Dr. Hani

PRINCIPLES OF FRACTURES

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Definition

- A Break in the structural **continuity** of bone.
- **Can be divided in to:**

w the bone protruding ↵

1. **closed (or simple)** If the overlying skin remains **intact**
2. **open (or compound) fracture;** *if the skin is* **breached** .

↑ Risk of infection

* in closed no infection Risk → bec no normal flora in Muscles

classification

- Can also be classified into:

  - **Simple fractures** are fractures that only occur along one line, splitting the bone into **two** pieces.

  - **Comminuted (multi-fragmentary) fractures** involve the bone splitting into **multiple** pieces

Fractures result from:

- (1) Injury
- (2)Repetitive stress
- (3)Abnormal weakening of the bone (‘pathological’)

TYPES OF FRACTURE

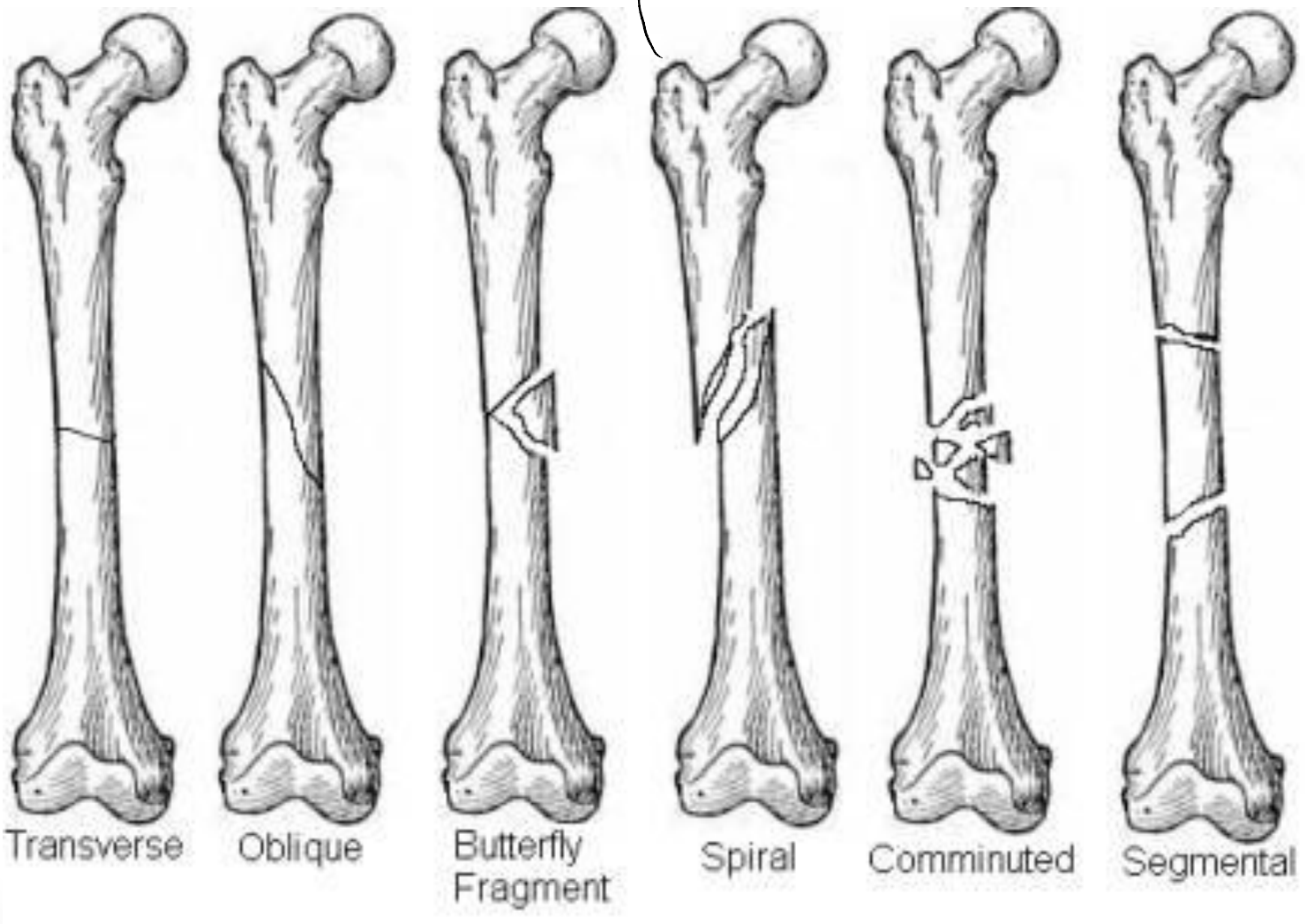
- Complete fractures
  - Transverse fracture
  - Oblique
  - spiral
  - compacted
  - comminuted
- In-complete fractures
  - Examples:
    - greenstick fracture.
    - Stress fracture
    - Compression

Complete Fractures → from one cortex to another

- **Complete Fracture:** A fracture in which bone fragments separate completely

✔ bone is split into two or more fragments.

- before rotation : long transverse
- after rotation : spiral



Complete Fractures types

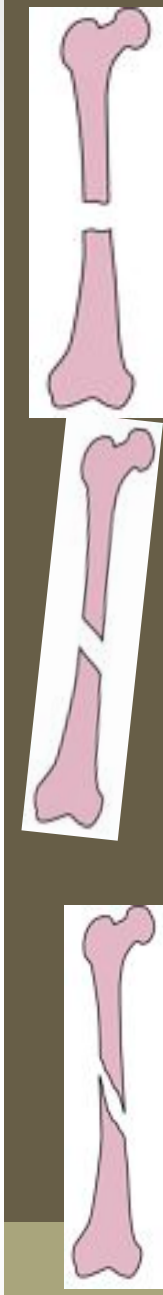
← stable - once you put the bone back in place it's stable

- **Transverse Fracture:** A fracture that is at a **right angle** to the bone's long axis.

Unstable → even if you put the bone back it's still unstable

- **Oblique Fracture:** A fracture that is **diagonal** to a bone's long axis.

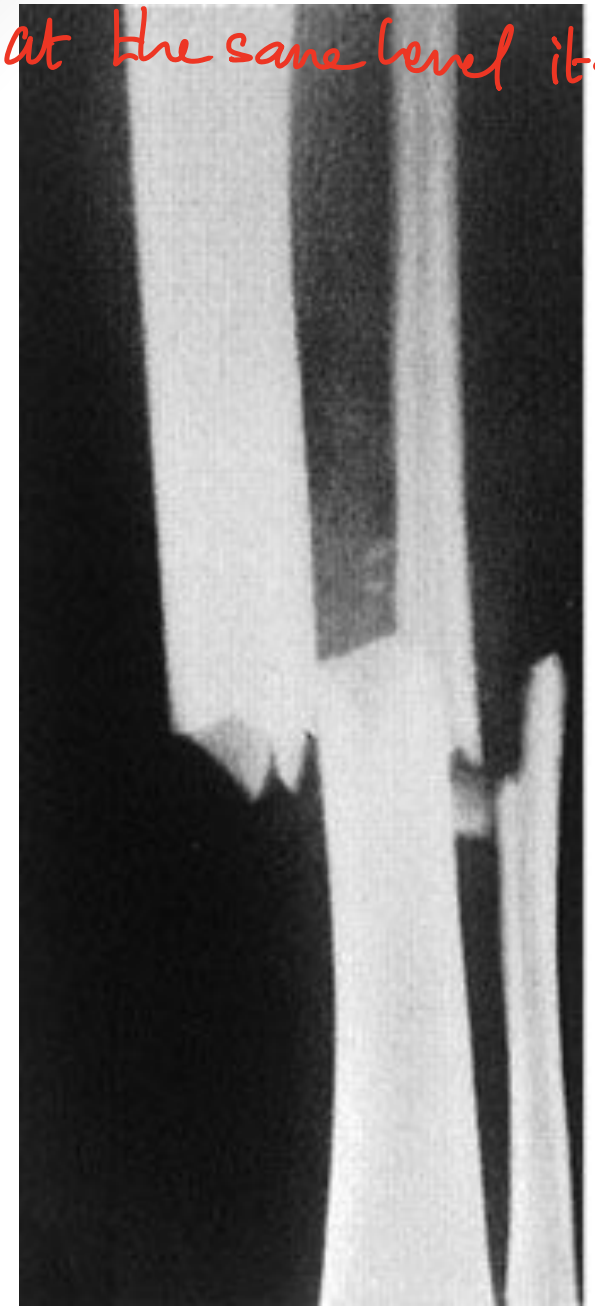
- **Spiral Fracture:** A fracture where at least one part of the bone has been **twisted**.



