Module 13

Nutrients Involved in Bone Health

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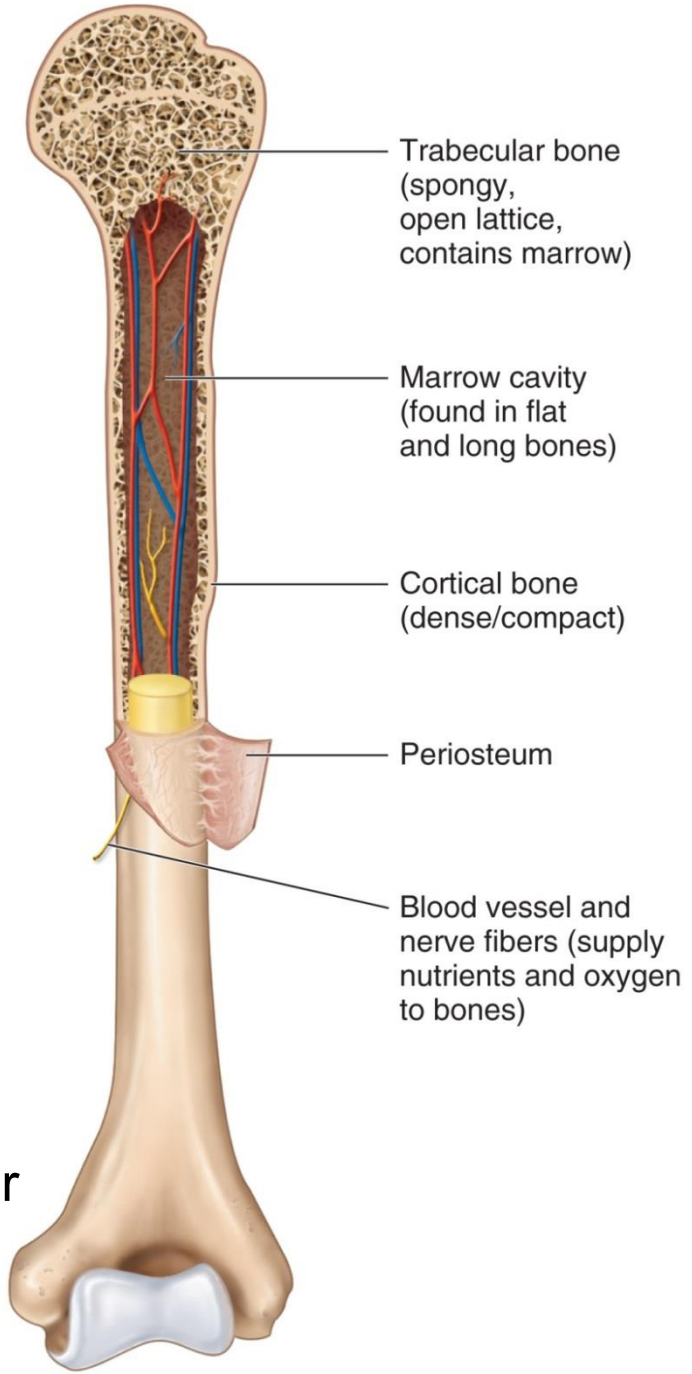
Learning Objectives

- Describe the process of bone synthesis and degradation and classify bone as either cortical or trabecular.
- List hormonal, lifestyle, and nutritional factors that influence bone health.
- List sources and functions of calcium, including its role in bone growth, maintenance, and repair.
- Describe the functions, recommendations, and sources of phosphorus and magnesium.
- Explain the functions, sources, synthesis and deficiency signs and symptoms of vitamin D
- Describe the process of osteoporosis development and prevention.
- Describe current methods used to assess bone health.

Bone Structure

- **Periosteum**
  - connective tissue covering all bones
  - has bone-forming potential
- **Cortical bone**
  - compact or dense bone found on outer surfaces of bone
- **Trabecular bone**
  - less-dense, more open structure
  - found in inner layer of bones
- **Bone marrow**
  - spongy tissue in flat bones and trabecular bones that contains stem cells



Bone Growth and Remodeling

- Bone is composed of approximately:
  - 65% minerals
  - 35% connective tissue
- Peak bone mass is achieved by age 30
- After age 30, bone resorption occurs at rate faster than bone synthesis
  - This leads to decrease in bone mass and bone mineral density

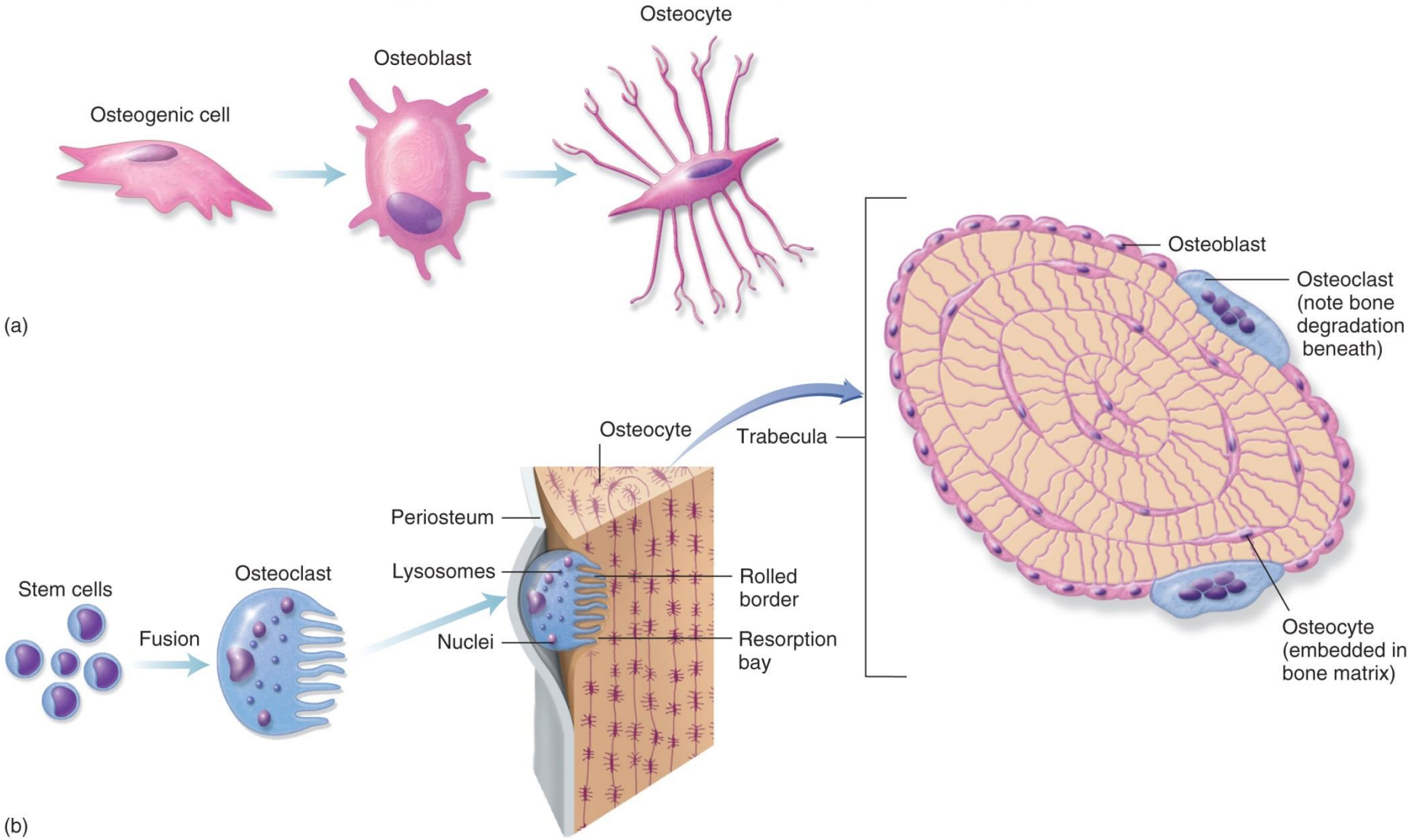
Bone Growth and Remodeling

- Degradation and synthesis of new bone
  - **Osteoclasts**
    - bone marrow breaks down or degrades small amounts of bone
  - **Resorption**
    - losing substance
    - bone resorption is part of initial process for remodeling and growth
  - **Osteoblast**
    - bone cells that initiate synthesis of new bone

