

Bone Remodeling & Repair Pathologies

*Skeletal system remodels
itself to maintain
homeostasis*

Remodeling

- Maintenance
 - replaces mineral reserves (**osteocytes**) of the matrix
- Remodelling
 - recycles (**osteoclasts**) and renews (**osteoblasts**) bone matrix

KEY CONCEPTS

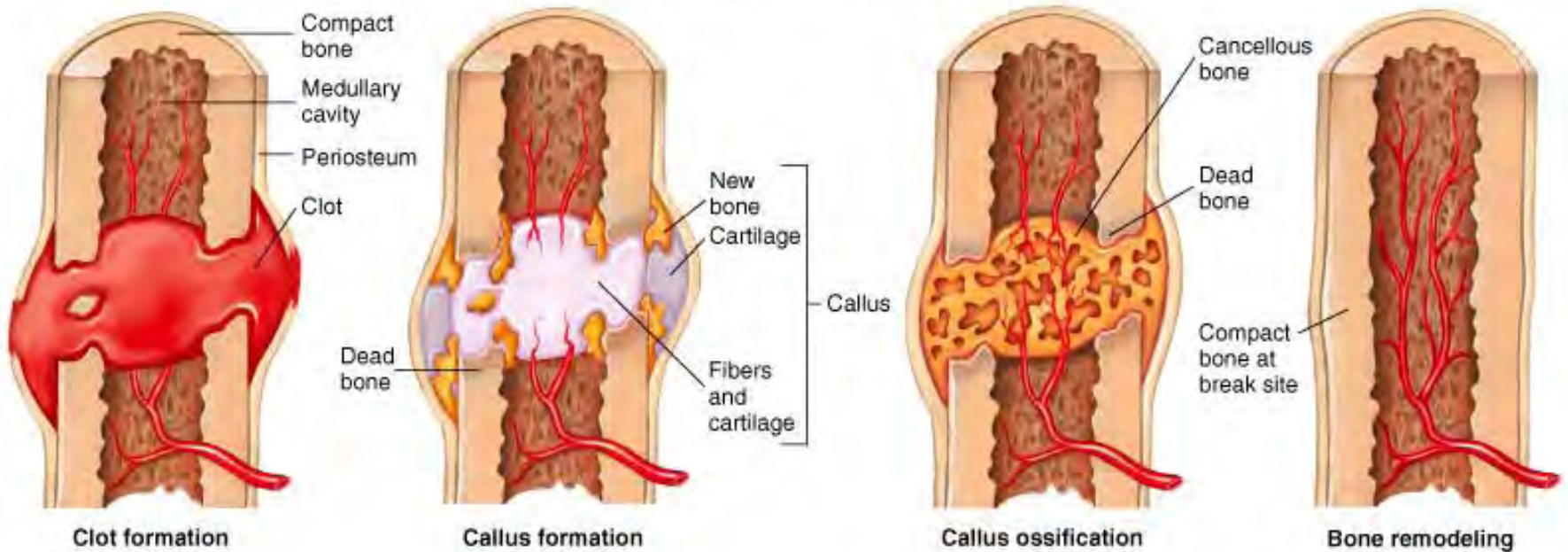
- Remodeling (deposition & degradation) is **continuous**
- Turnover *rate* is variable
 - If deposition exceeds removal, bones get stronger
 - If degradation exceeds replacement, bones get weaker

Remodeling

1. Responsible for bone **growth**
 - Remodeling of cancellous bone at the epiphyseal plate
 - Addition of new bone on outer surface
2. Changes in bone **shape**
3. Adjustment to physical stresses
4. Repair
5. Ca^{2+} regulation in body fluids

Fracture Repair

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1. When a bone is broken, a clot forms in the damaged area.

