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Bone Marrow, Bone Growth, and Remodeling

Study Guide — Musculoskeletal System

Pre-med/IB-style MCQs on red vs yellow marrow, hematopoiesis, bone growth (endochondral vs intramembranous), growth plates, and the roles/regulation of osteoblasts, osteocytes, and osteoclasts.

40 items — Study Guide with Answers

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1 **Which statement BEST describes the main functional difference between red and yellow bone marrow in a healthy adult?**

A Red marrow stores fat for long-term energy; yellow marrow produces most blood cells.

B **Red marrow is the main site of blood cell production; yellow marrow is mainly fat storage.** ✓

C Red marrow forms the bone matrix; yellow marrow forms cartilage.

D Red marrow produces only platelets; yellow marrow produces only red blood cells.

E Red marrow is found only in children; yellow marrow is found only in adults.

▶ **Explanation:** Red marrow is hematopoietic (makes RBCs, many WBCs, platelets). Yellow marrow is rich in adipocytes (fat) and is less active in hematopoiesis in normal conditions. Adults can still have red marrow, especially in axial bones.

2 **In a healthy adult, most active red bone marrow is found primarily in the:**

A Diaphysis (shaft) of the femur and tibia

B Distal phalanges of the fingers

C **Axial skeleton (e.g., pelvis, vertebrae, sternum, ribs) and proximal ends of some long bones** ✓

D Outer epidermis and dermis

E Articular cartilage of joints

▶ **Explanation:** With age, much marrow in long bone shafts becomes yellow. Red marrow remains concentrated in the axial skeleton (pelvis/vertebrae/sternum/ribs) and some proximal long-bone regions (e.g., proximal femur/humerus).

3 **Which pairing is correct for where key lymphocytes mature?**

- A B cells mature in the thymus; T cells mature in bone marrow
- B **B cells mature in bone marrow; T cells mature in the thymus ✓**
- C Both B and T cells mature mainly in the spleen
- D Both B and T cells mature mainly in the liver in adults
- E Neither B nor T cells mature in any organ; they mature only in blood

▶ **Explanation:** B cells mature in bone marrow, while T cells mature in the thymus. The spleen and lymph nodes are important for immune responses, but not the main "maturation" sites for these lymphocytes.

4 After severe blood loss, the body needs increased blood cell production. Which adaptive change can occur in bone marrow?

- A Red marrow is permanently replaced by yellow marrow to save energy.
- B Yellow marrow is replaced by cartilage to stabilize the bone.
- C Osteoclasts stop functioning so that marrow can fill with blood.
- D **Some yellow marrow can convert back toward red marrow to increase hematopoiesis. ✓**
- E The bone marrow switches to making hormones instead of blood cells.

▶ **Explanation:** Under increased demand (e.g., blood loss), the body can expand hematopoiesis and some yellow marrow can shift toward more hematopoietic (red) activity. It's a functional adaptation, not cartilage replacement.

5 A hallmark feature of hematopoietic stem cells (HSCs) is that they can:

- A **Self-renew and give rise to multiple blood cell lineages ✓**
- B Differentiate only into red blood cells, never immune cells

- C Turn directly into osteoclasts without any intermediate steps
- D Divide only once and then permanently stop
- E Produce ATP for the body as their main role

▶ **Explanation:** HSCs are defined by self-renewal and multipotency (they can generate multiple blood lineages over time). They are not specialized energy producers, and they don't only make RBCs.

6 Platelets are produced most directly by:

- A Mature red blood cells splitting in half
- B Neutrophils releasing membrane fragments
- C Osteoblasts secreting clotting vesicles
- D Plasma proteins assembling into discs
- E **Fragmentation of megakaryocytes in the bone marrow** ✓

▶ **Explanation:** Platelets are cell fragments shed from megakaryocytes in bone marrow. RBCs do not split to form platelets, and osteoblasts are bone-forming cells, not platelet producers.