- ✔ The **fracture pattern on x-ray** can help predict behavior after reduction **how?**
- ✔ **answer**: In a **transverse** fracture the fragments usually **remain in place after reduction; if it is oblique or spiral, they tend to shorten and re-displace even if the bone is splinted**

* Both bones fractured at the same level to be transverse.

if not at the same level its obligne or spiral



(a) Transverse

(b) segmental

(c) spiral

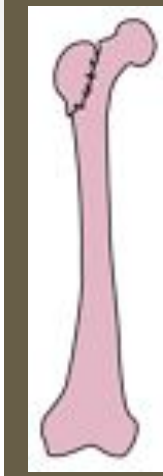
Complete Fractures types

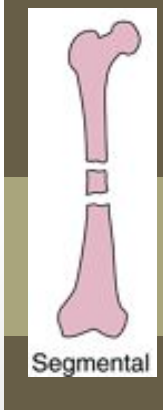
- **Compacted (impacted) Fracture:** A fracture caused when bone fragments are driven into each other or(the fragments are jammed tightly together) **and the fracture line is indistinct**

- **Comminuted Fracture:** → small peices
  - Fracture that occurs at two levels with free segment between them which there are more than two fragments.
  - often unstable because there is poor interlocking of the fracture surfaces.

- **Segmental fracture** : 3 pieces with one piece floating

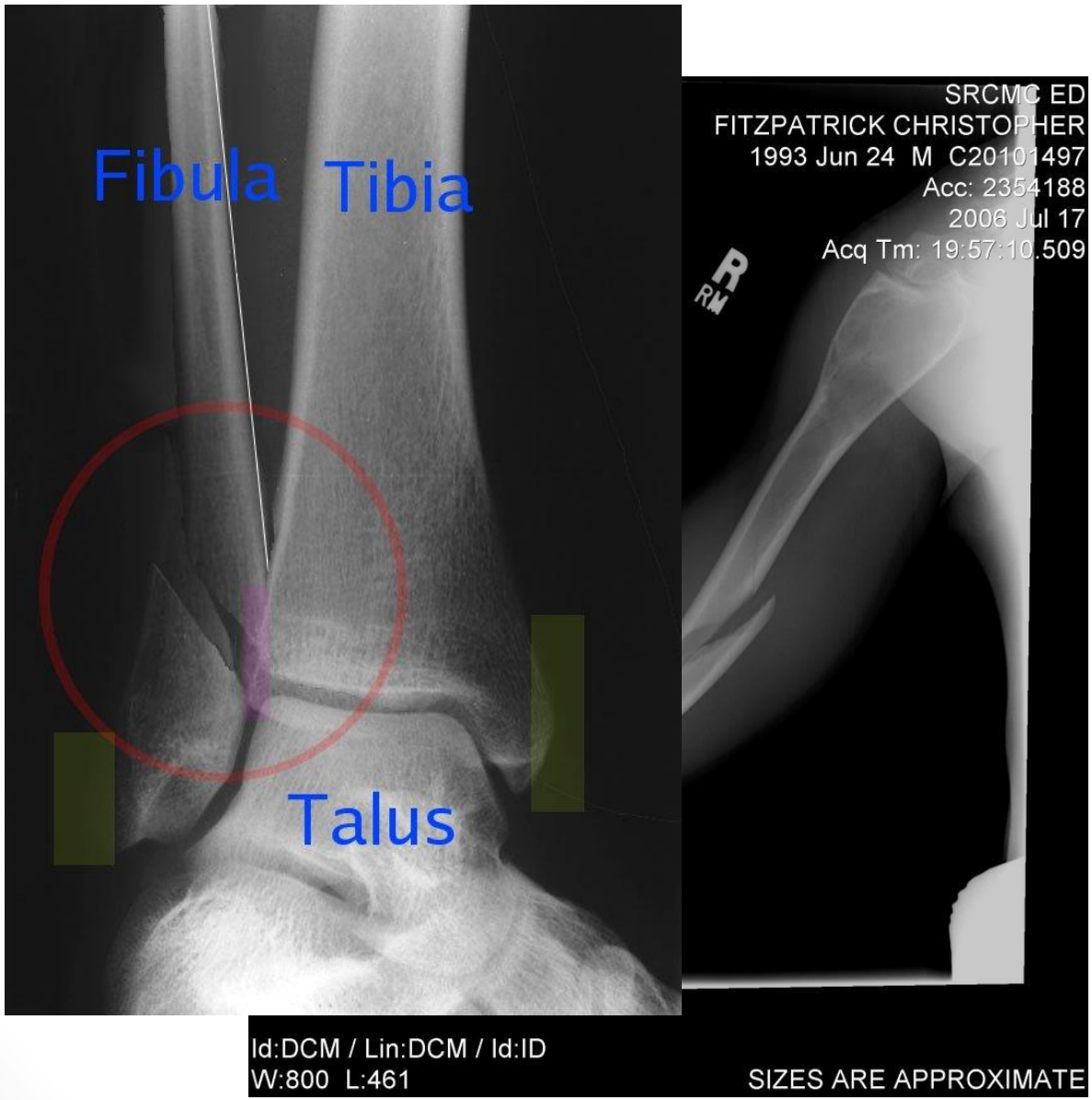
One whole segment of bone



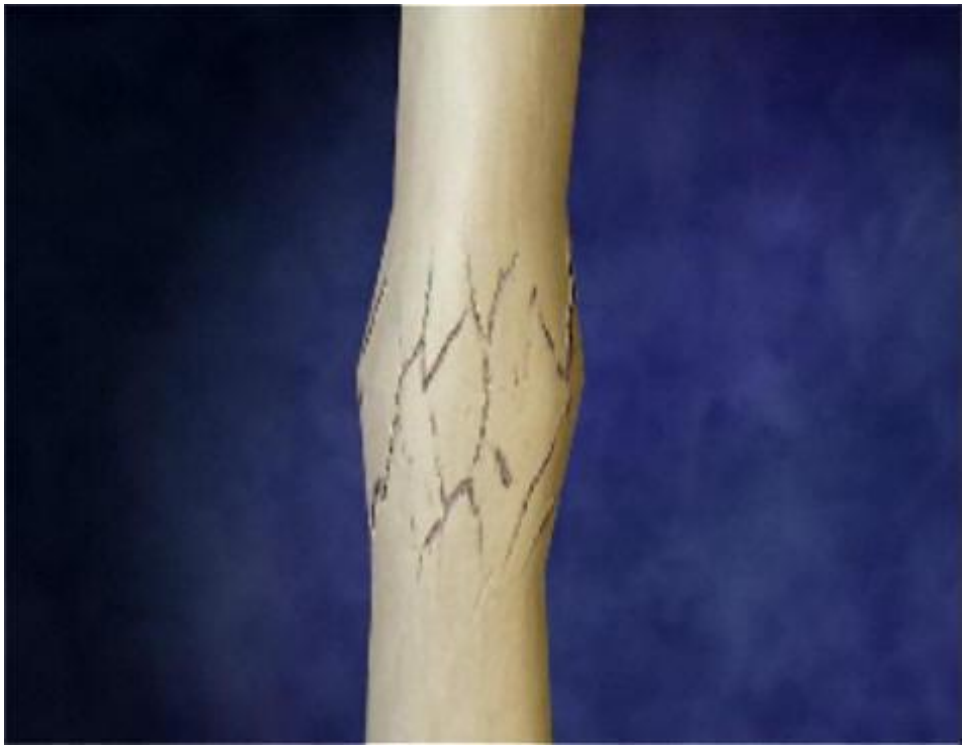


Oblique fracture

Spiral



Impacted fracture



Deformation → Elastic → change of shape with power applied on it and Reversed in shape after power reduction

→ plastic → the change in shape stays the same

children bones ←

Adult bones ← brittle → no change "تغاير القوه" until is broken

Incomplete fractures

- ✔ **Fracture where bone is <u>incompletely divided</u> and the <u>periosteum</u> remains in <u>continuity</u>**

1- Greenstick fracture: the bone is **buckled or bent** .

- seen in <u>children</u> >>>bones are more <u>springy</u> than those of adults.
- **Children** can also sustain injuries where the bone is <u>plastically deformed</u> without there being any crack visible on the x-ray.
- **Torus fractures**, also known as **buckle fractures**, are <u>incomplete fractures</u> of the shaft of a long bone that is characterized by bulging of the cortex. They are usually seen in children, frequently involving the distal radial <u>metaphysis</u>.
- **Bow fracture:** bone become curved along its longitudinal axis.