Bone Growth and Remodeling

- **Hydroxyapatite**
  - crystalline compound containing calcium, phosphorus, sometimes fluoride
  - also known as bone mineral
- **Osteocyte**
  - osteoblast embedded into the bone matrix
- **Bone mineral density**
  - total mineral content of bone at a specific bone site divided by width of bone at site
  - generally expressed as grams per cubic centimeter

Bone Remodeling



Biological Factors

TABLE 11-1 ▶ Biological Factors Associated with Bone Status

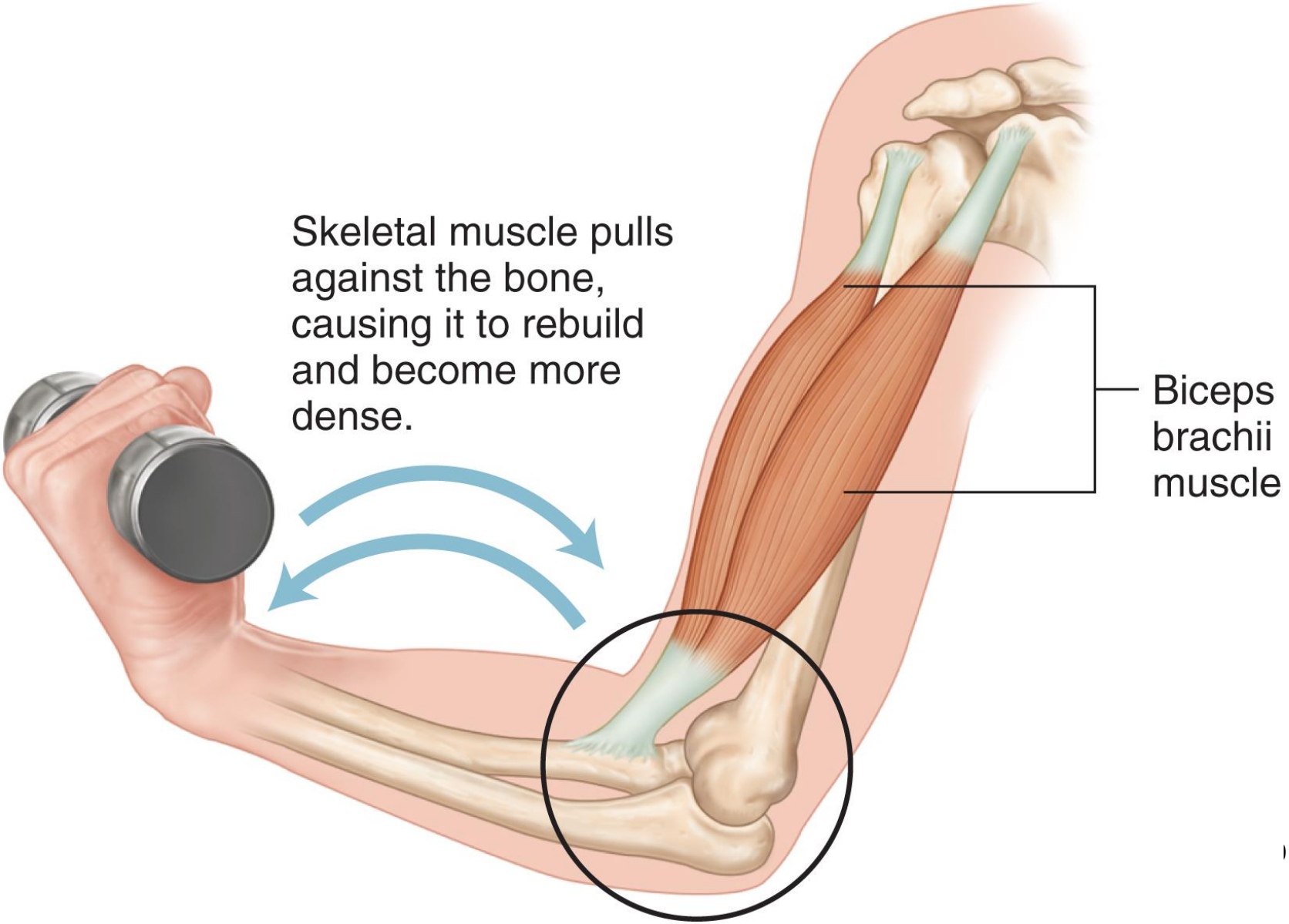
Biological Factors	Effect on Bone Status
Sex	Women have lower bone mass and density than men.
Age	Bone loss occurs after age 30.
Ethnicity	Individuals of Caucasian or Asian heritage are at greater risk for poor bone health than individuals of African descent.
Frame size	People with "small bones" have a lower bone mass.

- Estrogen has been shown to stimulate bone formation
  - Any sign of menstrual irregularities (defined as no menstrual period 3 consecutive months or more) is reason to see a physician
  - For women reaching menopause bone loss accelerates

Modifiable Lifestyle Factors

- Physical activity: Weight-bearing exercise, associated with greater bone mineral density
- Smoking and excessive alcohol intake decreases bone mass
  - Smoking lowers estrogen level in blood
- Diet
  - High intake of phosphorus, caffeine, and sodium adversely affect bone health
  - Diet rich in fruits, vegetables, grains, lean protein helps maintain bone density
  - Calcium, Vitamin D, Vitamin K, Magnesium
- Medications

Increasing Bone Density



Calcium Functions

- Represents 40% of all minerals in body
- Bone growth, development, and maintenance
  - 99% of calcium in body is used to strengthen bones and teeth
- Muscle contraction
- Cellular metabolism, enzymes, and hormonal responses
- Maintaining cell integrity
- Promoting cell differentiation

