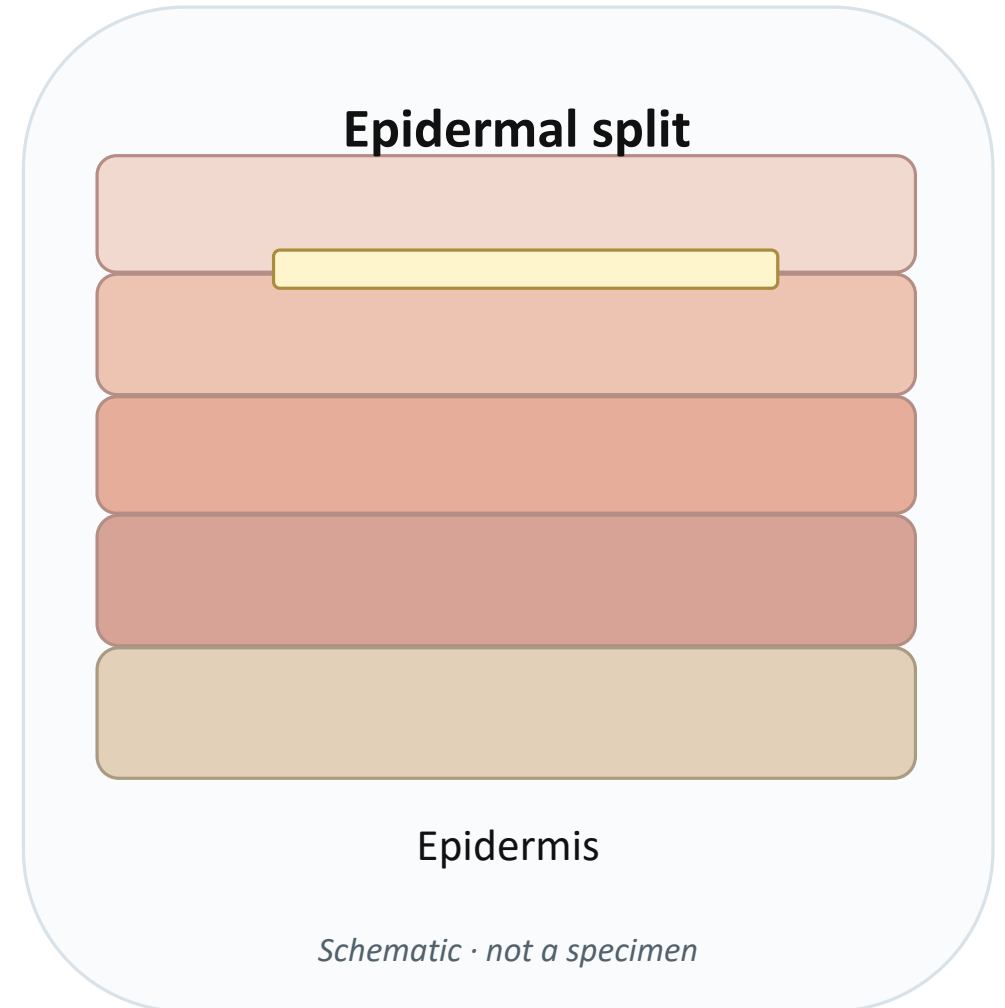
Loss of epidermal integrity has consequences



A structural defect explains why extensive exfoliation is clinically consequential.

Bullous impetigo is toxin-associated and localized

- Exfoliation occurs locally at the infected skin site.
- Impetigo is restricted to the superficial epidermis.
- Localized disease differs in distribution from scalded-skin syndrome.

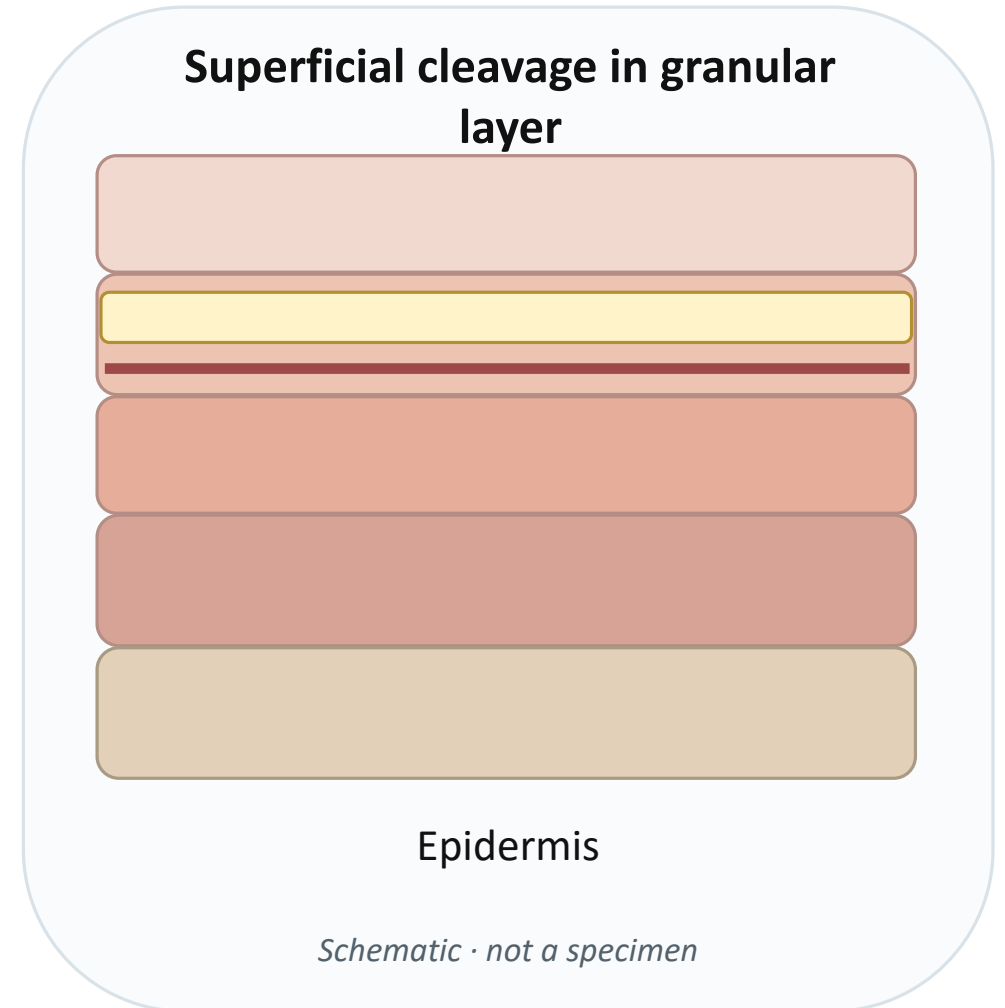


Scalded-skin syndrome is generalized

- Also termed Ritter disease.
- Most frequent in children with a staphylococcal focus in skin or nasopharynx.
- A widespread sunburn-like rash progresses to fragile bullae and skin loss.

