

Mechanical Trauma

Morphologic patterns • mechanisms • tissue repair • organ-specific injury

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Learning outcomes

Identify mechanical determinants

Interpret wound morphology

Link injury to tissue repair

Recognize bone and CNS complications

Mechanical trauma among physical agents

- Physical injury includes mechanical, thermal, electrical, and ionizing-radiation mechanisms.
- Mechanical trauma is defined by force transfer into tissues.
- Thermal and electrical damage have separate mechanisms and are not the focus here.

Mechanical

Thermal

Electrical

Ionizing radiation

Three determinants of tissue damage

- The colliding object contributes geometry and contact characteristics.
- The energy discharged at impact determines the mechanical loading.
- The tissue or organ determines the resulting structural and functional injury.

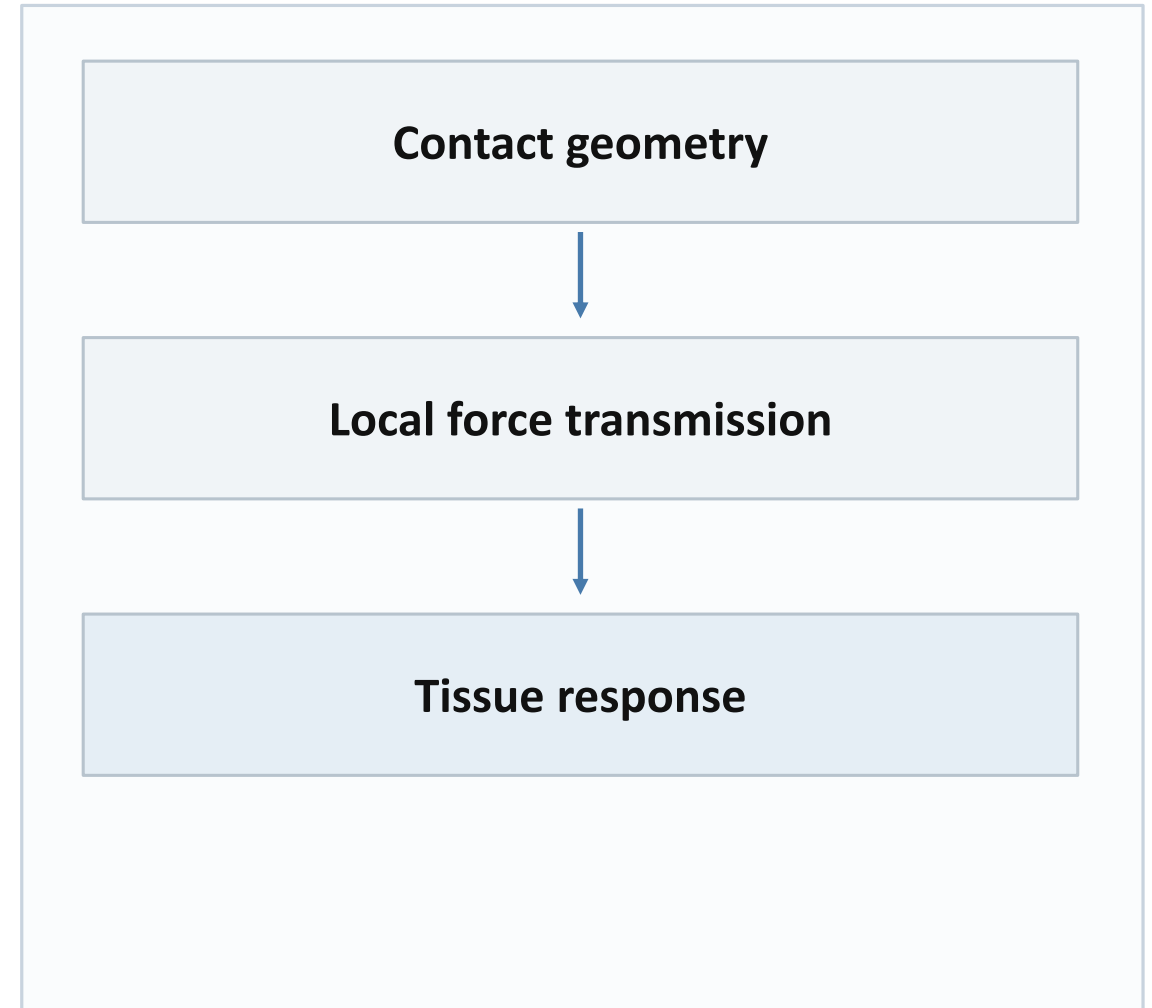
Object shape

Impact energy

Recipient tissue

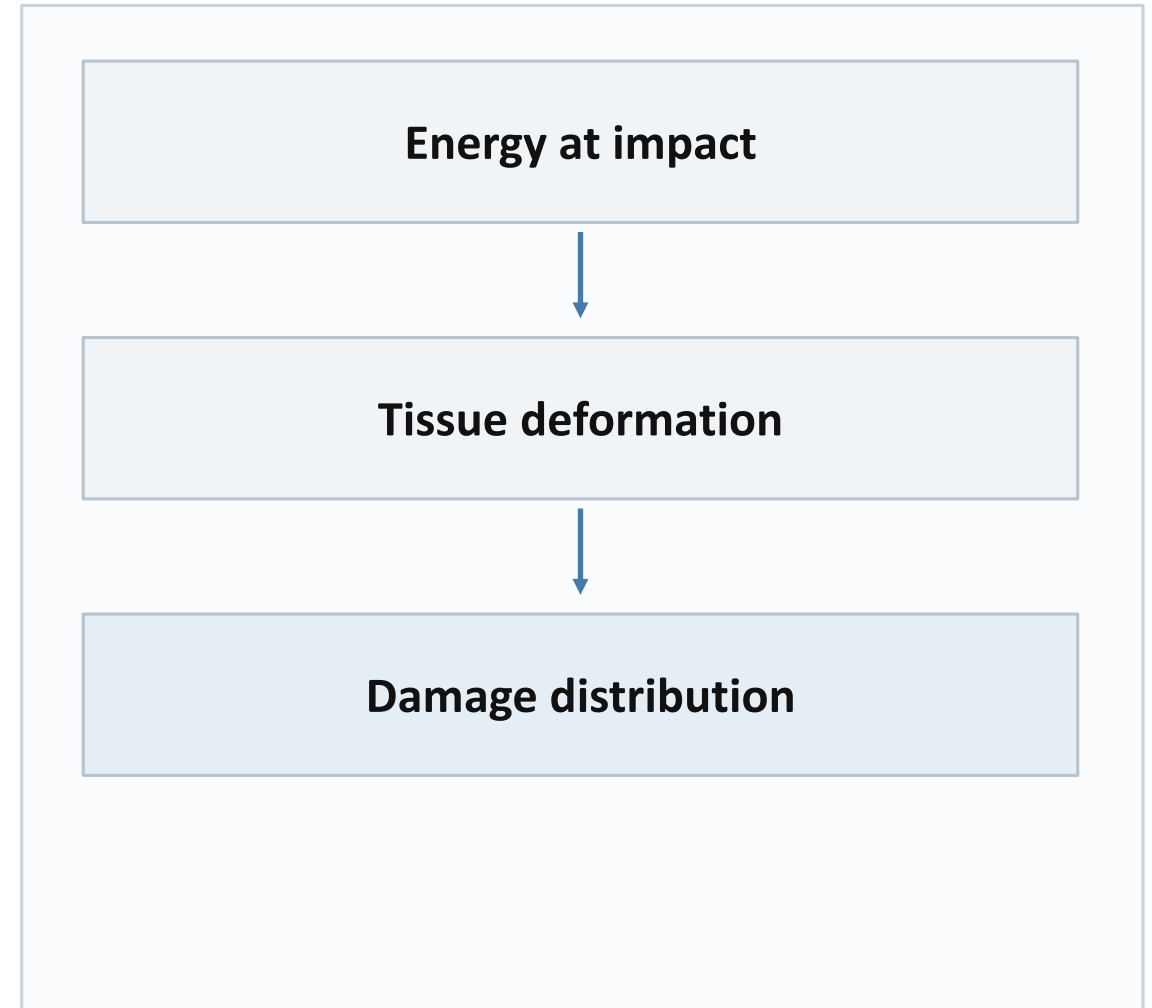
Object shape changes the injury pattern

- Force delivered by an object is distributed over its contact region.
- A broad blunt contact differs from a narrow penetrating contact.
- Interpret morphology in conjunction with the other two determinants.



Impact energy changes injury severity

- The amount of energy discharged during the collision is a principal determinant.
- A single surface pattern need not capture the extent of deeper damage.
- Energy and its distribution should be considered together.



Recipient tissue changes consequences

- Soft tissues share broad wound-response patterns.
- Cranial, cerebral, and skeletal structures have unique injuries.
- Anatomical location can make even a localized lesion life-threatening.

Soft tissue

Bone

Brain / spinal cord

The same force can produce different outcomes

- A blow to skin can produce a bruise or an open wound.
- In bone, a force may produce structural discontinuity.
- In the CNS, mechanical loading can disrupt vessels, parenchyma, or axons.

Skin / soft tissue

Bone

CNS

Five named soft-tissue patterns

- Abrasions and contusions are distinct from open tears and penetrations.
- Lacerations, incised wounds, and puncture wounds are separately identified.
- The categories describe injury morphology, not a complete forensic diagnosis.

Abrasion

Contusion

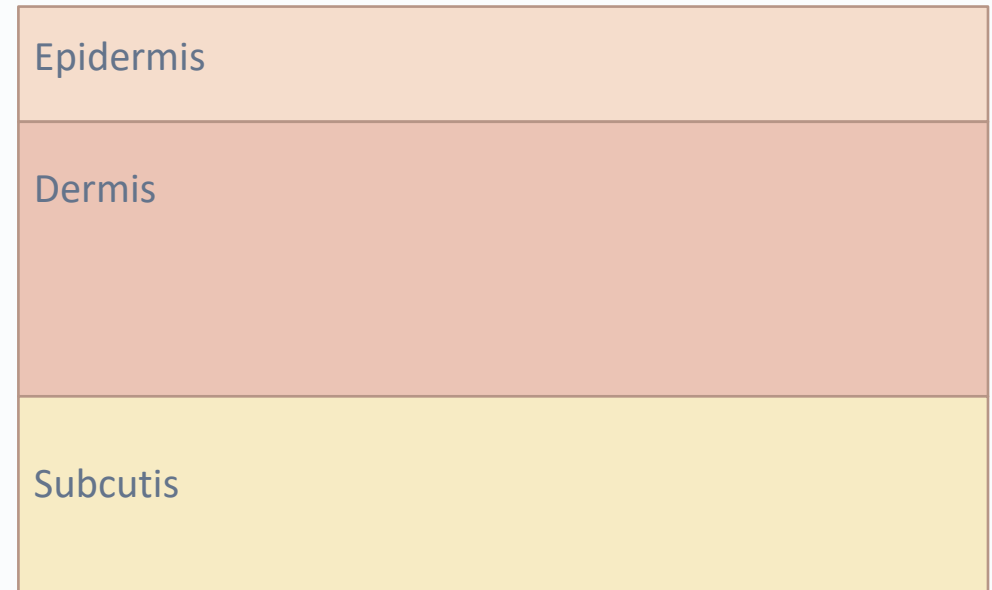
Laceration

Incised wound

Puncture wound

Surface appearance and tissue depth

- Evaluate whether the surface is intact or disrupted.
- Consider whether the principal injury is superficial, within soft tissues, or traverses deeper structures.
- Surface morphology is one part of injury assessment.

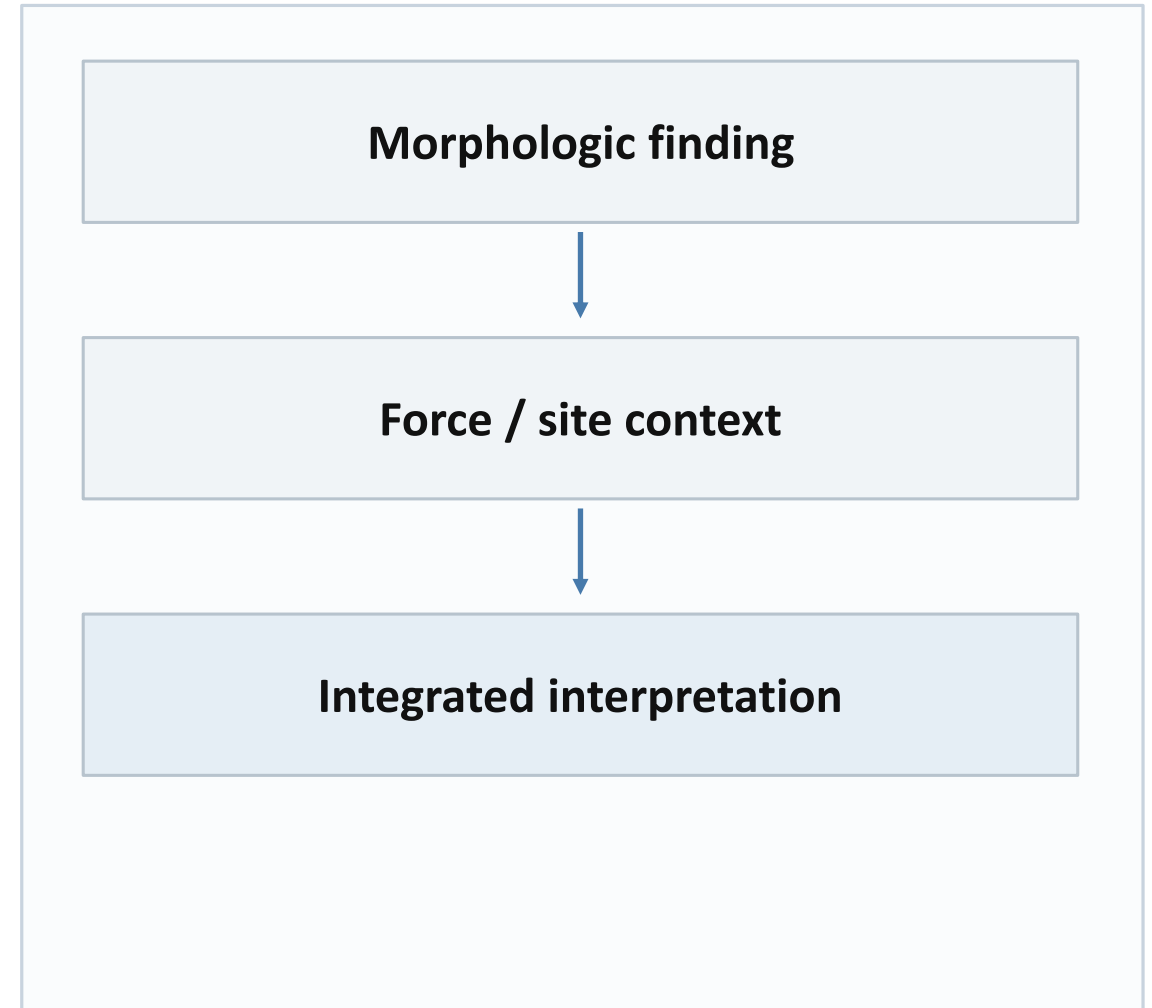


Surface

Schematic: Simplified tissue layers; Not a specimen

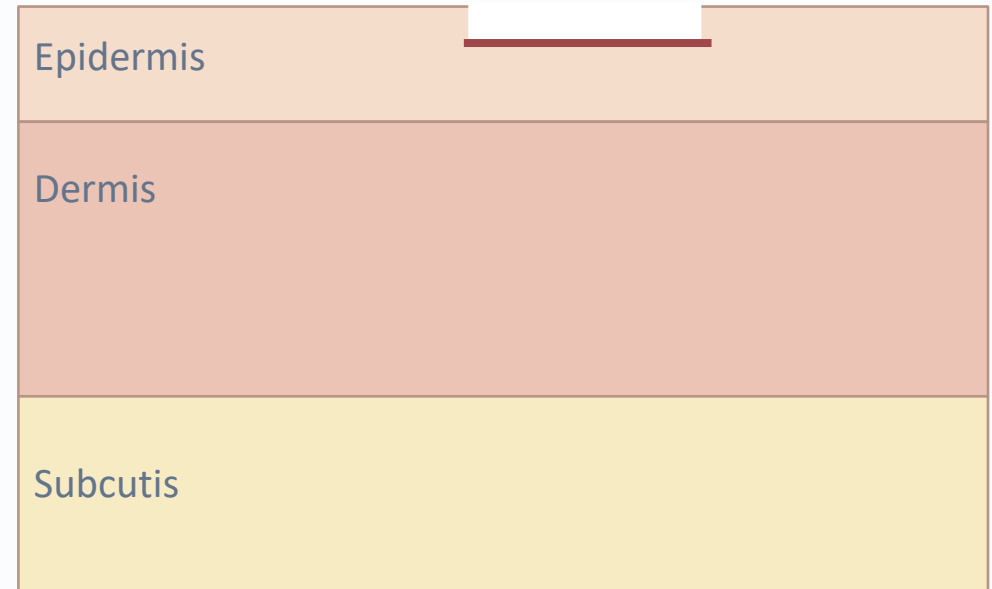
Classify the dominant traumatic pattern

- First identify the principal observed tissue change.
- Then integrate likely contact characteristics with injured anatomy.
- Multiple patterns may coexist after a single impact.



Abrasion: The surface-injury category

- Abrasion as a distinct soft-tissue trauma pattern.
- Use the term for superficial surface damage rather than a deep tear or bruise.
- Its clinical significance depends on accompanying tissue injury.

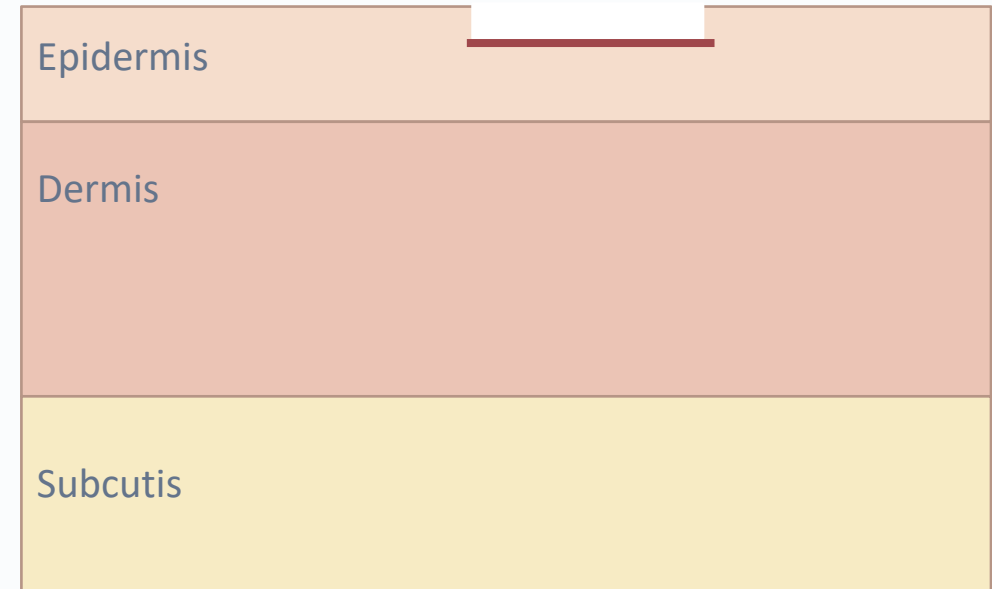


Superficial injury

Schematic: Simplified tissue layers; Not a specimen

Surface injury and barrier disruption

- Skin is a mechanical barrier to microbial entry.
- A traumatic surface defect can compromise local barrier integrity.
- Do not assume the presence or absence of deeper injury from the surface lesion alone.

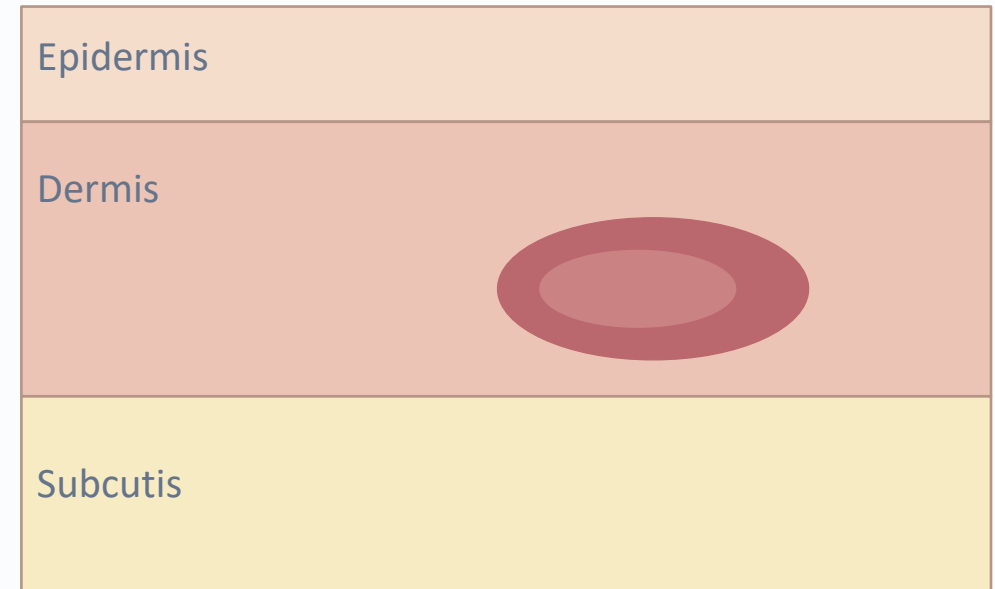


Surface breach

Schematic: Simplified tissue layers; Not a specimen

Contusion: Injury after blunt loading

- Cerebral contusion by analogy with a bruise caused by blunt trauma.
- Vascular disruption and extravasation may accompany tissue displacement.
- An intact surface does not establish intact underlying tissue.