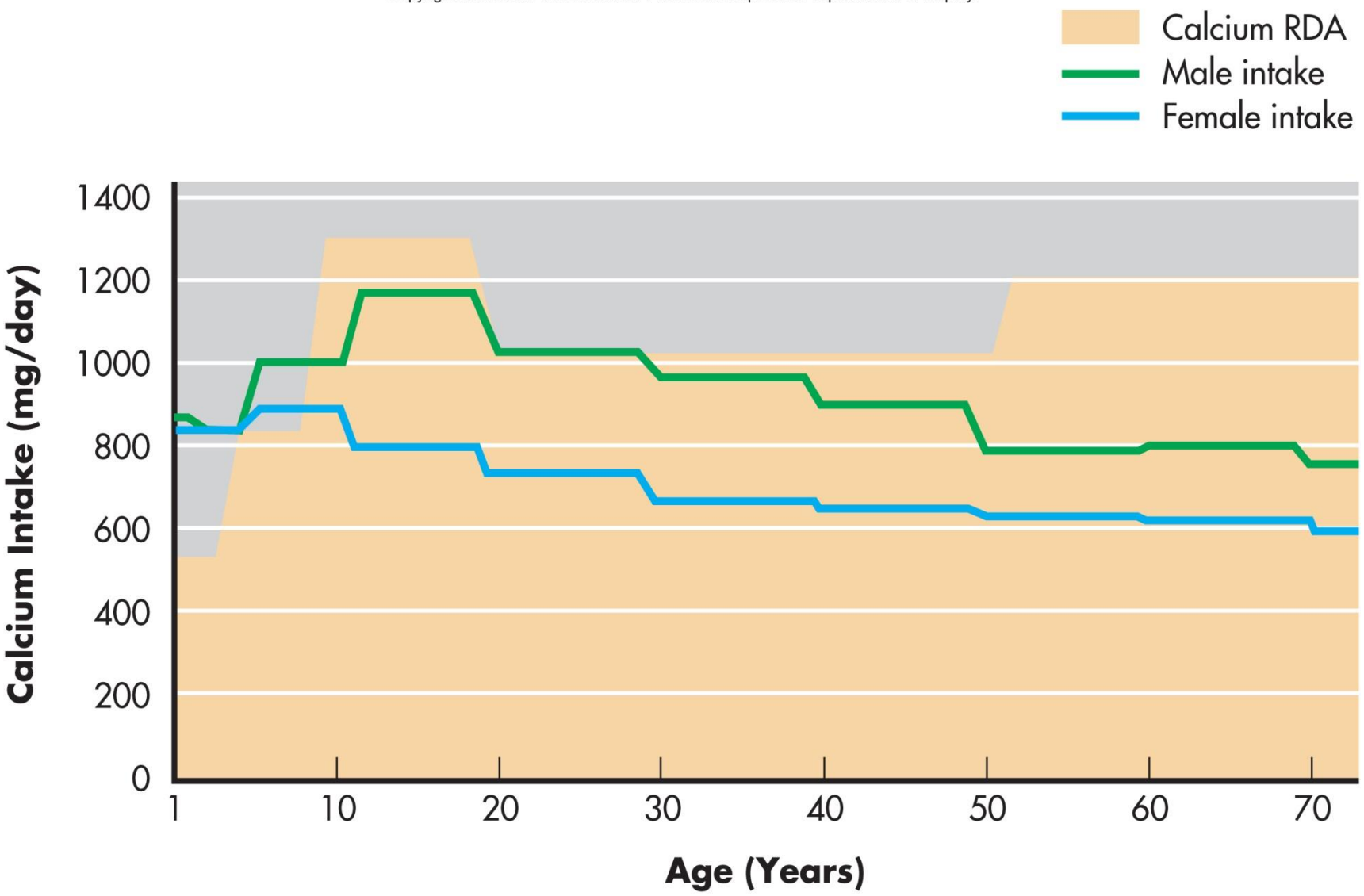
Additional Functions and Health Benefits

- Increased calcium intake and lower risk of bone fractures
- Adequate Ca lowers risk of colon cancer
- Lowers risk of kidney stone formation
- Decreases lead absorption
- 800-1,200 mg Ca/day can lower BP
- 1,200 mg Ca/day + low fat, low cholesterol diet can improve lipid profile if high cholesterol

Getting Enough Calcium

- RDA is 1,000 mg/day for adults up to 50
- RDA is 1,200 mg/day for adults 51+ y.o.
- Average US intake:
  - 800 mg/day for women
  - 1,000 mg/day for men
- Rule of 300s, estimate calcium **intake**
  - 300mg food throughout day, 300mg for each cup of milk, calcium-fortified beverage, tofu, almonds

Gap in recommended dietary intake of calcium and daily consumption of calcium in males and females in the U.S.



Avoiding Too Much Calcium

- UL is 2,500 mg
- Ca supplements can cause:
  - Gas
  - Bloating
  - Constipation
- High intake of calcium can:
  - Increase risk of kidney stones
  - Increased urinary and blood calcium levels leads to headaches, kidney failure, tissue calcification, and decreased absorption of other minerals

Calcium Absorption

Bioavailability: degree to which a consumed nutrient is absorbed and used by the body

- Calcium absorption increased by:
  - High need – growth, pregnancy, lactation
  - High levels of parathyroid hormone and vitamin D
  - Lactose present in diet
  - Food contents moving through GI tract
  - Acidic environment of stomach
- Calcium absorption decreased by:
  - Phytic acid
  - Oxalates
  - Tannins
  - Vitamin D deficiency
  - Diarrhea
  - Increasing age
  - Certain medications

Food Sources of Calcium

- Milk & milk products
  - Yogurt, cheese etc.
- Non-dairy milk & products
- Dark green leafy vegetables
- Almonds, legumes
- Sardines
- Canned salmon
- Calcium-fortified juice

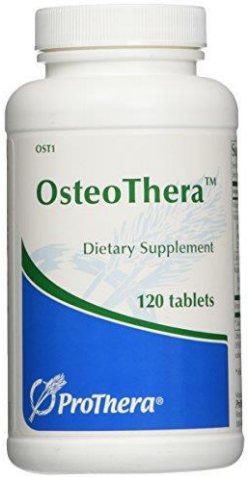
Dairy products, such as milk and cheese, provide about 75% of the calcium in North American diets

Calcium Supplementation

TABLE 11-3 ▶ Calcium Supplement Comparisons

Supplement form
Calcium carbonate (40% calcium) • Forms: tablets, chewable tablets, soft chews • Most common form • Least expensive • Needs acid environment in stomach, so take with acid food or take with meals
Calcium citrate (21% calcium) • Forms: pills, liquid • Best absorbed • Most expensive • *Does not* need acid environment to be absorbed • Pills can be quite large • Liquid (colloidal) form sometimes easier to tolerate

- Supplements:
  - Keep to 500 mg/less per dose
  - Look for USP label



Supplement Facts
Serving Size 2 Capsules

Amount Per 2 Capsules		% Daily Value
Vitamin D3 (as cholecalciferol)	200 I.U.	50%
Vitamin K (50% as vitamin K1 phytonadione, 25% as vitamin K2 menaquinone-4, and 25% as vitamin K2 menaquinone-7)	200 mcg	250%
Calcium (as calcium citrate-malate)	250 mg	25%
Magnesium (as TRAACS® magnesium bisglycinate chelate, magnesium oxide**)	100 mg	25%
Boron (as boron aspartate-citrate)	0.5 mg	*

* Daily value not established

Other Ingredients: Vegetarian capsule (hydroxypropyl methylcellulose, water), cellulose, and L-leucine.

**Albion® Laboratories

Vitamin D and Calcium Supplementation to Prevent Fractures Task Force Conclusions

- Not enough evidence to determine if vitamin D and calcium supplements can **prevent** fractures in men/women who have not gone through menopause.
- There is enough evidence to recommend against daily supplementation with 400 IU **or less** of vitamin D and 1000 milligrams **or less** of calcium for the primary prevention of fractures in noninstitutionalized postmenopausal women because lower doses of vitamin D and calcium supplements do not prevent fractures in older women and may increase the risk of kidney stones.

