CHAPTER-5 (Part-B)

Skeletal system

Please review the section on bone tissue in Histology

Functions of the skeletal system

- Provides a structural framework for the body- supporting soft tissues and providing attachment sites for muscles.
- Protection of internal organs.
- Assisting skeletal muscles to produce movement.
- Helping maintenance of mineral homeostasis.
- Haemopoiesis, the formation of blood cells in the marrow.
- Triglyceride storage in the yellow marrow of adult bones.

Structure of a typical long bone

Look at the diagram of the long bone. You will need to learn some new terminology.

- The shaft is called the **diaphysis**.
- The ends are called the **epiphyses.**
- Between the diaphysis and the epiphysis are the **metaphyses**, which includes the **epiphyseal plate** in growing bones.
- **Hyaline cartilage** at the ends of bones reduces friction and absorbs shock at freely moveable joints.
- Covering the surface of the bone is the **periosteum**, a connective tissue covering. It functions to protect the bone tissue, assist in regeneration of new bone tissue, nourish the bone and as a point of muscle attachment.
- The space within the diaphysis is the **marrow cavity.**
- The lining of the medullary cavity is called the **endosteum.**

The epiphyseal ends of a long bone are filled with spongy bone, whilst the diaphysis is made up of compact bone surrounding a medullary cavity. The medullary cavity contains the red marrow in children, which matures to form yellow bone marrow in adults. Lining the medullary cavity is the endosteal membrane or endosteum, which contains osteoblasts cells.

Blood and Nerve supply to the bone

Periosteal arteries and nerves enter the diaphysis via the Volkmann's canals supplying the periosteum and outer part of compact bones. The nerves supplying the periosteum are rich in sensory nerves, and are sensitive to pain, and sensations such as lever stress tension or tearing as a result of the inability to bear the stress, such as in a fracture.

The large nutrient artery enters through the nutrient foramen (foramen - hole or passage) of the compact bone near the centre of the diaphysis, into the

medullary cavity, where it divides into the proximal and distal branches. These branches supply blood to the inner part of compact bone, and spongy bone tissue up to the epiphyseal plates.
The ends of the long bones are supplied by the metaphyseal and epiphyseal arteries. Veins and nerves accompany these arteries.

Ossification (bone formation)

There are two types of ossification: Intramembranous ossification and Endochondral ossification. Intramembranous ossification is the formation of bone from or within fibrous connective tissue membranes. Endochondral ossification is the formation of bone from hyaline cartilage models.

Intramembranous ossification
Forms the flat bones of the skull and the mandible.
1. Ossification forms from osteogenic cells as they differentiate to osteoblasts and lay down matrix.
2. The matrix calcifies and the osteoblast becomes an osteocyte.
3. The calcifying matrix centres join forming bridges of trabeculae that constitute spongy bone with red marrow between.
4. The periosteum initially forms a collar of spongy bone that is then replaced by compact bone.

Endochondral ossification
Forms most of the bones of the body.
1. Initially a cartilage model develops.
2. This is followed by the growth of the cartilage model.
3. Next the primary ossification centre develops in the diaphysis.
4. In the epiphysis secondary ossification centres develop.
5. Finally articular cartilage and the epiphyseal plate are formed.

Bone Growth

Up to the age of 25, bones grow in length and thickness.

Growth in Length
Study the following:
- Nature and location of the epiphyseal plate.
- Cellular constitution and processes occurring within the four cartilaginous zones (resting, proliferating, hypertrophic and calcified cartilage).
- The process by which bone is lengthened on the diaphyseal side of the epiphyseal plate.
- The meaning of the term epiphyseal line.

Growth in Thickness
Study the following:
- The formation of the groove for the periosteal blood vessel.
- Subsequent formation of the endosteum.
- Formation of new lamellae and forming of a new osteon.

- Formation of outer circumferential lamellae by osteoblasts.
- Destruction of medullary cavity by osteoclasts (Read Endochondral Ossification - development of primary ossification centre if you have not already studied the Embryology Module).

Factors affecting the growth of bone

Hormonal regulation

During childhood:
Human growth hormone (hGH) produced by the pituitary gland stimulates production for insulin-like growth factors (IGFs) by bone tissue and the liver.
IGFs:

- Promote cell division at the epiphyseal plate and periosteum
- Enhance synthesis of proteins required for bone matrix.

Hormones T3 and T4 from the thyroid gland and insulin from the pancreas are also essential for normal bone growth.

