

Chapter 4

The Biomechanics of Human Bone Growth and Development

Basic Biomechanics, 6th edition
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Composition and Structure of Bone

What is **stiffness**?

(**stress/strain** in a loaded material;
stress divided by the relative amount
of change in shape)

What is **compressive strength**?

(**ability to resist compression**)

Composition and Structure of Bone

What contributes to stiffness and compressive strength in bone?

- calcium carbonate
- calcium phosphate

Composition and Structure of Bone

What contributes to flexibility and tensile strength (ability to resist tension) in bone?

(collagen)

What is the effect of aging on collagen in bone?

(collagen is progressively lost and bone brittleness increases with aging)

Composition and Structure of Bone

What else affects bone strength?

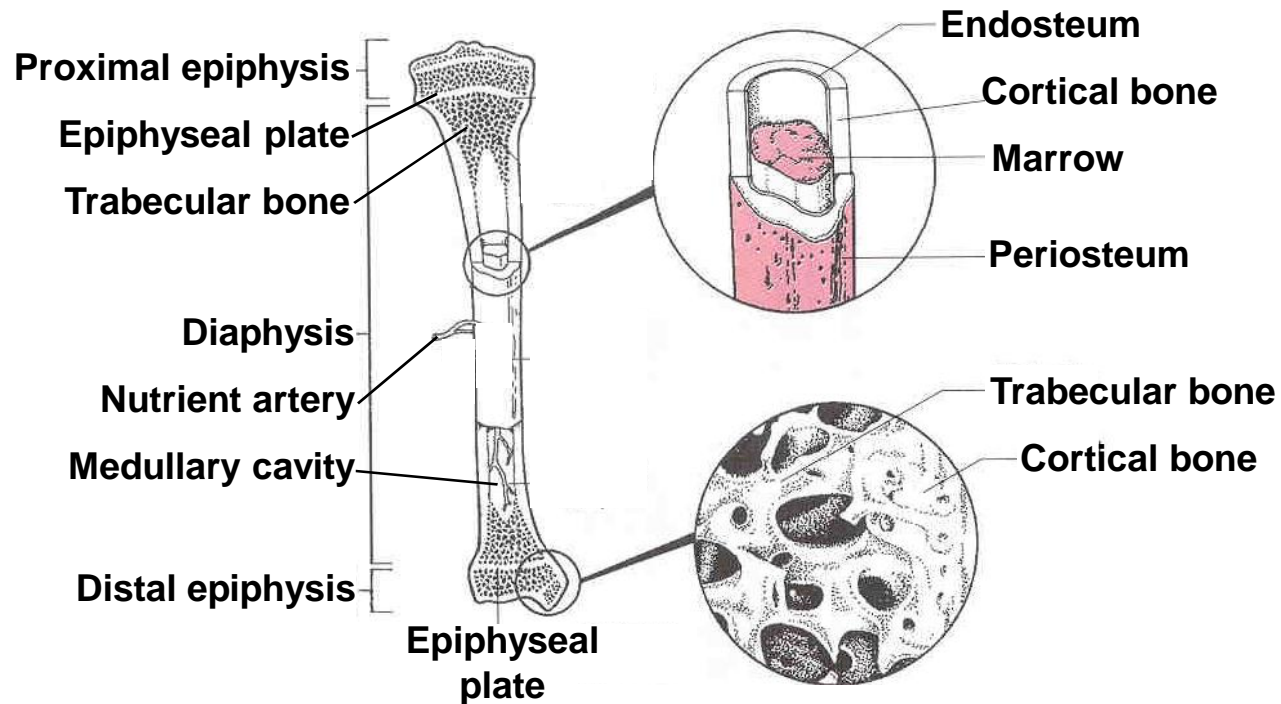
- **water content** of bone, which comprises 25%-30% of bone weight
- **bone porosity**, or the amount of bone volume filled with pores or cavities

Composition and Structure of Bone

Categories of bone based on porosity:

- **cortical bone**: compact mineralized bone with low porosity; found in the shafts of long bones
- **trabecular (or cancellous) bone**: less compact bone with high porosity; found in the ends of long bones and the vertebrae

Composition and Structure of Bone



Structures of **cortical** (compact) and **trabecular** (spongy) bone.

Composition and Structure of Bone

What else does **bone porosity** affect?

- because **cortical** bone is stiffer than trabecular bone, it can withstand **greater stress but less strain**
- because **trabecular** bone is spongier than cortical bone, it can undergo **more strain before fracturing**