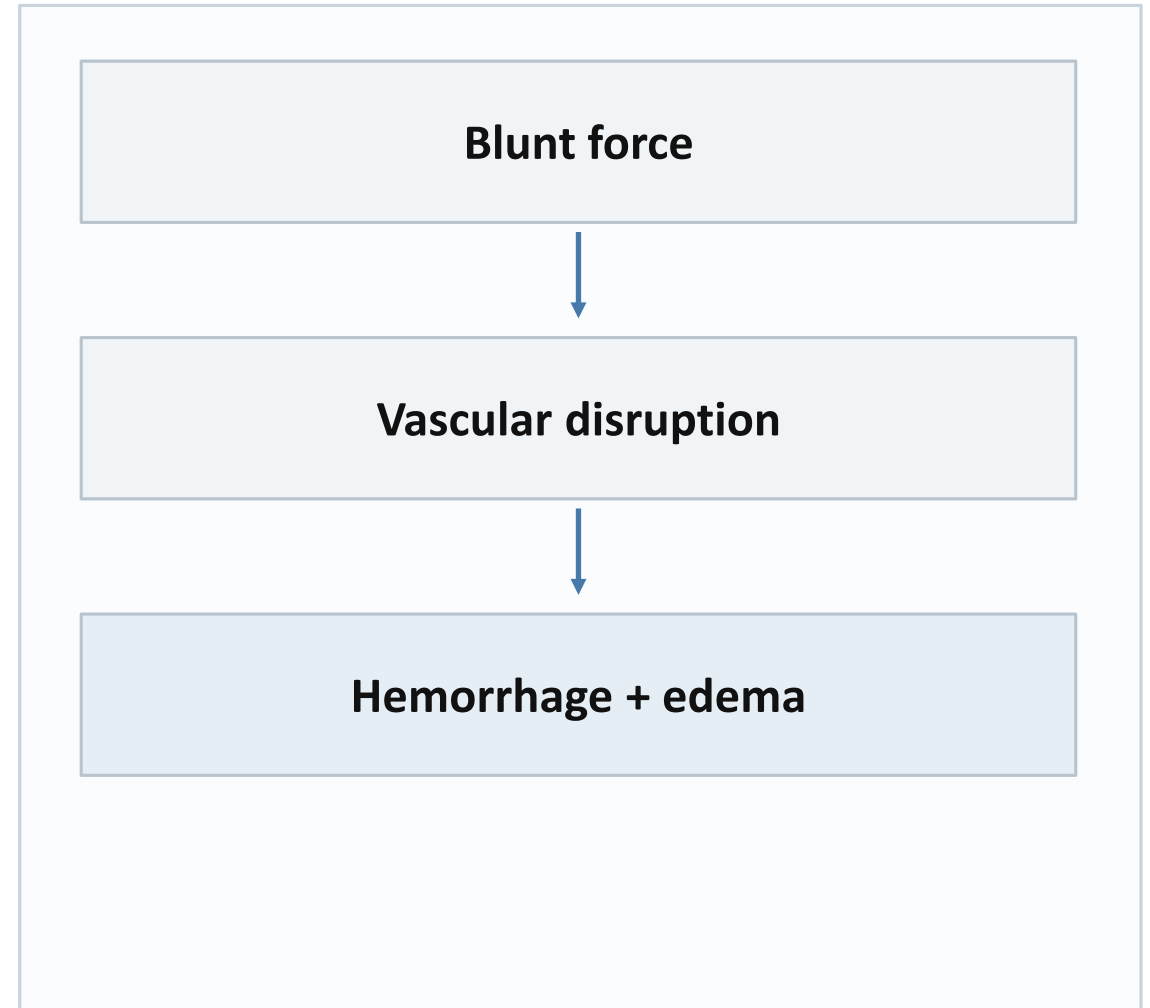


Blunt impact

Schematic: Simplified tissue layers; Not a specimen

Why contusions are hemorrhagic

- Mechanical tissue displacement can tear small vascular channels.
- Blood escapes into surrounding tissues as the vessels are disrupted.
- Edema may accompany the hemorrhagic injury.



Contusion versus tissue laceration

- Contusion emphasizes bruising and hemorrhagic parenchymal damage.
- Laceration emphasizes tearing of tissue architecture.
- In the brain, both are direct injuries from transmitted kinetic energy.

CONTUSION

Bruise-like
damage

LACERATION

Tissue tearing

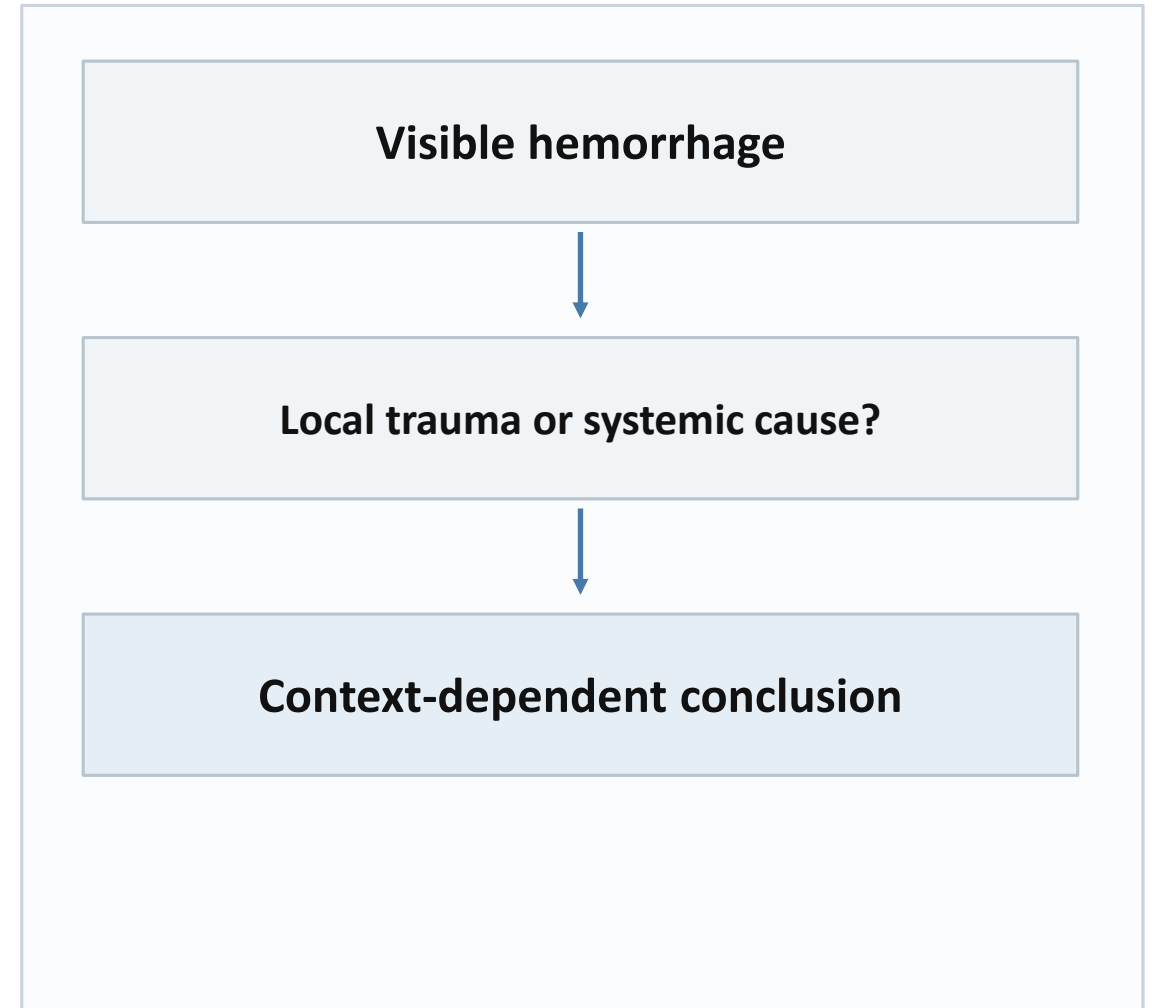
Bruise, ecchymosis, and hematoma

- A contusion names a mechanically produced injury pattern.
- Ecchymosis describes an area of extravasated blood in skin or mucosa.
- Hematoma is a collection or mass of extravasated blood.

INJURY MECHANISM	HEMORRHAGIC MORPHOLOGY
Contusion	Ecchymosis / hematoma

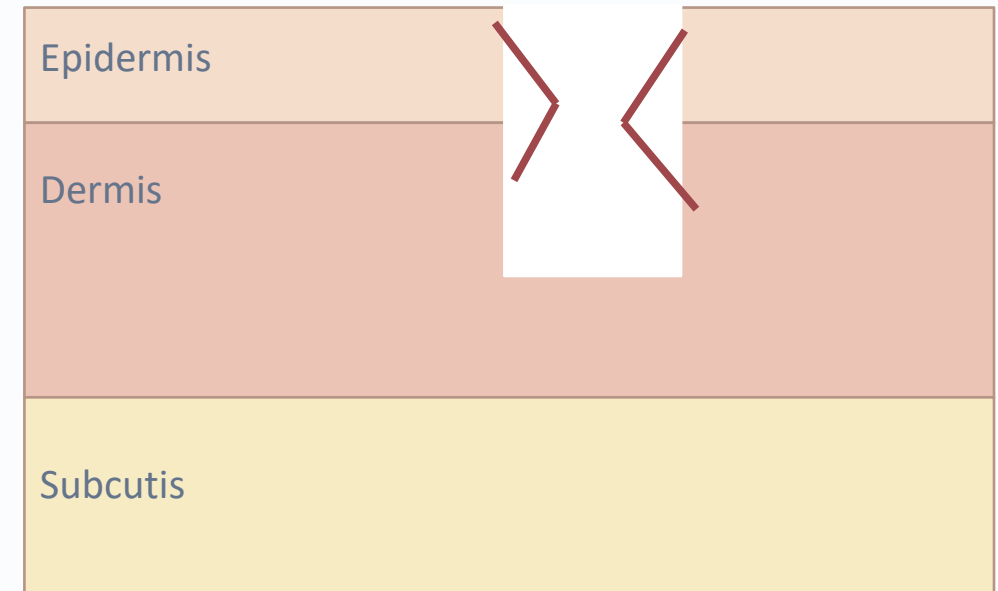
Hemorrhagic appearance has alternatives

- Not every bruise-like hemorrhage establishes direct impact.
- Robbins also links purpura and ecchymoses to systemic small-vessel disorders.
- Use mechanism and clinical context when interpreting bleeding.



Laceration: Disruption by tearing

- In the CNS chapter, a laceration is defined as penetrating injury with tissue tearing.
- It produces structural disruption rather than only vascular leakage.
- The significance depends on the tissue and structures involved.

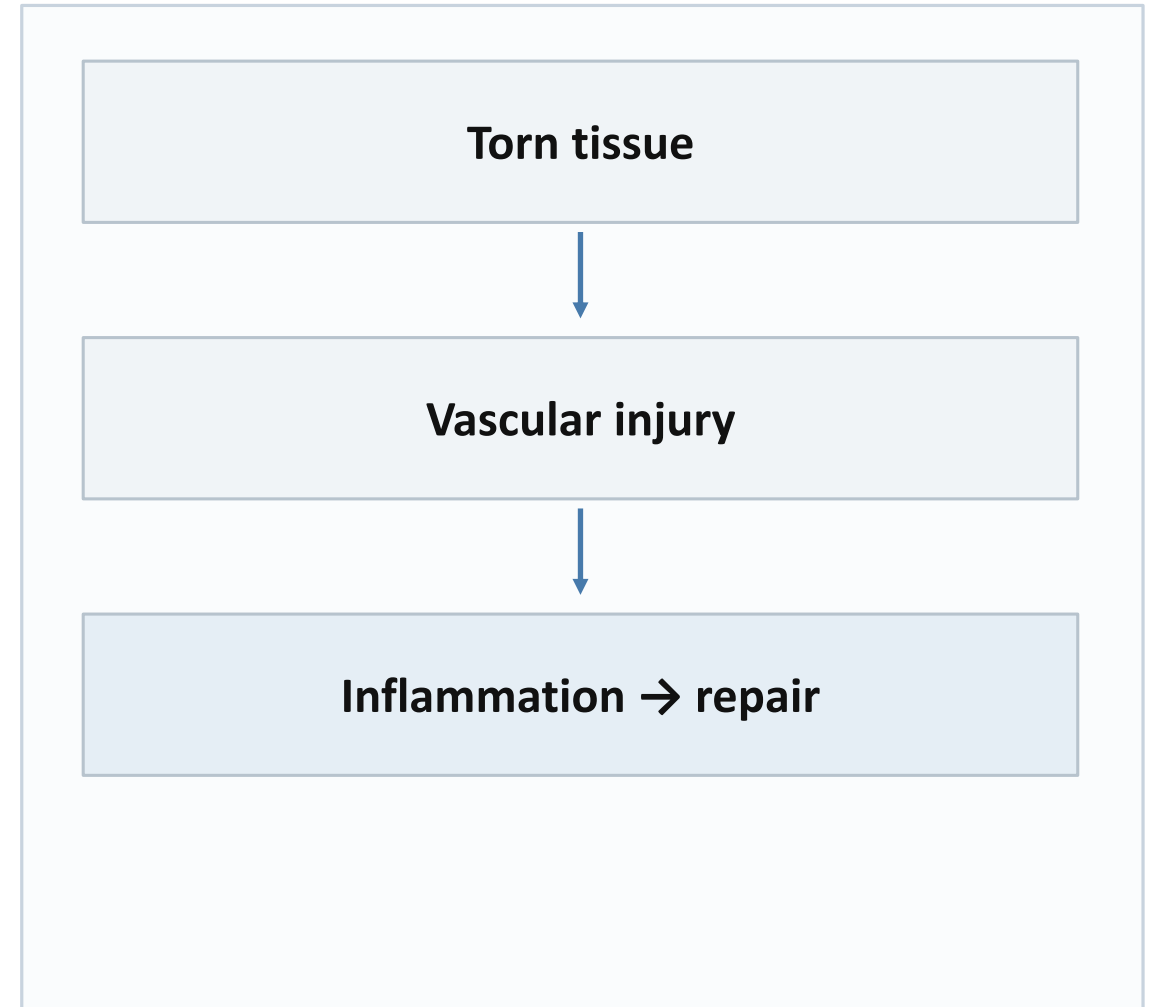


Tear

Schematic: Simplified tissue layers; Not a specimen

Tissue tears can affect multiple structures

- An open tear may interrupt surface and deeper tissue continuity.
- Vascular disruption adds hemorrhage to mechanical tissue loss.
- The relative amount of tissue loss helps determine repair by regeneration or scar.



Why wound geometry matters to repair

- Small, well-apposed edges favor epithelial continuity.
- Large tissue defects and irregular wound margins require more granulation tissue and scarring.
- The healing pattern depends on wound dimensions and tissue condition.

WELL-APPOSED

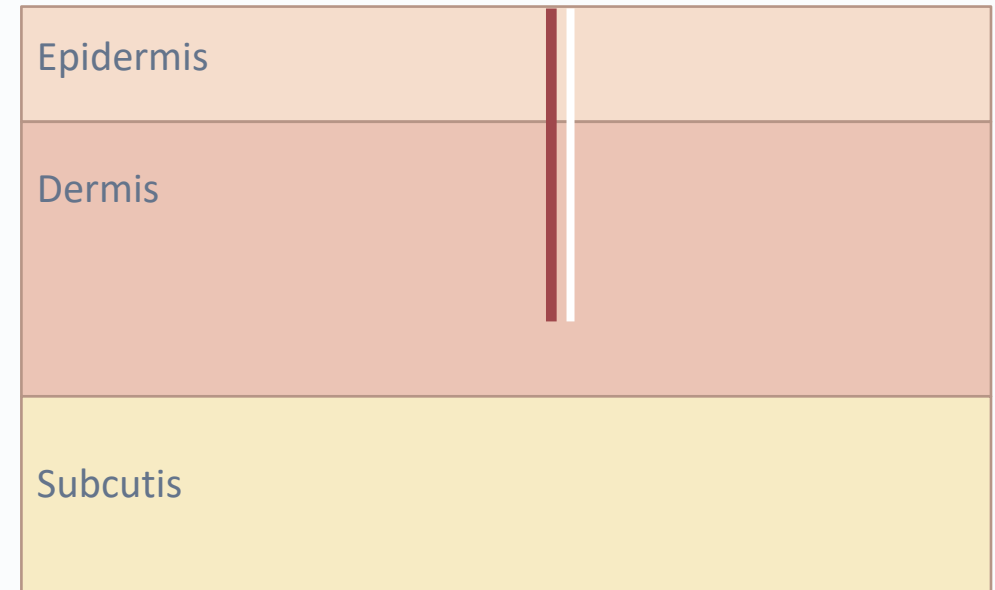
More primary
union

LARGE / IRREGULAR

More secondary
union

Incised wounds: A separate wound category

- Incised wounds separately from lacerations.
- The classic clean surgical incision provides the textbook example for primary intention healing.
- A wound description should distinguish cutting from tissue tearing when supported by morphology.

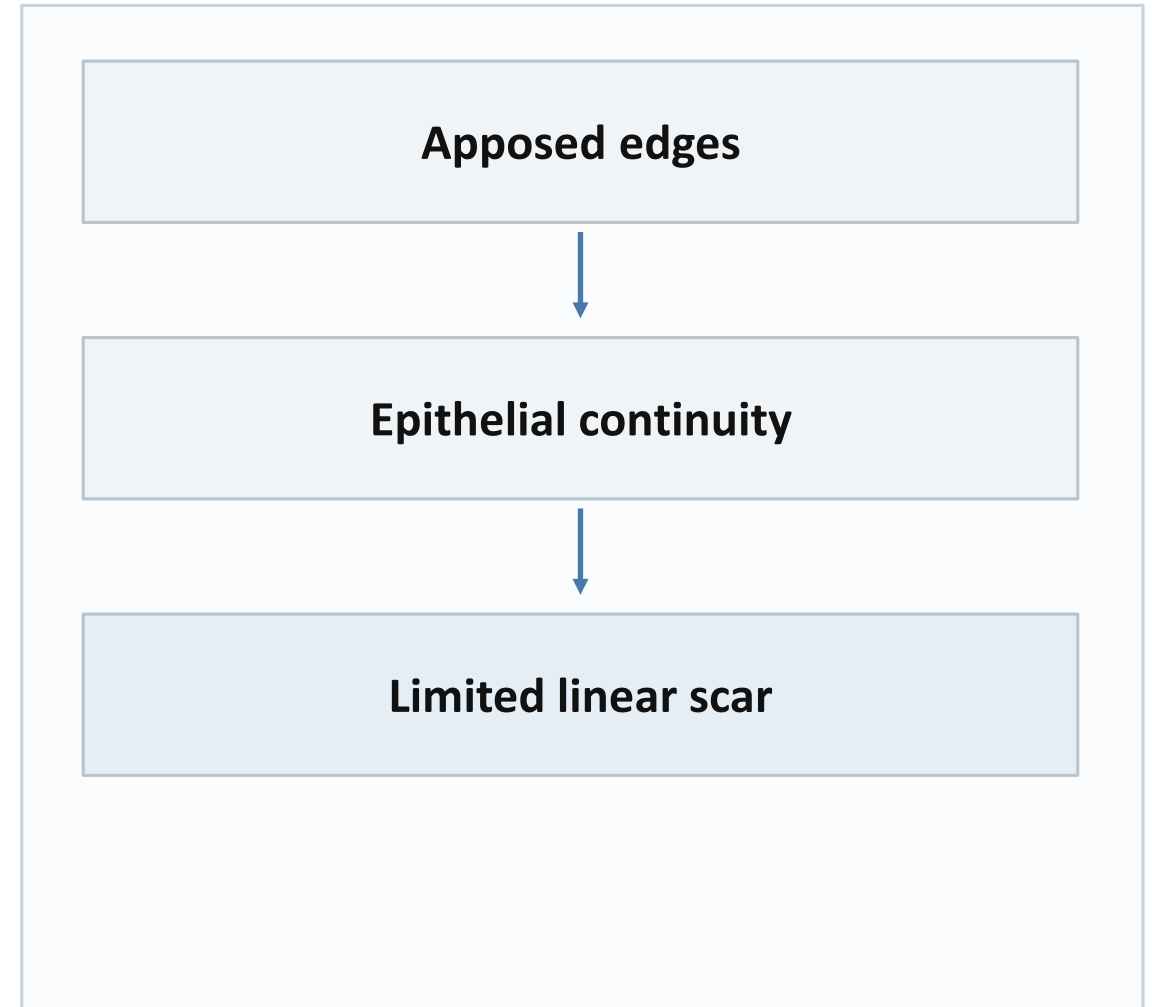


Linear incision

Schematic: Simplified tissue layers; Not a specimen

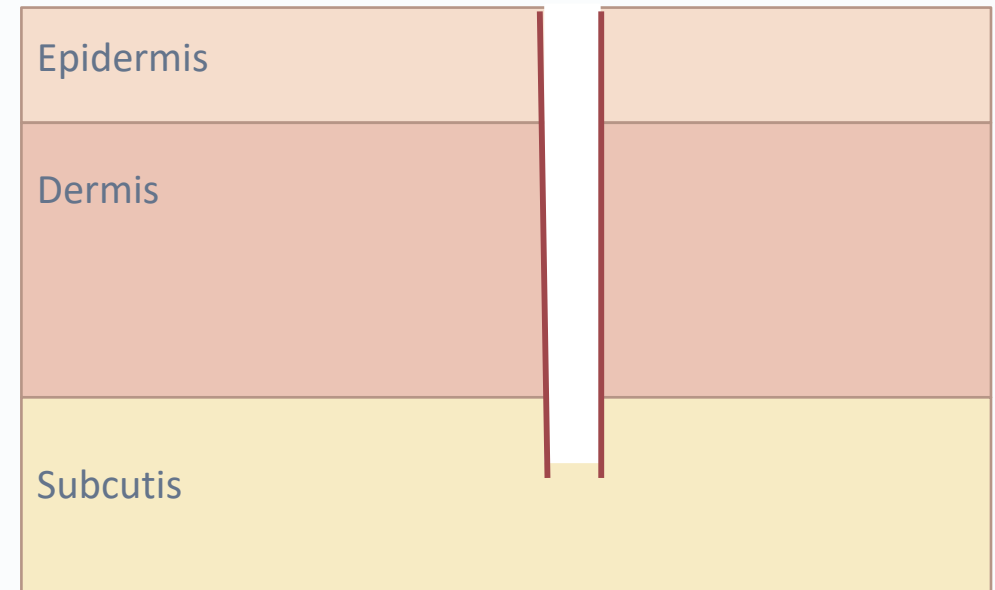
Clean incisions illustrate primary union

- The epidermal edges can migrate across a narrow defect.
- Relatively little granulation tissue and scar are required.
- First intention is typical of a surgically clean, well-apposed incision.



