Bone Remodeling & Repair Pathologies
Skeletal system remodels itself to maintain homeostasis
Remodeling

• Maintainence
  - 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

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 \( \text{Ca}^{2+} \) salts stimulate osteoblasts
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.
Ca$^{2+}$ Regulation

- Ca$^{2+}$ homeostasis is maintained by hormones having OPPOSING effects:
  - Calcitonin and parathyroid hormone control storage (bones), absorption (small intestine), and excretion (kidneys) of Calcium
Ca$^{2+}$ Regulation

- You drink some milk
  - Vitamin D (in your fortified milk?) aids Ca$^{2+}$ absorption in small intestine
  - Absorptive cells deliver Ca$^{2+}$ to blood
  - Blood delivers Ca$^{2+}$ to osteoblasts
Ca$^{2+}$ Regulation

- Blood Ca$^{2+}$ level drops below set point
  - Parathyroid hormone (PTH) is released
    - Stimulates osteoclasts
    - Increases Ca$^{2+}$ retention in kidneys
    - Stimulates active vitamin D production
Ca\textsuperscript{2+} Regulation

- Blood Ca\textsuperscript{2+} level rises above set point
  - Calcitonin (hormone) is secreted from thyroid gland
    - Inhibits osteoclasts
    - Increases Ca\textsuperscript{2+} 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.

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 lower blood calcium levels, which inhibits calcitonin secretion.

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.

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Ca\textsuperscript{2+} & 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** \((\text{Ca}^{2+}, \text{P})\) necessary for normal ossification
  - **Vitamin D**; necessary for \(\text{Ca}^{2+}, \text{P}\) 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 $\text{Ca}^{2+}$
    - Inadequate absorption of $\text{Ca}^{2+}$
    - 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