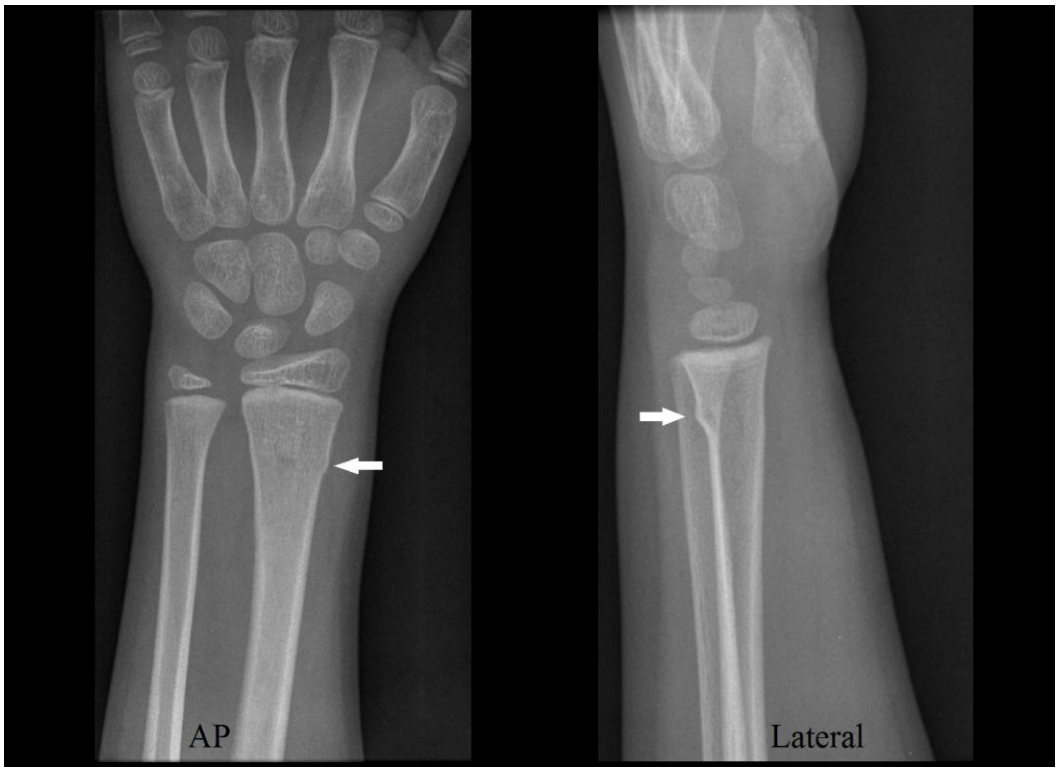
Greenstick fracture

plastic deformity

Greenstick fracture of radius and ulna.

- **buckle or torus fracture**

at one side of cortex that doesn't reach the other side



BOW fracture

no fracture seen
only deformation
is seen

Incomplete fractures

- **Compression fractures** *occur when* cancellous (spongy) bone is crumpled.
  - This happens **in adults**
  - and typically where this type of bone structure is present.

- **e.g:**
- ✔ in the vertebral bodies

  when the front portion of a vertebra in the spine collapses due to osteoporosis
- ✔ calcaneum
- ✔ tibial plateau

Compression fracture

dec in height of the vertebrae →

More principles

- A **stable** **fracture** is one which is likely to stay in a good (functional) position while it heals.
- An **unstable** **Fracture** is likely to angulate or rotate before healing and lead to poor function in the long term
- Fracture of the **bony components of the joint** is called ~~fracture-dislocation~~. Intra-Articular fracture
  - E.g. shoulder fracture dislocation and elbow fracture dislocation.
- **Burst** **fracture**, occur in vertebra due to severe violence, acting vertically on a straight spine.

* Distal femur condyles if fractured is named
↳ intra articular fracture

↳ not named fracture Dislocation Unless there is fracture + Joint Dislocation

Mechanism of fracture

- 1) force

- 2) fatigue or stress fracture

Mechanism of fracture

A- by force:

- Most fractures are caused by sudden and excessive force.

1. **Direct force**
2. **Indirect force**

Forces

- With a **direct force** *the bone breaks at the point of* impact; the soft tissues also are damaged.
- A direct blow usually splits the bone **transversely** or may bend it so as to create a break with a **'butterfly' fragment.**

- Damage to the overlying skin is common; if crushing occurs, the fracture pattern will be **comminuted** with extensive soft-tissue damage.

- *With* **an indirect force** the bone breaks at a distance from where the force is applied; soft-tissue damage at the fracture site is not inevitable.