Task Force statement can be viewed at:
http://www.uspreventiveservicestaskforce.org/uspstf12/vitamind/vitdfact.pdf

Functions of Phosphorus

- Component of hydroxyapatite
  - contributes to bone and teeth strength
- Part of DNA and RNA
  - critical for cellular replication
- Primary component of ATP
- Allows enzymes and B vitamins to function
- Component of phospholipid membrane
- Maintains blood pH and fluid balance

Getting Enough Phosphorus

- The RDA
  - 700mg, both men and women
  - 1,250mg young people 9 to 18
  - Average daily adult consumption is 1,000-1,600mg
- Efficiently absorbed by the body
  - Enhanced by vitamin D
- Deficiency possible in preterm infants, vegans, people with alcoholism, older people on nutrient-poor diets, and people with long-term bouts of diarrhea

Food Sources of Phosphorus

- Naturally abundant in many foods
- Milk, cheese, meat, bread, provide most
- Nuts, fish, breakfast cereals, bran, eggs
- From food additives
- Absorption 55% to 80%

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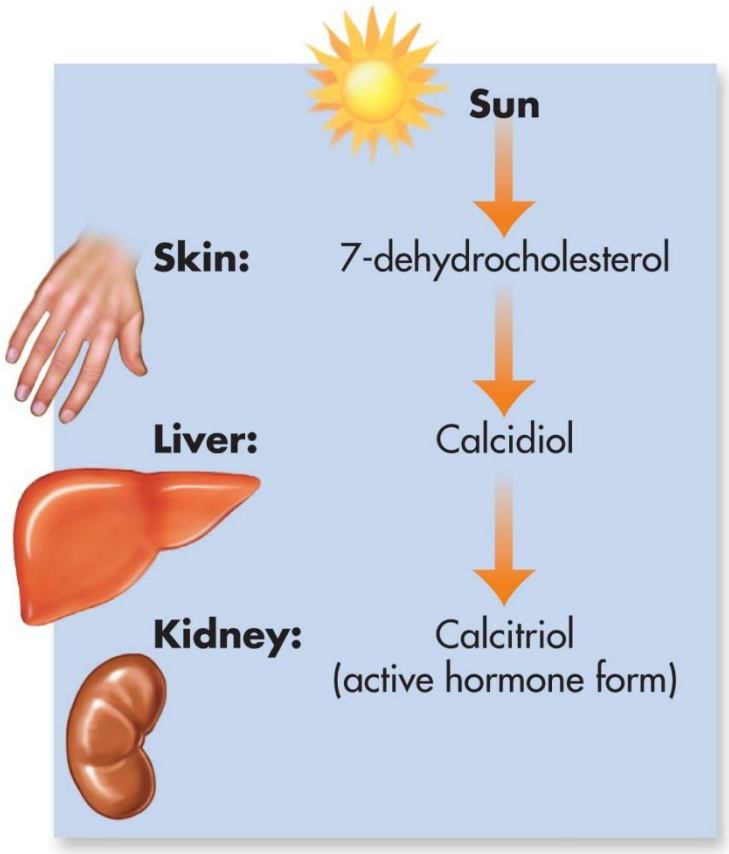
Trail Mix rich in phosphorus

Avoiding Too Much Phosphorus

- UL is 3-4 g/day
- High intake increases risk of tissue calcification and stone formation
- Chronic imbalance in phosphorus-to-calcium ratio can increase risk of low bone mineral density

Vitamin D

- Fat-soluble, essential
- Produced in the skin when exposed to UV light
- Cholesterol is vitamin D precursor
- Vitamin D is a hormone
- Activation occurs in liver and kidneys

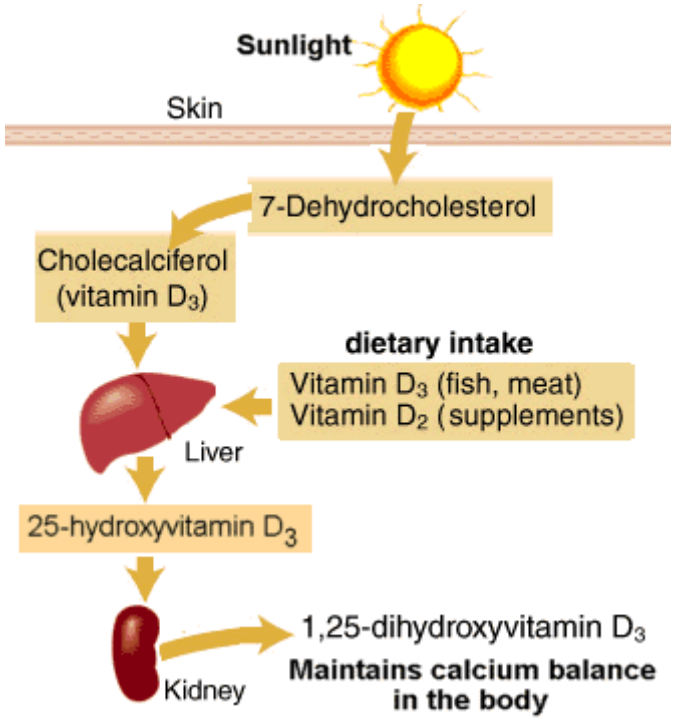


Forms of Vitamin D

- **Vitamin D_2**
  - synthetic product derived from irradiation of plant sterols (ergosterol)
  - used in some supplements
- **Vitamin D_3**
  - more commonly used in supplements and to fortify foods
- Sunlight exposure causes precursor to vitamin D **(7-dehydrocholesterol)** found in the skin to convert to D_3

Forms of Vitamin D

1. Intake of Vitamins D_2 and D_3 and/or exposure to sunlight
2. Vitamins D_2 and D_3 travel to liver
3. Converted to **25-hydroxyvitamin D_3 (calcidiol),** main form of vitamin D found in blood
4. **25-hydroxyvitamin D_3 (calcidiol),** chemically converted in kidneys to **1, 25-dihydroxyvitamin D_3 (calcitriol)**, the biologically active form of vitamin D



Vitamin D: Functions

- Maintains calcium and phosphorus levels in blood
  - Regulates absorption of calcium and phosphorus from small intestine
  - In combination with parathyroid hormone (PTH) and calcitonin, it regulates calcium excretion via kidney
  - Regulates calcium through bone remodeling
- Involved in:
  - gene expression
  - cell growth regulation
  - neuromuscular and immune function
  - reduction of inflammation

Vitamin D: Functions

- Binds to and affects cells of:
  - Immune system
  - Brain and nervous system
  - Skin
  - Muscles
  - Reproductive organs
- May decrease certain types of cancer risk

Vitamin D and Sun Exposure

- Amount of sun exposure needed to activate vitamin D is affected by:
  - Skin color
  - Age
  - Time of day
  - Latitude and strength of UV light
  - Exposure time
  - Season

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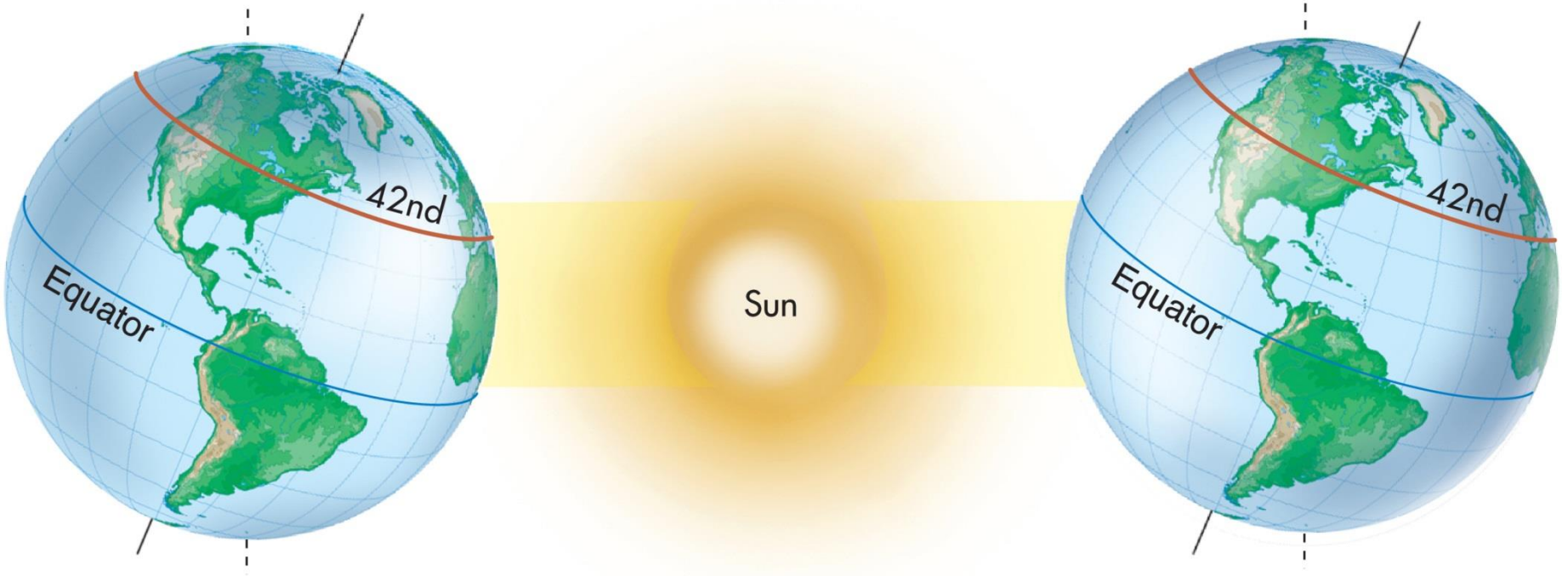
Seasonal Variations to Sunlight Intensity