Scalded-skin syndrome: Cleavage plane

- Desquamation occurs high in the epidermis, at the granular layer.
- Superficial cleavage explains the fragile epidermal covering.
- The depth of cleavage helps distinguish competing exfoliative disorders.



Scalded-skin syndrome versus TEN

Feature	Staphylococcal SSSS	Toxic epidermal necrolysis
Immediate cause	Exfoliative staphylococcal toxins	Drug hypersensitivity
Cleavage depth	Granular layer of epidermis	Epidermal–dermal junction
Teaching discriminator	Superficial epidermal split	Deeper epidermal detachment

Localized versus generalized exfoliation

Bullous impetigo

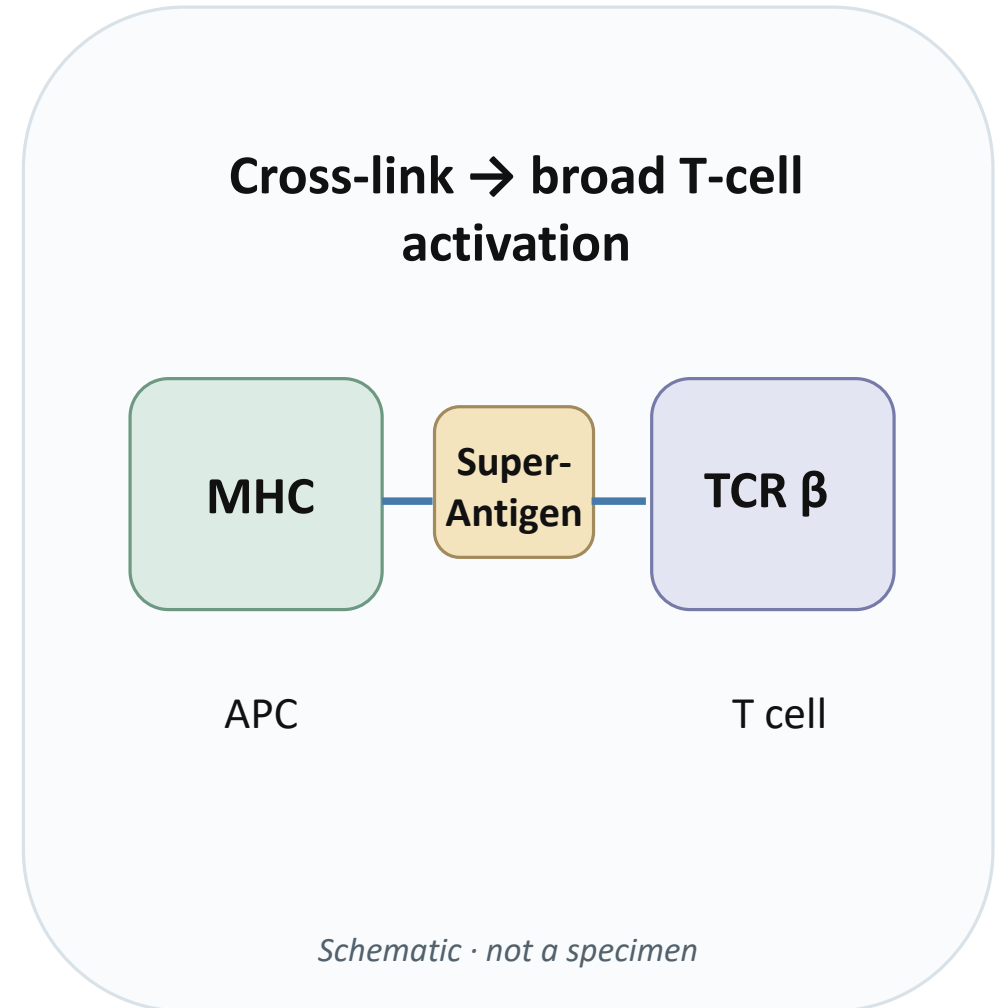
- Local exfoliation at an infected site.
- Superficial epidermis involved.

Scalded-skin syndrome

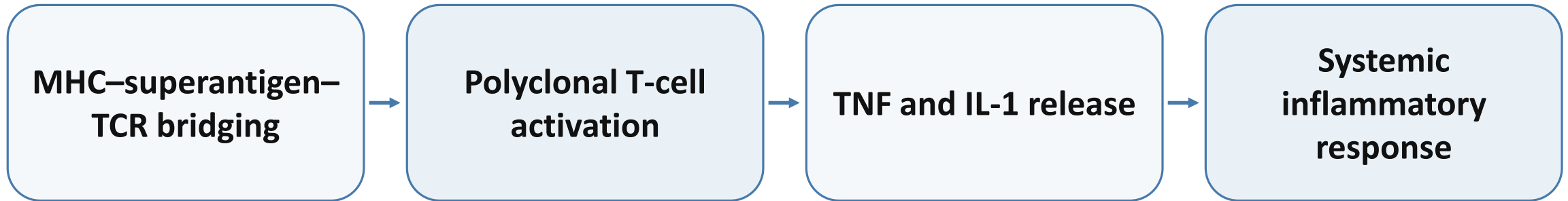
- Widespread superficial epidermal loss.
- Often follows a distant skin or nasopharyngeal focus.

Superantigens bypass ordinary specificity

- Bacterial superantigens bind conserved regions of MHC molecules.
- They also engage relatively conserved regions of the T-cell receptor β chain.
- The result is extensive polyclonal T-cell stimulation.



Mass T-cell activation amplifies inflammation



As many as 20% of T cells may be stimulated in this mechanism.

TNF and IL-1 connect toxin to shock

- Superantigen-stimulated lymphocytes release large quantities of cytokines.
- TNF and IL-1.
- Excessive systemic inflammation can produce shock and multiorgan dysfunction.

