Lecture 8

The skeletal system II - Physiology of Osseous Tissue

Plan of the Lecture

1. Mineral Deposition and Resorption
    a. Mineral deposition
    b. Mineral resorption
2. Calcium Homeostasis
    a. Calcitriol
    b. Calcitonin
    c. Parathyroid Hormone
3. Phosphate Homeostasis
4. Other Factors Affecting Bone

LEARNING OUTCOMES

1. describe the processes by which minerals are added to and removed from bone tissue;
2. discuss the role of the bones in regulating blood calcium and phosphate levels;
3. name the main hormones that regulate bone physiology, and describe their effects.

Mineral deposition (mineralization) is a crystallization process in which calcium, phosphate, and other ions are taken from the blood plasma and deposited in bone tissue, mainly as needlelike crystals of hydroxyapatite. Deposition begins in fetal ossification and continues throughout life. Mineral resorption is the process of dissolving bone. It releases minerals into the blood and makes them available for other uses. Resorption is carried out by osteoclasts. They have surface receptors for calcium and respond to falling levels of calcium in the tissue fluid. Hydrogen pumps in the ruffled border of the osteoclast secrete hydrogen ions into the tissue fluid, and chloride ions follow by electrical attraction. The space between the osteoclast and the bone thus becomes filled with concentrated hydrochloric acid with a pH of about 4. The acid dissolves the bone minerals. The osteoclast also secretes an acid-tolerant enzyme (protease) that digests the collagen of the bone matrix.

Calcium plays roles in communication among neurons and in muscle contraction, blood clotting, and exocytosis. It is also a second or third

messenger in many cell signaling processes and a cofactor for some enzymes. The skeleton is a reservoir
for these minerals. Minerals are deposited in the skeleton when the supply is ample and withdrawn when they are needed for these other purposes.

A calcium deficiency is called hypocalcemia. It causes excessive excitability of the nervous system and leads to muscle tremors, spasms, or tetany—the inability of the muscle to relax. Tetany begins to occur as the plasma Ca^{2+} concentration falls to 6 mg/dL. A blood calcium excess is called hypercalcemia. In this
condition, excessive amounts of calcium bind to the cell surface, increasing the charge difference across the membrane and making sodium channels less responsive. In addition, calcium ions bind to membrane proteins that serve as sodium channels and inhibit them from opening.

Calcitriol behaves as a hormone—a blood-borne chemical messenger from one organ to another. It is called a vitamin only because it is added to the diet, mainly in fortified milk, as a safeguard for people who do not get enough sunlight to initiate adequate synthesis in the skin.

Calcitonin plays an important role in children but has only a weak effect in most adults. The osteoclasts of children are highly active in skeletal remodeling and release 5 g or more of calcium into the blood each day. By inhibiting this activity, calcitonin can significantly lower the blood calcium level in children. In adults, however, the osteoclasts release only about 0.8 g of calcium per day. Calcitonin cannot change adult blood calcium very much by suppressing this lesser contribution.

Phosphate levels are not regulated nearly as tightly as calcium levels. Nor, apparently, do they need to be; changes in plasma phosphate level are not associated with any immediate functional disorder. Calcitriol raises the phosphate level by promoting its absorption from the diet by the small intestine. This makes sense, because one effect of calcitriol is to promote bone deposition, and that requires both calcium and phosphate. Parathyroid hormone, on the other hand, lowers the blood phosphate level by promoting its urinary excretion.

Bone growth is especially rapid in puberty and adolescence, when surges of growth hormone, estrogen, and testosterone promote ossification. These hormones stimulate rapid multiplication of osteogenic cells, matrix deposition by osteoblasts, and multiplication and hypertrophy of the chondrocytes in the metaphyses

Check yourself! The questions for self-control

1. Describe the role of collagen and seed crystals in bone mineralization. 2. Why is it important to regulate blood calcium concentration within such a narrow range?
3. What effect does calcitonin have on blood calcium concentration, and how does it produce this effect? Answer the same questions for parathyroid hormone.
4. How is vitamin D synthesized, and what effect does it have on blood calcium concentration?

Recommended readings:

1. Kenneth S Saladin - Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education)
2. Barbara Gylys - Medical Terminology Systems (2012, F.A. Davis Company)