Summer solstice
(Northern Hemisphere tilts toward the sun)

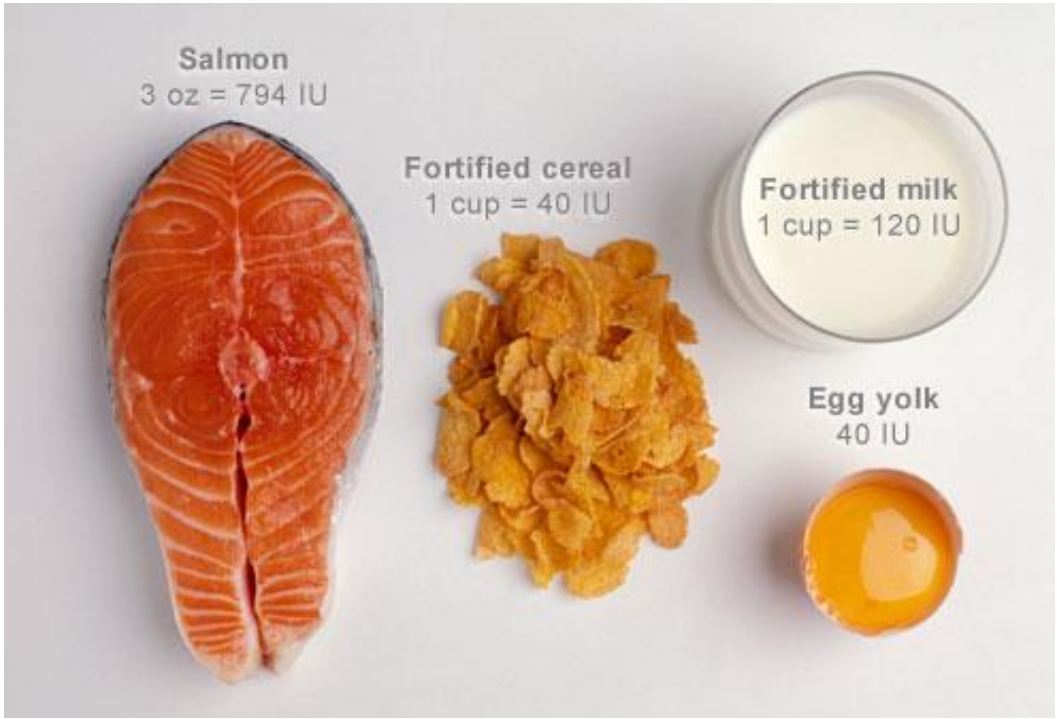
Winter solstice
(Northern Hemisphere tilts away from the sun)

TABLE 11-4 ▶ Factors That Impair Vitamin D Status

Factor	Description
Inadequate sun exposure • Northern latitudes • Excess clothing (e.g., robes/veils) • Air pollution (i.e., smog) • SPF >8 • Excessive time spent indoors (e.g., due to health, work, or environmental conditions)	Limited exposure to UVB reduces the skin's ability to synthesize vitamin D.
Age	Vitamin D synthesis by the skin decreases. Vitamin D activation by the kidneys decreases.
Dark skin pigmentation	Melanin reduces the skin's ability to produce vitamin D, particularly for older adults and especially among women.
Inadequate dietary intake	Dietary intake of vitamin D is unable to compensate for inadequate skin synthesis of vitamin D.
Exclusive breastfeeding or low consumption of infant formula	Infants typically have limited sun exposure. Breast milk is a poor source of vitamin D. Infant formula contains vitamin D, but young infants may not consume adequate quantities to meet needs.
Fat malabsorption • Liver disease • Cystic fibrosis • Weight-loss medications	Poor absorption of dietary fat limits absorption of vitamin D from the small intestine.
Obesity	Release of vitamin D stored in subcutaneous fat is inefficient.
Liver diseases	Vitamin D activation by the liver decreases.
Kidney diseases	Vitamin D activation by the kidneys decreases.

Getting Enough Vitamin D

- RDA is 15 mcg (600 IU) for healthy people 1-70
- RDA is 20 mcg (800 IU) for age 71+
- Food sources are limited



Vitamin D Deficiency

- With ↓ levels of vitamin D:
  - Osteomalacia
  - Intestinal calcium absorption decreases
  - Rickets

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Vitamin D Supplements

- American Academy of Pediatrics recommends 400 IU/day for:
  - Children and adolescents with less than 400 IU/day intake
  - Exclusively breastfed infants beginning within the first few days o life
- 1 cup milk = 100 IU vitamin D

Vitamin D Repletion

The cumulative dosage is more important than dosing frequency, so the choice of daily, weekly, or monthly dosing can be based on patient preference.

- Children 1-18 years of age
  - 2,000 IU/d of vitamin D3 for at least 6 weeks or with 50,000 IU once a week for at least six weeks to achieve adequate blood levels, followed by maintenance therapy of 600-1,000 IU/day.
- Adults
  - 50,000 IU of vitamin D3 once a week for 8 weeks or 6,000 IU of vitamin D3 daily to achieve adequate blood levels, followed by maintenance therapy of 1,500-2,000 IU/day.
- Obese patients, patients with malabsorption syndromes, and patients on medications affecting vitamin D metabolism a higher dose is recommended

Recommendations from the Endocrine Society

Avoiding Too Much Vitamin D

- UL is 100 mcg (4000 IU) per day
- High vitamin D intake results in increased blood calcium
- Toxicity symptoms:
  - Weakness
  - Loss of appetite
  - Diarrhea and vomiting
  - Confusion
  - Increased urine output
- Toxicity does not occur from sun source

Magnesium

Think of magnesium as the relaxation mineral. Anything that is tight, irritable, crampy, and stiff — whether it is a body part or an even a mood — is a sign of magnesium deficiency.

This critical mineral is actually responsible for over 300 enzyme reactions and is found in all of your tissues — but mainly in your bones, muscles, and brain. You must have it for your cells to make energy, for many different chemical pumps to work, to stabilize membranes, and to help muscles relax.

Magnesium (Mg) Functions

- Bone contains 60% of the body's magnesium
- Nerve and heart function
- Relax muscles after contraction
- Assists in 300+ enzymatic reactions
- Provides rigidity to bones
- Resistance to tooth decay
- Lower risk of type 2 diabetes
- Mental health?
  - Anxiety and depression
- Sleep quality

Psychiatr Pol. 2015;49(6):1277-87. doi: 10.12740/PP/OnlineFirst/42047.

The serum concentration of magnesium as a potential state marker in patients with diagnosis of bipolar disorder.

[Article in English, Polish]

Siwek M[1], Styczeń K[1], Sowa-Kućma M[2], Dudek D[1], Reczyński W[3], Szewczyk B[2], Misztak P[2], Opoka W[4], Topór-Mądry R[5], Nowak G[2].