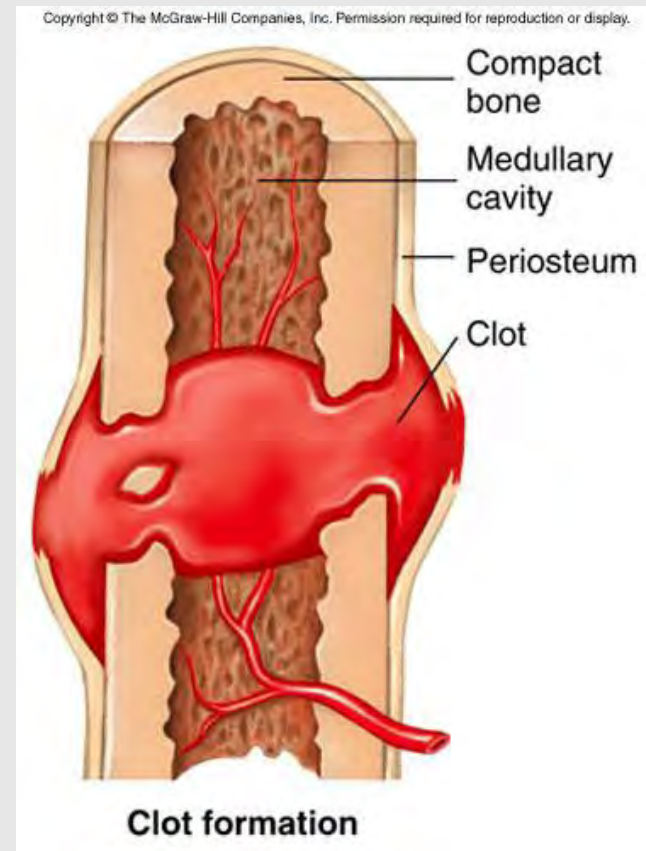
2. Blood vessels and cells invade the clot and produce a fibrous network and cartilage between the broken bones, called a callus.

3. Osteoblasts enter the callus and form cancellous bone.

4. The cancellous bone is slowly remodeled to form compact bone and the repair is complete.

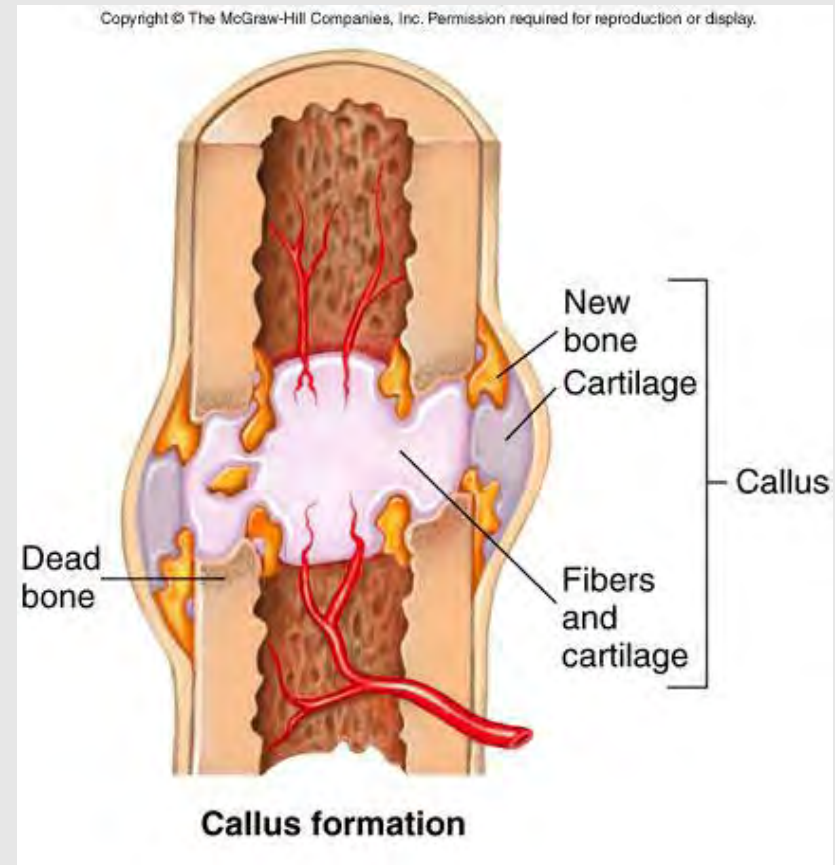
Fracture Repair

- Fracture breaks blood vessels within bone
 - Excessive bleeding forms a blood clot