Toxic shock syndrome: Exposure settings

Historical association

Colonized hyperabsorbent tampons

Other recognized foci

Vagina and infected operative sites

Microbial cause

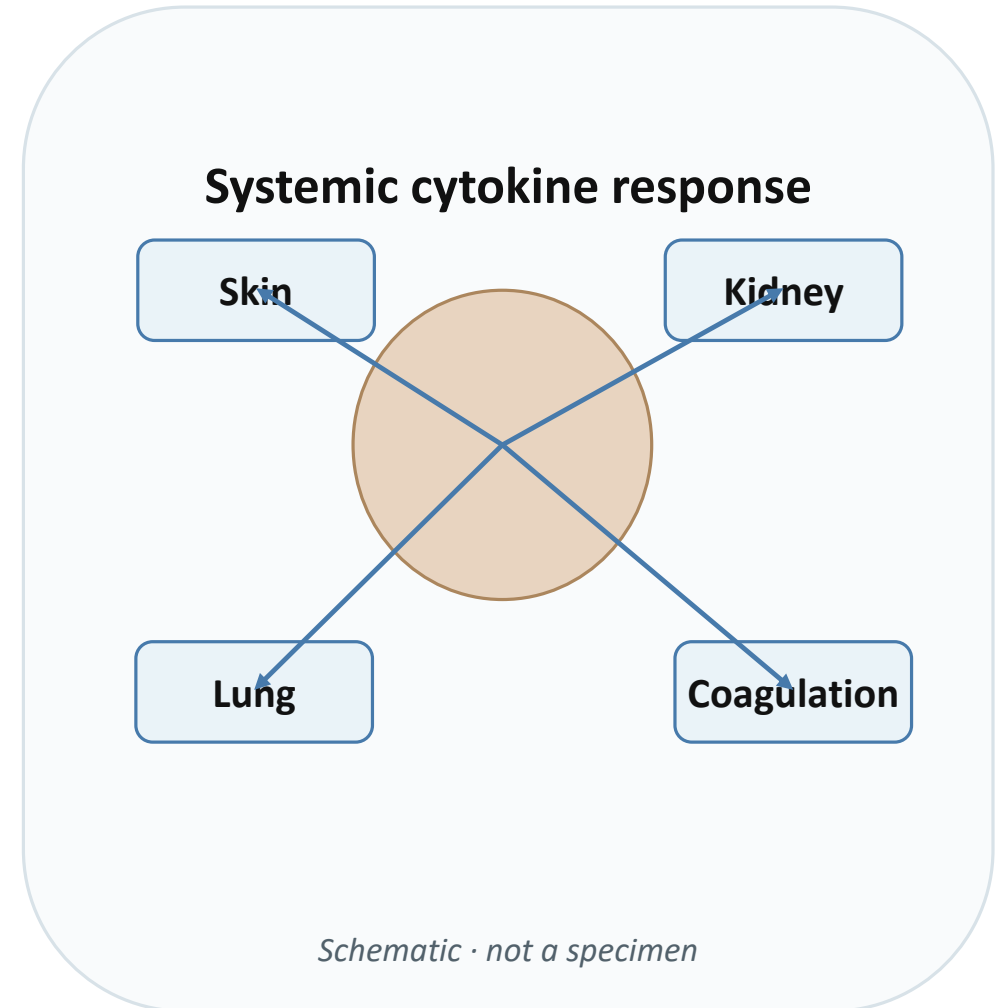
S. Aureus; *S. Pyogenes* can also cause TSS

Toxic shock is a multisystem syndrome

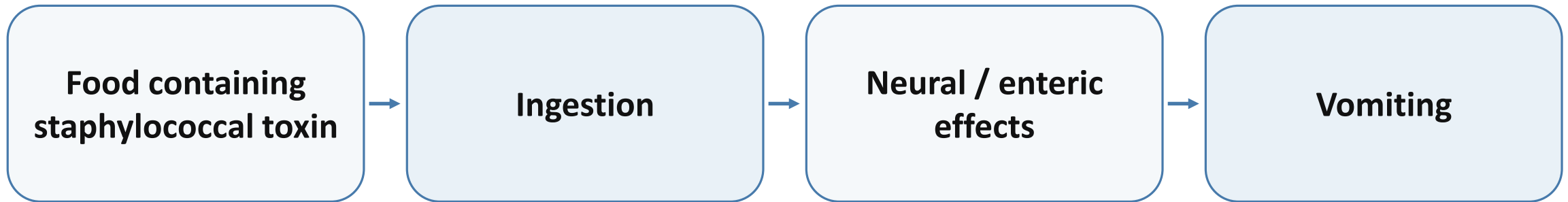
Clinical domain	Textbook-reported finding
Hemodynamic	Hypotension / shock
Skin and local tissue	Generalized erythematous rash; focal soft-tissue necrosis
Kidney and coagulation	Renal failure; coagulopathy
Liver and lung	Liver disease; respiratory distress

Toxic shock: Local growth, systemic effects

- The bacterial focus may remain localized while toxins act systemically.
- Cytokine amplification accounts for the widespread clinical manifestations.
- Prompt recognition matters because the syndrome can be fatal.



Food poisoning is a toxin-mediated presentation



Robbins suggests CNS or enteric nervous-system involvement; The precise mechanism is not established in the excerpt.