During puberty:
Androgens and oestrogens cause a “growth spurt” during teenage years. Oestrogens promote sexually characteristic changes in the female skeleton, e.g. a wider pelvis. Sex steroids (particularly oestrogens) shut down growth at epiphyseal plates, so bone elongation halts.

Nutritional requirements
Bone matrix contains abundant inorganic mineral salts:

- Calcium phosphate
- Calcium carbonate
- Magnesium hydroxide
- Fluoride
- Sulphate

For proper bone growth calcium and phosphorous are needed in considerable amounts, whilst the other mineral salts are needed in smaller amounts. Iron and manganese are also required.

Vitamin D plays a major role in calcium absorption and homeostasis: The fat-soluble vitamin:

- Promotes calcium absorption from the intestines.
- Increases calcium deposition into bones.
- Helps mobilise calcium and phosphorous from bones.
- Helps regulate excretion of calcium from the kidney.

Because of its regulatory action, normal calcification does not occur in its absence.

Vitamin C is needed for synthesis of collagen, and for differentiation of osteoblasts into osteocytes.
Vitamins K and **B12** are needed for protein synthesis
Vitamin A stimulates osteoblast activity.

Bone remodelling

This is an ongoing process accomplishing the following:

- Renewal of bone tissue before deterioration.
- Redistribution of bone matrix along lines of mechanical stress.
- Final phase of fracture repair.

Osteoclasts first destroy old bone matrix (bone resorption).

1. Osteoclasts attach tightly to the bone surface; endosteum or periosteum.
2. A leak-proof seal is formed between the edges of the cell and bone, forming a pocket between the two.
3. Osteoclast releases lysosymal enzymes and acids into the pocket.
4. Enzymes digest organic material including collagen fibres; acids dissolve minerals.
5. Degraded material enters osteoclast by endocytosis and is excreted on the opposite side by exocytosis.
6. Products of resorption diffuse into interstitial fluid and local capillaries.

Osteoclasts work together in groups to carve out small tunnels in old bone tissue; they then depart and the osteoblasts move in to rebuild the matrix. Many of the hormones affecting bone remodelling are the same as those affecting bone growth.

Bone fracture and repair

Study the definitions of the common types of fracture, including stress fractures.

Study the following steps in the repair of bone fractures:

1. Formation of fracture haematoma
2. Fibrocartilaginous callus formation
3. Bony callus formation
4. Bone remodelling (see above)

A good blood supply together with the relevant vitamins, minerals and hormones are essential for effective healing.

Mineral homeostasis.

The blood plasma level of Ca^{2+} is maintained between 9-11 mg/100ml. This is essential to ensure the efficient function of nerve cells, cardiac muscle tissue and many enzymes. Even small changes outside this range can prove fatal e.g. too high, and the heart can arrest. Too low, and breathing can cease. As the body's major calcium reservoir, bone tissue (under hormonal control) serves to buffer the blood Ca^{2+} level.

When blood Ca^{2+} falls:

- Any change is detected by the parathyroid gland cells.
- Signal leads to increased levels of cyclic AMP in cytosol
- Cyclic AMP triggers a series of reactions resulting in the "switching on" of the gene for the production of parathyroid hormone (PTH).
- Which releases increased amounts of PTH into the blood
- The effect of PTH in bone tissue is to increase the number and activity of osteoclasts.
- Therefore bone resorption is speeded up.

When blood Ca^{2+} rises, the hormone calcitonin is thought to make a potential contribution to bone homeostasis, however its role is uncertain as excess or diminished levels of the hormone do not appear to result in clinical pathology.

- The change is detected by parafollicular cells in the thyroid gland
- Calcitonin secreted by parafollicular cells and is released into the blood
- The effect of calcitonin is to inhibit the activity of the osteoclasts
- Resulting in acceleration of Ca^{2+} uptake by bones and hence the Ca^{2+} deposition into bones

Reaction of bone tissue to mechanical stress

The constant downward pull of gravity and the contraction of skeletal muscles are the two major mechanical stresses imposed on bone tissue. When the amount of regular stress is increased (e.g. when starting an exercise programme) the bone tissue is adapted to cope by the increased deposition of mineral salts and the increased production of collagen fibres.

If mechanical stress is reduced or removed (e.g. prolonged bed rest or astronauts in space) resorption outstrips formation resulting in the loss of bone mass (up to 1% per week). Regular weight-bearing activities are therefore an essential part of a healthy lifestyle in order to help build and retain bone mass.