Less than the Direct injury

- Although most fractures are due to a combination of forces (twisting, bending, compressing or tension)

❑ **The x-ray pattern reveals the dominant mechanism:**

1. • **Twisting causes a spiral fracture**
2. • **Compression causes a short oblique fracture.**
3. • **Bending results in fracture with transversely or a triangular 'butterfly' fragment;**
4. • **Tension tends to break the bone; in some situations it may simply avulse a small fragment of bone at the points of ligament or tendon insertion**

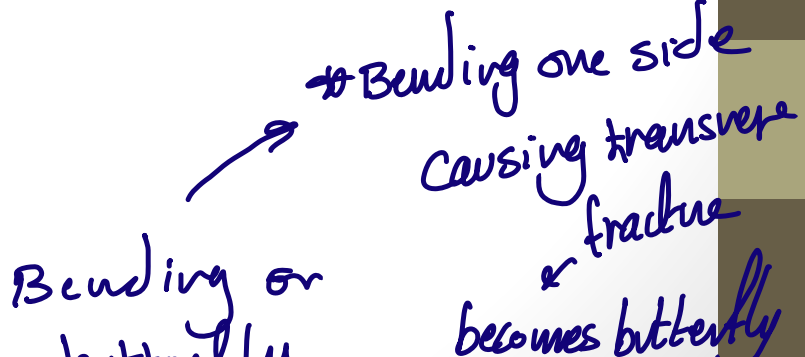
Note: The above description applies mainly to the long bones.

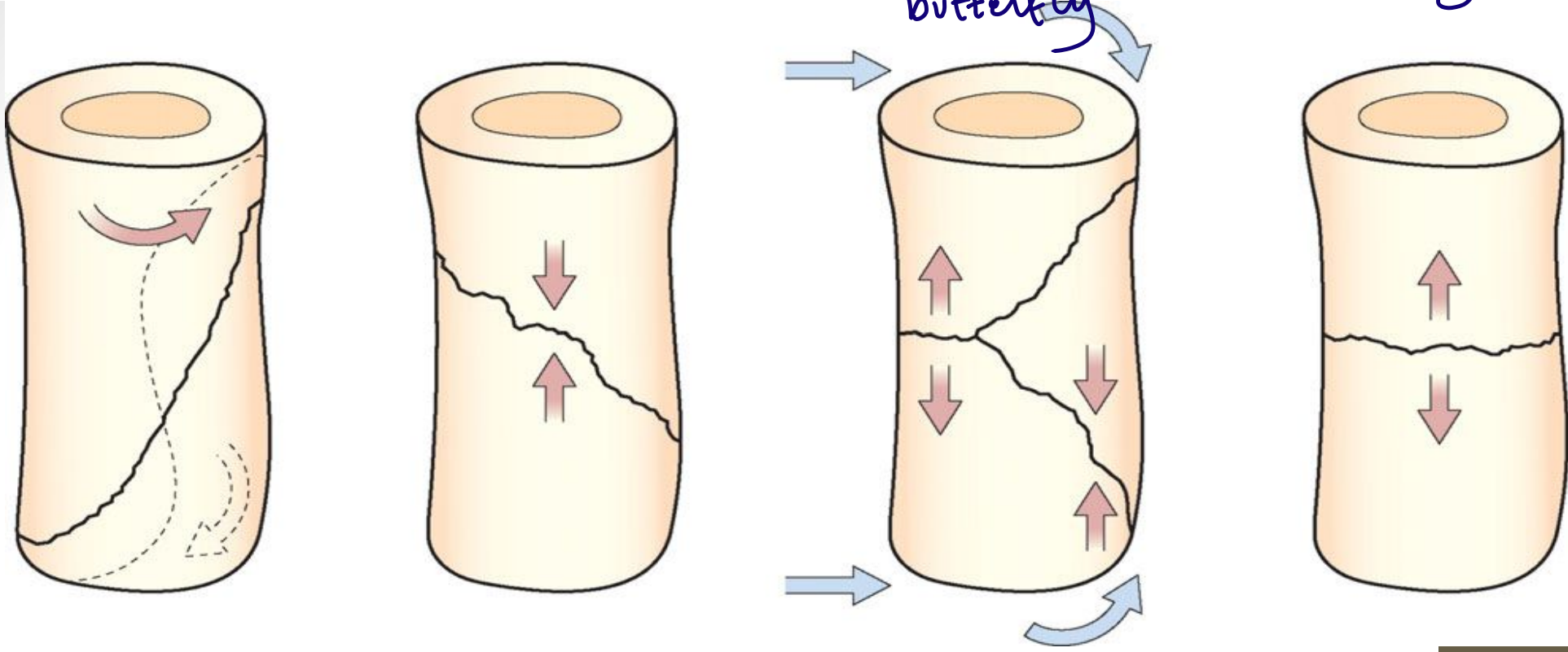
eg scaphoid, usually not apparent, put in cast if sus w a clean x-ray, or do an MRI

✔**A cancellous bone, such as a vertebra or the calcaneum, when subjected to Sufficient force, will split or be crushed into an abnormal shape**

Soft tissue damage

- **It could be either:**
- **Low energy fractures** like closed spiral fractures, and it cause moderate soft tissue damage.
- **High energy fractures** like comminuted fractures and it cause severe tissue damage, **no** matter whether it open or close.





Mechanism of injury Some fracture patterns suggest the causal mechanism: (a) spiral pattern (twisting); (b) short oblique pattern (compression); **(c) triangular 'butterfly' fragment (bending) and (d) transverse pattern (tension)**

- ✔ **Spiral and** some (long) oblique patterns are usually due to **low-energy** indirect injuries
- ✔ **Bending** and **transverse** patterns are caused by **high-energy** direct trauma.

B- FATIGUE OR STRESS FRACTURES

normal bone + Abnormal Load

- **Definition:** These fractures occur :
- ✔ in **normal** bone
- ✔ which is subject to **repeated heavy loading**.
  - Examples: typically in **athletes**, **dancers** or **military personnel** who have grueling exercise programmes.
  - **Mechanism:**>>>These high loads create minute deformations that initiate the normal process of **remodeling** – a combination of bone resorption and new bone formation in accordance with **Wolff's law.(**states that **bones will adapt to the degree of mechanical loading**, such that an increase in loading will cause the architecture of the internal, spongy bone to strengthen, followed by the strengthening of the cortical layer)
  - When exposure to stress and deformation is repeated and prolonged, **resorption** occurs faster than replacement and leaves the area liable to fracture

- exp : marching fracture
- if callous seen w fracture / sus stress fracture

A similar problem occurs in individuals who are on medication that alters the normal balance of bone resorption and replacement; stress fractures are increasingly seen in patients with chronic inflammatory diseases who are on treatment with **steroids** or methotrexate.

Fatigue fractures

- fatigue fractures, is caused by the application of abnormal stress on a bone that has normal elastic resistance, The stress placed on bone causes **resorption and microfractures**.

- **insufficiency fractures**, On the other hand, occurs when normal muscular activity stresses a bone that is deficient in mineral or elastic resistance

✔ Can occur anywhere but most commonly **2nd metatarsal** followed by **Fibula** and **Tibia**.

- **Clinically,** Pain with gradual onset, examination will show local tenderness… after weeks there will be swelling.

PATHOLOGICAL FRACTURES

- Definition: Fractures may occur even with normal stresses if the bone has been **weakened** by a change in its structure

e.g. :

General:

- ✔ in osteoporosis
- ✔ osteogenesis imperfecta
- ✔ Paget's disease

Specific site:

- ✔ through a **lytic lesion** (e.g. a bone cyst or a metastasis).

* According to causes

1 Regular 2 stress 3 insufficiency 4 pathological

PATHOLOGICAL FRACTURES 2

Local causes:

- Bone infection (osteomyelitis).
- Benign tumors (enchondroma, giant cell tumor).
- Malignant tumor (osteosarcoma , Ewing sarcoma and metastatic carcinoma).