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Rapid recovery from major depression using magnesium treatment

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Anxiety and Depression

Magnesium deficiency induces anxiety and HPA axis dysregulation: Modulation by therapeutic drug treatment

S.B. Sartori, N. Whittle, A. Hetzenauer, N. Singewald

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Magnesium intake and depression in adults.

Tarleton EK[1], Littenberg B[2].

Author information

Abstract

BACKGROUND: Depression is a common and often disabling disorder. Magnesium supplementation has been linked to improvement in depressive symptoms, but consensus on the relationship between magnesium and depression has not been reached.

METHODS: The purpose of this study was to test the existence of an association between dietary magnesium intake and depression in the adult US population. A cross-sectional, population-based data set (National Health and Nutrition Examination Survey) was used to explore the relationship of magnesium intake and depression in 8894 US adults (mean age, 46.1 years; 47.4% men) from 2007 to 2010. Using logistic regression to model the relationship between the presence of depression (Patient Health Questionnaire score ≥5) and low magnesium intake (<184 mg/day), we examined the risk ratio (RR) of magnesium intake and its 95% confidence interval.

RESULTS: After adjusting for all potential confounders, the strength of the association of very low magnesium intake with depression was statistically significant (RR = 1.16; 95% CI, 1.06-1.30). Adjusting for all other covariates, low magnesium intake was associated with depression in subjects younger than age 65 (RR, 1.22; 95% CI, 1.06-1.40; P = .007) but seemed to be protective in seniors (RR, 0.75; 95% CI, 0.56-0.98; P = .032).

CONCLUSIONS: We found a significant association between very low magnesium intake and depression, especially in younger adults. The finding of the potential protective effect of low magnesium intake in older adults is surprising and warrants further investigation.

Getting Enough Magnesium

- RDA:
  - 400 mg/day for men
  - 310 mg/day for women
- DV on food labels: 400 mg/day
- Average U.S. consumption is less than RDA
  - meaning we should increase consumption of magnesium-rich foods

Factors that deplete magnesium

  - Refining grains reduces magnesium content by 80%

Sources of Magnesium

- Found in chlorophyll and comes from plant sources:
  - Squash, whole grains, bran, beans, nuts, seeds, broccoli
- Animal products: Milk and meats
- Some magnesium in chocolate
- Hard tap water
- Coffee (espresso, not brewed)
- Bath of Epsom salts

Magnesium Absorption

- High phosphorus diet reduces absorption
  - Coffee and soda
- High fiber (phytate) diet reduced Mg absorption
- Low protein diet reduced Mg absorption
- Magnesium loss can be caused by:
  - Heavy perspiration
  - Prolonged vomiting or diarrhea
  - Diuretic use
  - Alcohol abuse (↑ urinary Mg excretion)

Magnesium: Deficiency

- Signs & Symptoms
  - Irregular heartbeat, sometimes accompanied by weakness, muscle pain, disorientation, and seizures
  - Decreased bone strength and bone volume
  - Poor bone development
  - Decreased bone formation
  - Depression?

- Alcoholism increases risk of deficiency
  - dietary intake may be poor
  - alcohol increases magnesium excretion in the urine

Avoiding Too Much Magnesium

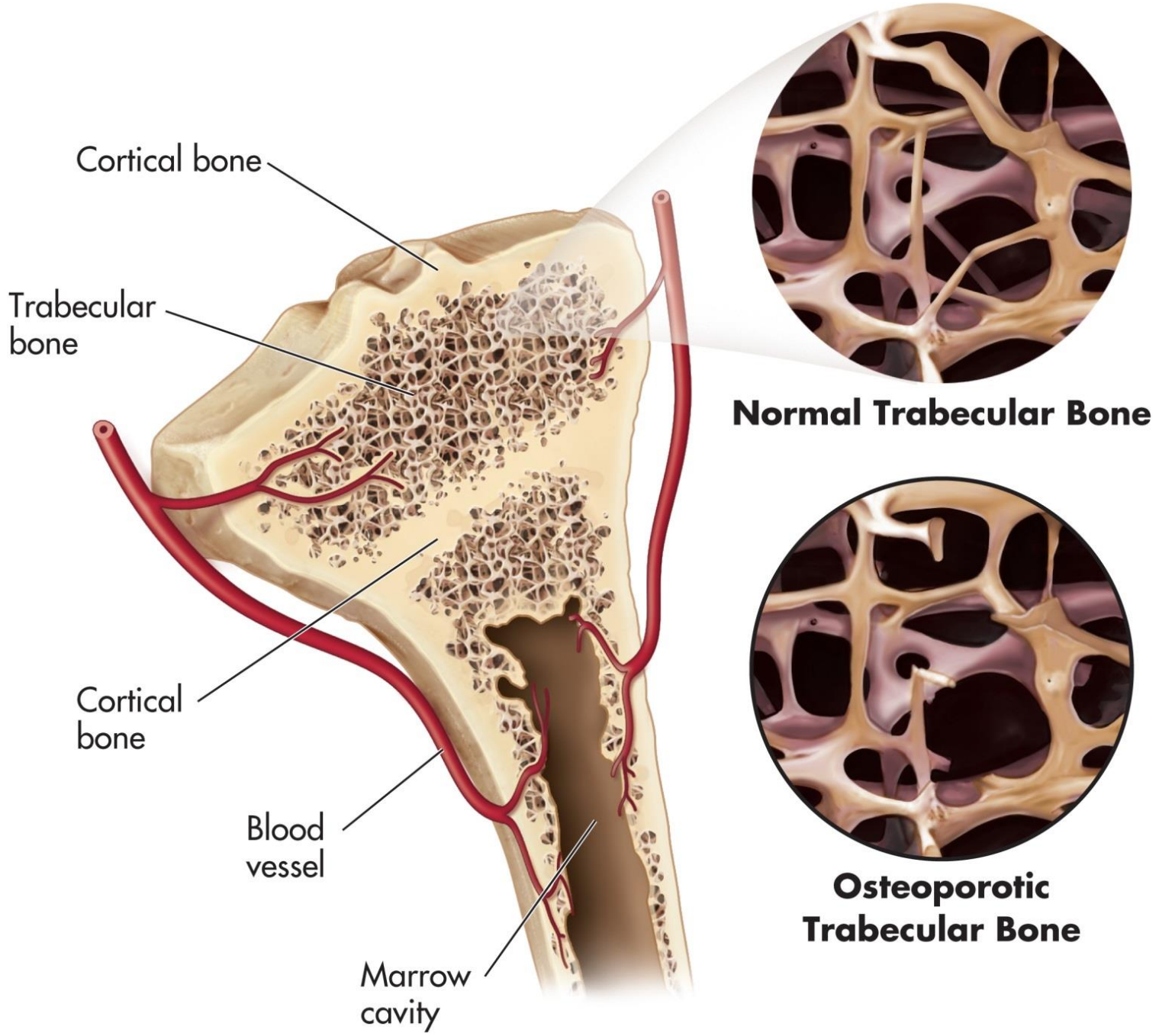
- UL: 350 mg/day
- Excessive Mg intake → diarrhea
- Toxicity can occur in:
  - People with kidney failure
  - Abuse of OTC laxatives and antacids with Mg (ex: milk of magnesia)