The constant breakdown and repair of bone is necessary for the maintenance of a healthy skeleton, which is structurally adapted to the ever-changing physical demands placed upon it. Osteoblasts are constantly forming new bone tissue. It is necessary then, that the osteoclasts re-dress this by reabsorbing old bone, to prevent the bones becoming too heavy and thick. Therefore, bone remodelling serves to renew bone tissue before deterioration sets in, and to redistribute bone matrix along the lines of mechanical stress.

Types of bones

Bones may be classified according to their shape.

- Long bone e.g. humerus
- Short bone e.g. trapezoid
- Flat bone e.g. sternum
- Irregular bone e.g. vertebra
- Sesamoid bone e.g. patella

Task:

Try to give at least one other example for each of the above types of bone shapes.

The Skeleton

The skeleton is divided into the **axial skeleton**, which is made up of 80 bones, and the **appendicular skeleton**, made up of 126 bones (most of which, you will be pleased to know, you should be able to identify and describe by the end of this course!)

1) The Axial skeleton is made up of:
The skull bones
Auditory ossicles (tiny bones found within the middle ear)
Hyoid bone
Ribs and sternum
Vertebral column

2) The Appendicular skeleton is made up of:
The bones of the upper (shoulder) girdle
The bones of the lower (pelvic) girdle
The upper and lower limbs

1) The Axial Skeleton:

The Skull:
Note: You are required to be able to identify the bones of the skull from a diagram, but in the main, not to describe their individual features. You are also required to be able to list the bones, which may, for instance, form the optic orbit, or within which the sinuses are found.
Please also learn the names of the sutures of the skull, and the names and locations of the paranasal sinuses.

Cranial bones:
1 Occipital bone
1 Frontal bone
1 Ethmoid bone
1 Sphenoid bone
2 Parietal bones
2 Temporal bones

Facial bones:
1 Vomer
1 Mandible
2 Nasal
2 Lacrimal
2 Zygomatic
2 Palatine
2 Maxilla
2 Inferior concha

Note that within the facial bones are foramina, through which blood vessels and nerves pass. The Mental foramen is one of the principal pulse points. Try to locate this on your own chin.

The **Temporal bone** is an important bone to intimately know the features of. It articulates with the mandible (jaw-bone) to form the temporomandibular joint. It also composes of the mastoid process, which houses the external auditory canal, and contains several air cells. This section of bone is used in the clinical examination of deafness.

The **Occipital bone** forms one of the points of attachment for the neck and back muscles. It also contains the very important foramen magnum, through which the spinal cord passes from the brain to the vertebral column. The occiput articulates with the atlas, the first vertebra of the vertebral column.

The **Ethmoid bone** forms a major portion of the nasal cavity. The cribiform plate of the ethmoid bone forms the roof of the nasal cavity, which features the olfactory foramina through which the olfactory neurons pass through.

The **Hyoid Bone** is unique in the skeleton in that it ‘floats freely’, without articulating directly with any other bones. It is located between the mandible and larynx in the anterior neck, and is suspended from the styloid processes of the temporal bones by ligaments and muscles. It functions to support the tongue, and provide a point of attachment for muscles of the tongue, neck and pharynx.

The Vertebral Column:

Terms:

Vertebral column –	The bony column of 32 vertebral bones extending from the atlas to the coccyx (note that the sacrum is made up of 5 fused segments and the coccyx 4)
Spinal cord –	The nervous tissue found within the bony vertebral column.

Task:

Please make a note of the five regions in the vertebral column, and the number of vertebrae, which make up each of these regions.

Note the three natural curves of the spine.
Note: The vertebrae are referred to in a short hand manner of speaking. For example, the fifth cervical vertebra is called C5, or the twelfth thoracic vertebra is referred to as T12.

Intervertebral discs:
These are the cartilaginous joints found between the vertebrae from C2 to the sacrum. The outer ring of fibrocartilage is known as the *annulus fibrosus*, and the elastic pulpy contents within, is the *nucleus pulposus*.
The discs function as strong joints, which permit limited movement, and serves as a shock absorber to vertical stress such as jogging.

Anatomy of a typical vertebra:

The Body:
This is the anterior part of the vertebra which supports the weight of the vertebrae immediately superior to it. It is a short cylindrical body, with surfaces for attachment of the intervertebral discs. The size of the body varies markedly between the cervical vertebrae to the lumbar, reflecting the weight bearing required by the different regions.