Food poisoning and TSS share a toxin class

Food poisoning

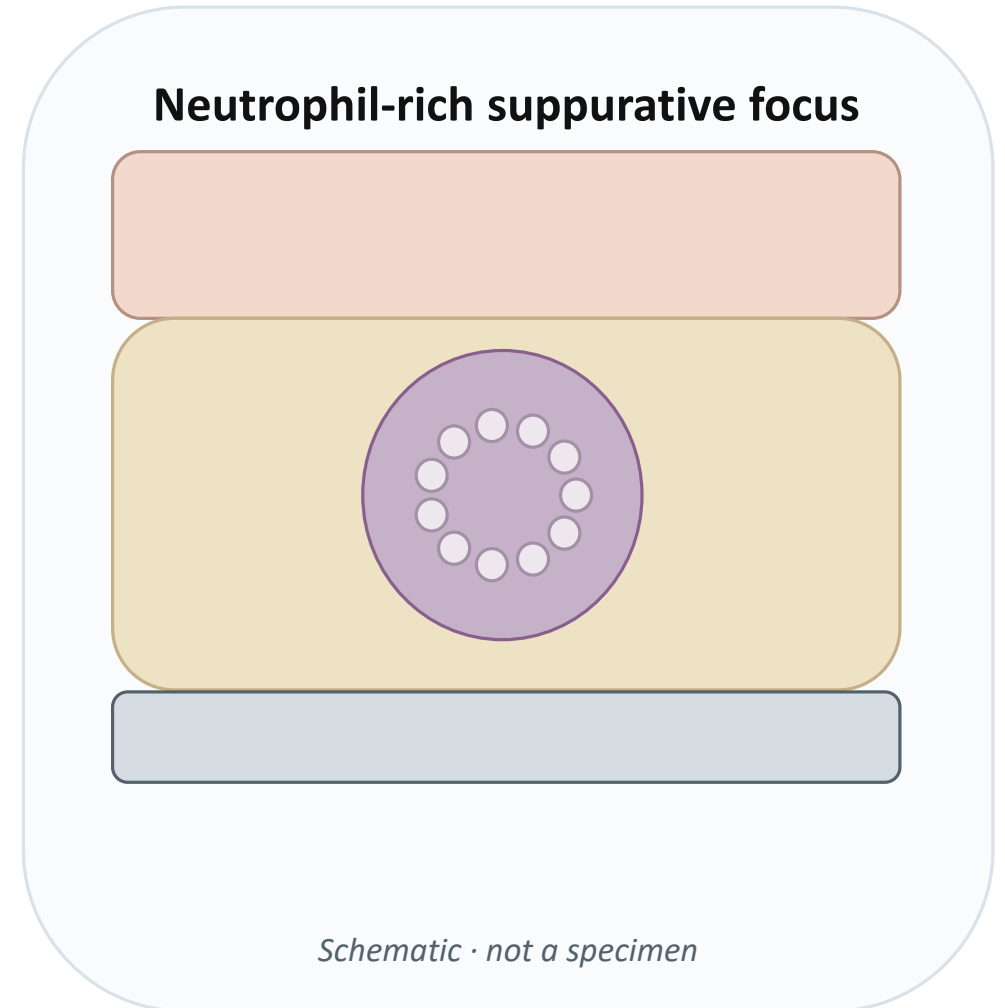
- Ingested superantigen-associated toxin.
- Vomiting is the highlighted manifestation.

Toxic shock syndrome

- Superantigen-dependent T-cell stimulation.
- Cytokine release with shock and organ injury.

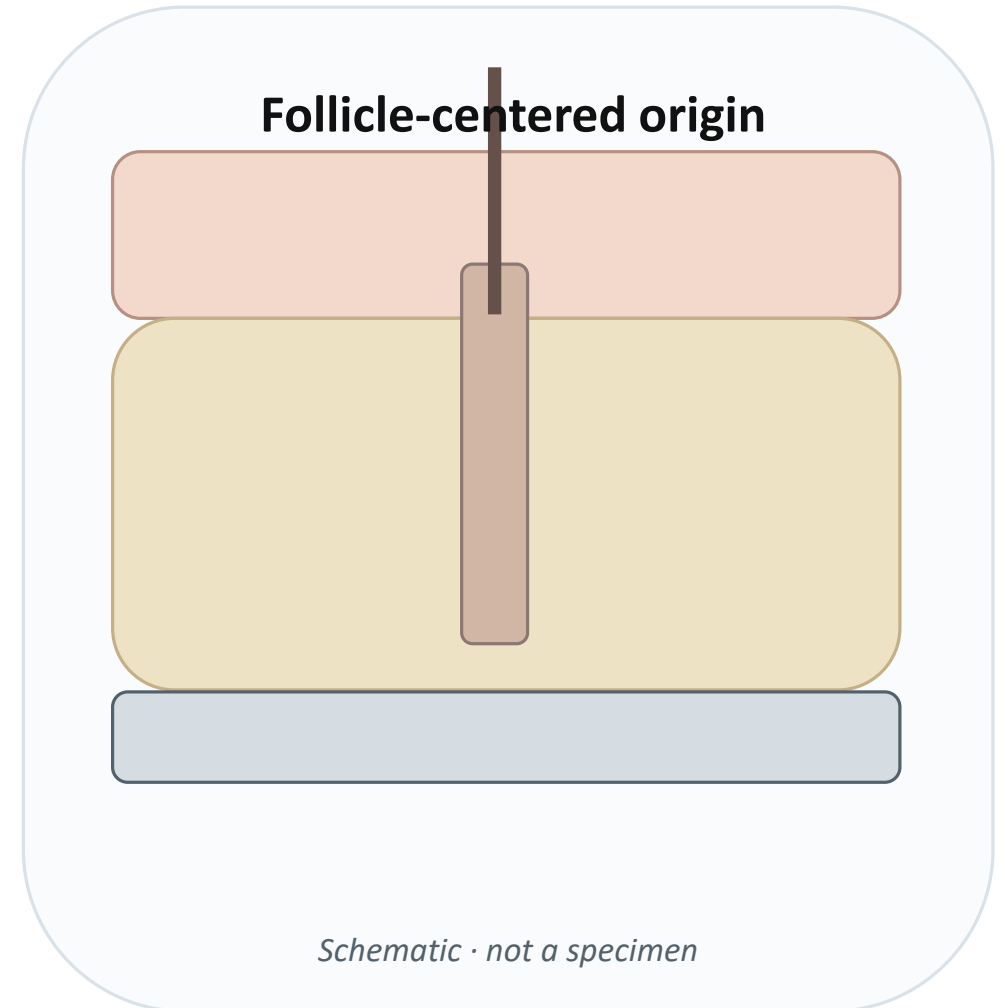
Pyogenic inflammation causes tissue destruction

- Neutrophilic suppuration characterizes *S. Aureus* lesions.
- Local tissue destruction distinguishes its pathology.
- This pattern recurs in skin, lungs, bones and heart valves.