Generalized causes:

- Congenital (osteogenesis imperfecta).
- Diffuse affection of bone (osteoporosis, rickets, uremic osteodystrophy)
- Other causes (Polyostotic fibrous dysplasia, Paget's disease, Gaucher's disease).

1- normal bone + ↑ pressure

4- weak bone + normal Quality

* Stress fatigue Insufficency → Repetion within a normal way "sitting all day"

↓

* Multible small traumas causing fracture

*Abnormal repetition of an activity

"used to sit, but walkes alot for many days"

- Boxing then having clavicle fracture"

* pathological

Single trauma caused a fracture

Those have no Hx of trauma

4 2 B

4 = hg / 2 = Diaphysis → B = Widge

Diaphyseal heg widge fracture

CLASSIFICATION OF FRACTURES

- Alphanumeric classification developed by **Muller and colleagues** has now been adapted and revised
- In this system, the

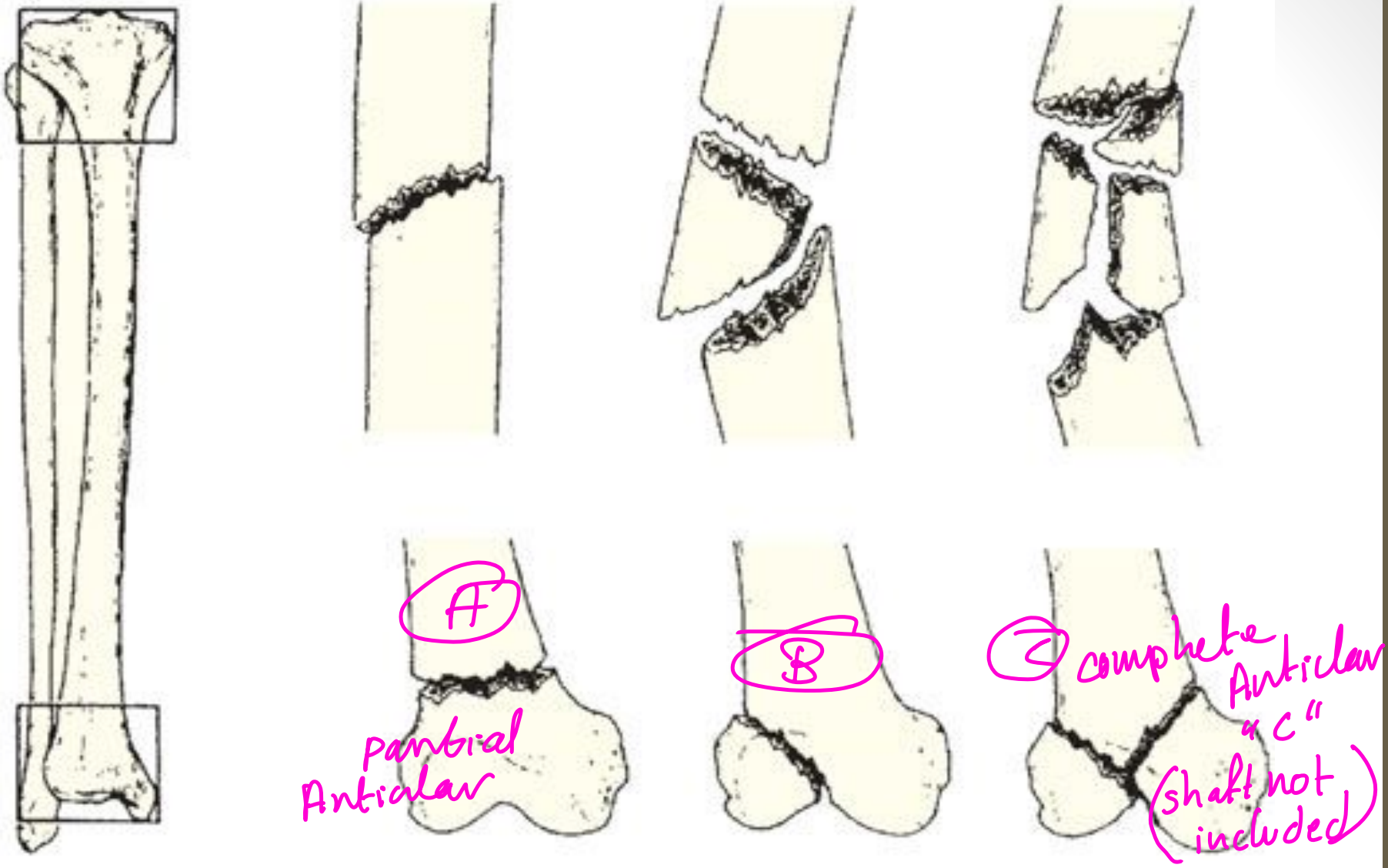
1. **first digit** specifies the bone (1=humerus, 2=Radius/ulna, 3=femur, 4=tibia/fibula).
2. **the second** the segment (1=proximal, 2=diaphyseal, 3=distal, 4=malleolar).
3. **A letter** specifies the fracture pattern

(for the diaphysis: A=simple, B=wedge, C=complex).

(for the metaphysis: A=extra-articular, B=partial articular, C=complete articular).

- **Two further numbers** specify the detailed morphology of the fracture

* Ex → fracture 11 → humerus. proximal



- Each long bone has three segments – **proximal, diaphyseal and distal**; the proximal
- and distal segments are each defined by a square based on the widest part of the bone.
- **(b,c,d) Diaphyseal fractures** may be simple, wedge or complex.
- **(e,f,g) Proximal and distal fractures may be extra-articular,** partial articular of complete articular