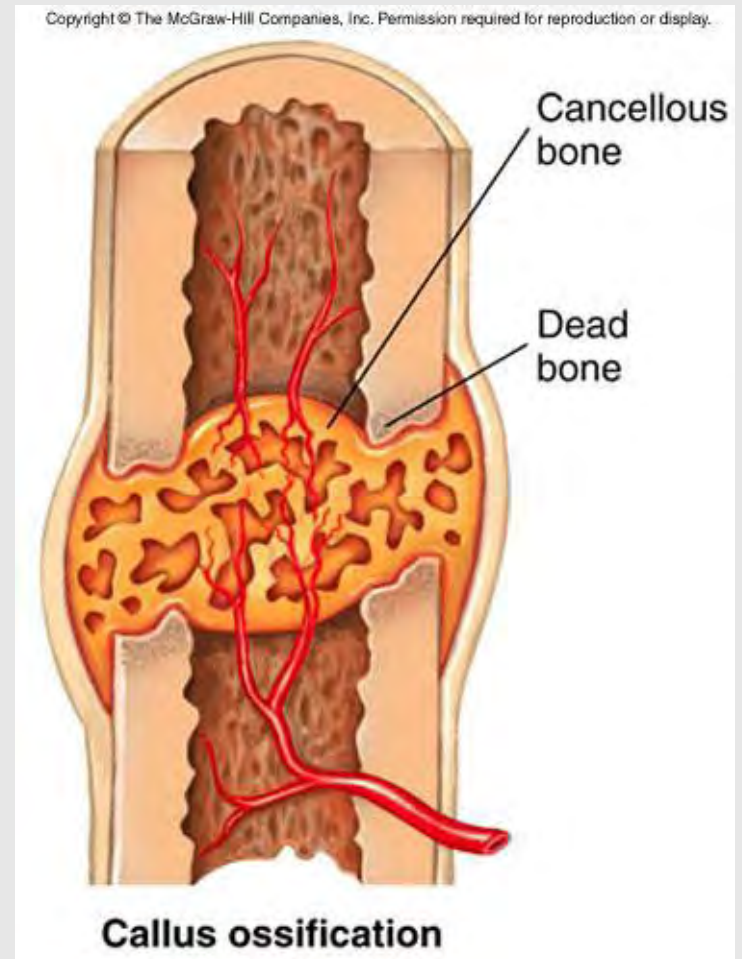
Fracture Repair

- Nearby blood vessels and cells invade clot
- Bring **fibroblasts**, which produce fibrous network of collagen and cartilage
- Zone of tissue repair = **callus**



Fracture Repair

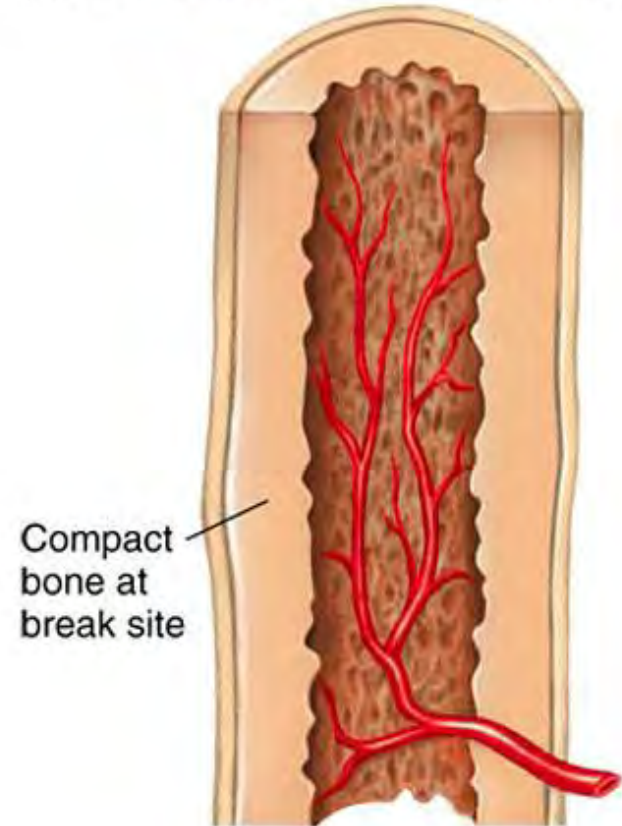
- Osteoblasts arrive, enter callus and form cancellous bone