7 At high altitude, oxygen levels are lower. Over time, many people produce more red blood cells. Which hormone most directly drives this increase in RBC production?

- A Insulin
- B **Erythropoietin (EPO)** ✓
- C ADH
- D Calcitonin
- E Aldosterone

▶ **Explanation:** Low oxygen stimulates increased erythropoietin (mainly from the kidneys), which signals the bone marrow to increase erythropoiesis. ADH/aldosterone regulate water/salt balance, not RBC production.

8 Which pairing correctly matches the typical developmental origin of osteoblasts and osteoclasts?

- A Osteoblasts: hematopoietic stem cells; Osteoclasts: mesenchymal stem cells
- B **Osteoblasts: mesenchymal stem cells; Osteoclasts: hematopoietic/monocyte lineage** ✓
- C Both osteoblasts and osteoclasts: mature red blood cells
- D Both osteoblasts and osteoclasts: neurons
- E Osteoblasts: viruses; Osteoclasts: bacteria

▶ **Explanation:** Osteoblasts arise from mesenchymal stem cells (connective tissue lineage). Osteoclasts are derived from hematopoietic precursors in the monocyte/macrophage lineage, which fits their "immune-cell-like" resorbing behavior.

9 Which bone cell is most directly responsible for resorbing (breaking down) bone tissue?

- A Osteoblast
- B Osteocyte
- C Chondrocyte
- D **Osteoclast** ✓
- E Erythrocyte

▶ **Explanation:** Osteoclasts resorb bone using acid and enzymes. Osteoblasts build bone; osteocytes maintain/monitor bone; chondrocytes make cartilage; erythrocytes carry oxygen.

10 **A cell in bone sits in a lacuna and extends long processes through canaliculi to communicate with nearby cells and sense mechanical stress. This cell is most likely a(n):**

- A **Osteocyte** ✓
- B Osteoclast
- C Osteoblast
- D Megakaryocyte
- E Hepatocyte

▶ **Explanation:** Osteocytes are mature bone cells embedded in bone matrix (lacunae) and communicate via canaliculi. They help sense strain and coordinate remodeling signals. Osteoclasts are large resorbing cells, not embedded network cells.

11 **Which event is most directly associated with osteoblast activity?**

- A **Secretion of osteoid (collagen-rich matrix) that later mineralizes** ✓
- B Digestion of bone using acid at a ruffled border
- C Formation of platelets from cytoplasmic fragments
- D Fusion of multiple monocytes to form a multinucleated resorbing cell
- E Production of antibodies as the main function

▶ **Explanation:** Osteoblasts synthesize osteoid (especially type I collagen) and promote mineral deposition. Acid-based resorption and multinucleated fusion describe osteoclasts, not osteoblasts.

12 **After the growth plates close, bones can still increase in thickness. Which process is primarily responsible for this increase in diameter?**

- A Endochondral ossification at the epiphyseal plate
- B **Appositional growth: osteoblasts add new bone on the periosteal surface ✓**
- C Chondrocytes dividing inside articular cartilage
- D Binary fission of osteocytes
- E Conversion of bone into cartilage to make it flexible

▶ **Explanation:** Bone thickening occurs by appositional growth: osteoblasts add layers to the outer surface (periosteum) while osteoclasts can reshape the inner surface (endosteum). Lengthening via growth plates is not possible after closure.

13 **Endochondral ossification is best described as:**

- A Bone forming directly from mesenchymal tissue without a cartilage stage
- B **Bone forming by replacing a cartilage model with bone tissue ✓**
- C Cartilage forming by replacing bone tissue
- D Bone forming only after birth in all bones
- E Bone forming only in the skull

▶ **Explanation:** Endochondral ossification uses a cartilage template that is gradually replaced by bone. It is crucial for long bone development and growth.

14 **Intramembranous ossification is most associated with forming:**

- A Most long bones (femur, tibia)

- B **Many flat bones of the skull (and parts of the clavicle)** ✓
- C Articular cartilage at joints
- D Intervertebral discs
- E Bone only after fractures, never during development

▶ **Explanation:** Intramembranous ossification forms bone directly from mesenchyme and is typical for many flat skull bones (and parts of the clavicle). Long bones typically form by endochondral ossification.