FRACTURES DISPLACEDMENT

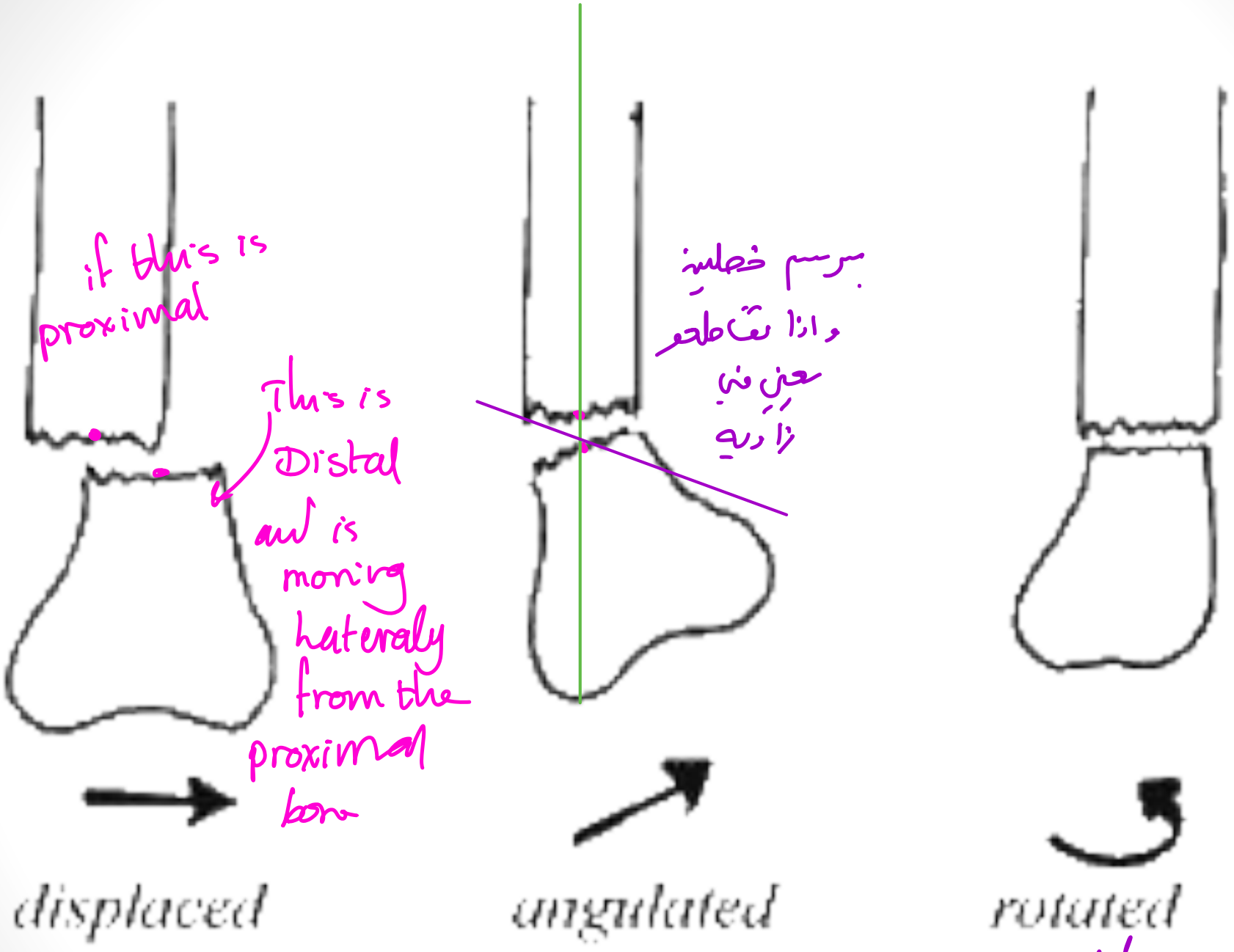
- After a complete fracture, the fragments usually become displaced, partly by the force of the injury, partly by gravity and partly by the pull of muscles attached to them.
- The **two main** fragments of fracture are commonly displaced.

- The following Displacements are recognized:
- **Translation ‘’shift’’**
- **Length**
- **Alignment ’’angulation’’**
- **Rotation ‘’ twist’’**

Displacement of the fracture fragments

1. **Translation (shift)** – *The fragments may be shifted* sideways, backward or forward in relation to each other, such that the fracture surfaces lose contact. (Distal according to proximal, from midpoint of fractured bone)
   - ✔ The fracture will usually unite as long as sufficient contact between surfaces is achieved;
   - ✔ this may occur even if reduction is imperfect, or even if the fracture ends are off-ended but the bone segments come to lie side by side.
2. **Angulation (tilt)** – *The fragments may be tilted or* angulated in relation to each other. (distal fragmented fracture acc to proximal)
   - ✔ Malalignment, if uncorrected, may lead to deformity of the limb.
3. **Rotation (twist)** – *One of the fragments may be* twisted on its longitudinal axis; the bone looks straight but the limb ends up with a rotational deformity. (2 joint have to be apparent inorder to assess rotation)
4. **Length** – *The fragments may be distracted and separated,* or they may overlap, due to muscle spasm, causing shortening of the bone

Axial shift


if this is proximal
This is Distal and is moving laterally from the proximal bone
displaced
برسم خطين واذا تقاطعو معين في زاوية
angulated
rotated
- no translation
- no Angulation

Rotation is NEVER acceptable

Angulation and **translation** to a **CERTAIN DEGREE** are acceptable

Shortening in **PEDIATRICS** to a **CERTAIN LIMIT** is acceptable

translation → ازاحه

FRACTURE HEALING

- The process of fracture repair varies according to the type of bone involved and the amount of movement at the fracture site

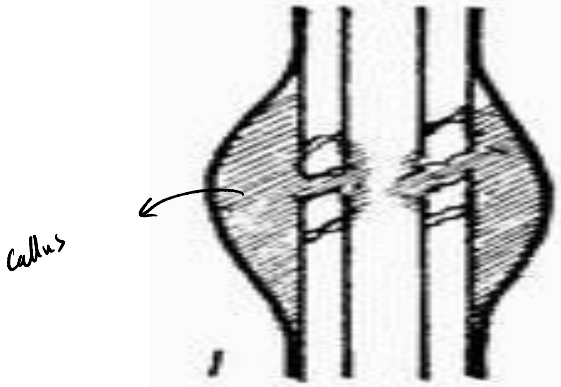
1. HEALING BY **CALLUS**
2. HEALING BY **DIRECT UNION**

HEALING BY CALLUS

- This is the '**natural**' form of healing in tubular bones; in the absence of rigid fixation, it proceeds in five stages:

1. *Tissue destruction and hematoma formation*

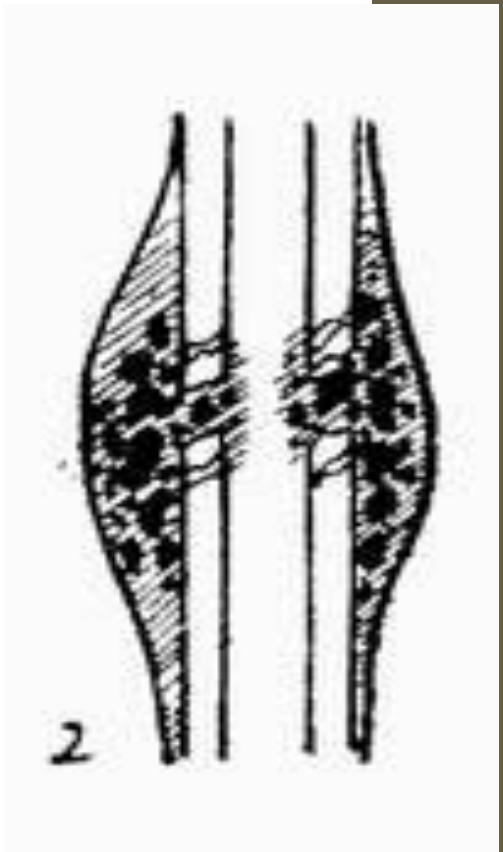
- Vessels are torn and a hematoma forms around and within the fracture.
- Bone at the fracture surfaces, deprived of a blood supply, dies back for a millimeter or two.



HEALING BY CALLUS

2. *Inflammation and cellular proliferation* –

- ***Within 8* hours** of the fracture there is an **acute** inflammatory reaction with
- **migration** of inflammatory cells
- the initiation of proliferation and differentiation of **mesenchymal stem cells** from the periosteum, the breached medullary canal and the surrounding muscle.
- The fragment ends are surrounded by cellular tissue, which creates a scaffold across the fracture site. vast array of inflammatory mediators (**cytokines and various growth factors**) is involved. The clotted hematoma is slowly absorbed and fine **new capillaries grow.**