Fracture Repair

- Cancellous bone remodeled into compact bone
- Only happens with **use**:
 - **Electrical currents** generated & propagated by Ca^{2+} salts **stimulate osteoblasts**

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Bone remodeling

Bones and Exercise

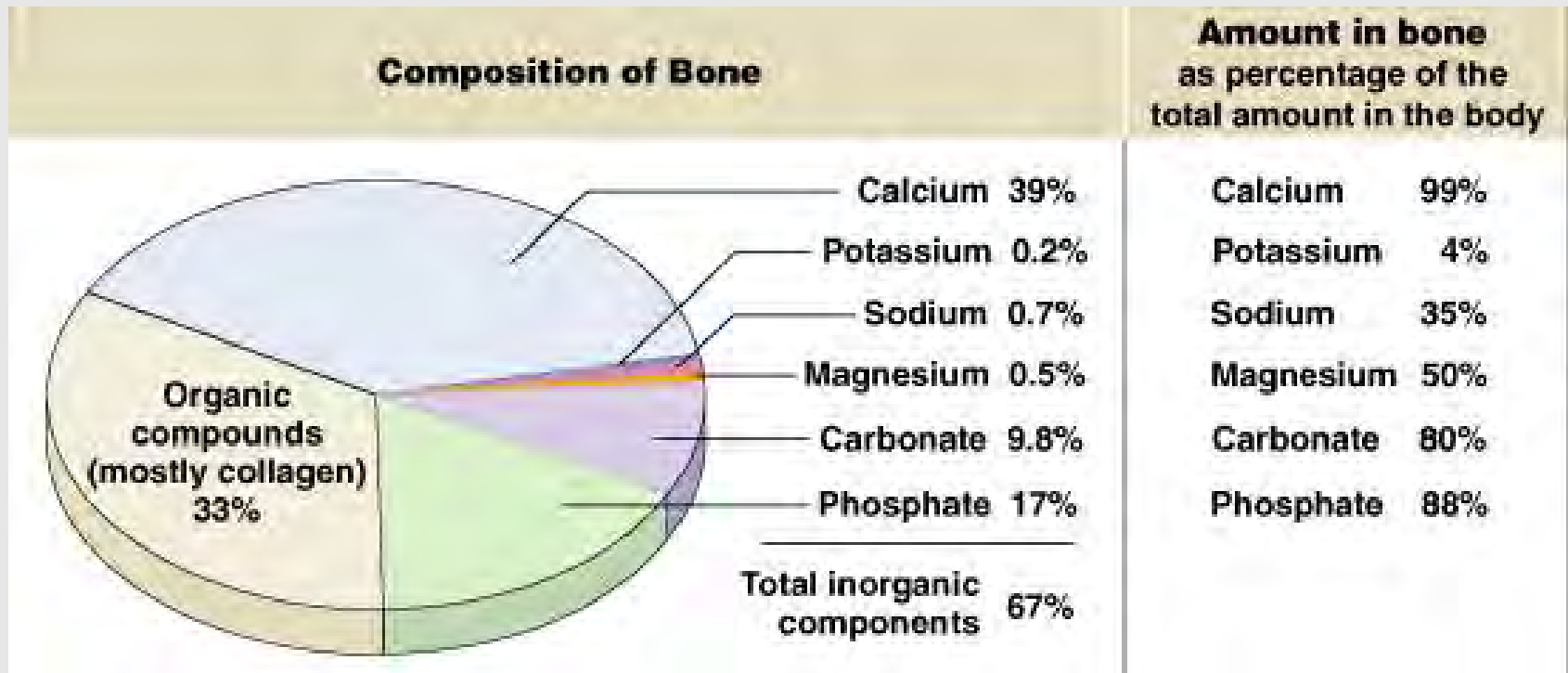
- Mineral recycling allows bones to adapt to **increased stress...**
 - Heavily stressed bones become thicker & stronger
- Or to **decreased stress...**
 - Bone degenerates quickly
 - Up to 1/3 of bone mass can be lost in a few weeks of inactivity
 - Use it or lose it!!
- **HOW?**