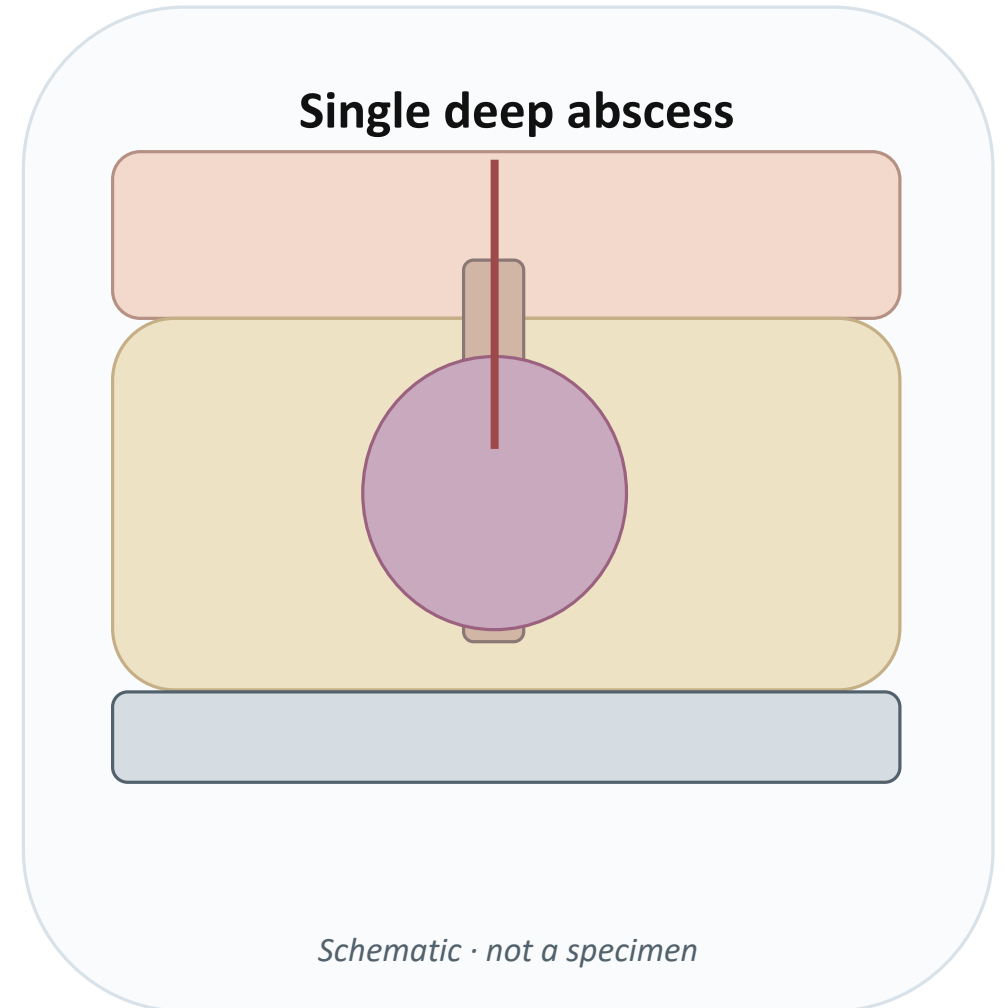
Cutaneous infection often starts at a follicle

- Most staphylococcal skin infections start around hair follicles.
- The explicit superficial exception is impetigo.
- Anatomical depth and lateral spread help classify the lesions.



Furuncle: A follicle-centered abscess

- A furuncle (boil) is focal suppuration involving skin and subcutis.
- It begins in a single hair follicle and enlarges into a deeper abscess.
- Overlying skin eventually thins and may rupture.

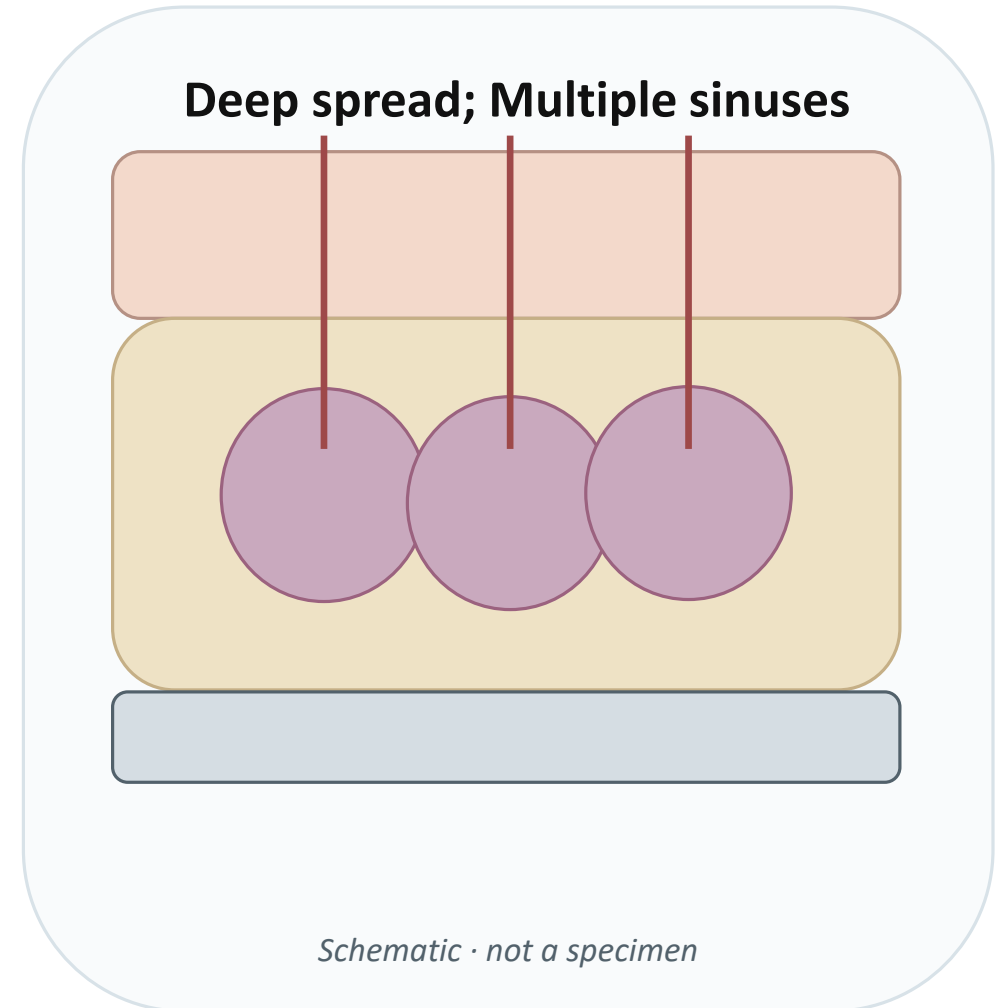


Furuncles can recur or appear in groups

- A furuncle may be isolated or multiple.
- Recurrence can occur in successive crops.
- Common locations are moist and hairy regions: Face, axillae, groin, legs and submammary folds.

Carbuncle: Deeper and laterally extensive

- Deep suppuration spreads laterally beneath the subcutaneous fascia.
- Tracts subsequently reach the surface through several nearby openings.
- Upper back and posterior neck are typical sites.