Puncture wounds: Depth deserves attention

- Puncture wounds as a distinct mechanical trauma pattern.
- A narrow surface opening does not exclude injury to deep structures.
- The damaged barrier can also permit entry of microorganisms.

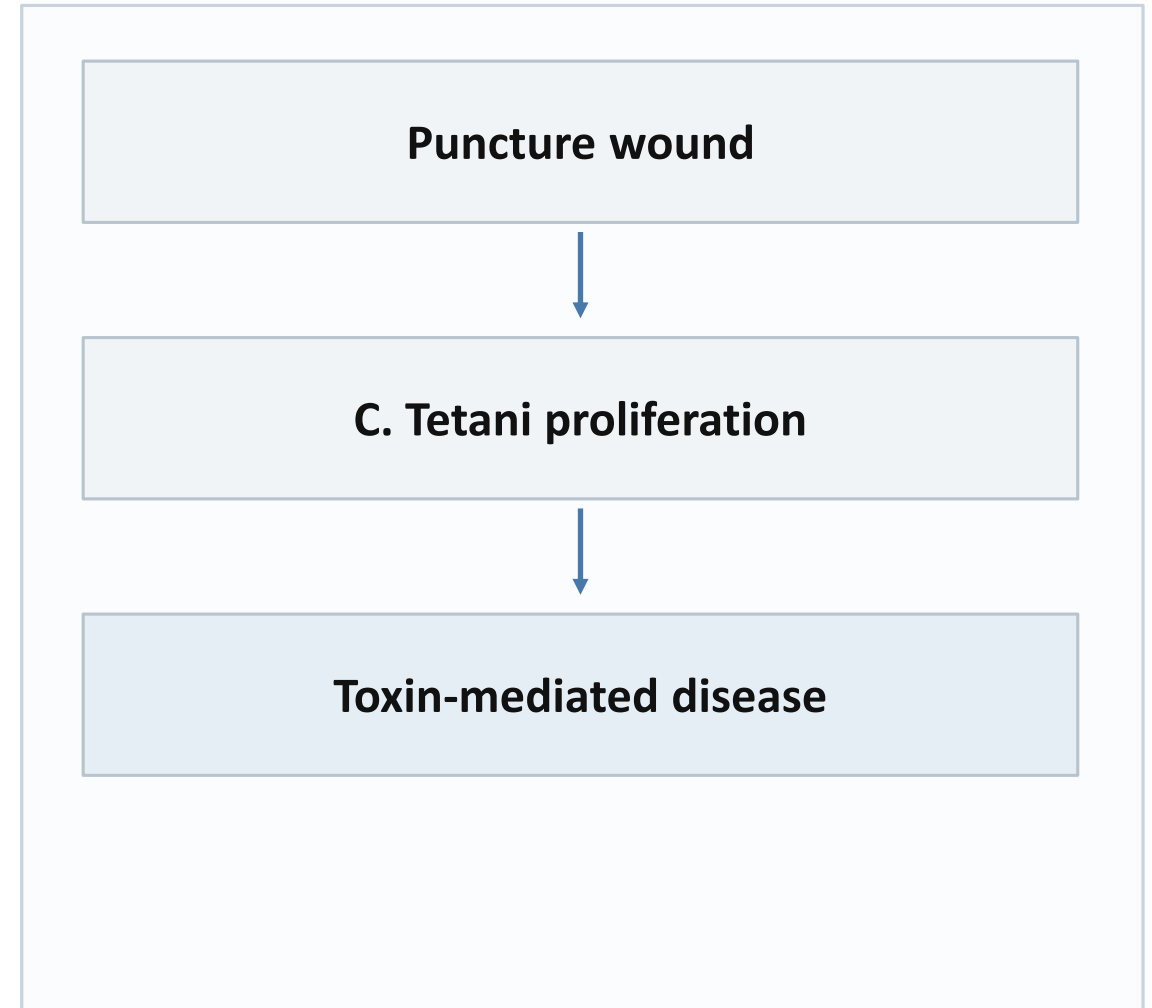


Narrow entry

Schematic: Simplified tissue layers; Not a specimen

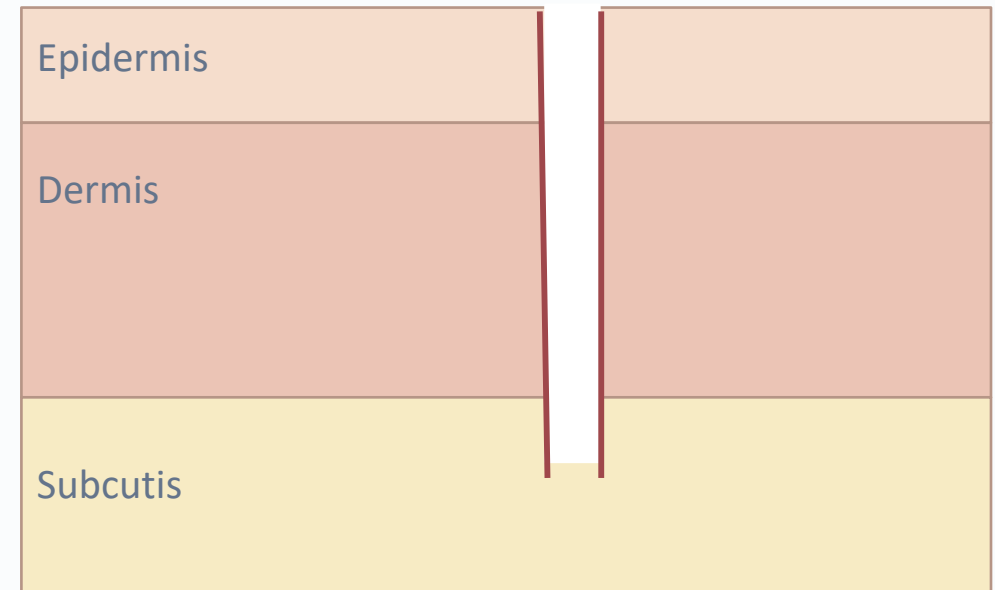
Puncture wounds and tetanus risk

- Puncture wounds as a setting for *C. Tetani* proliferation.
- Tetanus is caused by toxin release from the organism.
- This example links a small wound with potentially serious consequences.



Puncture site and hidden damage

- Analyze what lies under the apparent entry site.
- Vessels, cavities, and other vital tissues may be injured without a large surface defect.
- The anatomy of the wound path matters in addition to the skin opening.



Entry site

Schematic: Simplified tissue layers; Not a specimen

Five patterns compared

- Abrasion: Chiefly surface damage; Contusion: Blunt-associated bruise.
- Laceration: Tissue tearing; Incised wound: Cutting pattern.
- Puncture: Narrow entry with potentially important depth.

Surface

Bruise

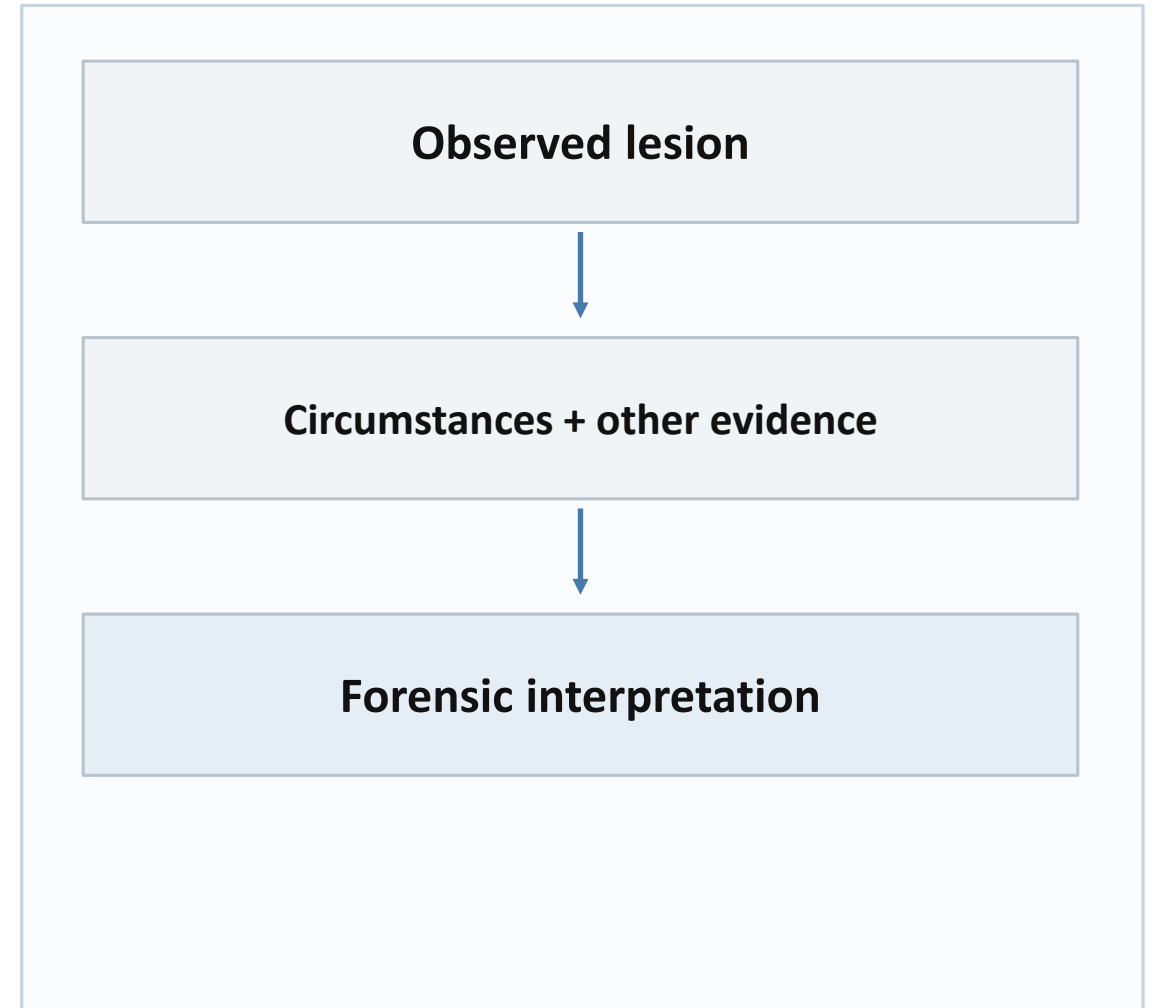
Tear

Cut

Penetration

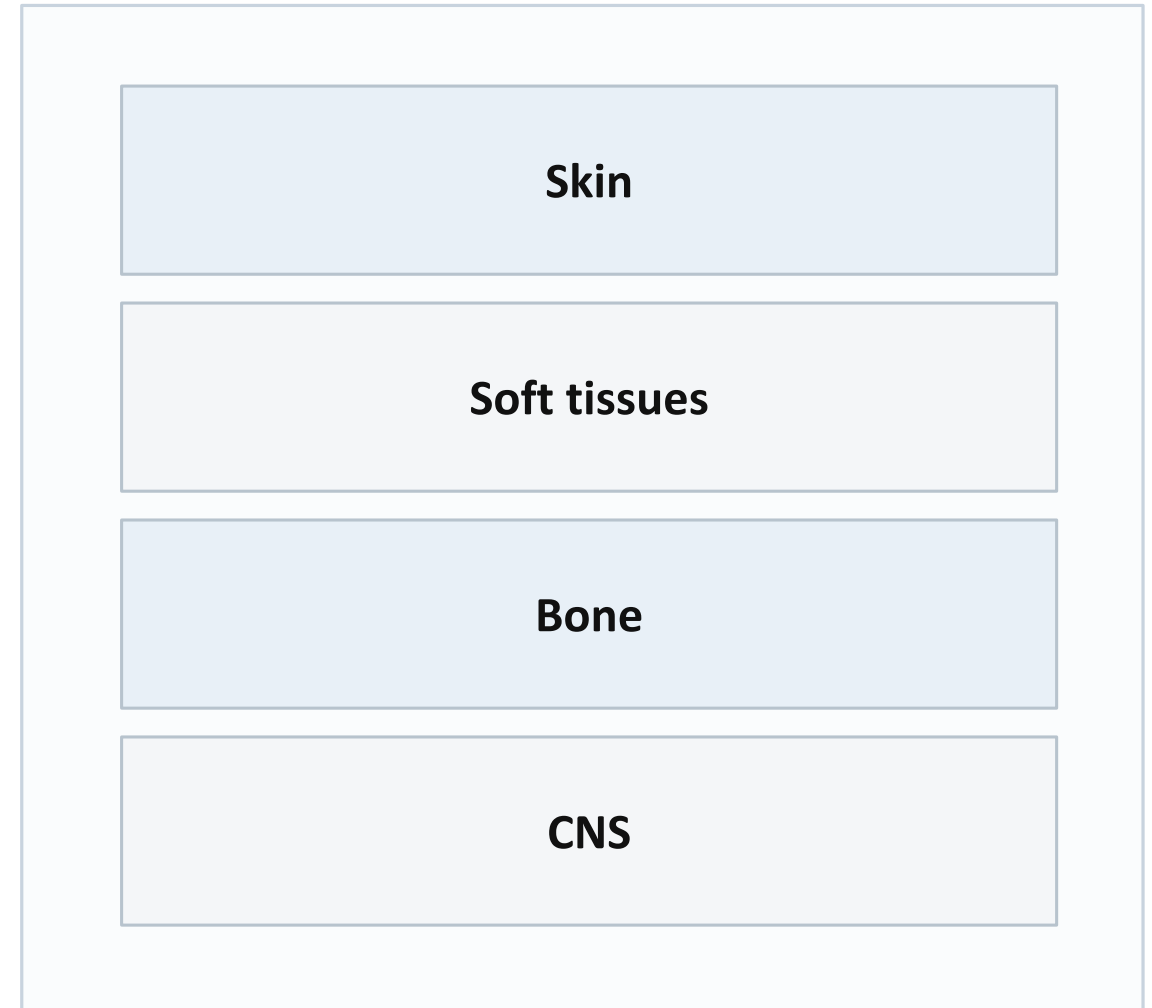
Morphology does not identify the whole event

- The mechanical trauma chapter treats these forms as a small sample of possible injuries.
- Forensic investigation may involve stabbing, shooting, traffic events, and blunt force.
- Neither one lesion nor one diagram establishes a unique cause.



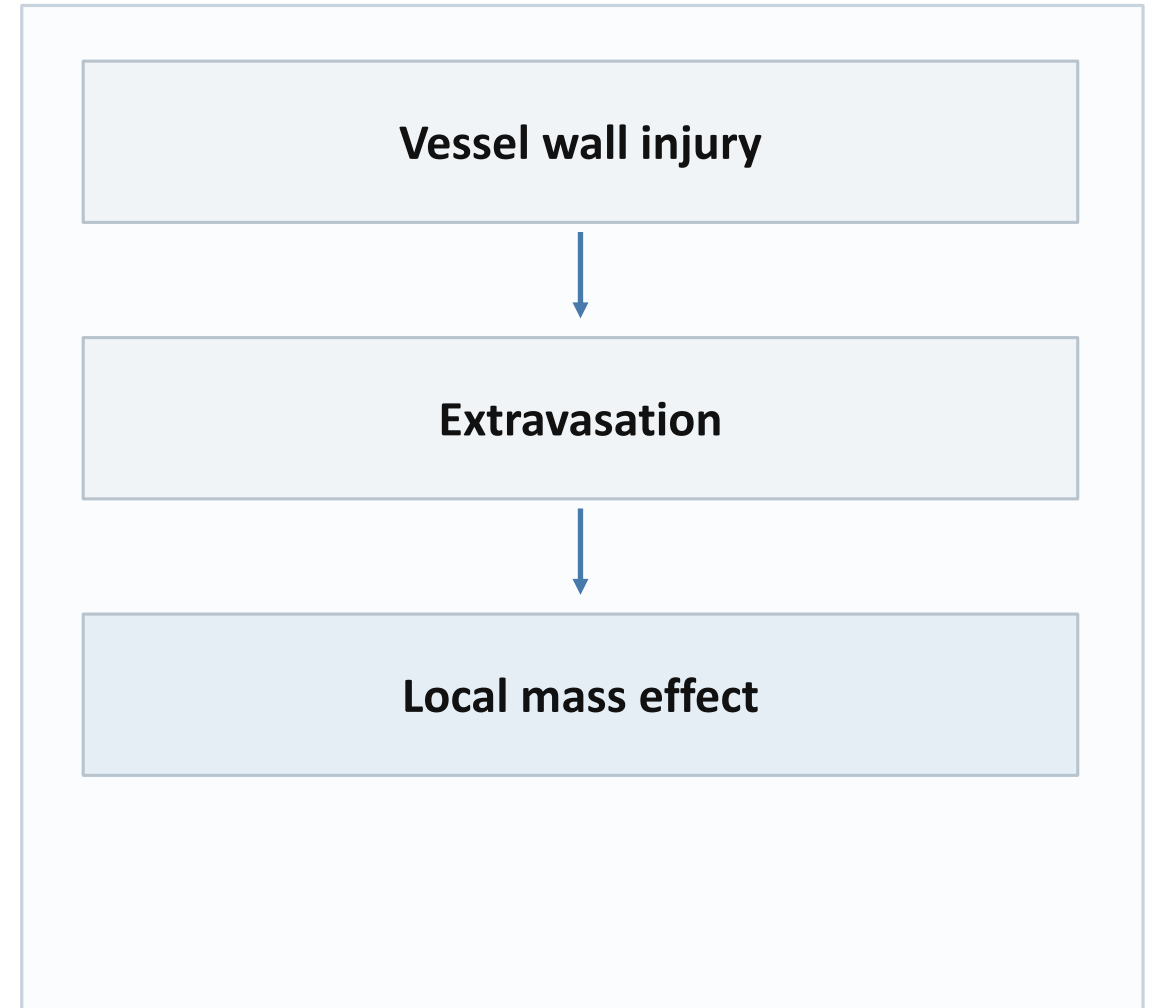
An injury may affect several tissue layers

- An impact may involve skin, soft tissues, blood vessels, and skeletal structures.
- For head trauma, fracture, parenchymal injury, and vascular injury can coexist.
- Layer-by-layer assessment is more informative than a single label.



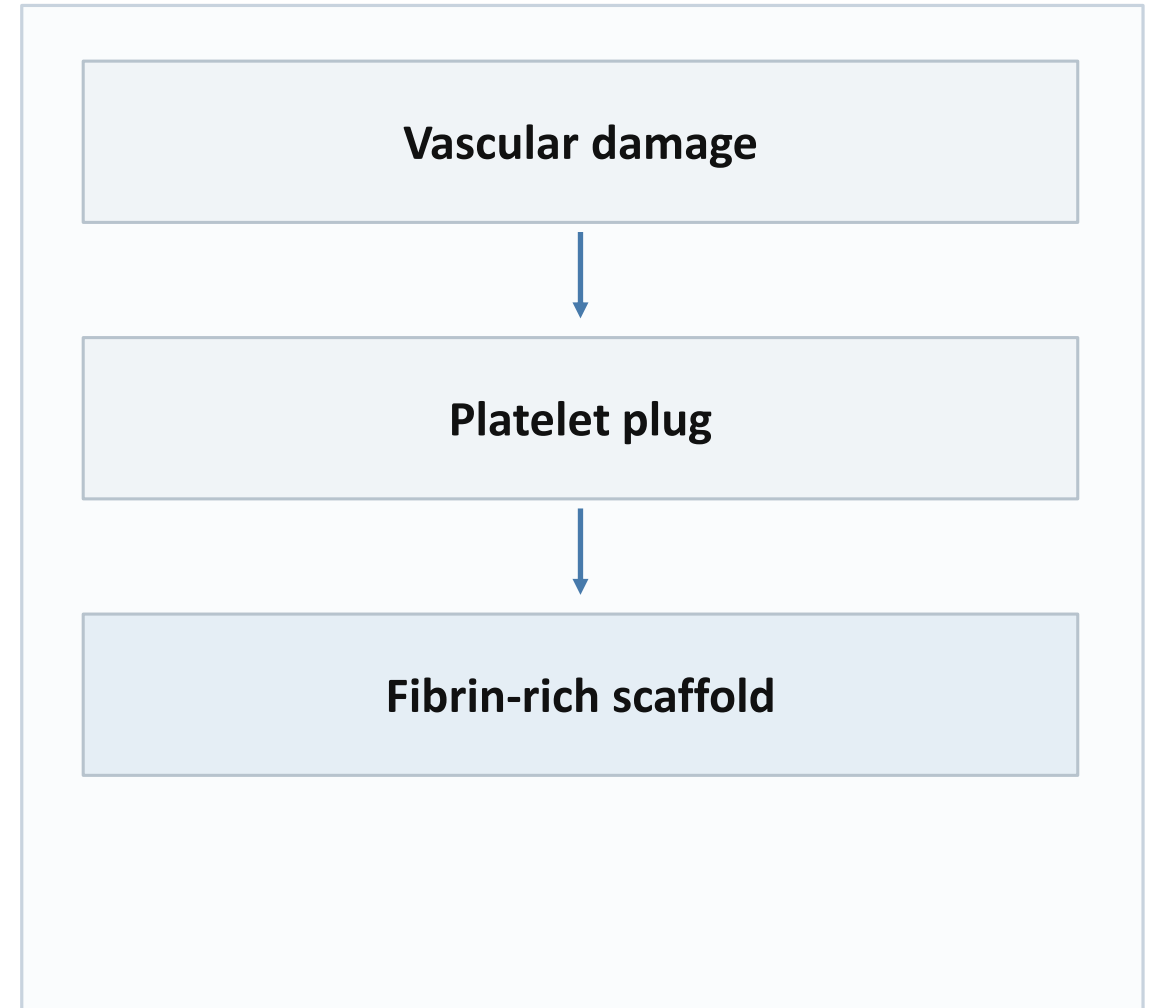
Mechanical vascular injury produces bleeding

- Rupture of vessels permits extravasation into tissues or compartments.
- Localization of bleeding determines its consequences.
- In the cranium, accumulated blood can compress brain tissue.