15 Longitudinal growth of a long bone in a child occurs primarily because:

- A Osteocytes divide rapidly in the diaphysis and push the bone longer
- B **Chondrocytes in the epiphyseal (growth) plate proliferate and enlarge, and the cartilage is replaced by bone** ✓
- C The periosteum turns into cartilage and stretches
- D Osteoclasts add new bone matrix at the epiphysis
- E Red marrow expands and physically lengthens the bone

▶ **Explanation:** Lengthening occurs at the growth plate: cartilage expands (chondrocyte proliferation/hypertrophy) and is then replaced by bone through endochondral ossification. Osteocytes do not drive bone elongation by dividing.

16 Which hormonal change is most directly linked to epiphyseal (growth plate) closure during puberty (in both sexes)?

- A Decreased insulin
- B **Increased estrogen signaling** ✓
- C Decreased thyroid hormone
- D Increased calcitonin only in males

E Increased aldosterone

▶ **Explanation:** Estrogen is the key signal driving growth plate closure in puberty for both sexes (testosterone can be converted to estrogen). This is why estrogen-related signaling strongly affects final height.

17 A 19-year-old with closed growth plates starts a strength program. Over months, their bones can adapt by becoming stronger mainly through:

A New length growth at the epiphyseal plates

B **Remodeling and appositional growth that changes bone thickness and internal structure** ✓

C Conversion of bone into cartilage to absorb force

D Immediate doubling of bone cell number by mitosis inside lacunae

E Bone becoming hollow to increase strength

▶ **Explanation:** After growth plate closure, bones do not grow longer, but they can remodel and increase thickness/strength in response to mechanical load. This improves resistance to stress without lengthening.

18 Parathyroid hormone (PTH) is released when blood Ca^{2+} is low. Which set of effects BEST matches the goal of PTH?

A Decrease bone resorption, decrease kidney Ca^{2+} reabsorption, decrease vitamin D activation

B **Increase bone resorption (indirectly), increase kidney Ca^{2+} reabsorption, increase vitamin D activation** ✓

C Increase bone formation only, with no kidney or gut effects

D Decrease intestinal Ca^{2+} absorption, increase urinary Ca^{2+} loss

E Increase calcitonin release to lower blood Ca^{2+}

▶ **Explanation:** PTH raises blood Ca^{2+} by promoting Ca^{2+} release from bone (largely via osteoclast activation through osteoblast signals), increasing renal Ca^{2+} reabsorption, and increasing activation of vitamin D, which boosts intestinal Ca^{2+} absorption.

19 Calcitonin is best described (at a basic level) as a hormone that tends to:

- A Raise blood Ca^{2+} by stimulating osteoclast activity
- B **Lower blood Ca^{2+} by inhibiting osteoclast activity** ✓
- C Raise blood glucose by stimulating glycogen breakdown
- D Close epiphyseal plates during puberty
- E Directly insert aquaporins into kidney collecting ducts

▶ **Explanation:** Calcitonin (from thyroid C cells) tends to lower blood Ca^{2+} by opposing osteoclast-mediated bone resorption. It is not the primary long-term regulator compared to PTH, but the direction of effect is important.

20 A child has bowed legs and delayed bone mineralization. Which deficiency is most consistent with this presentation?

- A **Vitamin D deficiency (rickets)** ✓
- B Excess vitamin D
- C Excess calcitonin
- D Erythropoietin deficiency
- E Insulin deficiency as the only cause

▶ **Explanation:** In children, vitamin D deficiency can cause rickets: the growth plate and newly formed bone cannot mineralize properly, leading to deformities like bowed legs. EPO deficiency affects RBC production, not bone mineralization.

21 **Which statement BEST distinguishes osteoporosis from osteomalacia?**

A Osteoporosis is caused by infection; osteomalacia is caused by viruses.