HEALING BY CALLUS

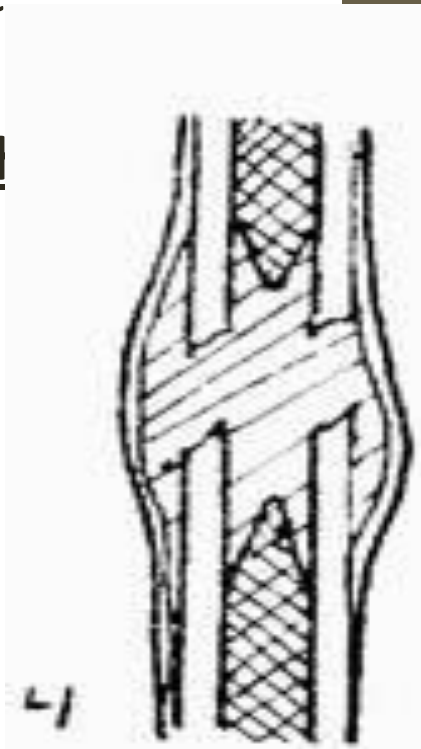
3. *Callus formation* – *The differentiating stem cells* provide **chrondrogenic** and **osteogenic** cell populations;

- given the **right conditions** – and this is usually the **local biological and biomechanical environment** – they will start forming bone or, in some cases, also cartilage.
- The cell population now also includes **osteoclasts** (probably derived from the new blood vessels), which begin to **mop up dead bone.**
- The **thick cellular mass**, with its islands of immature bone and cartilage, forms the **callus** or splint on the **periosteal and endosteal surfaces.**
- As the immature fiber bone (or '**woven' bone**) becomes more densely mineralized, movement at the fracture site decreases progressively and at about **4 weeks** after injury the fracture '**unites**'.

HEALING BY CALLUS

4. *Consolidation* – *With continuing osteoclastic and* osteoblastic activity, the woven bone is transformed into **lamellar bone**.

- The system is **now rigid** enough to allow osteoclasts to burrow through the debris at the fracture line, and close behind them.
- Osteoblasts fill in the remaining gaps between the fragments with new bone.
- This is a **slow process** and it may be **several month** before the bone is strong enough to carry normal loads.



HEALING BY CALLUS

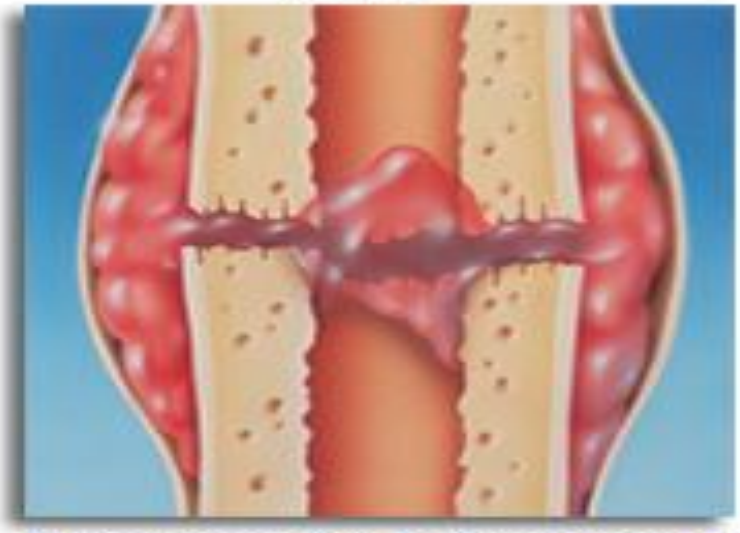
5. *Remodeling*

✔ *The fracture has been bridged by a* **cuff of solid bone**.

- Over a period of months, **or even years**, this crude 'weld' is reshaped by a continuous process of alternating bone resorption and formation.
- **Thicker lamellae** are laid down where the <u>stresses are high</u>, unwanted buttresses are carved away and the medullary cavity is reformed.
- Eventually, and **especially in children**, the bone reassumes something like its normal shape.

Fracture Healing Process

Week 1



Hematoma (or Inflammation)

Weeks 2-3

Soft Callus

Weeks 4-16

Hard Callus

Weeks 17 & Beyond

Remodeling

HEALING BY DIRECT UNION

very Rapid

↳ Depends on immobilization

- Clinical and experimental studies have shown that callus is the response to movement at the fracture site
- It serves to **stabilize the fragments as rapidly as possible..** a necessary precondition for bridging by bone.
- If the fracture site is **absolutely immobile** – for example, an impacted fracture in cancellous bone, or a fracture rigidly immobilized by a metal plate – **there is no stimulus for callus**

↳ gives absolute fixation & no micro-movements, this facilitates "direct healing"

- Nail & casts don't give absolute fixation, this facilitates "indirect healing"

* Cutting Cones?

تجسير فراغات من الجهتين

* ↑pressure on bone → ↑bone density

↓stress on bone → Osteoporosis

* over weight, early they have ↑bone Density.

but with time those people stop moving so ↓bone stress → osteoporosis

The best prophylaxis for osteoporosis is Exercise

HEALING BY DIRECT UNION

- **Instead**, osteoblastic new bone formation occurs **directly** between the fragments.
- Gaps between the fracture surfaces are invaded by **new capillaries and osteoprogenitor cells** growing in from the edges, and new bone is laid down on the exposed surface **(*gap healing*).**

Where the crevices are ***very narrow*** (less than 200 µm), osteogenesis produces **lamellar bone**; wider gaps are filled first by woven bone, which is then remodeled to lamellar bone.

By 3–4 weeks the fracture is solid enough to allow penetration and bridging of the area by bone remodeling units, i.e. **osteoclastic 'cutting cones'** followed by **osteoblasts**.

- Where the exposed fracture surfaces are in intimate contact and held rigidly from the outset, internal bridging may occasionally occur without any intermediate stages **(contact healing)**.

* The metal you insert in the surgery has to be metal shearing not metal bearing. To Give the bone a little stress to

Bearing: المسمار يحمل الوزن easy to prevent Osteoporosis يحمل الوزن

Comparison

- **Healing by callus**, though less direct (the term 'indirect' could be used) has distinct advantages:
  - it ensures **mechanical strength** while the bone ends heal, and with increasing stress the callus grows stronger and stronger (an example of **Wolff's law**).

- **With rigid metal fixation**, on the other hand, the absence of callus means that there is a **long period** during which the bone depends entirely upon the metal implant for its integrity.
  - Moreover, the implant diverts stress away from the bone, which may become **osteoporotic** and **not recover fully** until the metal is removed.

UNION, CONSOLIDATION AND NON-UNION

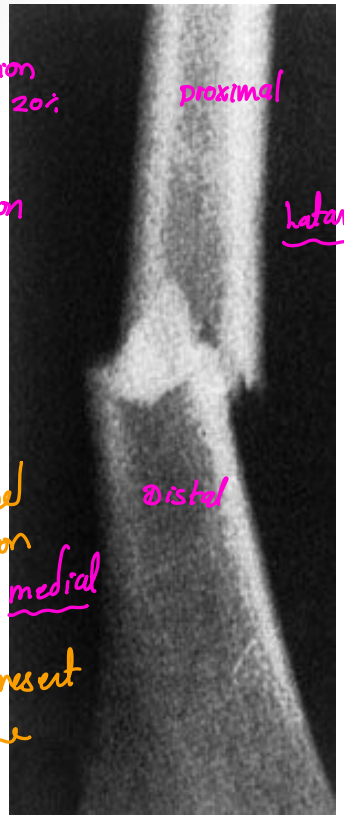
- ***Union*** **–** *Union is incomplete repair; the ensheathing* callus is calcified.

- **Clinically** the fracture site is
  - ✔ still a little **tender** on percussion
  - ✔ though the bone **moves in one piece** (and in that sense is united),
  - ✔ Attempted angulation is **painful**.
- **X-Rays** show the **fracture line** still clearly visible, with **fluffy callus** around it.
  - Repair is incomplete and it is not safe to subject the unprotected bone to stress.