Bone thickens

- Increased stresses build **muscle**
 - Muscles attach to bones via tendons @ bony projections
 - Increased muscle size and strength demand larger attachments
- Compressive and tensile forces cause Ca^{2+} crystals to produce tiny electrical currents that **stimulate osteoblasts**
 - Bone matrix is deposited faster than it is removed

Skeleton as Calcium Reserve

- Bones store calcium and other minerals
- **Calcium** is the most abundant mineral in the body



Functions of Ca^{2+}

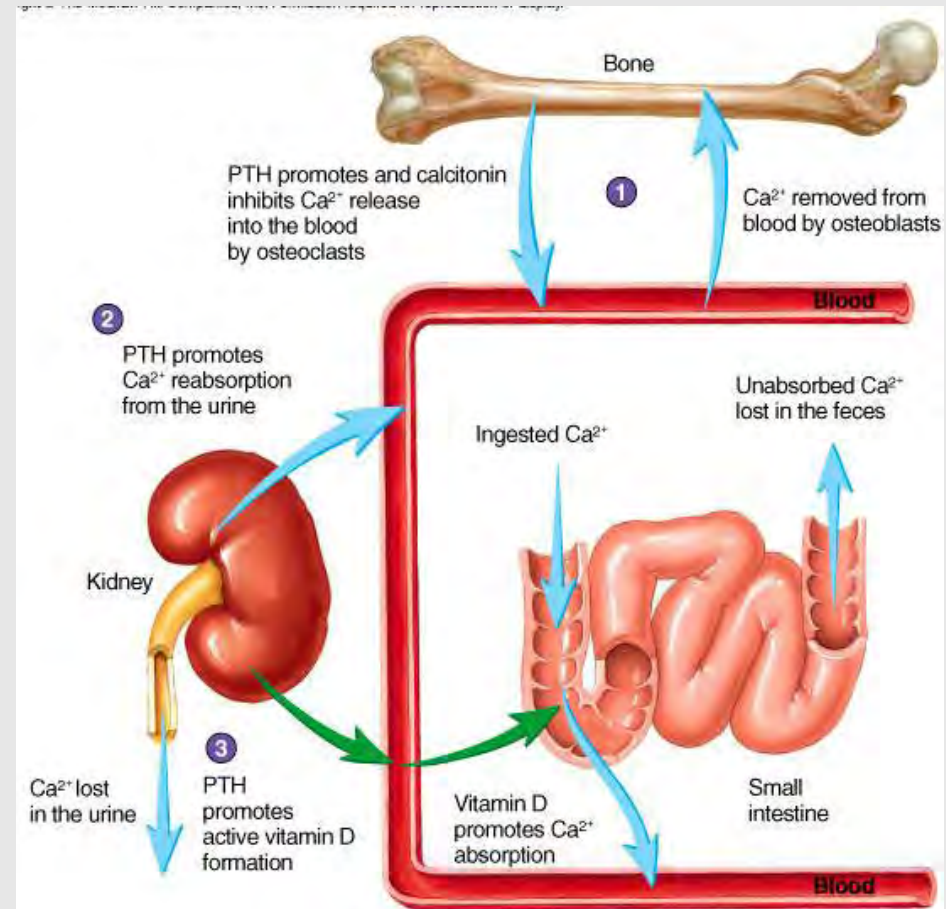
- Ca^{2+} ions are vital to:
 - Membrane function
 - Changes permeability of cells membranes to Na^+
 - Neurons
 - Neurotransmitter; influences sensitivity to excitation
 - Muscle cells, especially heart cells
 - Directly transmits stimuli; influences heart rate and blood pressure.