Micronutrients That Function in Bone Health

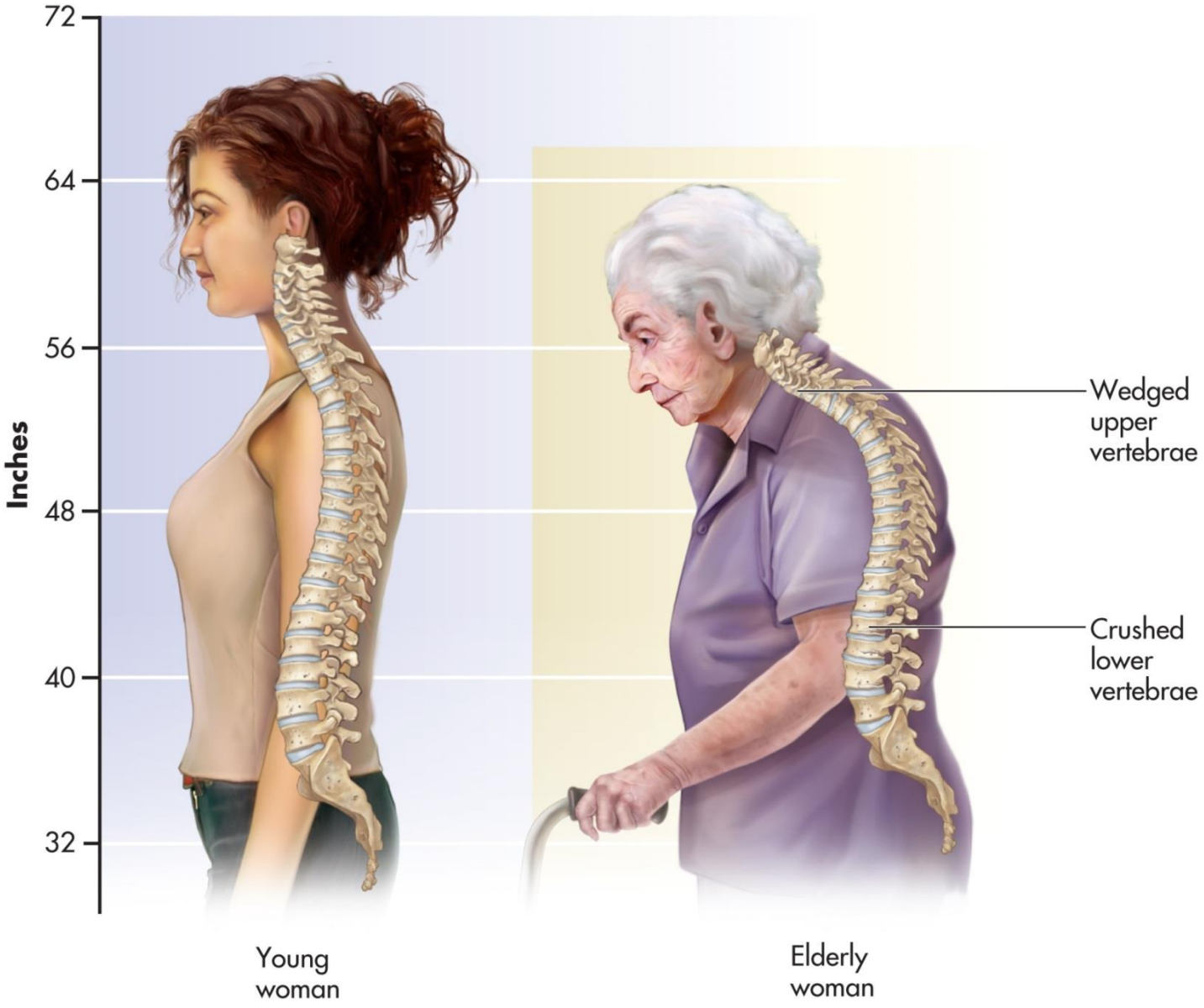
- **Vitamin C-**promotes bone health through its antioxidant activity
- **Iron-**required by an enzyme that converts vitamin D to its active form
- **Zinc-**cofactors for enzymes of bone remodeling
- **Copper and Silicon-**contribute to collagen synthesis
- **Vitamin K-**calcium-binding ability in bone proteins
- **Boron-**bone structure and strength

Osteoporosis

- Defined as:
  - presence of a stress-induced fracture OR
  - a T-score of 22.5 or lower. Bones are porous and fragile due to low mineral density
- *HP 2020* identified prevention of osteoporosis as one of its major focus areas
- 12 million Americans over the age of 50 currently have osteoporosis
  - 9.6 million are women
  - 2020 estimate
    - 10.5 million women
    - 3.3 million men