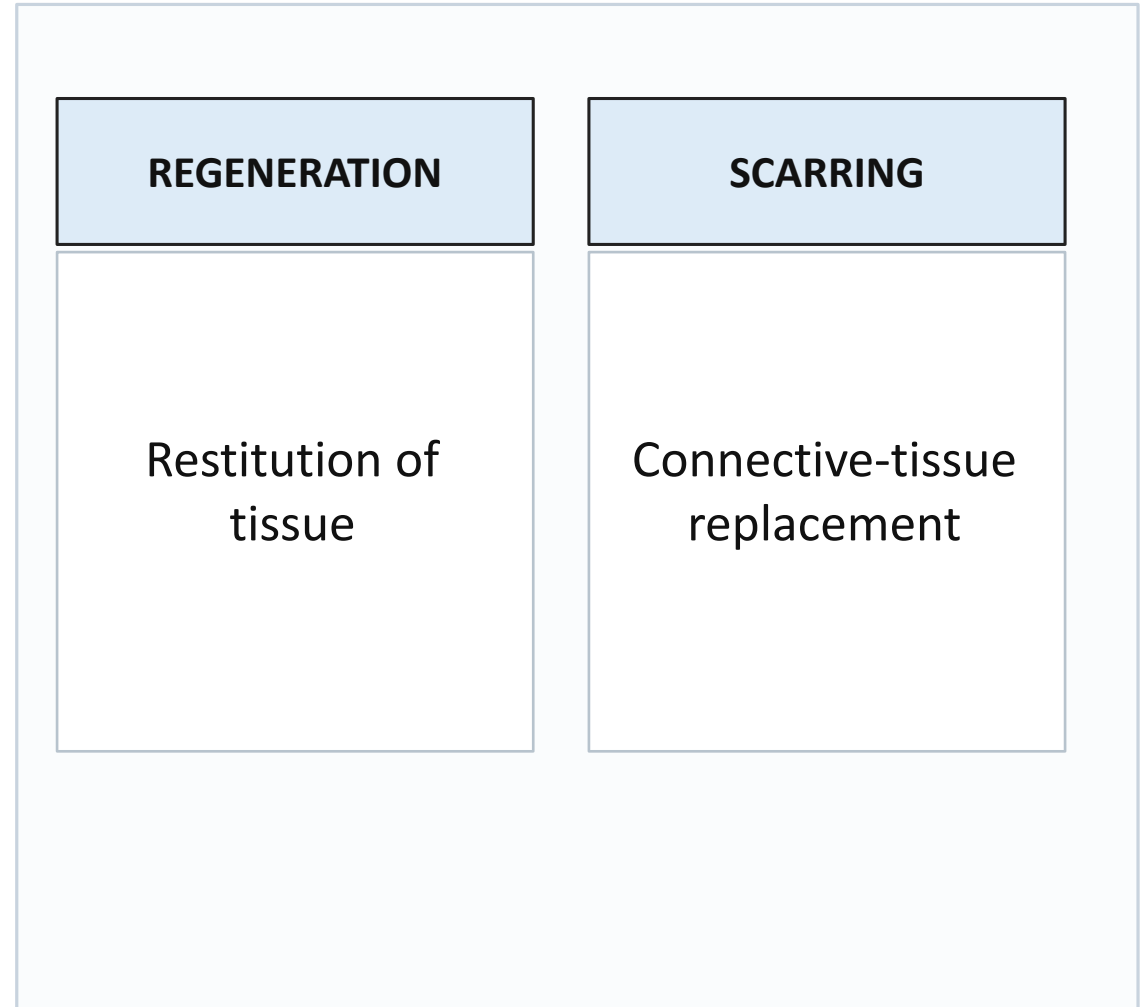
Hemostasis follows tissue disruption

- A platelet-rich hemostatic plug forms promptly after injury.
- The plug arrests bleeding and supplies a provisional scaffold.
- A more stable clot supports subsequent cell recruitment.



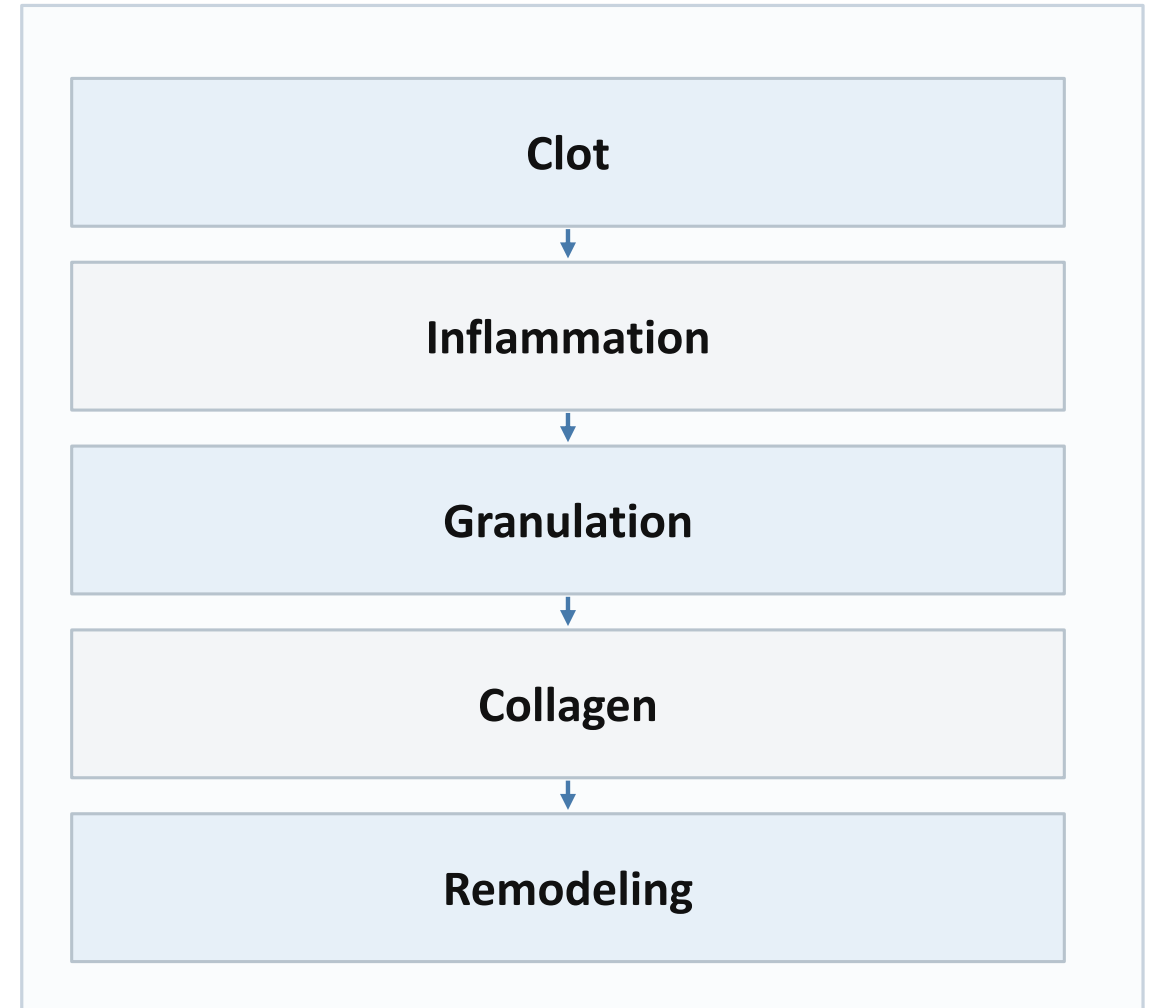
Repair depends on structural preservation

- Regeneration can replace lost cells when proliferative capacity and framework permit.
- Injury to supporting architecture favors connective-tissue replacement.
- A scar patches rather than fully restores the original organization.



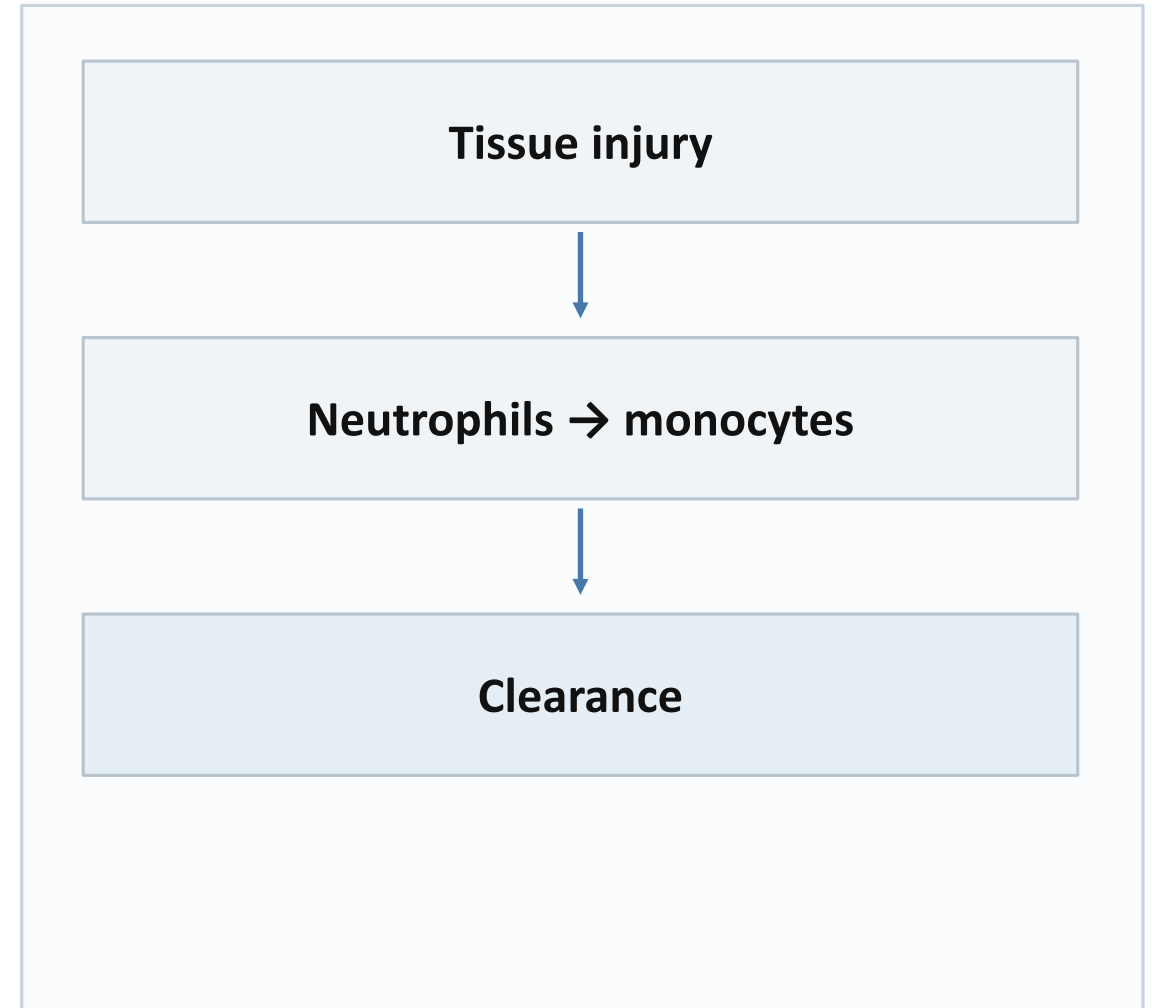
Major phases of wound repair

- Clot formation is followed by inflammation.
- Angiogenesis, fibroblast activity, and new extracellular matrix build granulation tissue.
- Collagen deposition and remodeling form the mature scar.



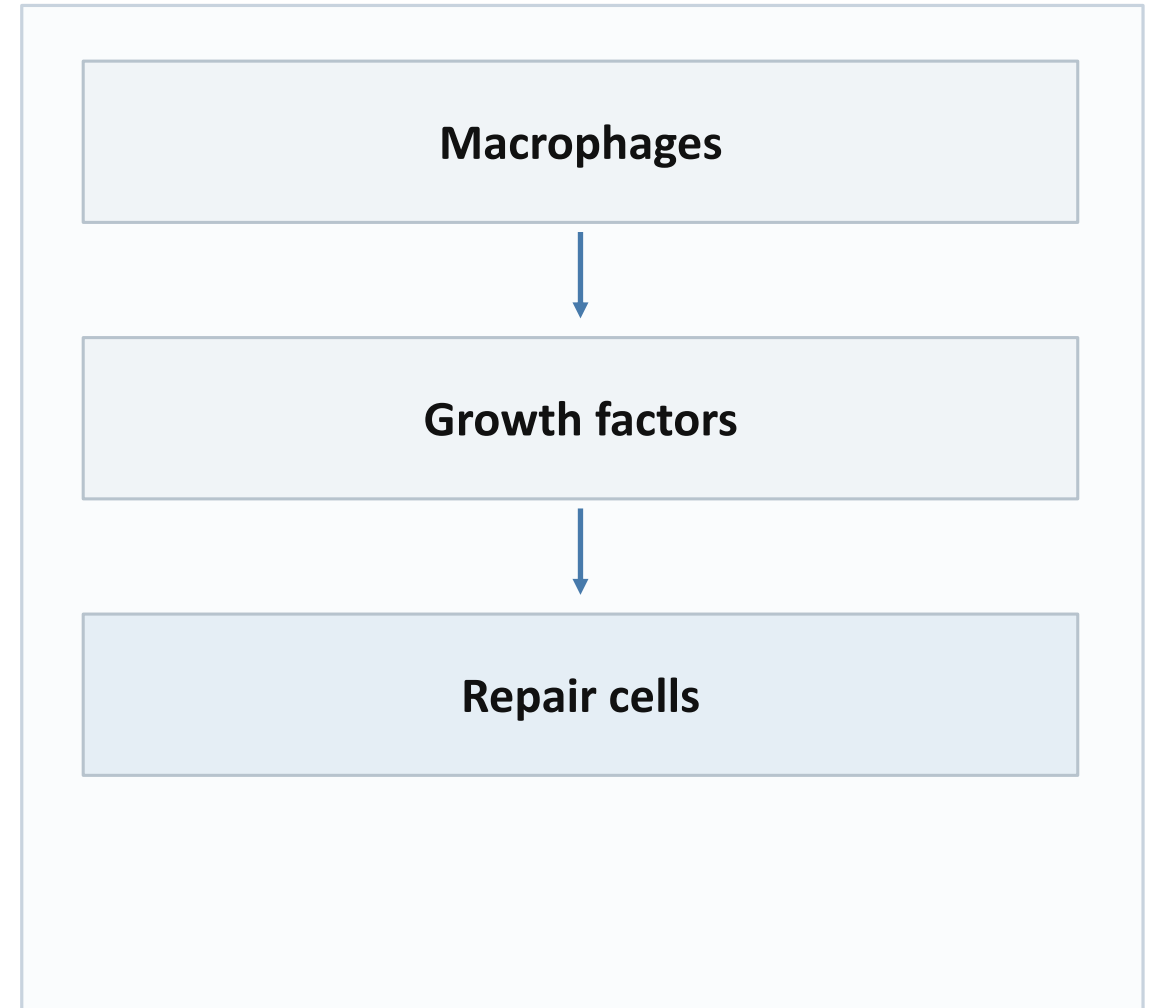
Acute inflammation clears injured tissue

- Neutrophils and then monocytes are recruited after injury.
- Inflammatory cells eliminate microbes and dead tissue.
- Persistence of infection or necrotic material can prolong repair.



Macrophages coordinate repair

- Macrophages remove debris and orchestrate the transition to tissue restoration.
- They produce cytokines and growth factors that recruit repair cells.
- They link inflammation to angiogenesis and fibrosis.



Angiogenesis supplies the wound bed

- New vessels grow from pre-existing vessels.
- Granulation tissue combines new capillaries with proliferating fibroblasts.
- This is a functional vascular-and-connective-tissue repair response.

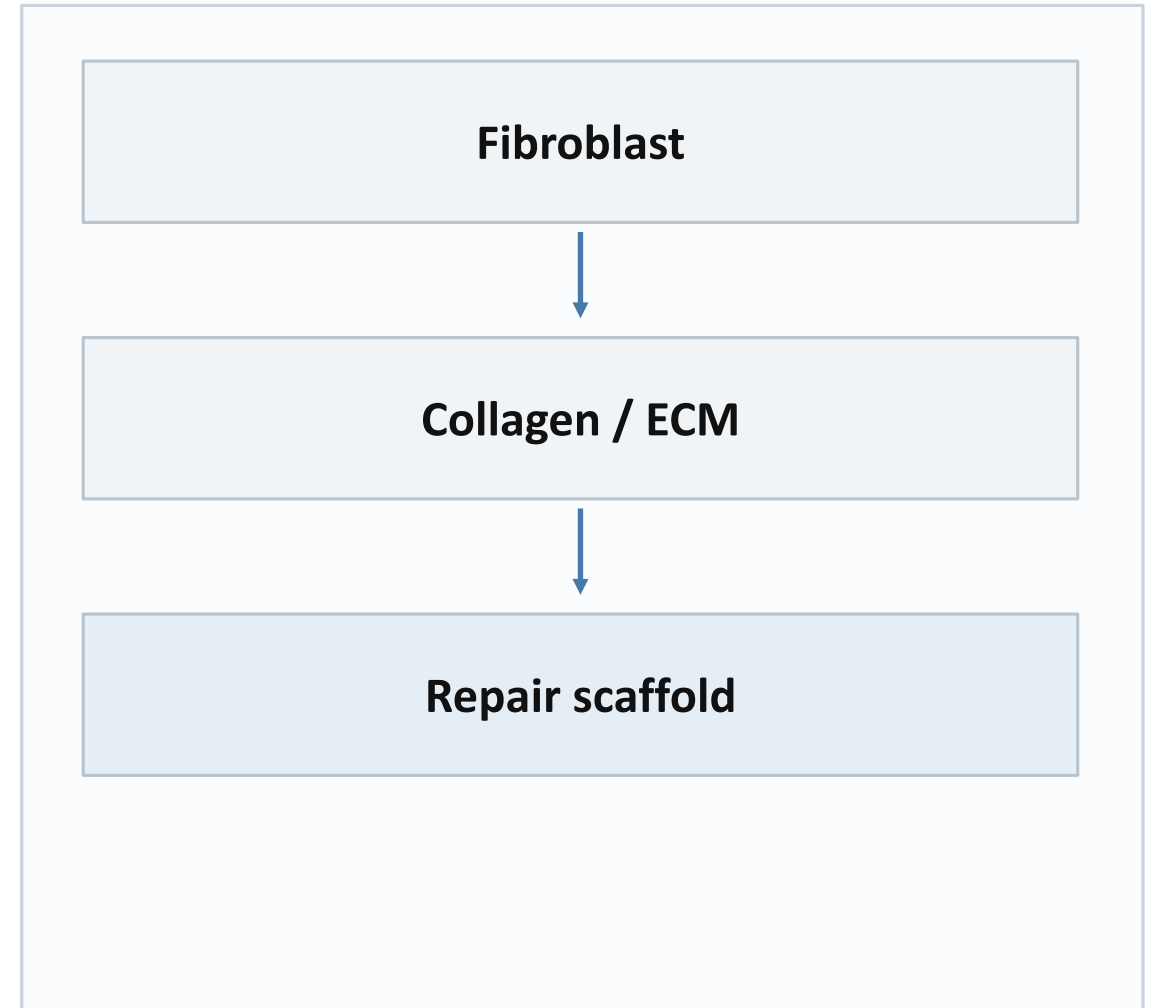
Capillary growth

Fibroblast influx

Granulation tissue

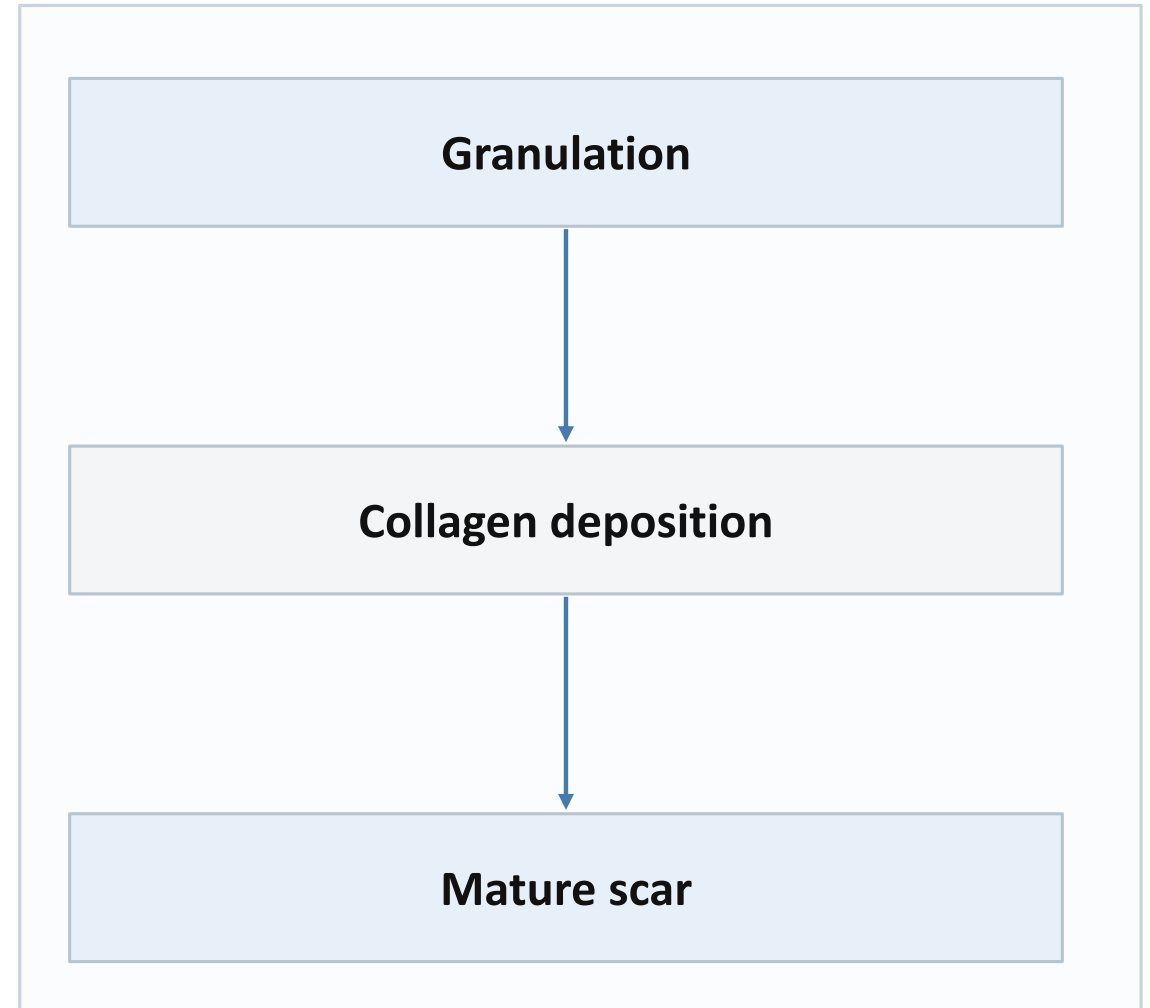
Fibroblasts build the extracellular matrix

- Fibroblasts migrate and proliferate in the repairing wound.
- Collagen deposition progressively increases tissue strength.
- The matrix is subsequently remodeled rather than remaining static.