Furuncle versus carbuncle

Feature	Furuncle	Carbuncle
Origin / extent	One follicle; focal deep abscess	Deep lateral spread beneath fascia
Surface opening	Often one central point	Multiple adjacent draining sinuses
Common locations	Moist, hairy areas	Upper back; posterior neck

Axillary suppuration and nail-fold infection

Hidradenitis

Textbook describes chronic suppurative apocrine-gland disease, often axillary.

Paronychia

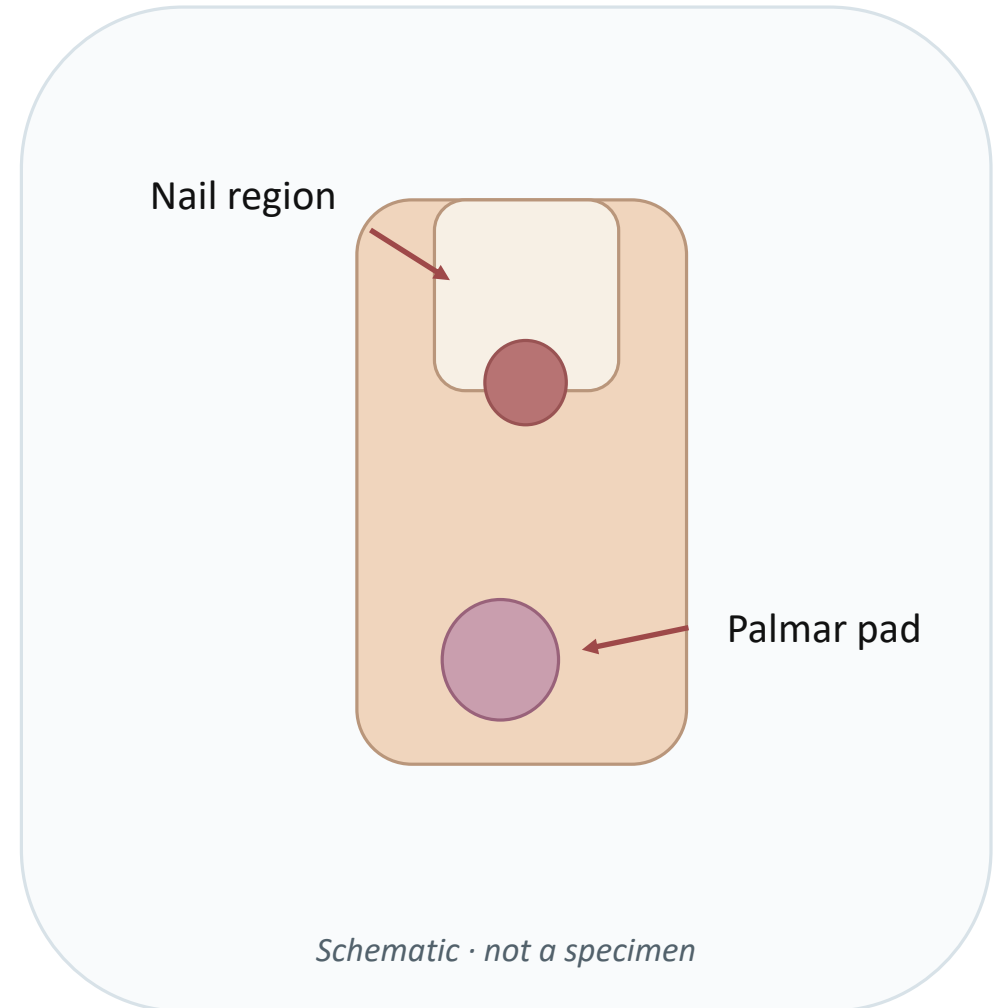
Infection centered on the nail bed / nail fold.

Felon

Painful suppuration on the palmar side of the fingertip.

Paronychia and felon can follow trauma

- Embedded splinters or other local injury may precede either infection.
- The confined distal anatomy contributes to marked pain.
- Deep spread can damage terminal phalanx or detach the nail.



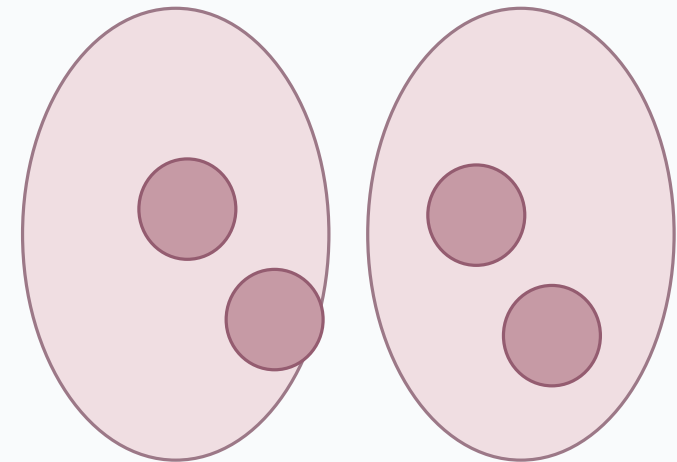
Cutaneous patterns: Classify by anatomy

Process	Primary anatomical level	Signature
Impetigo	Superficial epidermis	Localized exfoliation
Furuncle	Follicle → skin/subcutis	Focal abscess
Carbuncle	Deep soft tissue / fascial spread	Several sinuses
Felon	Palmar fingertip	Painful localized suppuration

Staphylococcal pneumonia destroys lung tissue

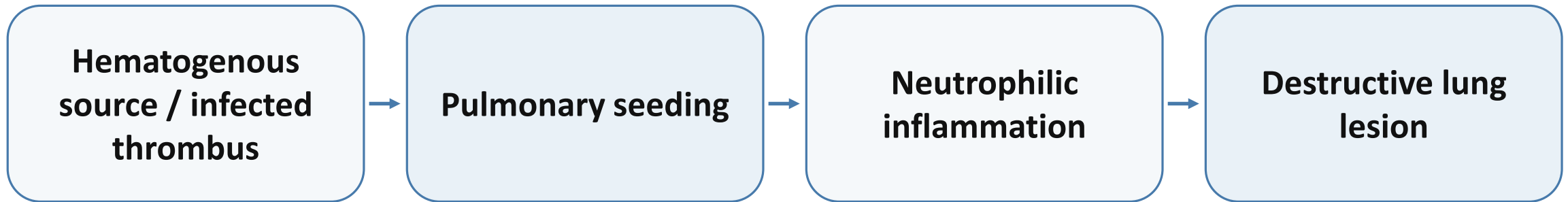
- Prominent polymorphonuclear infiltrate is present.
- Compared with pneumococcal pneumonia, the excerpt emphasizes greater tissue destruction.
- The pulmonary lesion is a manifestation of pyogenic disease.