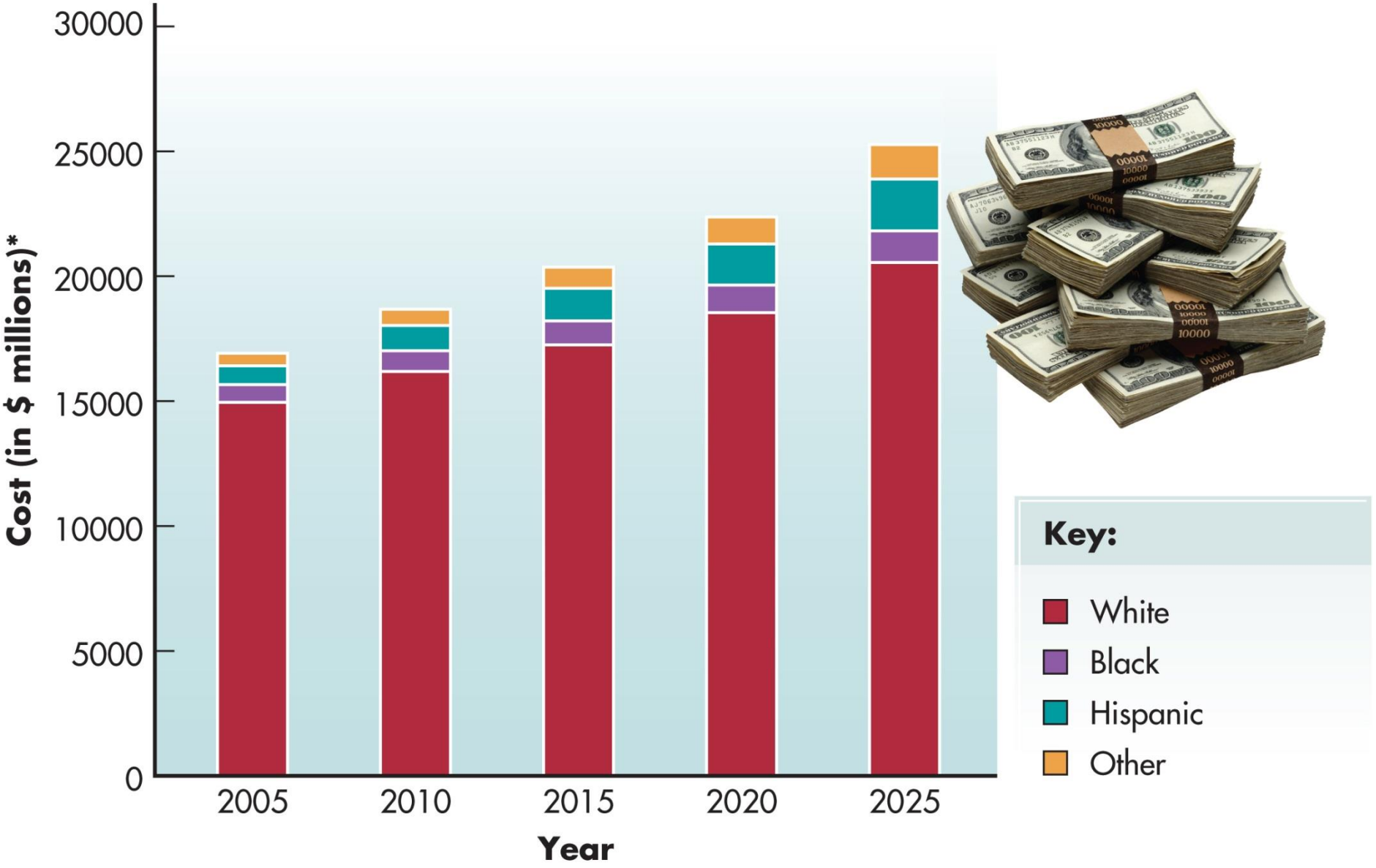
Normal and Osteoporotic Woman



Osteoporosis Facts

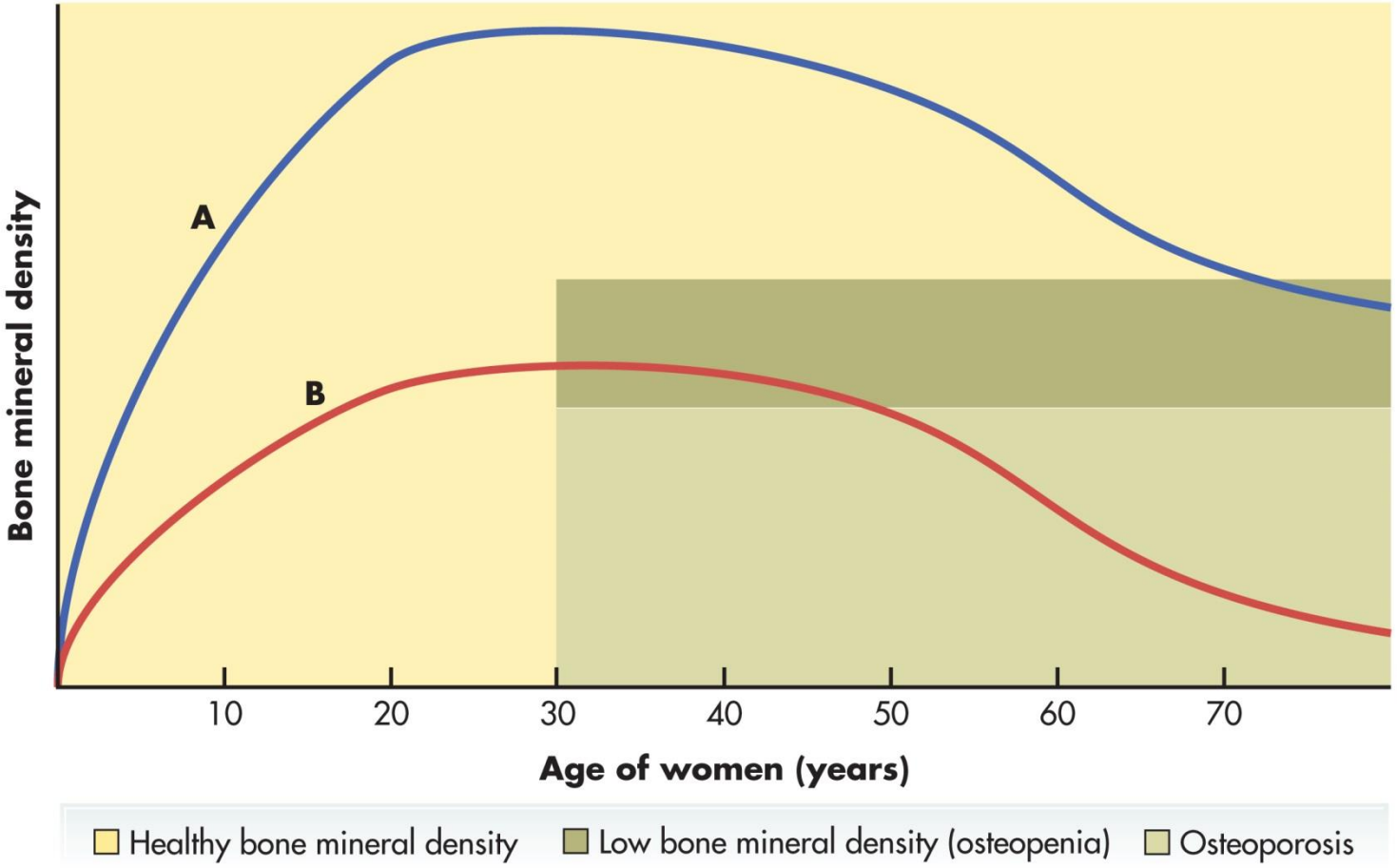
- Osteoporosis in the US has led to:
  - 2 million bone fractures per year
  - 300,000 broken hips
  - Escalating medical costs to reach $25 billion by year 2025
  - Only 40% regain their earlier independence

Projected Economic Burden of Osteoporosis



* Projected costs are not adjusted for inflation.

Relationship Between Peak Bone Mass and the Ultimate Risk of Developing Osteoporosis



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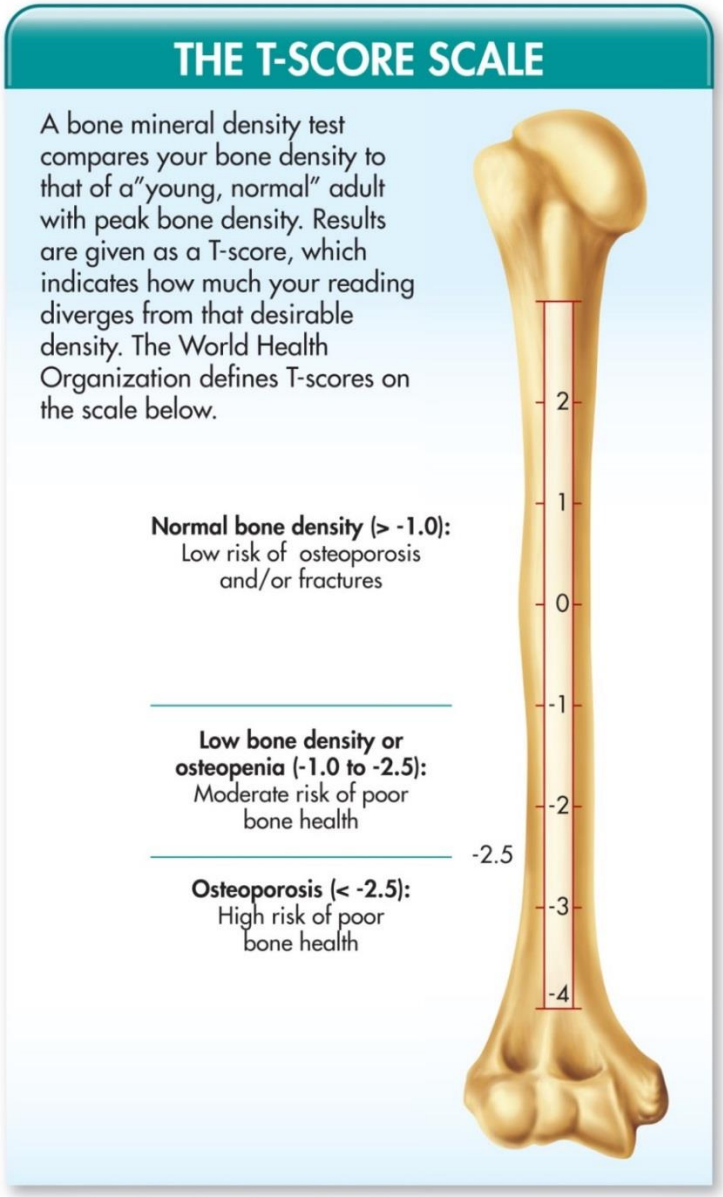
Kyphosis, or curvature of the upper spine, results from demineralization of the vertebrae. It occurs in men and women.

DEXA

- Dual energy x-ray absorptiometry
- Takes less than 15 minutes
- Bone blocks path of low level x-ray
- DEXA measurement generates T score



Who Should Have DEXA?

- National Osteoporosis Foundation 2010 recommendations
  - All women age 65+ and men 70+
  - Younger postmenopausal women aged 50-69 who are at risk
  - **Perimenopausal women with low body weight, prior low-trauma fracture, on high risk medications (ex: steroids)**
  - Adults with fracture after age 50
  - Adults with health conditions on long-term steroids
  - Anyone being considered for osteoporosis meds