Ca²⁺ Regulation

- Ca²⁺ homeostasis is maintained by hormones having **OPPOSING** effects:
 - **Calcitonin** and **parathyroid hormone** control **storage** (bones), **absorption** (small intestine), and **excretion** (kidneys) of Calcium

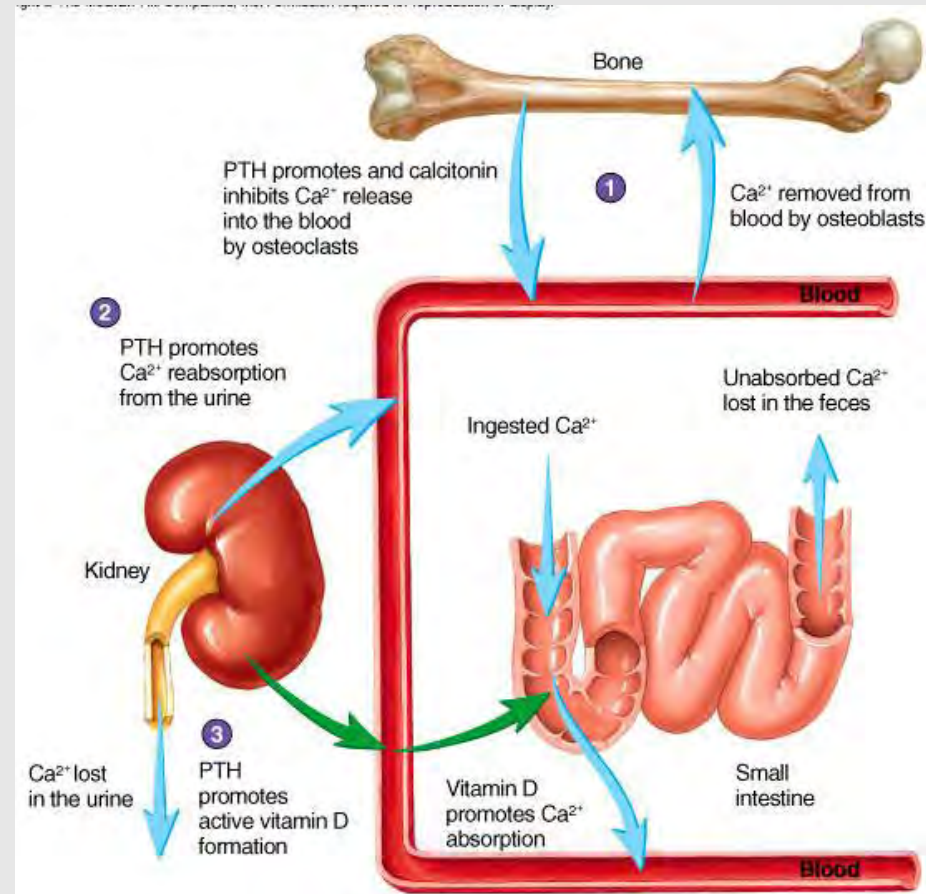
Ca²⁺ Regulation

- You drink some milk
 - Vitamin D (in your fortified milk?) aids Ca²⁺ absorption in small intestine
 - Absorptive cells deliver Ca²⁺ to blood
 - Blood delivers Ca²⁺ to osteoblasts