=> Removing the metal is not recommended exc in specific cases (e.g. children)
=> intra-articular fracture have to anatomically reduced
=> AO principles 1. internal reduction 3. Early motion control
2. Tration 4. Blood supply supervision

- ***Consolidation –*** *is complete repair;* the calcified callus is **ossified**.
- **Clinically** the fracture:
- ✔ site is **not** tender, **no movement** can be obtained and attempted angulation is **painless**.
- **X-rays** show:
  - the fracture line to be **almost obliterated** and crossed by **bone trabeculae**, with **well-defined callus** around it.
  - Repair is *complete* and further protection is unnecessary.

- ***Non-union –*** *Sometimes the normal process of fracture* repair is **thwarted** and the bone **fails to unite.**

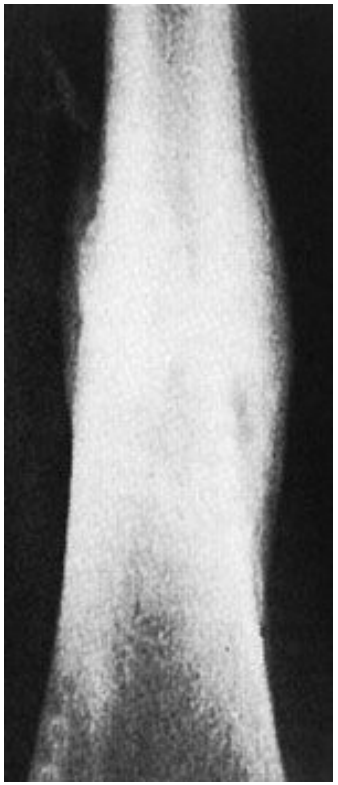


* Translation medially by 20%
* Lateral Angulation
* Pattern of fracture is Transverse
* Rotation? can't be Judged bec the Rotation is Judged when two Joints are present in the image

(a) Fracture

* more Translation (25%)
* less Angulation

(b) union



(c) consolidation

(d) Bone remodeling

* Thickness of bone at fracture area - here its almost back to normal
* Bone marrow cavity: now its Continous

* Complication of fracture *

Causes of non-union

- (1) distraction and **separation of the fragments**, sometimes the result of interposition of soft tissues between the fragments;
- (2) **excessive movement** at the fracture line;
- (3) a severe injury that renders the **local tissue is nonviable** or nearly so;
- (4) a **poor local blood supply**
- (5) **infection**.

Of course **surgical intervention**, if ill-judged, is another cause!

Non-unions

- ✔ Non-unions are **septic or aseptic.**
- ✔ In the latter group, they can be either **stiff or mobile** as judged by clinical examination. The mobile ones can be as free and painless **as to give the impression of a false joint** (*pseudarthrosis).*

- ❖ **On x-ray**, *non-unions are typified by*
  - a **lucent line** still present between the bone fragments;
  - sometimes there is **exuberant callus** trying but failing to bridge the gap (**hypertrophic non-union**) *or* no proper internal fixation
  - At times none at all (**atrophic non-union**) *with a sorry,* withered appearance to the fracture ends

↳ impaired healing

What is the cause of…

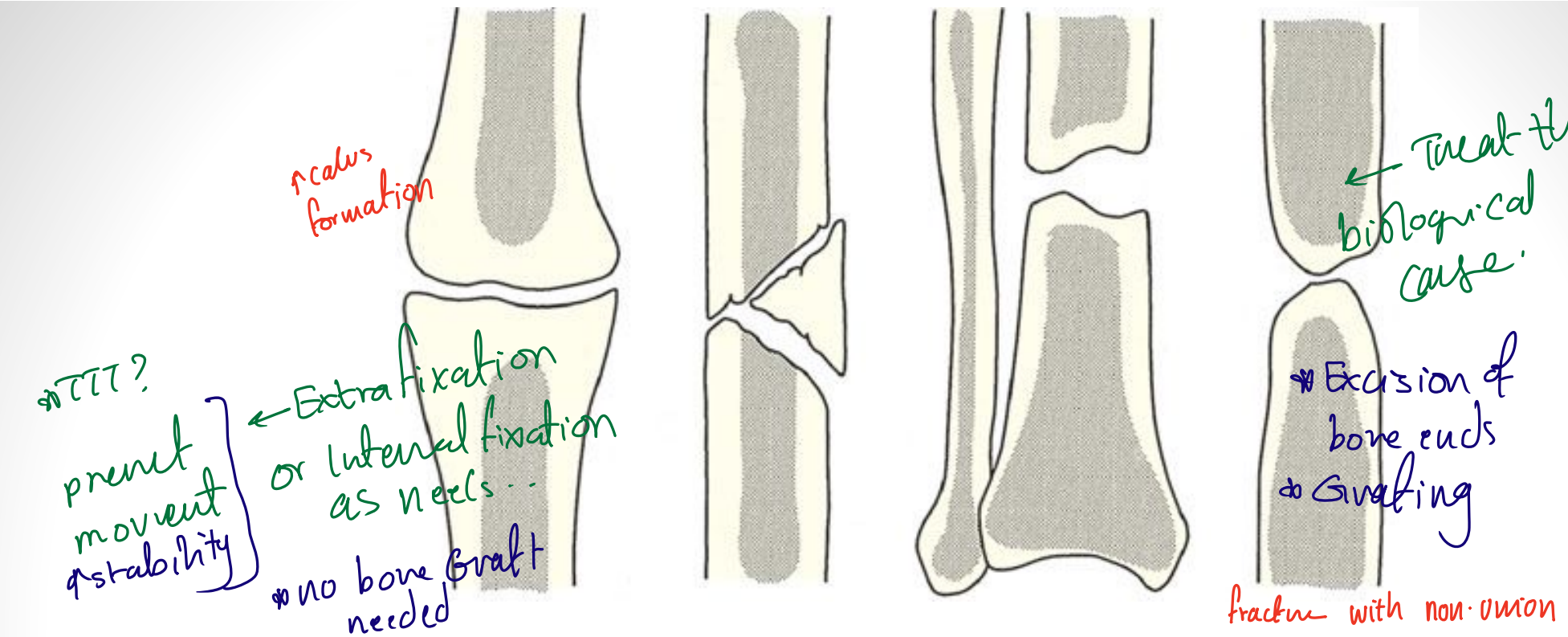
- **Atrophic non-union**?

Vascular supply compromise

- **Hypertrophic** non-union?

Excessive mobility= callus keeps <u>failing</u>

A b c D



- **Aseptic non-unions are generally** divided into **hypertrophic** and **atrophic** types.
- Hypertrophic non-unions often have **florid streams of callus** around the fracture gap – the result of **insufficient stability**.
- They are sometimes given colorful names, such as:
- **(a) elephant's foot. In contrast, atrophic non-unions** usually arise from an impaired repair process; they are classified according to the x-ray appearance as **(b) necrotic**, **(c) gap and (d) atrophic**

Mechanical cause prevents healing

Biological cause

Time factor

- The **rate** of the bone healing depends on:
- 1-type of the **bone**.
- 2-type of **fracture**.
- 3- **blood supply**
- **4-general constitution**.
- **5- pt. age.**

+ age is a variable

Average time for healing	Upper limb	Lower limb
Callus visible	2-3 weeks	2-3 weeks
union	4-6 weeks	8-12 weeks
consolidation	6-8 weeks	12-16 weeks

Thank you