Destructive neutrophilic foci



Schematic · not a specimen

Routes leading to staphylococcal pneumonia



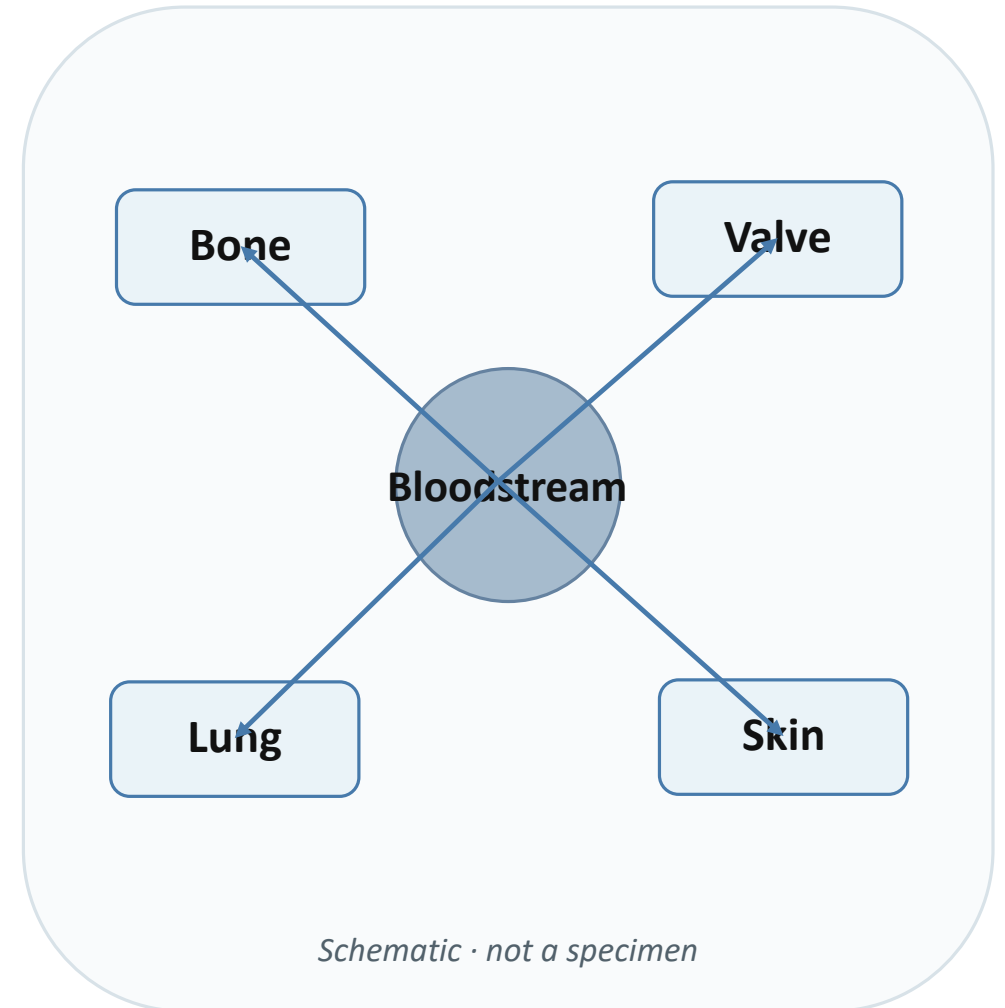
Influenza is also identified as an important predisposing condition.

Influenza creates a predisposing setting

- S. Aureus pneumonia may follow or complicate influenza.
- The preceding viral illness is a clinical clue to the possibility of bacterial lung infection.
- Tissue-destructive inflammation is the key morphologic feature highlighted by Robbins.

Bacteremia may seed distant organs

- *S. Aureus* causes sepsis, osteomyelitis and endocarditis in addition to localized abscesses.
- The source also describes pneumonia arising via the bloodstream.
- Distant infection sites can share the same neutrophilic destructive pattern.



Deep-organ infection preserves the pyogenic theme

Bone

Osteomyelitis: Pyogenic bone infection

Heart valve

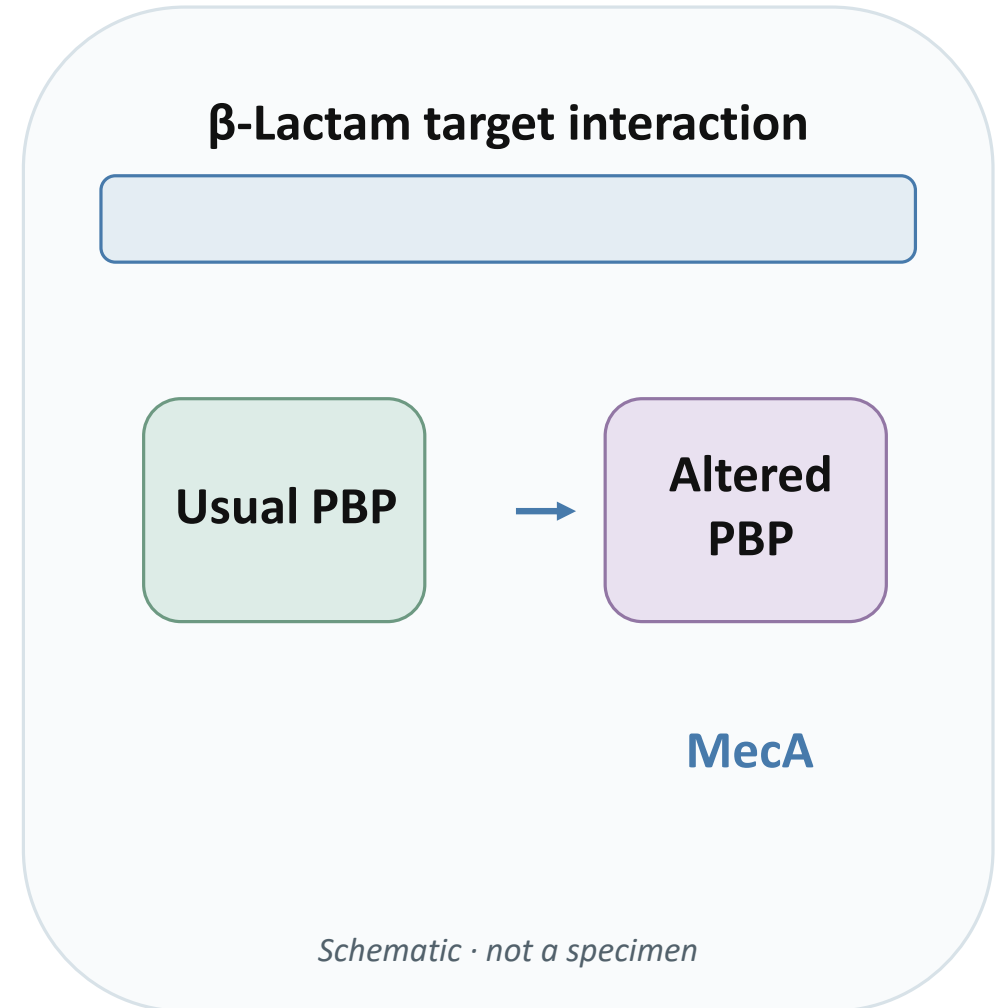
Endocarditis: Infection involving valve structures