B **Osteoporosis is reduced bone mass with relatively normal mineralization; osteomalacia is defective mineralization of osteoid.** ✓

C Osteoporosis affects only children; osteomalacia affects only adults.

D Osteoporosis is too much calcium deposition; osteomalacia is too much collagen deposition.

E Osteomalacia is caused by too much estrogen; osteoporosis is caused by too much growth hormone.

▶ **Explanation:** Osteoporosis mainly means less bone (lower density/mass), but what is present is typically mineralized normally. Osteomalacia (adult) and rickets (child) involve impaired mineralization of osteoid, often linked to vitamin D issues.

22 **A genetic condition causes osteoclasts to be nonfunctional. Bones become very dense on X-ray, but fracture easily, and the patient develops anemia. Which explanation BEST connects these findings?**

A Dense bone always means stronger bone, so fractures cannot happen; anemia is unrelated.

B Without osteoclasts, bone cannot be formed at all, causing hollow weak bones.

C **Without osteoclast resorption, bone becomes abnormally dense but poorly remodeled and brittle, and marrow cavities can narrow, reducing blood cell production.** ✓

D Osteoclast failure increases red marrow space, causing anemia.

E Osteoclasts normally produce hemoglobin, so their failure directly causes anemia.

▶ **Explanation:** This describes osteopetrosis logic: defective resorption → dense but disorganized/brittle bone and reduced marrow space → decreased hematopoiesis → anemia (and sometimes infection risk).

23 **In normal bone remodeling, which sequence is most typical at a remodeling site?**

- A Osteoblasts deposit new bone → osteocytes digest it → osteoclasts seal the area
- B **Osteoclasts resorb bone → osteoblasts form new bone ✓**
- C Chondrocytes resorb bone → osteoclasts form bone
- D Platelets form bone → osteoblasts remove it
- E Bone remodeling happens only in childhood, not in adults

▶ **Explanation:** Remodeling typically begins with osteoclast-mediated resorption, followed by osteoblast-mediated formation to replace what was removed. Remodeling continues throughout life.

24 **A person wears a cast and does not use their leg muscles for weeks. Which change is most expected in the immobilized bone (basic principle)?**

- A Increased bone density because bones always strengthen when unused
- B **Decreased bone density due to reduced mechanical load (disuse), shifting remodeling toward resorption ✓**
- C Bone converts to cartilage to keep the leg flexible
- D Growth plates reopen to compensate for immobility
- E Red marrow is completely eliminated immediately

▶ **Explanation:** Wolff's law: bone adapts to load. Reduced mechanical stress tends to decrease bone formation and/or increase resorption, lowering density over time.

25 **Which order best matches the typical stages of fracture healing (simplified)?**

- A Remodeling → hematoma → hard callus → soft callus

- B **Hematoma (clot) → soft callus → hard callus → remodeling ✓**
- C Soft callus → hematoma → remodeling → hard callus
- D Hard callus forms first, then the blood clot appears later
- E Fractures heal mainly by osteocytes dividing to fill the crack overnight

▶ **Explanation:** A fracture typically forms a hematoma (clot/inflammation), then a soft callus (fibrocartilage), then a hard bony callus (woven bone), then remodeling toward stronger lamellar bone.

26 Why is the periosteum important in bone repair after a fracture?

- A **It contains osteoprogenitor cells and contributes blood supply, helping generate new bone at the fracture site. ✓**
- B It is the main site of red blood cell production in adults.
- C It secretes ADH to reduce urine output during healing.
- D It is made of cartilage that directly turns into muscle.
- E It prevents any remodeling so the fracture stays rigid forever.

▶ **Explanation:** The periosteum is rich in blood vessels and osteogenic (bone-forming) precursor cells that support fracture repair and appositional growth. It's not a hormone source and not a hematopoietic organ itself.