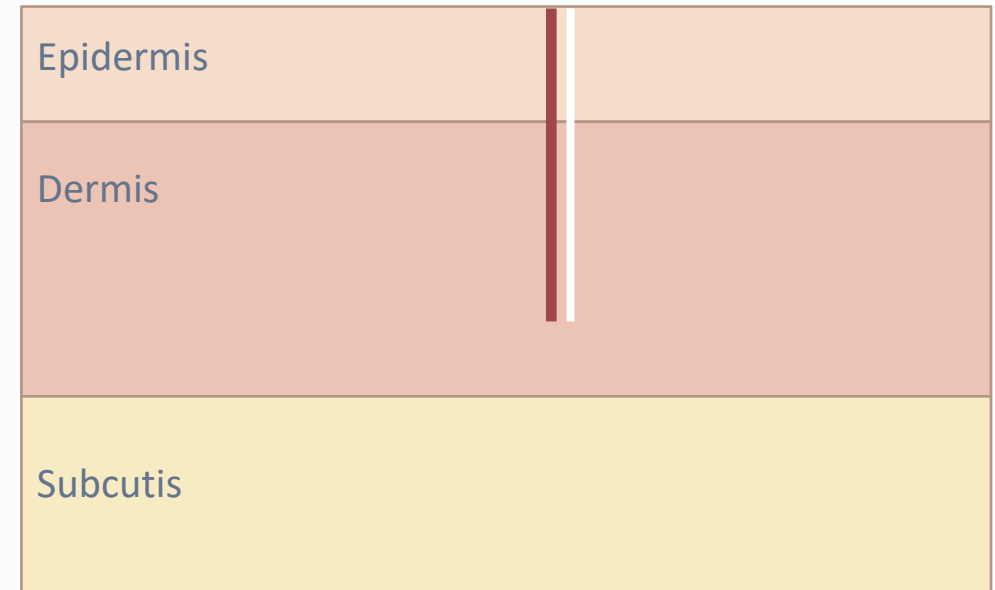
Scar remodeling changes wound architecture

- The repair response transitions from highly cellular granulation tissue.
- Collagen remodeling produces a more mature fibrous scar.
- The result restores tissue continuity but not necessarily original architecture.



Primary intention: Narrow, clean defects

- The wound margins are well apposed and the defect is small.
- Epithelial regeneration predominates, with less granulation and contraction.
- The usual outcome is a relatively neat linear scar.

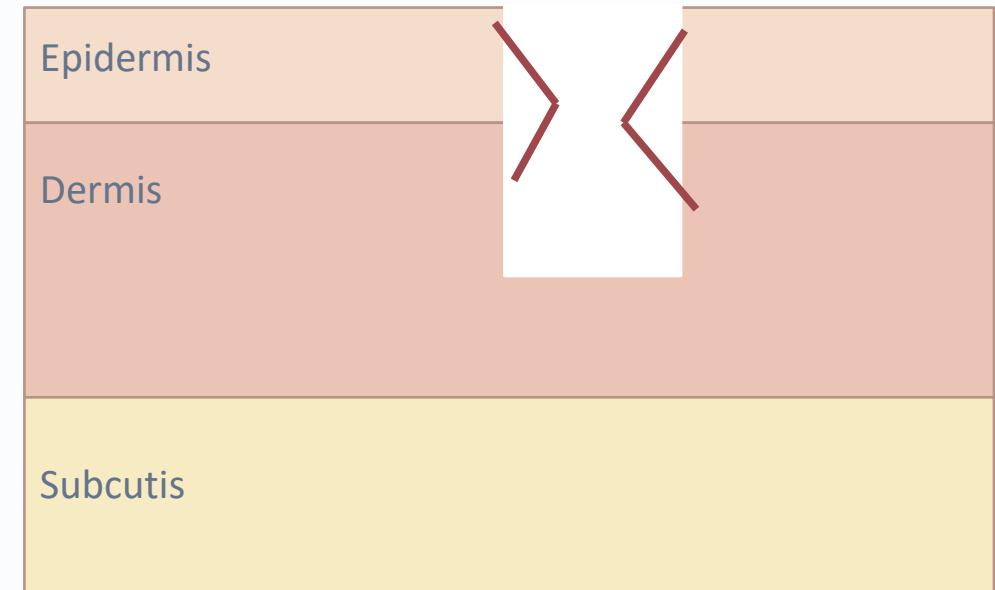


Minimal gap

Schematic: Simplified tissue layers; Not a specimen

Secondary intention: A larger defect

- Large, irregular, or often infected wounds trigger a stronger inflammatory reaction.
- Abundant granulation tissue and wound contraction accompany healing.
- Healing is longer and generally leaves a more irregular scar.

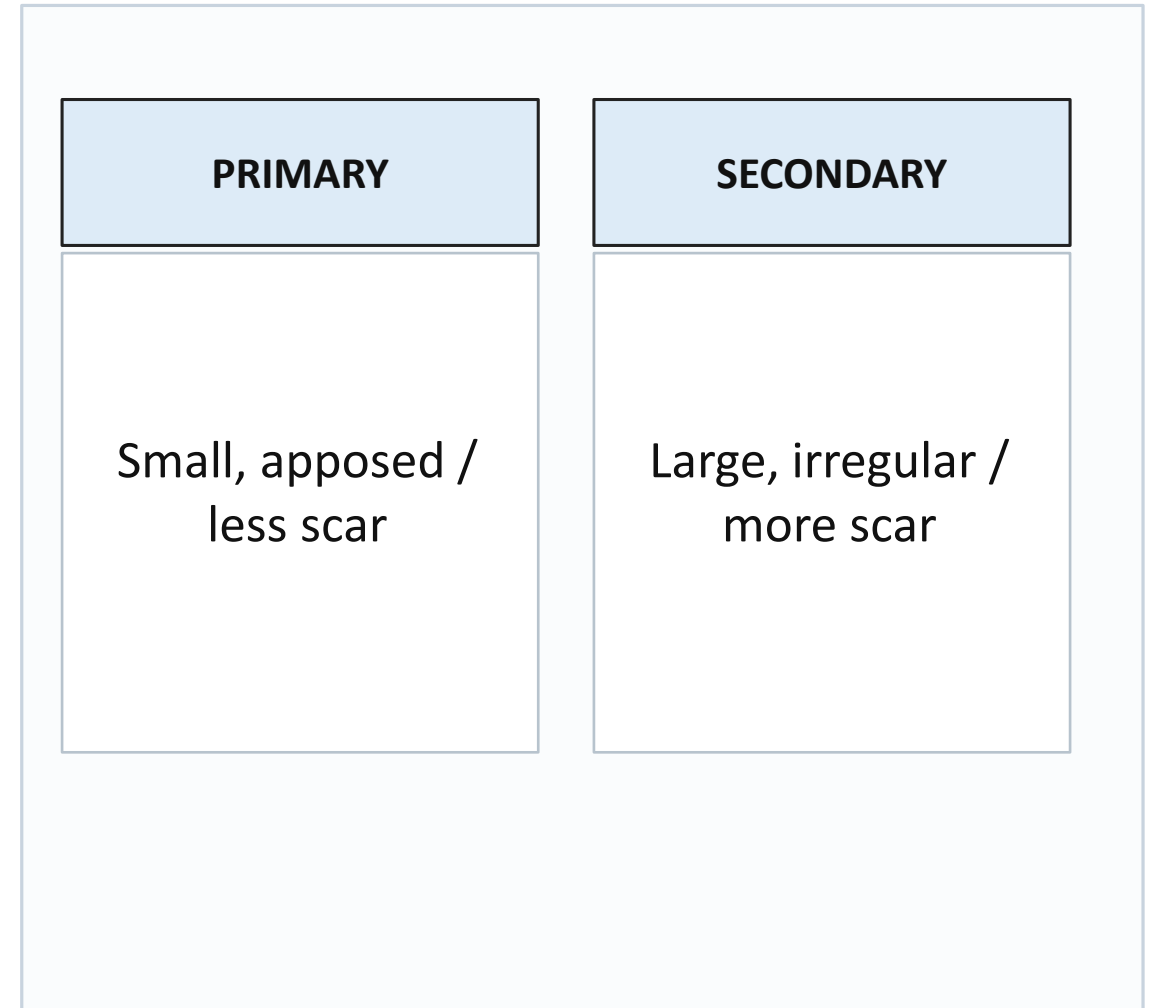


Large defect

Schematic: Simplified tissue layers; Not a specimen

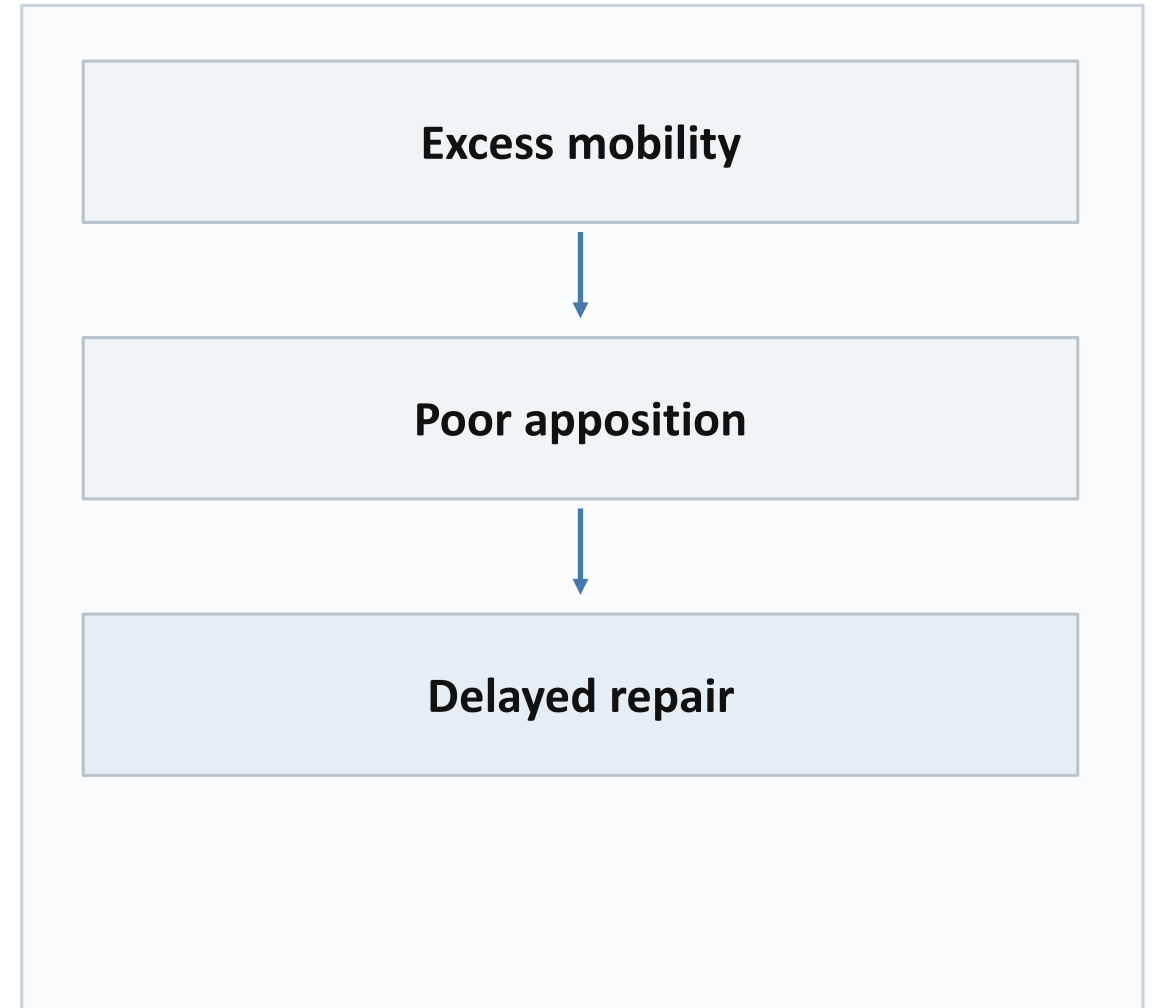
Primary versus secondary intention

- The distinction reflects wound size, edge apposition, inflammation, contraction, and scar formation.
- It does not simply reflect whether the original injury was accidental or surgical.
- Use wound architecture to predict which repair process dominates.



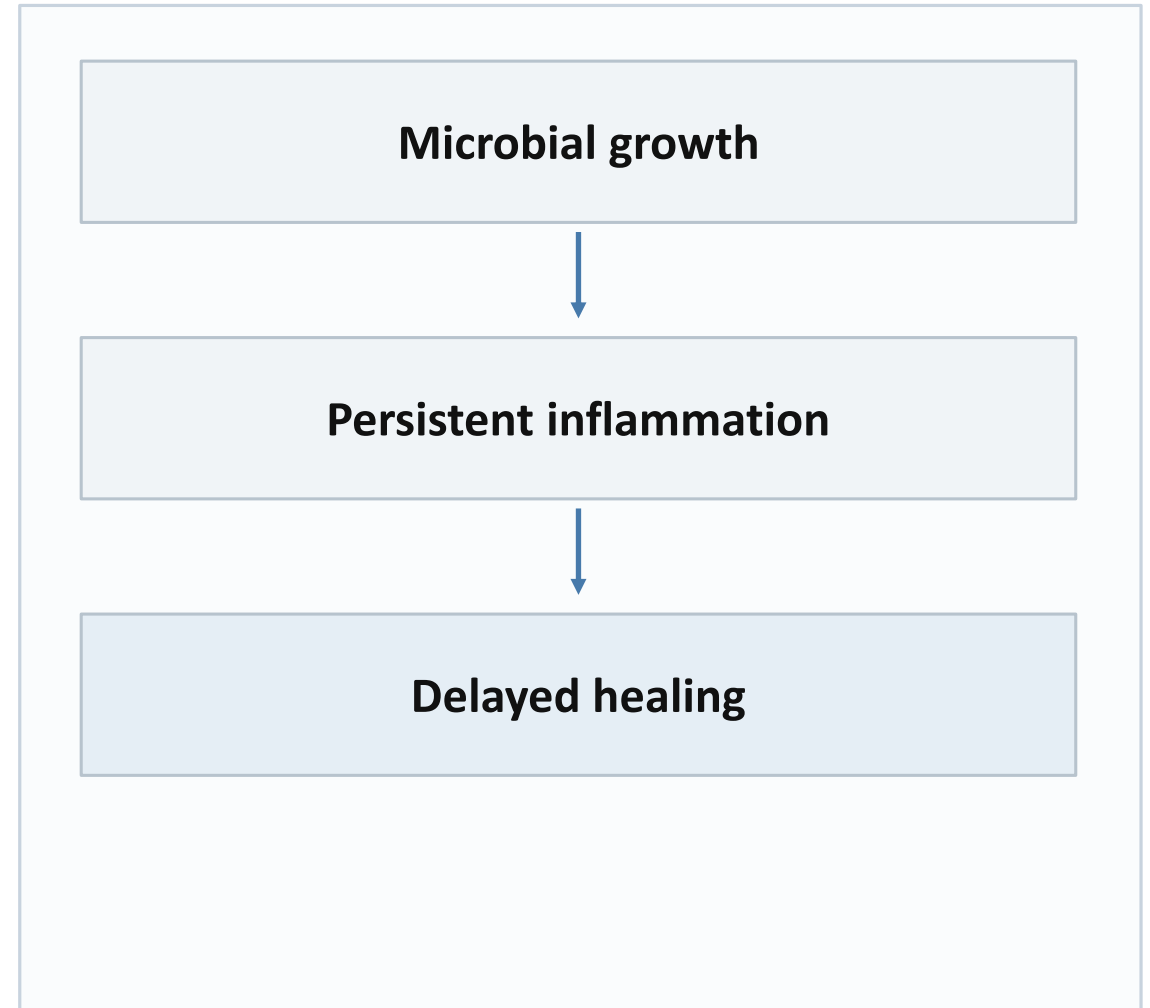
Mechanical movement can impair apposition

- Excessive local mobility disrupts alignment of wound edges.
- Fractures and skin grafts as examples where movement impairs healing.
- Mechanical stress may compromise stable repair.



Infection delays wound healing

- Infection is a major cause of delayed repair.
- It prolongs the inflammatory phase and can increase local tissue injury.
- Wound infection and wound geometry interact with patient factors.



Systemic and local modifiers of healing

- Diabetes and vascular insufficiency compromise tissue repair.
- Protein or vitamin C deficiency inhibits collagen synthesis.
- Foreign material, pressure, and excessive mobility add local impediments.