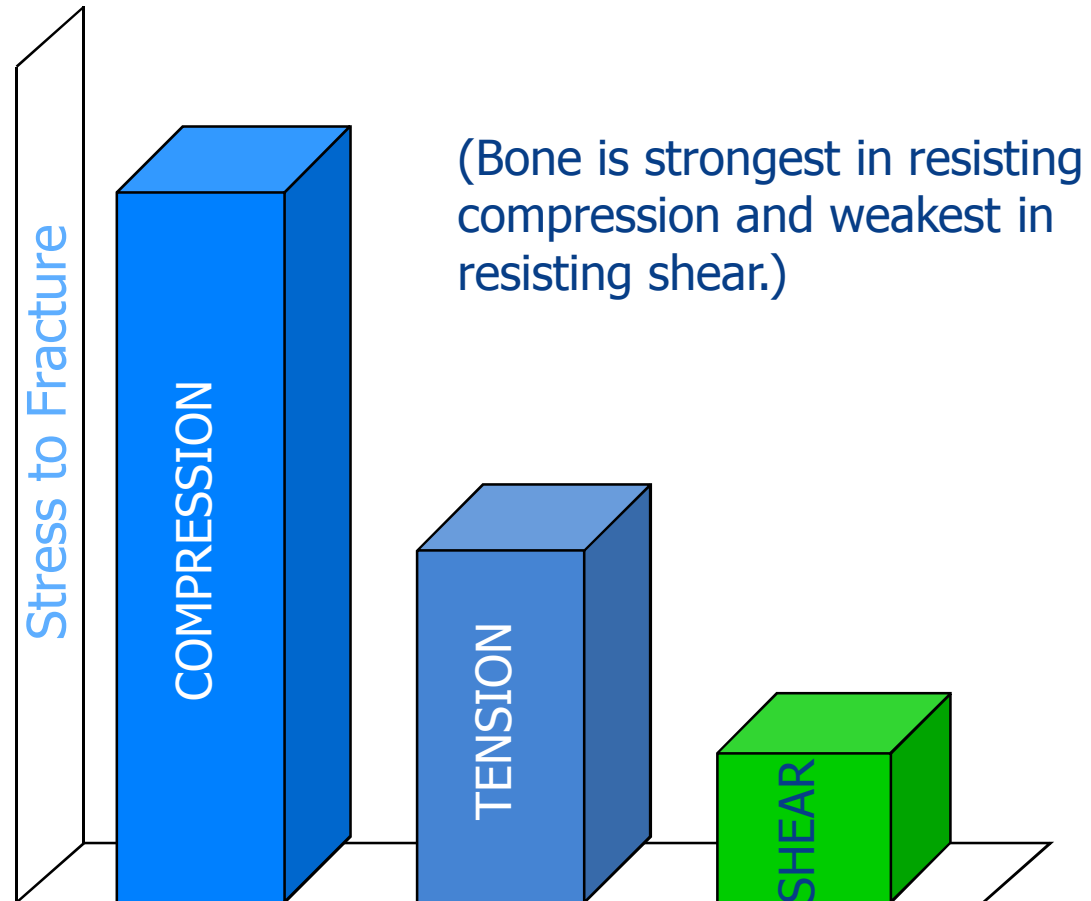
Composition and Structure of Bone

How does the **structure** of bone affect its strength?

(bone is **anisotropic**, it has different strength and stiffness depending on the direction of the load)

Composition and Structure of Bone

How does
the structure
of bone
affect its
strength?



Types of bones

- axial skeleton: skull, vertebrae, sternum, ribs
- appendicular skeleton: bones composing the body appendages

Types of bones

- **short bones:** approximately cubical; include the carpals and tarsals
- **flat bones:** protect organs & provide surfaces for muscle attachments; include the scapulae, sternum, ribs, patellae, some bones of the skull

Types of bones

- **irregular bones:** have different shapes to serve different functions; include vertebrae, sacrum, coccyx, maxilla
- **long bones:** form the framework of the appendicular skeleton; include humerus, radius, ulna, femur, tibia, fibula

Bone Growth and Development

How do bones grow in length?

(the epiphyses, or epiphyseal plates, are growth centers where new bone cells are produced until the epiphysis closes during late adolescence or early adulthood)

Bone Growth and Development

How do bones grow in circumference?

- the inner layer of the **periosteum**, a double-layered membrane covering bone, builds concentric layers of new bone on top of existing ones
- specialized cells called **osteoblasts** build new bone tissue and osteoclasts resorb bone tissue

Bone Response to Stress

How do bones respond to training?

- just like muscle, bones respond to certain kinds of training by hypertrophying
- according to Wolff's law, the densities, and to a lesser extent, the sizes and shapes of bones are determined by the magnitude and direction of the acting forces

Bone Response to Stress

How is Wolff's law carried out?

- Osteoblasts and osteoclasts are continually building and resorbing bone, respectively.
- Increased or decreased mechanical stress leads to a predominance of osteoblast or osteoclast activity, respectively.

Bone Response to Stress

What kinds of activity tend to promote bone density?

(weight bearing exercise, since the larger the forces the skeletal system sustains, the greater the osteoblast response)

Bone Response to Stress

What tends to diminish bone density?

- lack of weight bearing exercise
- spending time in the water, (since the buoyant force counteracts gravitational force)
- bed rest
- traveling in space outside of the earth's gravitational field

Osteoporosis



Osteoporosis is a disorder involving decreased bone mass and strength with pain and one or more fractures resulting from daily activity.

Osteoporosis

Who is affected by osteoporosis?

- **Type I (postmenopausal)** osteoporosis affects about 40% of women after age 50
- **Type II (age-associated)** osteoporosis affects most women and men after age 70

Osteoporosis

Are younger people ever affected by osteoporosis?

- The female athlete triad includes:
 - disordered eating
 - amenorrhea, and
 - osteoporosis

Osteoporosis

How can **osteoporosis** be prevented and treated?

(regular weight bearing exercise is the key to prevention and treatment)

Osteoporosis

How can **osteoporosis** be prevented and treated?

- postmenopausal hormone replacement
- adequate dietary calcium and vitamin D
- avoiding smoking and excessive consumption of protein, caffeine, and alcohol