27 Which statement about spongy (trabecular) bone is most accurate?

- A It has no blood supply and therefore cannot remodel.
- B It is usually found only in the shaft of long bones.
- C **It has a lattice-like structure and often contains red marrow, helping with blood cell production. ✓**
- D It is made mostly of cartilage and cannot contain marrow.

E It is weaker because it has no collagen.

▶ **Explanation:** Spongy bone forms a trabecular network, commonly in epiphyses and flat bones, and can house red marrow. It is living tissue with blood supply and remodeling capability.

28 **The basic structural unit of compact bone is the:**

- A Alveolus
- B Nephron
- C **Osteon (Haversian system)** ✓
- D Sarcomere
- E Axon

▶ **Explanation:** Compact bone is organized into osteons: concentric lamellae arranged around a central (Haversian) canal. The other choices are units of lung, kidney, muscle, and nerves.

29 **The central (Haversian) canal of an osteon primarily contains:**

- A Cartilage cells and synovial fluid
- B **Blood vessels and nerves that supply the bone** ✓
- C Air to oxygenate osteocytes directly
- D Bone marrow that produces red blood cells
- E A growth plate that lengthens the bone

▶ **Explanation:** Haversian canals house blood vessels and nerves. Marrow is found in marrow cavities/spaces, not inside each osteon's central canal, and growth plates are at bone ends in developing individuals.

30 **Which is the BEST overall reason long bones have a medullary (marrow) cavity in the shaft?**

- A To store digestive enzymes for the intestine
- B **To reduce bone weight while providing space for marrow (fat storage and/or hematopoiesis depending on age/need)** ✓
- C To allow growth plates to reopen in adults
- D To provide a place for mitochondria to replicate
- E To prevent blood vessels from entering the bone

▶ **Explanation:** A hollow cavity reduces weight without sacrificing much strength and provides space for marrow (yellow fat-rich marrow in many adult long bone shafts; red marrow when hematopoietic demand is high or in specific regions).

31 **Why is bone considered a key organ in mineral homeostasis?**

- A Because it produces most insulin for the body
- B **Because it stores large amounts of calcium and phosphate that can be exchanged with the blood** ✓
- C Because it is the main site of oxygen exchange
- D Because it stores glycogen as its main energy reserve
- E Because it removes CO2 from the blood directly

▶ **Explanation:** Bone mineral (hydroxyapatite) contains most of the body's calcium and phosphate. Remodeling and hormonal control allow the body to maintain stable blood Ca^{2+} and phosphate levels.

32 During early fetal development, before bone marrow becomes the main hematopoietic site, blood cell production occurs primarily in the:

- A **Liver and spleen ✓**
- B Pancreas and stomach
- C Thyroid and parathyroid glands
- D Skin and hair follicles
- E Cartilage of the growth plates

▶ **Explanation:** In early development, hematopoiesis occurs in sites like the liver and spleen (and earlier stages elsewhere). Later, bone marrow becomes the dominant hematopoietic organ.

33 Which statement about parathyroid hormone (PTH) and bone is MOST accurate at a basic conceptual level?

- A PTH always increases bone mass regardless of dose and timing.
- B **Continuous high PTH tends to increase bone resorption; carefully timed intermittent PTH can stimulate bone formation more. ✓**
- C PTH acts only on cartilage and never on bone.
- D PTH lowers blood calcium as its main job.
- E PTH works by inserting aquaporin channels into the collecting duct.

▶ **Explanation:** The key idea is direction and context: overall, PTH's role is to raise blood Ca^{2+}. In sustained high levels it promotes resorption; intermittent signaling can favor formation (a classic "timing matters" concept).

34 Osteoclasts do not usually have a direct "PTH receptor" that makes them turn on instantly. Instead, PTH most often increases osteoclast activity by acting on osteoblast-lineage cells to increase:

A Hemoglobin production

B **A signal that promotes osteoclast formation/activation (e.g., RANKL)** ✓

C Insulin secretion into bone matrix

D Myelin production around osteoclasts

E Chitin deposition to strengthen bone

▶ **Explanation:** A useful concept trap: osteoclasts are often regulated indirectly. Osteoblast-lineage cells can increase pro-osteoclast signals (like RANKL), which drives osteoclast differentiation and activation, increasing resorption.