The Vertebral Arch:
This structure lies posterior to the vertebral bodies, and forms the spinal canal, which houses the spinal cord, and the protective layers (or meninges) are the dura, arachnoids and pia mater.
The vertebral arch is composed of two pedicles, which link posteriorly with the laminae to form the vertebral foramen or canal. The vertebral notches of the pedicles permit an intervertebral foramen to form, which provides the space for a single spinal nerve to emerge from the spinal cord.

The Processes:
There are seven processes
One **spinous** process
Two **transverse** processes
Two **superior articular** processes
Two **inferior articular** processes

Task:

As you read through Tortora, please make tabulated notes of the very important structural differences found between the vertebrae of the various regions of the vertebral column.
The Atlas and Axis are particularly unusual vertebrae; please take special note of their structure and how this contributes towards their effective functioning. As you do so, it would be helpful to colour the remaining parts of the vertebral plates.

The Thorax
This is made up of the sternum, twelve pairs of ribs, and the vertebral column.

The Sternum
A narrow flat bone made up of three portions:

1. The superior **manubrium** with one suprasternal, and two clavicular notches. It articulates with the clavicles (sternoclavicular joints), and the first two ribs (sternocostal joints)
2. The **middle body** articulates directly or indirectly (note how the costal cartilages of ribs 8-10 are fused) with ribs 2-10.
3. The inferior **xiphoid process**. This serves as a point of attachment to some abdominal muscles.

Between the manubrium and the body of the sternum, is a joint known as the **sternal angle**. This angle is an important landmark in the clinical examination when examining the locations of the chambers of the heart. Try to locate this angle on your own sternum.

The Ribs:
There are twelve pairs of ribs, and each articulates directly with its corresponding vertebra posteriorly.

Ribs 1-7 Are known as true ribs (vertebrosternal ribs). They are in direct contact with the sternum by the costal (hyaline) cartilage.
Ribs 8-10 Are referred to as false ribs (vertebrochondral ribs) due to their fusion of the costal cartilage.
Ribs 11-12 Are also false ribs, but as they do not articulate at all with the sternum, they are referred to as 'floating ribs.'

Task:

Please take special note of the articulating facets of the ribs, and how these facets hang together with the rest of the thoracic cavity.
You may like to review the mechanisms of breathing in relation to the structure of the thorax.

<u>The Appendicular Skeleton:</u>

This division of the skeleton is made up of the pectoral and pelvic girdles, and the limbs attached to these girdles.

The Pectoral Girdle:
Functions to attach the upper limbs to the axial skeleton.
Each girdle is made up of:

- 1 clavicle – articulates with the sternum at the *sternoclavicular joint*
- 1 scapula – articulates with the clavicle at the *acromioclavicular joint*, and the humerus at the *glenohumeral joint*.

The scapula:
It is important for you to know, and be able to label, all the landmarks of this bone.

Task:
Try to locate the spine of your own scapular. Move you fingers laterally along it, until you reach the acromion. Now palpate the sternoclavicular joint. Move laterally along the clavicle until it joins with the acromion. Feel around the acromioclavicular joint. Now continue to move your fingers laterally until you come to the next bony prominence – the greater tubercle of the humerus, which is found at the extreme lateral end of the shoulder girdle. Bring your fingers anteriorly and medially and feel the coracoid process, this is deep to the lateral end of the pectoralis major muscle.

The **coracoid process**, the **acromion** and the **greater tubercle/tuberosity**, represent the three important surface landmarks of the pectoral girdle.

The Upper Limbs:
These are made up of:
- 1 Humerus
- 1 Ulna
- 1 Radius
- The Carpals
- The Metacarpals
- The Phalanges

The Humerus:
The important thing to note here, is the relative instability of the ball and socket joint of the shoulder girdle. This girdle relies primarily on the muscles and ligaments for its stability. Please take care to learn the landmarks and articulations of the olecranon joint (the elbow joint).

Task:

On your own elbow, palpate the medial and lateral epicondyles. Move medially to locate the olecranon fossa, and to palpate how the ulna fits into this joint.
Note how the olecranon of the ulna fits into the olecranon fossa of the humerus. Note the capitulum and the trochlea of the humerus, and the articulations between these structures and the ulnar and radius.

The Ulnar and Radius:
Become familiar with the locations of these two bones, and the fact that they have the ability to twist over each other as you pronate and supinate your hand. Note that they articulate with each other in two places: The proximal radioulnar joint, and the distal radioulnar joint.
The distal end of the radius articulates with the carpal bones to form the radiocarpal joint.