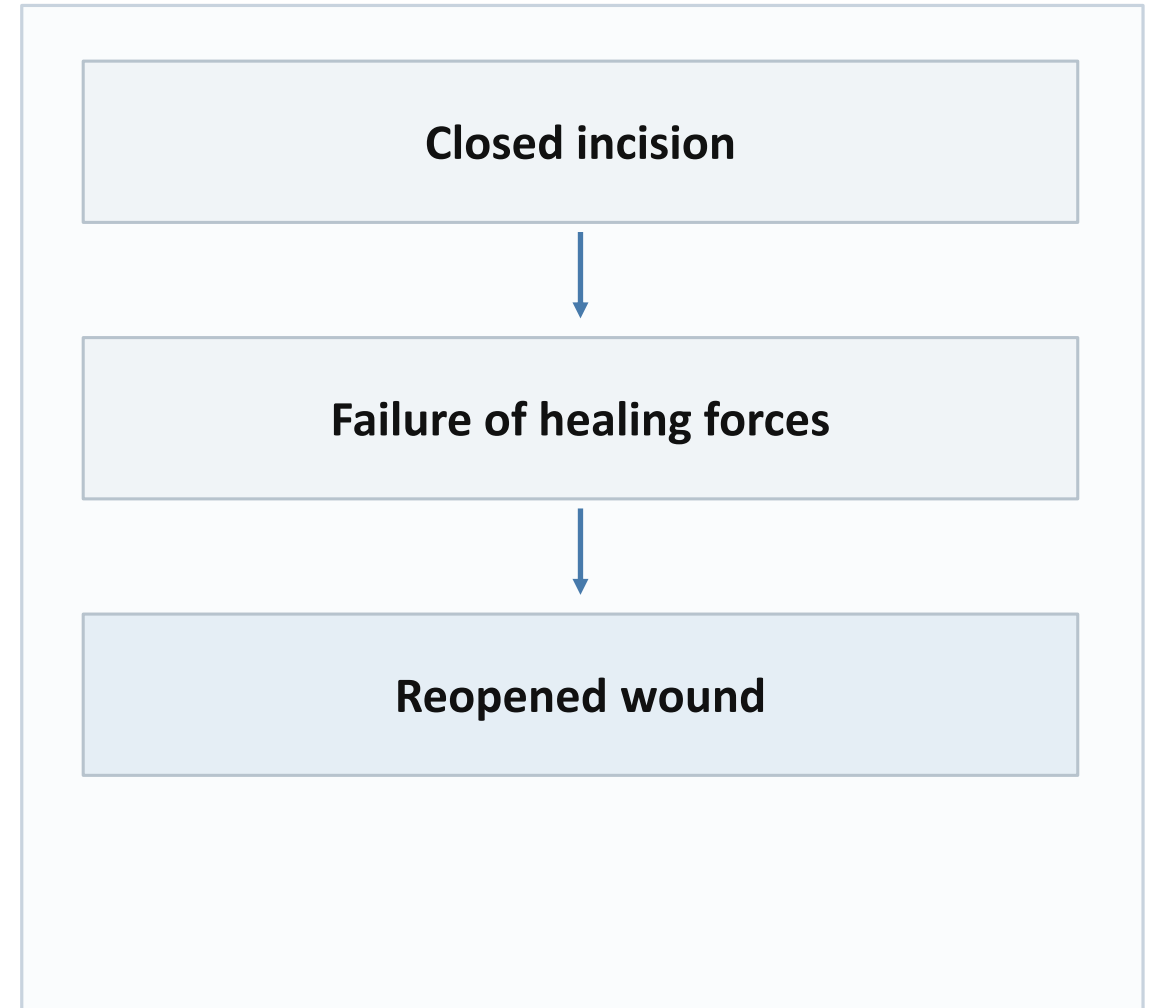
Perfusion

Nutrition

Mechanical / foreign-body factors

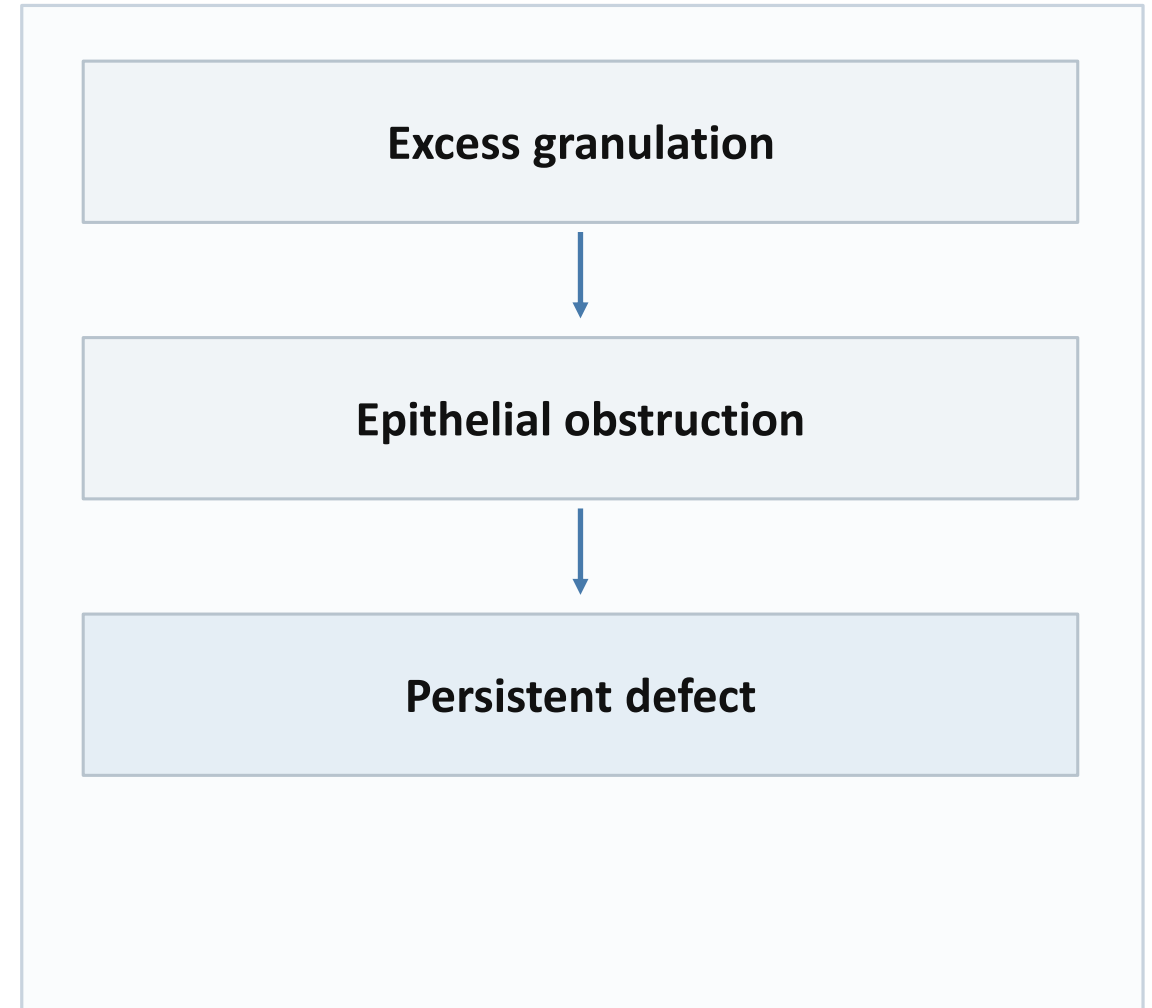
Wound dehiscence: Loss of wound apposition

- A previously closed incision can reopen internally or externally.
- Obesity, malnutrition, infection, poor perfusion, and mechanical factors.
- Abdominal wounds may dehisce after severe coughing or vomiting.



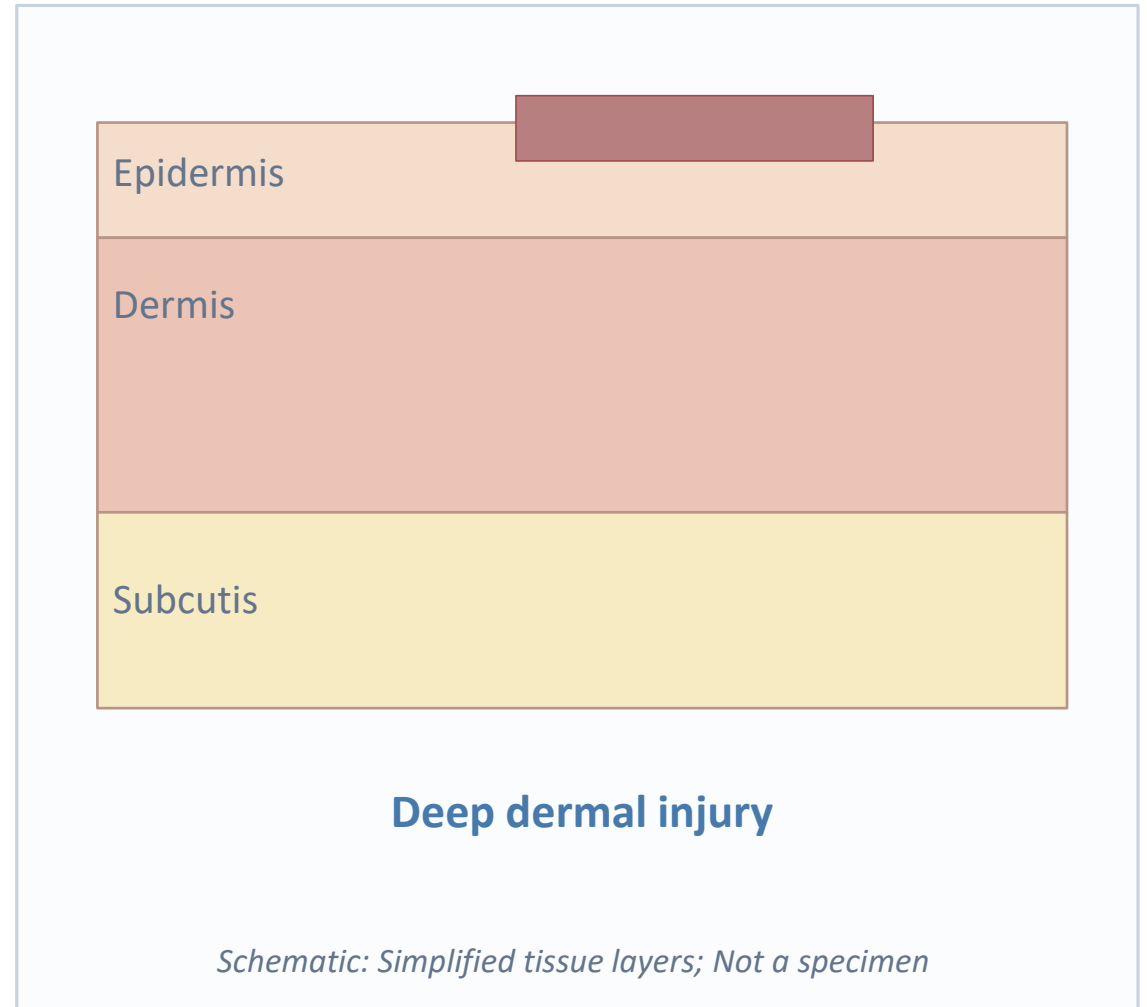
Excessive granulation obstructs closure

- Granulation tissue may proliferate above the wound surface.
- Excessive tissue can impede re-epithelialization.
- This is abnormal repair, not an additional traumatic wound category.



Hypertrophic scars remain wound-centered

- Excessive collagen deposition can produce a raised scar.
- Hypertrophic scars with deep dermal thermal or traumatic injury.
- These lesions often regress over time.



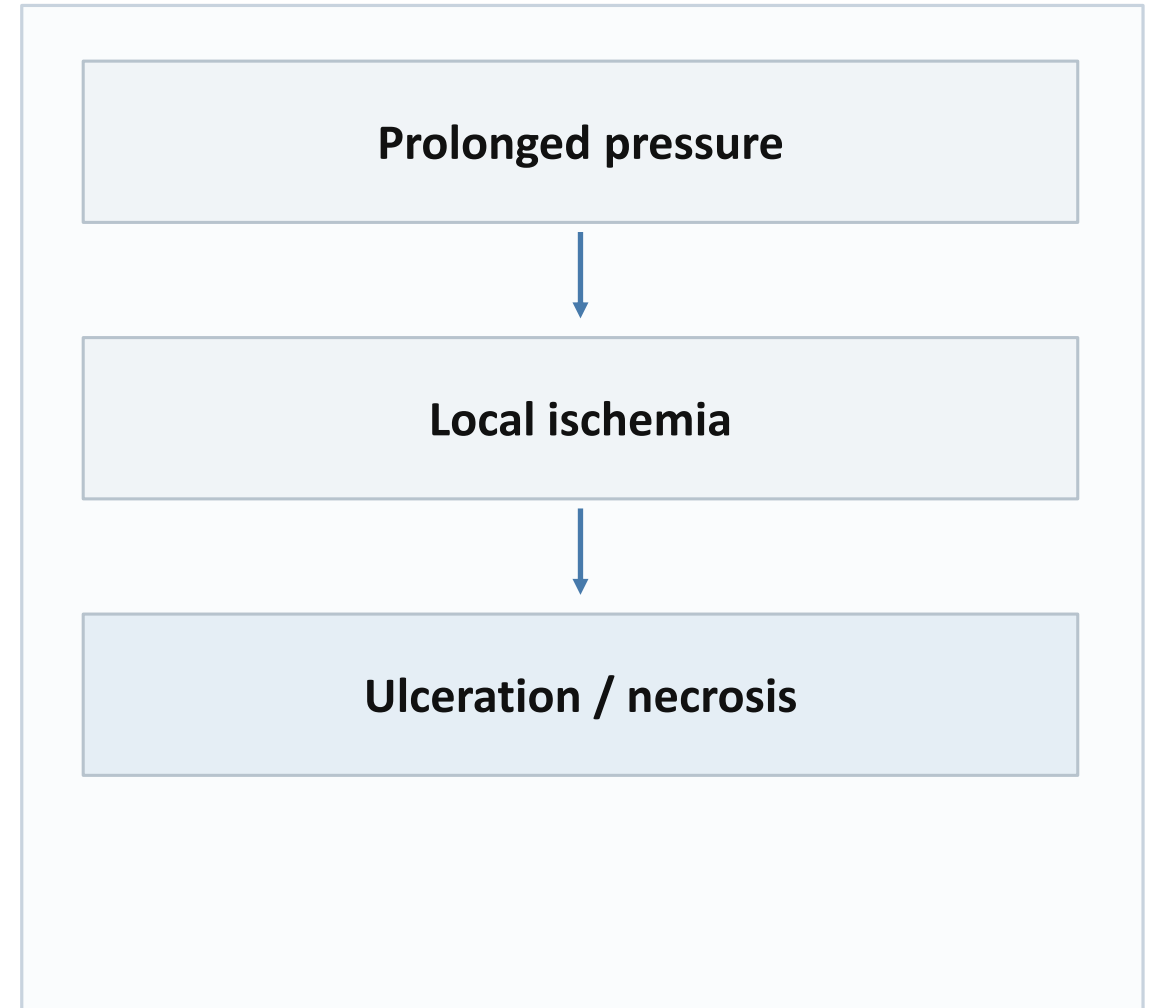
Keloids extend beyond the original wound

- A keloid extends past the original wound borders and does not regress.
- A personal predisposition contributes to the response.
- Do not conflate a raised hypertrophic scar with a keloid.

HYPERTROPHIC	KELOID
Within wound / may regress	Beyond borders / persists

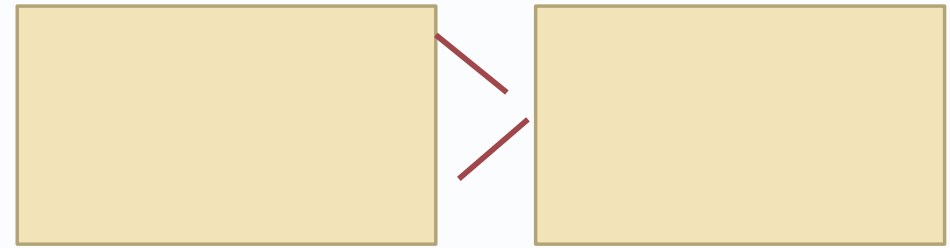
Sustained pressure causes ischemic injury

- Prolonged compression against underlying bone can produce pressure sores.
- The injury results from local ischemia and tissue necrosis.
- This illustrates a mechanical mechanism without an acute collision.



Bone injury differs from soft-tissue injury

- Robbins directs bone trauma to its dedicated musculoskeletal chapter.
- A fracture is structural discontinuity of bone under force.
- Fracture type and stability influence repair and complications.



Fracture gap → Loss of continuity

Fracture descriptors define distinct features

- Simple/compound distinguish whether bone communicates with skin.
- Comminuted and displaced describe fragmentation and alignment.
- Stress, greenstick, and pathologic fractures describe other important mechanisms or contexts.

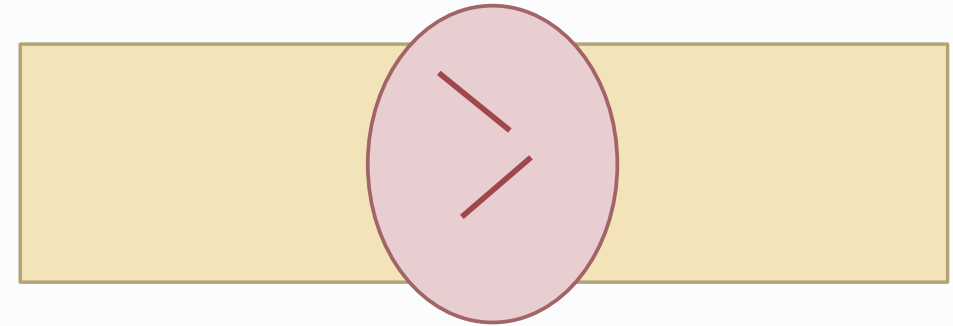
Skin communication

Fragmentation / alignment

Special fracture context

Fracture hematoma begins bone repair

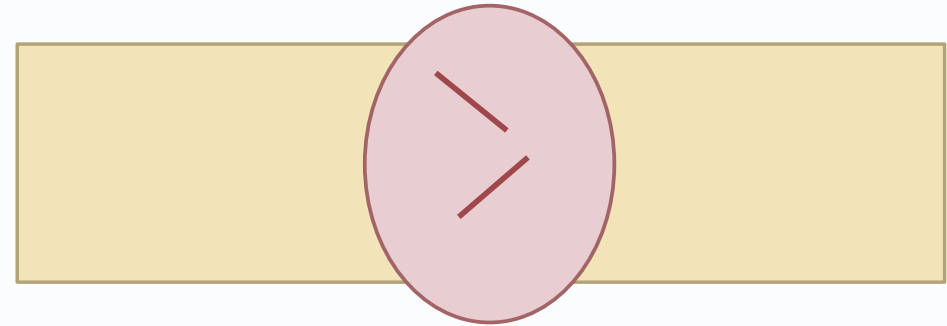
- Torn vessels form a hematoma around the fracture.
- The fibrin clot provides a scaffold for inflammatory and mesenchymal cells.
- Growth factors activate osteoprogenitor cells and bone remodeling activity.



Fracture → Hematoma → Cell recruitment

Fracture callus matures in stages

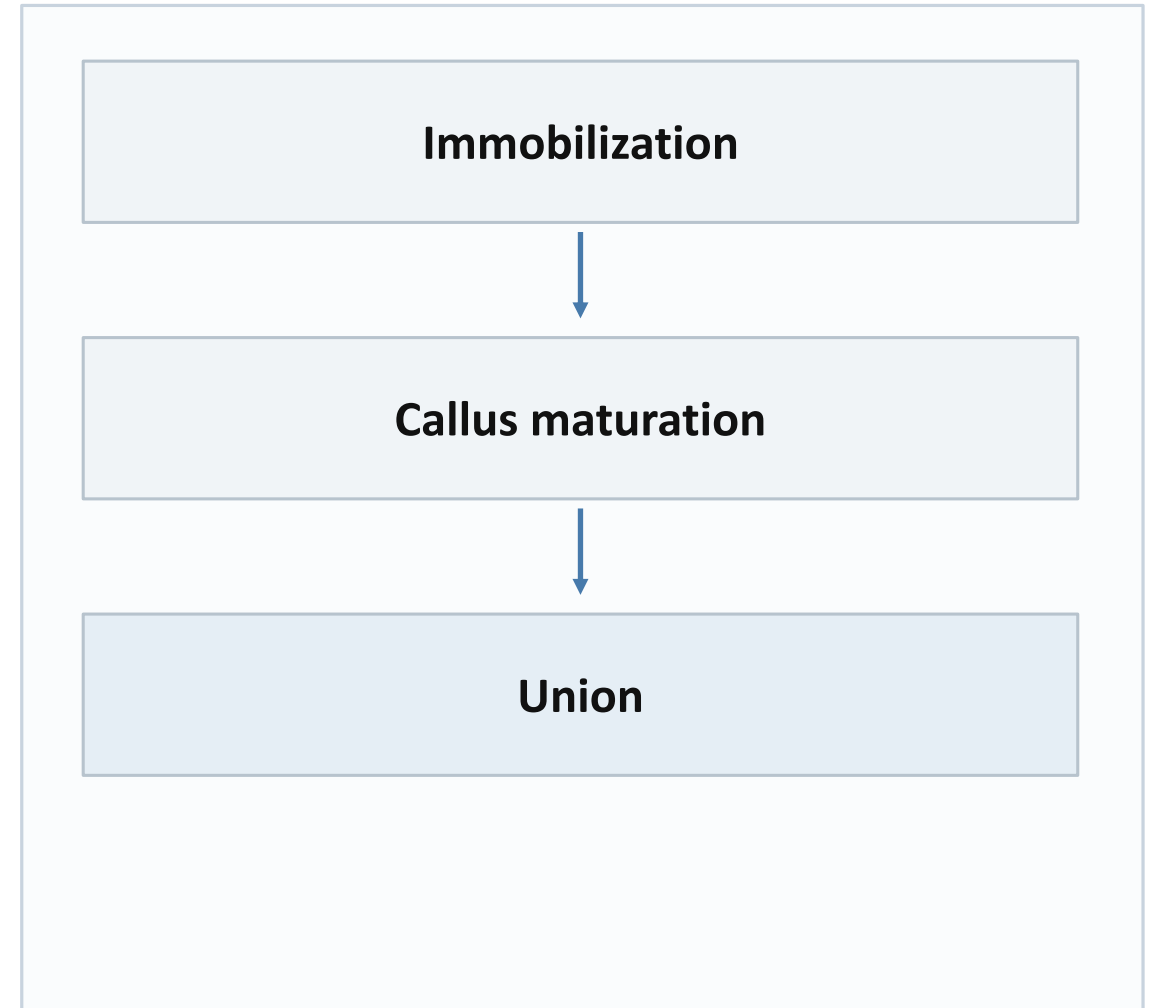
- A soft callus bridges fracture ends with limited rigidity.
- Woven bone deposition converts it to a bony callus.
- Mineralization and remodeling progressively improve mechanical strength.