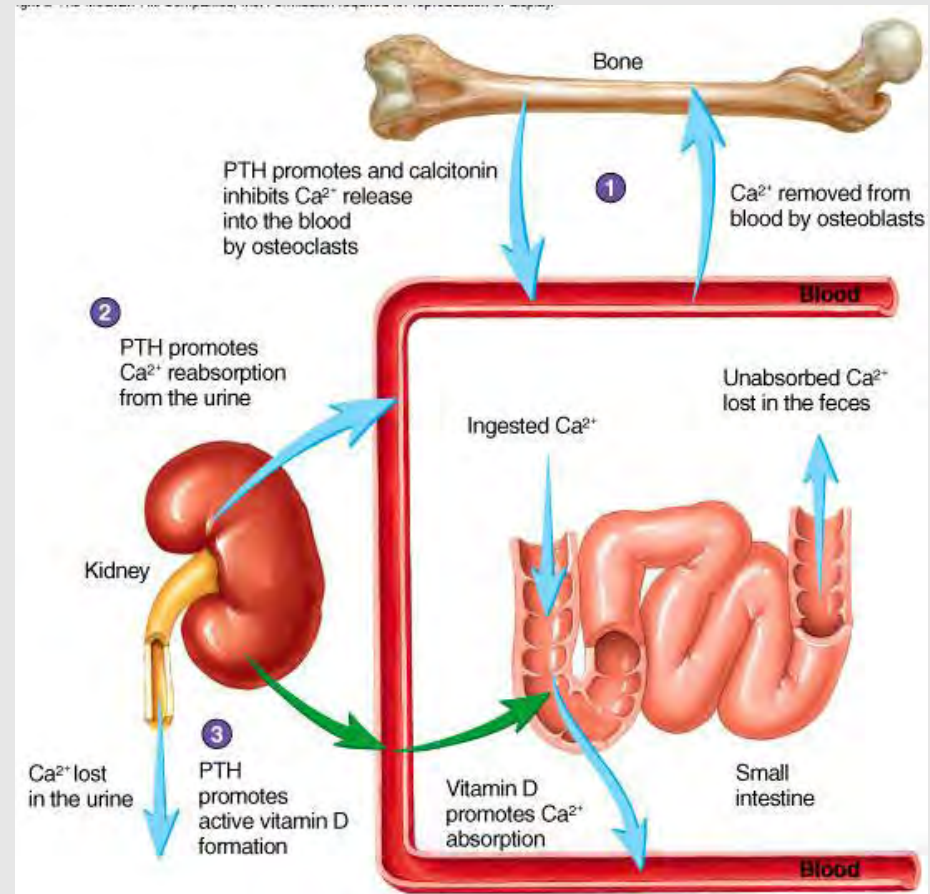
Ca²⁺ Regulation

- Blood Ca²⁺ level drops *below set point*
 - Parathyroid hormone (PTH) is released
 - **Stimulates** osteoclasts
 - **Increases** Ca²⁺ retention in kidneys
 - **Stimulates** active vitamin D production



Ca²⁺ Regulation

- Blood Ca²⁺ level rises *above set point*
 - **Calcitonin** (hormone) is secreted from thyroid gland
 - **Inhibits** osteoclasts
 - **Increases** Ca²⁺ excretion at the kidneys



Rising blood calcium signals the thyroid gland to secrete calcitonin.*

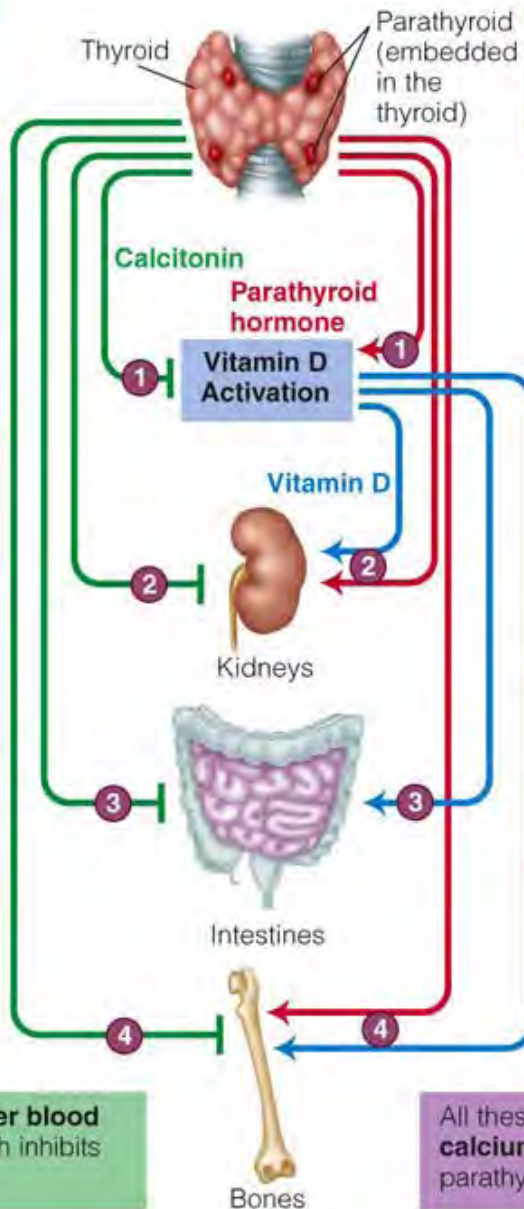
1 **Calcitonin** inhibits the activation of vitamin D.