Carpals, Metacarpals and Phalanges:
With these bones, it is not necessary to know the names of each carpal bone. Do, however, note the pisiform bone, which is a sesamoid bone.
Carpal bones (wrist bones) articulate with the metacarpal bones (palm bones) at the carpometacarpal joints. The heads of the metacarpal bones articulate with the proximal phalanges to form the metacarpophalangeal joints (knuckles).
The phalanges are the fingers, and are made up of three rows – except for the thumb, which is made up of only two. The joints are referred to as the proximal and distal interphalangeal joints.

The Pelvic Girdle:
The pelvic girdle is made up of two coxal (hip) bones which are united anteriorly at the symphysis pubis, and posteriorly at the sacroiliac joints. The coxal bones are made up of three fused bones:

1. Ilium
2. Ischium
3. Pubis

The union of the above three bones is found within the acetabular fossa of the hip.

Note:
Make sure that you learn the landmarks of the coxal bones.
Note how the sacrum fits into the pelvic girdle like a keystone- this is appropriate as the pelvic girdle bears most of the weight of the body.
Also take note of the differences between the male and female pelvis as a result of the function of childbirth in women, and possibly ease of running (hunting) in the male.
See how much deeper the acetabulum is when compared to the glenoid cavity, and appreciate how more stable this ball and socket joint is, when measured against the ball and socket joint of the shoulder.

The Lower Limbs:

These are made up of:

- The Femur
- The Patella
- The Tibia
- The Fibula
- The Tarsals
- The Metatarsals
- The Phalanges

The Femur:
Note the head of the femur, and how deeply it fits into the acetabulum. The greater and lesser trochanter projections serve as points of attachment for tendons. Try to palpate the greater trochanter on the lateral aspect of your own hip.

The distal end of the femur forms part of the knee joint. It expands to form the medial and lateral epicondyles, which articulate with the medial and lateral condyles of the tibia. The patellar fits into the intercondylar fossa of the humerus at the patellofemoral joint. The patella is classified as a sesamoid bone as it developed with the quadriceps tendon and has no direct articulation with other bones.

The Tibia and Fibula:
The tibia bone lies medial to the fibula, and articulates with the humerus at the medial and lateral tibiofemoral joints. The tibia articulates with the fibular at the proximal and distal tibiofibular joints.
The proximal portion of the tibia is expanded to form the medial and lateral condyles. Inferior to the patella is the tibial tuberosity, which you can palpate on your own knee, and which forms a point of attachment for the patellar ligament.

The expanded distal portion of the fibula is known as the lateral malleolus, and articulates with the talus to form the ankle. Medial to this prominence is the medial malleolus. These two prominences are important for the location of a pulse point. This is the dorsalis pedis.

Tarsals, Metatarsals and Phalanges:
For this section, take note of the calcaneus bone, and its relation to the talus, tibia and fibula bones, which form the ankle.
Note the location of two other sesamoid bones beneath the medial metatarsal bone. Note, also, the arrangement of the metatarsals and phalanges are similar to that of the metacarpals and phalanges of the hand. Note also the three arches of the foot.

Task:
Ask a kind friend to offer their foot for you to examine.
Try to locate the medial and lateral malleolus prominences.
Locate the calcaneus bone on the heel, and note the Achilles tendon.
Observe the lateral longitudinal arch, the transverse arch and the medial arch of the foot.
Experiment the range of movement with dorsiflexion, plantarflexion, inversion and eversion with the feet.

Self-assessment questions

Chapter-5

1. Write an account on the sliding filament theory of in muscle contraction

2. Draw and label a diagram of a neuromuscular junction

3. List at least 2 muscles which perform:

   a) Shoulder flexion
   b) Shoulder extension
   c) Shoulder abduction
   d) Shoulder adduction
   e) Elbow flexion
   f) Elbow extension
   g) Wrist Flexion
   h) Wrist Extension
   i) Finger flexion
   j) Finger extension
   k) Finger abduction
   l) Finger adduction
   m) Hip flexion
   n) Hip extension
   o) Knee flexion
   p) Knee extension
   q) Ankle dorsiflexion
   r) Ankle plantarflexion
   s) Big toe extension

4. Name the principal muscles of respiration.

5. Name four muscles or group of muscles of perform extension of the spine and four for flexion of the spine.

6. Without looking at your textbooks attempt to label the following plates:
   Plate-7
   Plate-12
   Plate-13
   Plate-14
   Plate-15
   Plate-16
   Plate-17