Blood / systemic

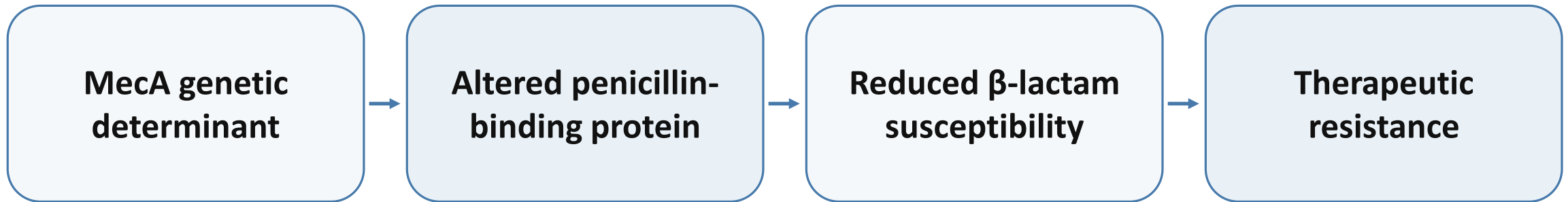
Sepsis and bacteremia with serious clinical consequences

MRSA: Resistance has a defined mechanism

- The *mecA* gene encodes an altered penicillin-binding protein.
- Changed target binding underlies resistance to penicillins and most cephalosporins.
- *MecA* resides within a larger mobile genetic element.



MecA is not a secreted toxin



Resistance mechanism rather than direct host-tissue injury.

MRSA occurs in health care and community settings

Health care-associated

- Historically the prominent reservoir.
- Hospital burden prompted extensive screening policies.

Community-associated

- Recognized since the 1980s.
- Now a common epidemiologic setting.

Hospital control and resistance are separate issues

- Infection-control improvements associated with screening after 2005.
- The MRSA proportion reported in the excerpt is high, but varies by setting and era.
- Resistance status does not substitute for identifying the anatomical focus and disease severity.

Case: A painful follicular lesion

Illustrative teaching vignette

A focal lesion begins at a hair follicle, deepens, and eventually forms a single draining point.

Which morphology best fits the account?

Furuncle: A single follicle-centered, suppurative abscess.

A carbuncle instead spreads deeply and produces multiple adjacent sinuses.

Case: Multiple adjacent drainage sinuses

Illustrative teaching vignette

A deep lesion on the posterior neck spreads laterally and erupts at several nearby surface points.

What anatomical process explains the pattern?

Carbuncle with deep fascial-plane spread.

The passage describes a lateral deep infection that tracks back to the skin.

Case: Child with widespread epidermal loss

Illustrative teaching vignette

A child with a staphylococcal skin focus develops diffuse erythema, fragile bullae and widespread superficial peeling.

Which toxin–substrate interaction is implicated?

Exfoliative A/B toxins cleave desmoglein 1.

Superficial epidermal cleavage is characteristic of staphylococcal scalded-skin syndrome.

Case: Rash, hypotension and organ failure

Illustrative teaching vignette

A patient with an infected surgical wound develops diffuse rash, shock, renal injury and respiratory distress.

Which pathogenic mechanism links the findings?

Superantigen-triggered polyclonal T-cell activation and cytokine release.

TNF/IL-1 amplification produces systemic inflammation rather than only local tissue injury.

Case: Persistent infection on prosthetic material

Illustrative teaching vignette

An infection involves an artificial cardiac-valve surface and remains difficult to clear despite host immune responses.

Name two supported persistence mechanisms.

Biofilm-associated attachment and evasion of phagocytosis.

The text links polysaccharide capsule and biofilm to prosthetic-surface infection.

Case: β -lactam treatment failure

Illustrative teaching vignette

A staphylococcal isolate has a resistance mechanism involving an altered penicillin-binding target.

Which determinant is most relevant?

MecA, encoding an altered penicillin-binding protein.

This is the mechanistic explanation of methicillin resistance in the source.

Pathogenesis-to-lesion integration

Pathogenic mechanism	Characteristic clinical / morphological outcome
Surface adherence and biofilm	Catheter / prosthetic-valve infection
Membrane-damaging toxins	Host-cell injury and lysis
Desmoglein 1 proteolysis	Bullous impetigo; scalded-skin syndrome
Superantigen activation	Food poisoning; toxic shock syndrome
Pyogenic inflammation	Furuncles, carbuncles, destructive pneumonia
Altered PBP (mecA)	MRSA antimicrobial resistance

Five distinctions that prevent diagnostic confusion

- Carriage does not establish invasive *S. Aureus* infection.
- Furuncle is focal; Carbuncle has deeper lateral spread and multiple sinuses.
- SSSS cleaves superficially; Toxic epidermal necrolysis separates more deeply.
- Toxin-mediated systemic disease differs from localized suppuration.
- MRSA names a resistance phenotype, not a distinct tissue morphology.

Reference and image interpretation

- Robbins, Cotran & Kumar. Pathologic Basis of Disease. 11th edition. Section: “Staphylococcal Infections.”
- Clinical and morphologic statements in this lecture follow the assigned textbook section.
- Anatomical and molecular drawings are schematic explanations—not clinical images or histopathologic specimens.