2 **Calcitonin** prevents calcium reabsorption in the kidneys.

3 **Calcitonin** limits calcium absorption in the intestines.

4 **Calcitonin** inhibits osteoclast cells from breaking down bone, preventing the release of calcium.

All these actions **lower blood calcium levels**, which inhibits calcitonin secretion.



Falling blood calcium signals the parathyroid glands to secrete parathyroid hormone.

1 **Parathyroid hormone** stimulates the activation of vitamin D.

2 **Vitamin D** and **parathyroid hormone** stimulate calcium reabsorption in the kidneys.

3 **Vitamin D** enhances calcium absorption in the intestines.

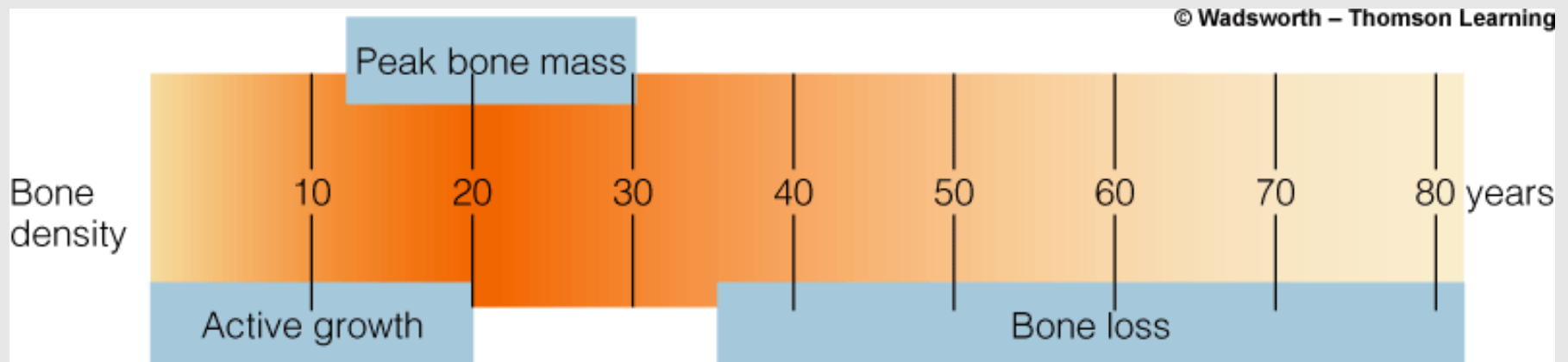
4 **Vitamin D** and **parathyroid hormone** stimulate osteoclast cells to break down bone, releasing calcium into the blood.

All these actions **raise blood calcium levels**, which inhibits parathyroid hormone secretion.

*Calcitonin plays a major role in defending infants and young children against the dangers of rising blood calcium that can occur when regular feedings of milk deliver large quantities of calcium to a small body. In contrast, calcitonin plays a relatively minor role in adults because their absorption of calcium is less efficient and their bodies are larger, making elevated blood calcium unlikely.

Ca²⁺ & Vitamin D

- Deficiency symptoms
 - In children: stunted growth; **rickets**
 - In adults: bone loss (**osteoporosis**) or improper mineralization (**osteomalacia**)



Rickets

- *Wrick*, to twist; bones become twisted
- Retarded bone growth caused by deficiencies of:
 - **minerals** (Ca^{2+} , P) necessary for normal ossification
 - **Vitamin D**; necessary for Ca^{2+} , P absorption in small intestine
 - Bones become soft, weak, easily broken
 - often in children with nutritional Vitamin D deficiencies or lack of sunlight

Osteoporosis

- *Osteo*, bone + *poros*, pore + *osis*, condition; Reduction in overall bone quality and quantity
 - Osteoclast activity exceeds osteoblast activity
 - Inadequate intake of Ca^{2+}
 - Inadequate absorption of Ca^{2+}
 - Lack of exercise
 - Lowered estrogen levels

Osteomyelitis

- *Osteo*, bone + *myelos*, marrow + *itis*, inflammation
 - Often caused by bacterial infection; leads to degradation of bone
 - **Staph** infections, usually introduced through wounds
 - **Tuberculosis**