**Soft callus → Woven bone callus →
Lamellar remodeling**

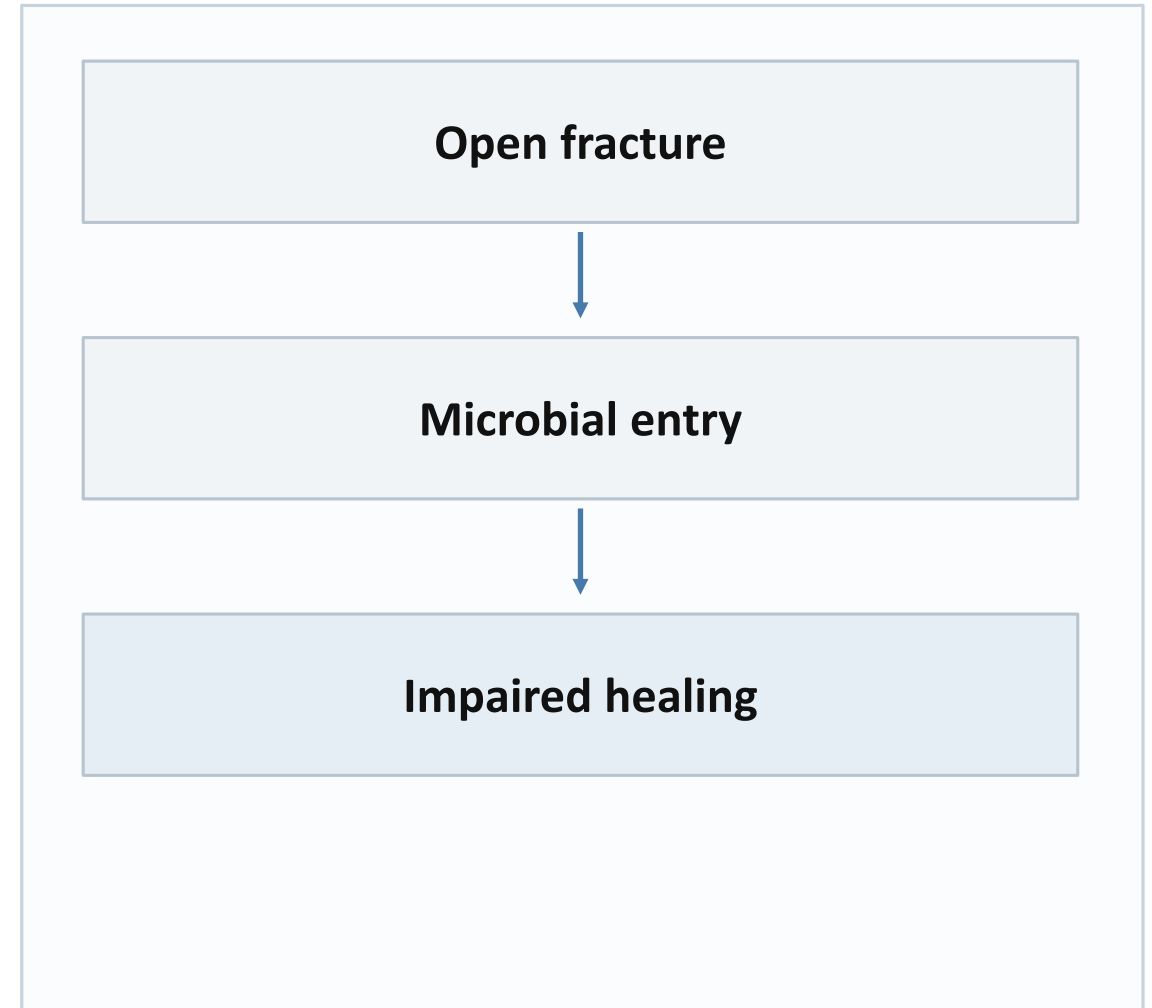
Mechanical stability shapes fracture union

- Immobilization favors orderly callus maturation.
- Excessive motion can delay union or cause nonunion.
- Persistent nonunion may form pseudoarthrosis.



Open fractures create infection risk

- A compound fracture communicates with the external surface.
- Infection as a serious obstacle to union, especially in open fractures.
- Tissue coverage and microbial contamination matter to repair.



Cranial trauma can injure three domains

- Skull fracture, parenchymal damage, and vascular injury often coexist.
- Severity depends on impact features and head motion.
- A penetrating or blunt blow may produce an open or closed injury.

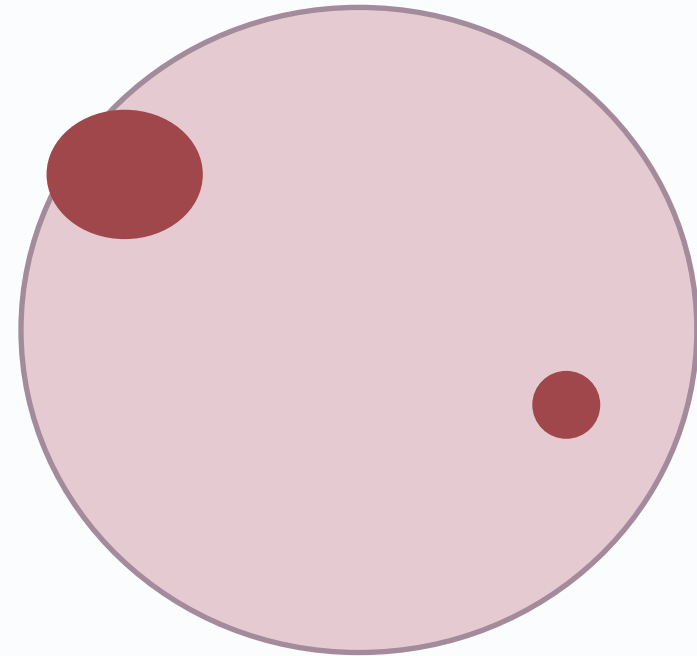
Skull

Brain parenchyma

Blood vessels

Skull fractures can signal additional injury

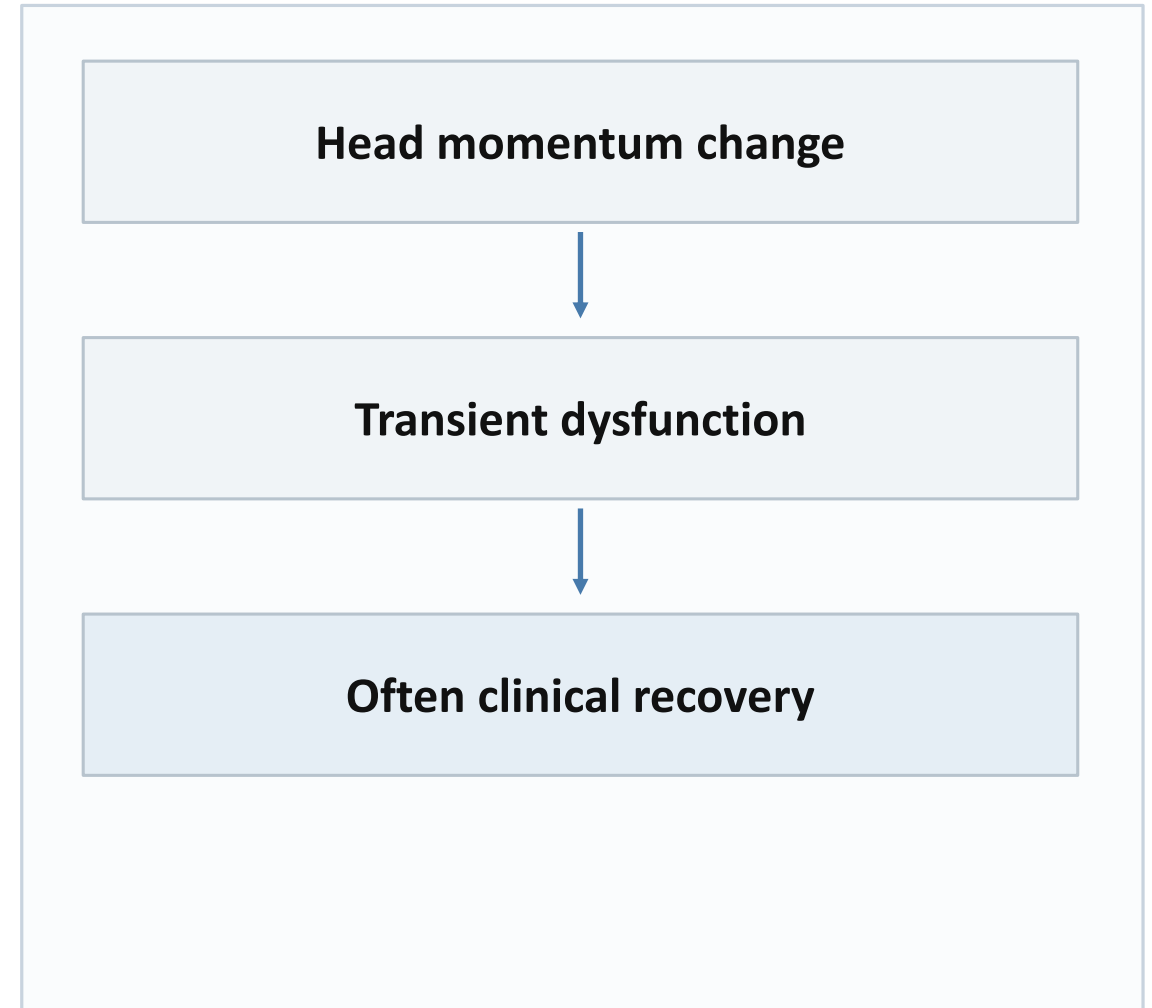
- A depressed fracture may displace bone toward the cranial cavity.
- Basal fractures can present with remote orbital or mastoid hematomas.
- CSF leakage and meningitis may complicate basal fractures.



Skull disruption / Potential CNS consequences

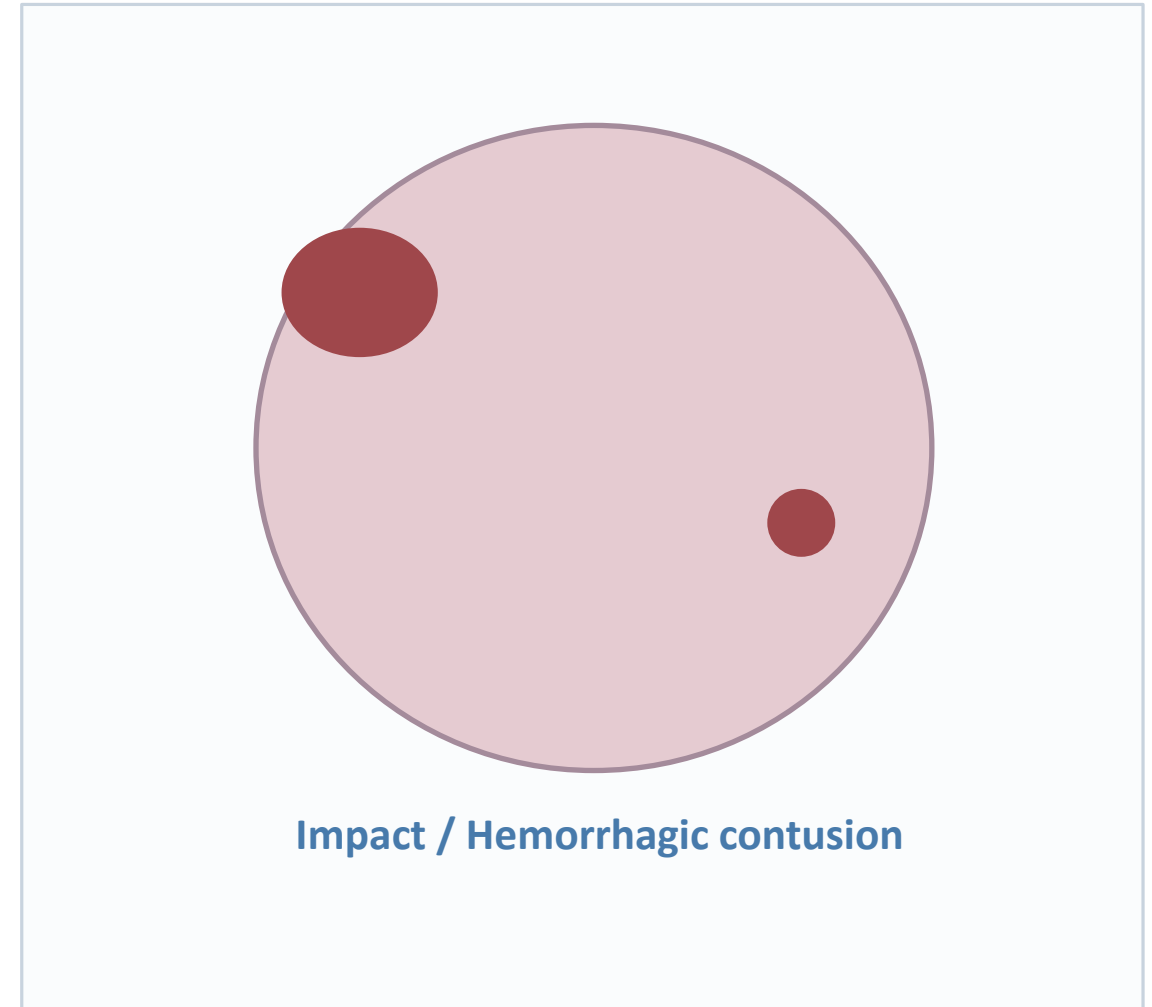
Concussion is a functional syndrome

- Robbins characterizes concussion by transient neurologic dysfunction after head injury.
- Clinical features may include loss of consciousness, amnesia, and reflex alterations.
- A concussion need not exhibit a visible macroscopic brain tear.



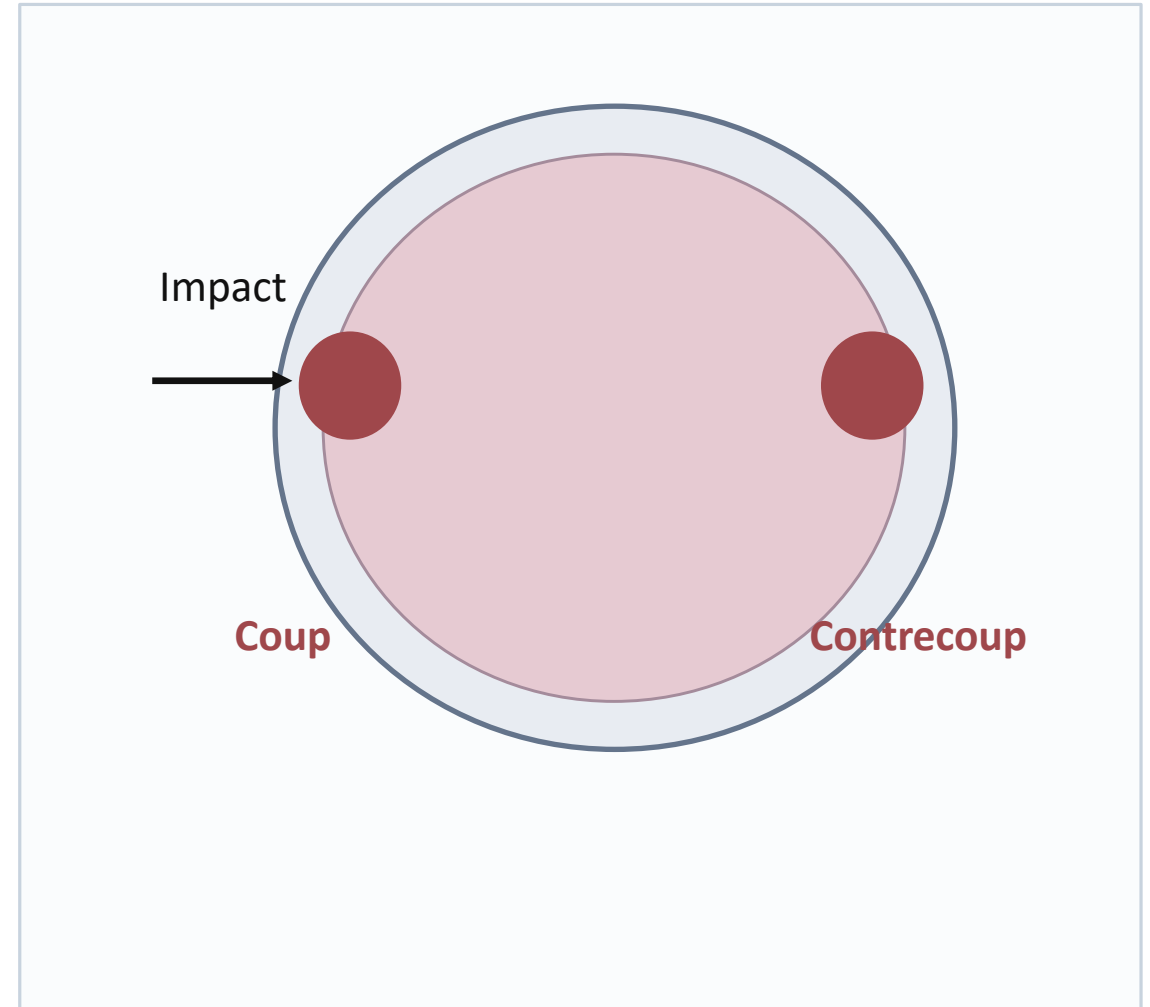
Brain contusion arises from transmitted energy

- Rapid deformation injures vascular channels and cerebral tissue.
- Edema and hemorrhage are prominent early features.
- Crests of gyri and frontal/temporal surfaces are particularly susceptible.



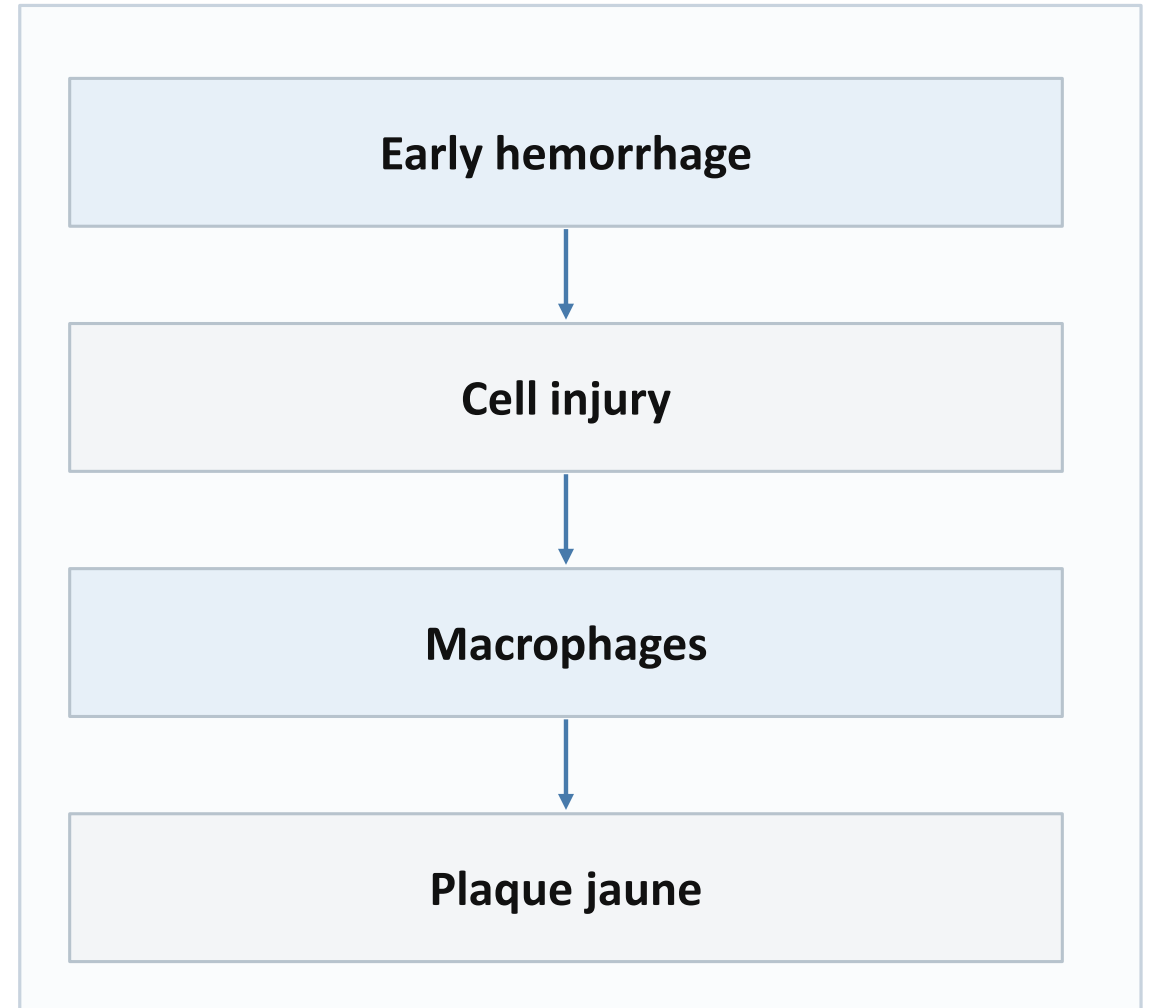
Coup and contrecoup injury depend on motion

- A coup contusion occurs at the point of impact.
- A contrecoup contusion occurs on the opposite brain surface.
- The distinction requires identifying the actual impact site.



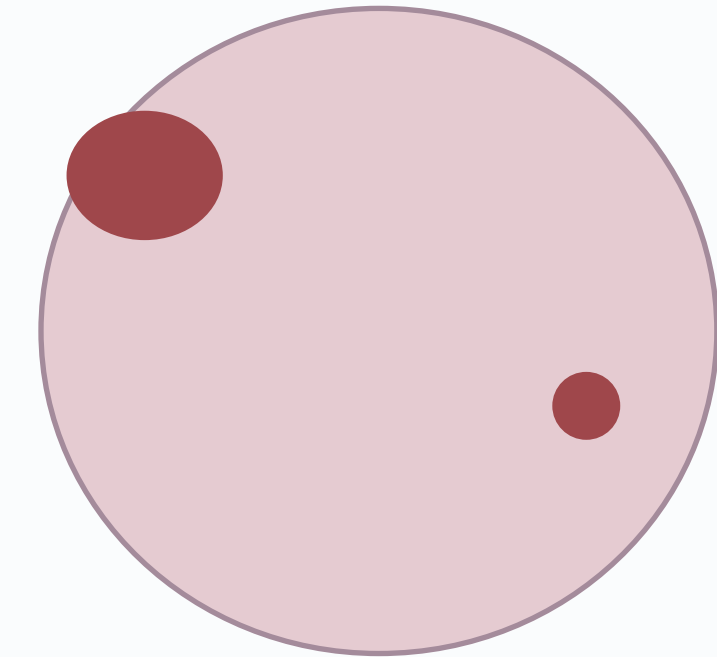
Cerebral contusions evolve morphologically

- Early lesions show edema and pericapillary hemorrhage.
- Later changes include neuronal necrosis and macrophage recruitment.
- Remote contusions may leave a yellow-brown depressed plaque with gliosis.