35 Which statement about osteocytes is correct?

A **Osteocytes are osteoblasts that became trapped in the bone matrix they secreted.** ✓

B Osteocytes are the same as osteoclasts but smaller.

C Osteocytes are red blood cell precursors in marrow.

D Osteocytes form cartilage, not bone.

E Osteocytes exist only in infants and disappear in adults.

▶ **Explanation:** Osteocytes are mature bone cells derived from osteoblasts. They reside in lacunae and help maintain bone and sense mechanical loading.

36 A bone marrow transplant can restore production of red cells, white cells, and platelets primarily because it provides:

A Osteoclasts to rebuild bone

B **Hematopoietic stem cells capable of generating all major blood cell lineages** ✓

C Mature red blood cells that can divide into new blood cells

D Only antibodies, which then turn into blood cells

E Calcium crystals to repair marrow DNA

▶ **Explanation:** The transplant works because hematopoietic stem cells can self-renew and differentiate into multiple blood lineages (RBCs, WBCs, platelets). Mature RBCs cannot divide to repopulate marrow.

37 As humans age, a common change in bone marrow is:

A Yellow marrow is progressively replaced by red marrow everywhere.

B **Red marrow is progressively replaced by yellow (fatty) marrow in many long bones.** ✓

C Bone marrow is replaced by cartilage in all bones.

D Bone marrow disappears entirely in healthy adults.

E All marrow becomes red again after puberty ends.

▶ **Explanation:** Aging is associated with more fatty (yellow) marrow, especially in long bones. Red marrow persists mainly in axial locations, and demand can shift marrow activity, but the general trend is increased marrow fat.

38 A disease replaces much of the red marrow space with non-hematopoietic tissue. Which blood finding is MOST directly expected?

A Increased red blood cells, increased white blood cells, increased platelets

B **Decreased red blood cells, decreased white blood cells, and decreased platelets (reduced overall hematopoiesis)** ✓

C Only decreased red blood cells; white cells and platelets are unaffected because they are made in the spleen

D Only decreased platelets; red blood cells are made in bone matrix

E No change in blood counts because marrow is not needed after birth

▶ **Explanation:** Red marrow is the major site of hematopoiesis in adults. Loss of functioning marrow can reduce multiple blood cell lines (RBCs, many WBCs, platelets), causing broad cytopenias rather than only one isolated change.

39 **Growth hormone (GH) supports normal height increase mainly by stimulating growth at the epiphyseal plates through:**

- A **Increased chondrocyte proliferation and activity (largely via IGF-1)** ✓
- B Immediate mineral dissolution by osteoclasts to lengthen bone
- C Conversion of bone into cartilage to stretch the skeleton
- D Stopping chondrocyte division so plates harden early
- E Direct formation of osteons in the growth plate to extend bone length

▶ **Explanation:** GH increases IGF-1 signaling, promoting growth plate cartilage expansion (chondrocyte proliferation/hypertrophy), which is then replaced by bone. Bone lengthening is not achieved by osteoclast "digging longer bones."

40 **A new drug strongly inhibits osteoclast activity. In the short term (before long-term compensations), which change is MOST consistent with this effect?**

- A **Less calcium is released from bone, tending to lower blood Ca^{2+} slightly** ✓
- B More calcium is released from bone, raising blood Ca^{2+} rapidly
- C Bone formation stops immediately because osteoclasts are the main bone-forming cells
- D Platelet production increases because osteoclasts make platelets
- E Epiphyseal plates reopen, allowing adults to grow taller

▶ **Explanation:** Osteoclasts release minerals by resorbing bone. If they are inhibited, less calcium is mobilized from bone, so (all else equal) blood calcium may trend downward. Osteoblasts—not osteoclasts—form bone, and growth plates do not reopen in adults.