Diffuse axonal injury is a shear-related lesion

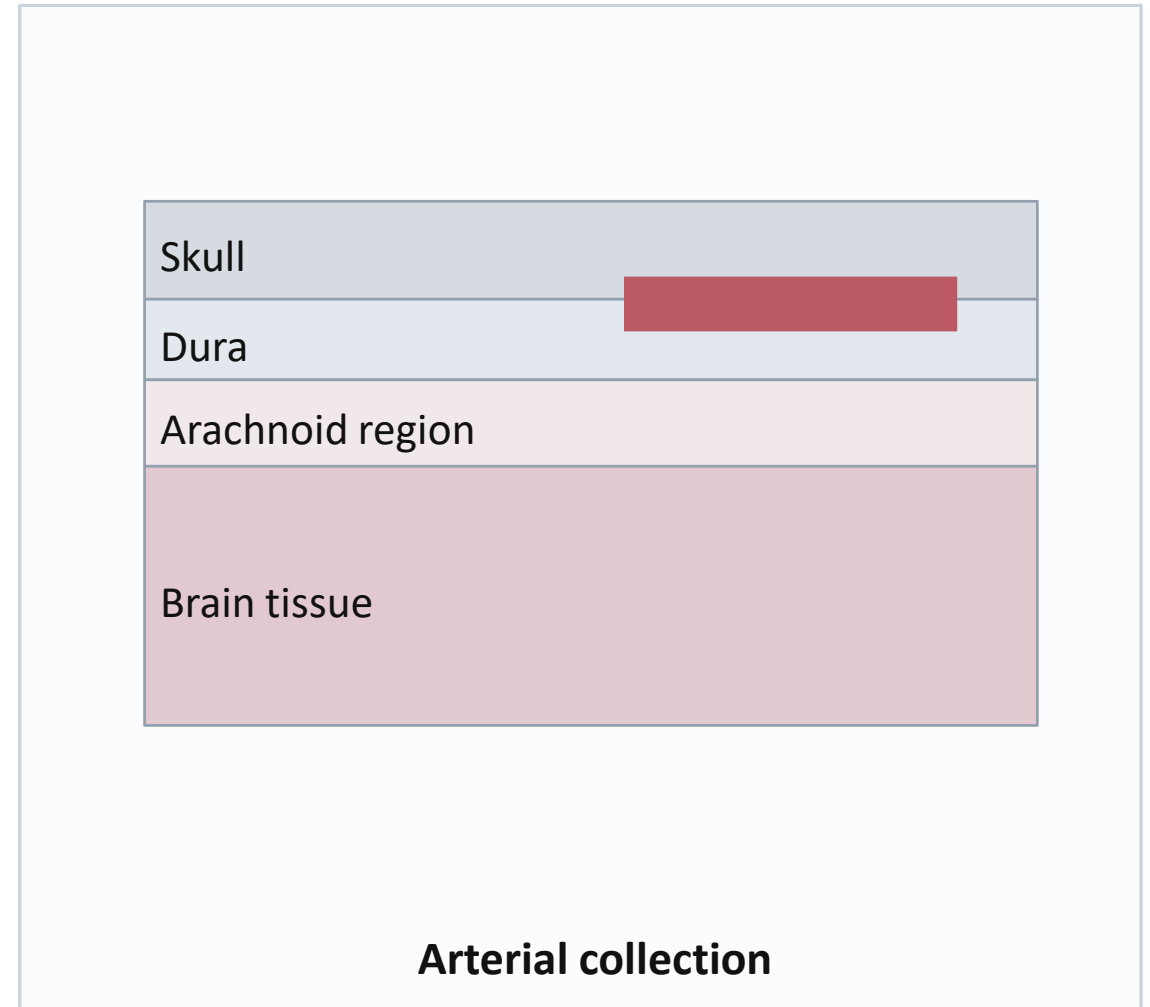
- Marked changes in angular acceleration can damage axons even without skull impact.
- Axonal swellings reflect disturbed axoplasmic transport.
- Deep white matter and brainstem pathways may be involved.



Angular acceleration / Axonal swellings

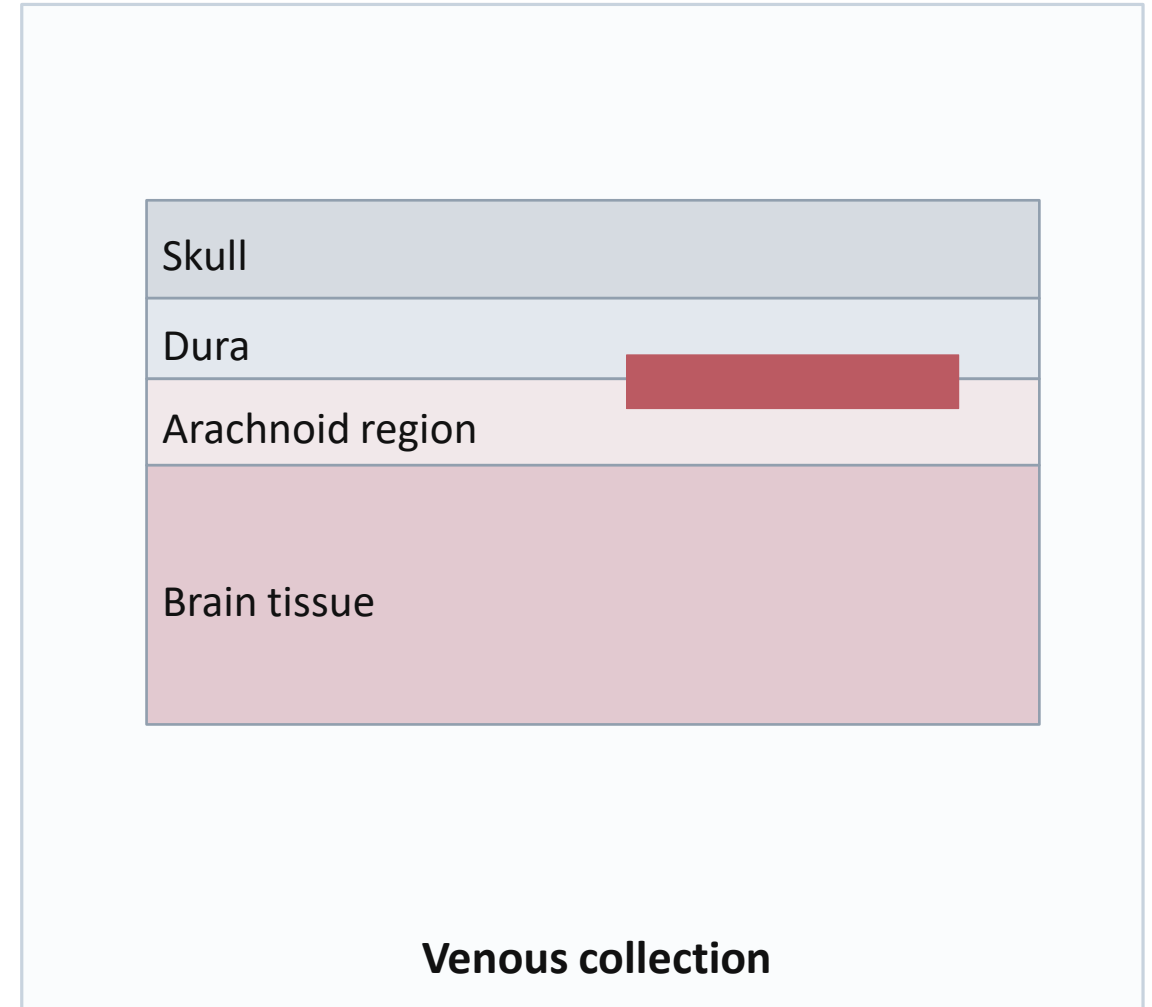
Epidural hematoma: Arterial bleeding

- A damaged meningeal artery may bleed between skull and dura.
- A temporal skull fracture can injure the middle meningeal artery.
- The expanding collection may cause life-threatening cerebral compression.



Subdural hematoma: Bridging-vein injury

- Displacement of the brain can tear veins crossing toward dural sinuses.
- Blood dissects within the dural border layers.
- Brain atrophy in older adults increases vulnerability.



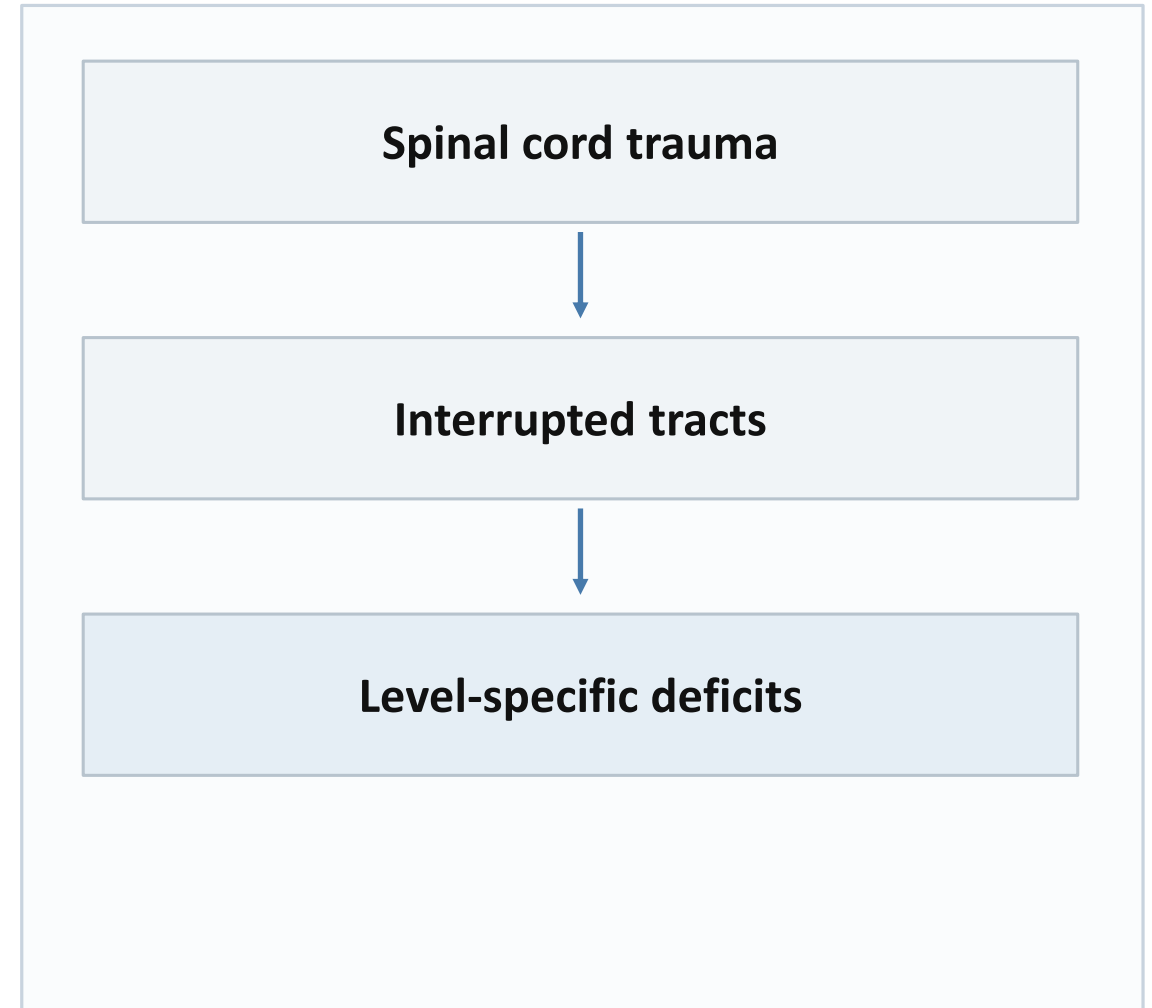
Epidural and subdural lesions differ

- Epidural: Usually meningeal arterial injury, often with skull fracture.
- Subdural: Torn bridging veins, sometimes after minor trauma.
- Both can compress underlying brain and require prompt evaluation.

EPIDURAL	SUBDURAL
Artery / skull–dura	Vein / dural border

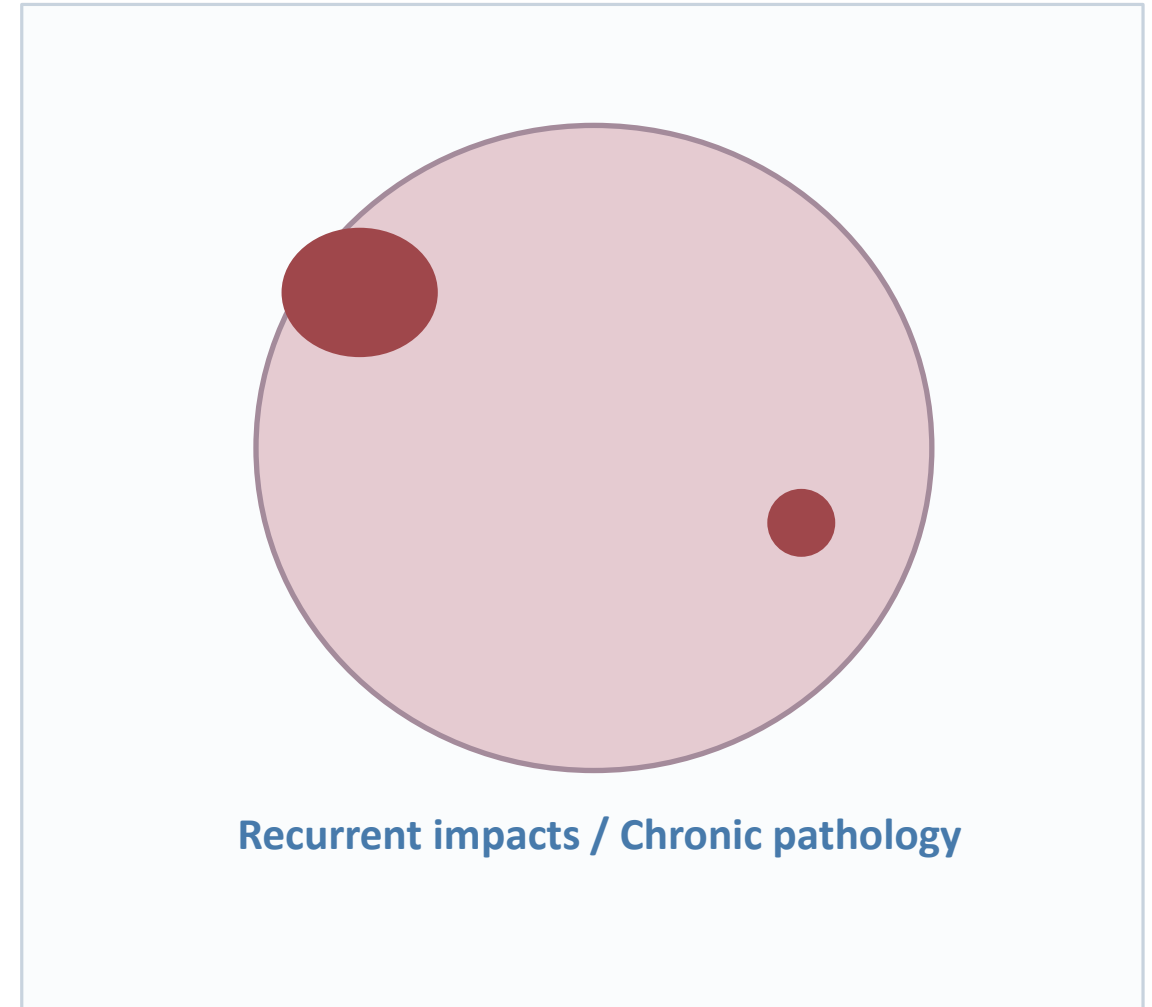
Spinal cord consequences depend on level

- Trauma may disrupt descending and ascending white-matter tracts.
- Thoracic damage can produce paraplegia; Cervical damage quadriplegia.
- High cervical injuries can compromise respiration.



Repeated head impacts may cause chronic injury

- Chronic traumatic encephalopathy after repetitive trauma.
- Characteristic pathology includes tau pathology in specific cortical locations.
- The determinants of progression remain incompletely established.



Forensic analysis begins with morphology

- Mechanical trauma includes wounds from shooting, stabbing, blunt force, and traffic events.
- Documented morphology is one part of reconstruction.
- Robbins explicitly directs detailed forensic practice to specialized references.



Forensic testing extends beyond morphology

- Molecular identity testing contributes to investigations.
- Analytical methods can establish presence of foreign chemicals.
- These complementary methods do not replace anatomical interpretation.

Morphology

Molecular identity

Chemical detection

Application: Blunt impact with bruising

- An injured region shows intact surface but subcutaneous hemorrhage.
- Which named soft-tissue pattern best fits the findings?
- What tissue event can explain the hemorrhage?

Discuss the lesion as a group

1. Pattern?

2. Mechanism?

3. What else could coexist?

Application: Delayed healing of an open wound

- A large irregular cutaneous defect remains inflamed and closes slowly.
- Predict first- versus second-intention healing.
- Identify local or systemic factors that could prolong repair.

Discuss the lesion as a group

1. Repair pattern?

2. Cause of delay?

3. Expected scar?

Application: Deterioration after head trauma

- A patient deteriorates after a head impact; An intracranial blood collection is suspected.
- Identify the key vascular sources for epidural and subdural hematomas.
- Explain why anatomy and bleeding compartment govern risk.

Discuss the lesion as a group

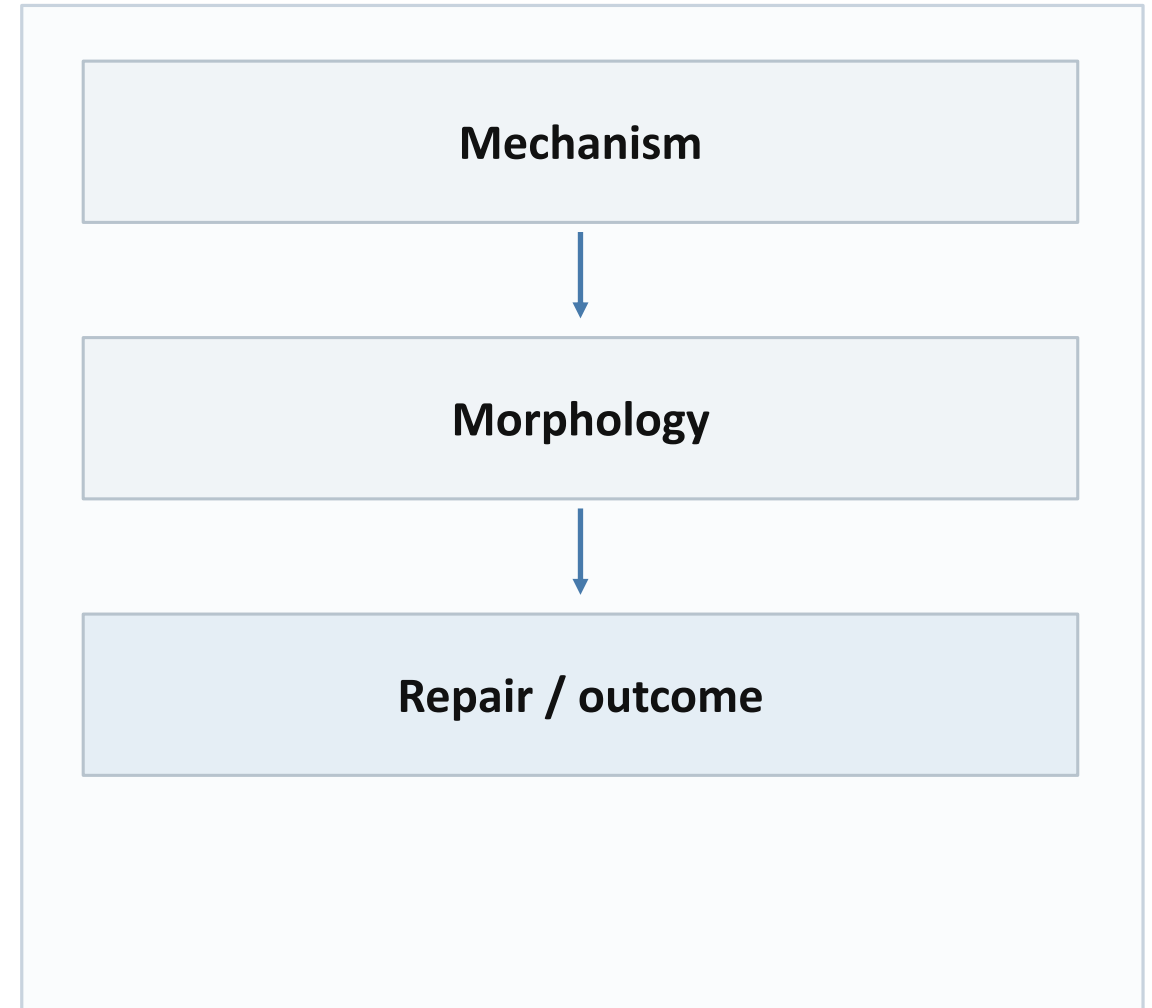
1. Vessel?

2. Compartment?

3. Mass effect?

A practical synthesis of traumatic injury

- Identify the impact context: Object, energy, and receiving tissue.
- Describe the morphologic pattern and any hemorrhage or structural disruption.
- Predict repair and assess organ-specific complications.



Reference framework

Robbins, Cotran & Kumar: Pathologic Basis of Disease, 11th ed. (2026).

Chapter 9: Environmental and Nutritional Diseases — Mechanical Trauma.

Supporting context: Chapter 3 (repair), Chapter 4 (hemorrhage), Chapter 26 (fractures), Chapter 28 (CNS trauma).