Chapter Four
Skeletal System

This week, we are going to explore the one concept most people quickly associate the study of anatomy and physiology with:

The Skeletal System

In order to move forward into this topic I would highly recommend reviewing the information back in Chapter Two since we will be spending a lot of time dealing with connective tissues.

The skeletal system is made up of three individual structures:

Bones, Cartilage, and Joints

If you add in the fact that your bones are responsible for creating all of your blood (another connective tissue), you can easily state that the majority of your skeletal system is made up of connective tissues.

This system performs five different functions for the human body:

Support

Our skeletal muscles are attached to bones through the use of **tendons** (a type of connective tissue proper). Without bones, however, there would be no rigid foundation to support these skeletal muscles and our bodies would look (for lack of a better term) like a sack of meat within the skin.

As you learned back in Chapter Two, *cartilage* is a flexible connective tissue found throughout the body and is primarily made of the protein *collagen*. It is cartilage which gives our bones protection and support while providing flexibility to our body.

Protection

Several of our vital organs such as the brain and heart are protected by various types of hardened bone. In addition, our blood is created within the protective walls of specific bones.

Movement

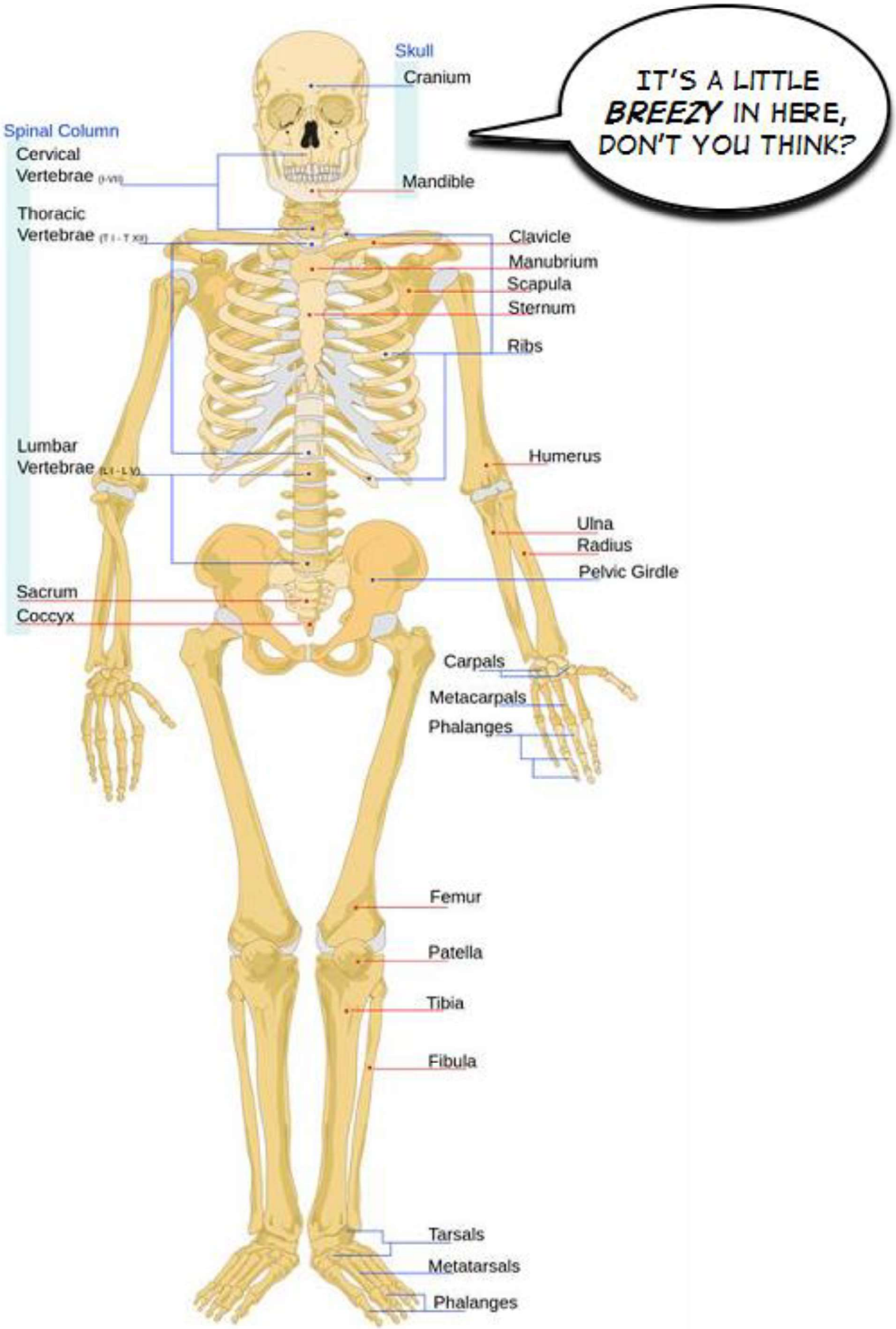
Our bones are attached to each other with a type of connective tissue proper called **ligaments**. These strong and flexible connective tissues allow our bones to act as levers when their attached skeletal muscles contract (get shorter). As our muscles contract, our bones are pulled together through their connections at the joints.

Blood formation (Hematopoiesis)

As stated above, our bones are the areas where new blood cells are being formed. We will explore this in more detail very soon!

Mineral storage

Within the human body, the majority of the elements calcium and phosphorus can be found within the bones and teeth. The large amount of these two elements gives our bones their rigid features. Both elements are very important to various functions of the human body which include the structure and function of our muscles, blood, and DNA. When additional calcium and phosphorus are needed throughout the body, these elements can be taken from the bones. If you recall from Chapter 2, the element phosphorus is used in the construction of cell membranes.


IT'S A LITTLE BREEZY IN HERE, DON'T YOU THINK?
Skull
Cranium
Mandible
Spinal Column
Cervical Vertebrae
Thoracic Vertebrae
Lumbar Vertebrae
Sacrum
Coccyx
Clavicle
Manubrium
Scapula
Sternum
Ribs
Humerus
Ulna
Radius
Pelvic Girdle
Carpals
Metacarpals
Phalanges
Femur
Patella
Tibia
Fibula
Tarsals
Metatarsals
Phalanges

Even though there are 206 bones in the typical human skeleton, you are **not** going to be asked to memorize all of them. You're welcome ☺

However, you should be familiar with all of the major bones of which there approximately thirty. The location of these bones can be found in two areas that have been labeled:

The Axial Skeleton and the Appendicular Skeleton

The **axial skeleton** is responsible for protecting the head, neck, and trunk of your body. These bones include the *skull*, the **vertebral column** (your spine), and the *rib cage*. The **appendicular skeleton** includes the rest of your bones such as the pelvis and all of the bones of your **extremities** (your arms and legs).

As you can see, our bones have a variety of structures and each has its own unique function as well. We can organize all of these bones into four different categories based upon their shape:

Long bones, Short bones, Flat bones, and Irregular bones

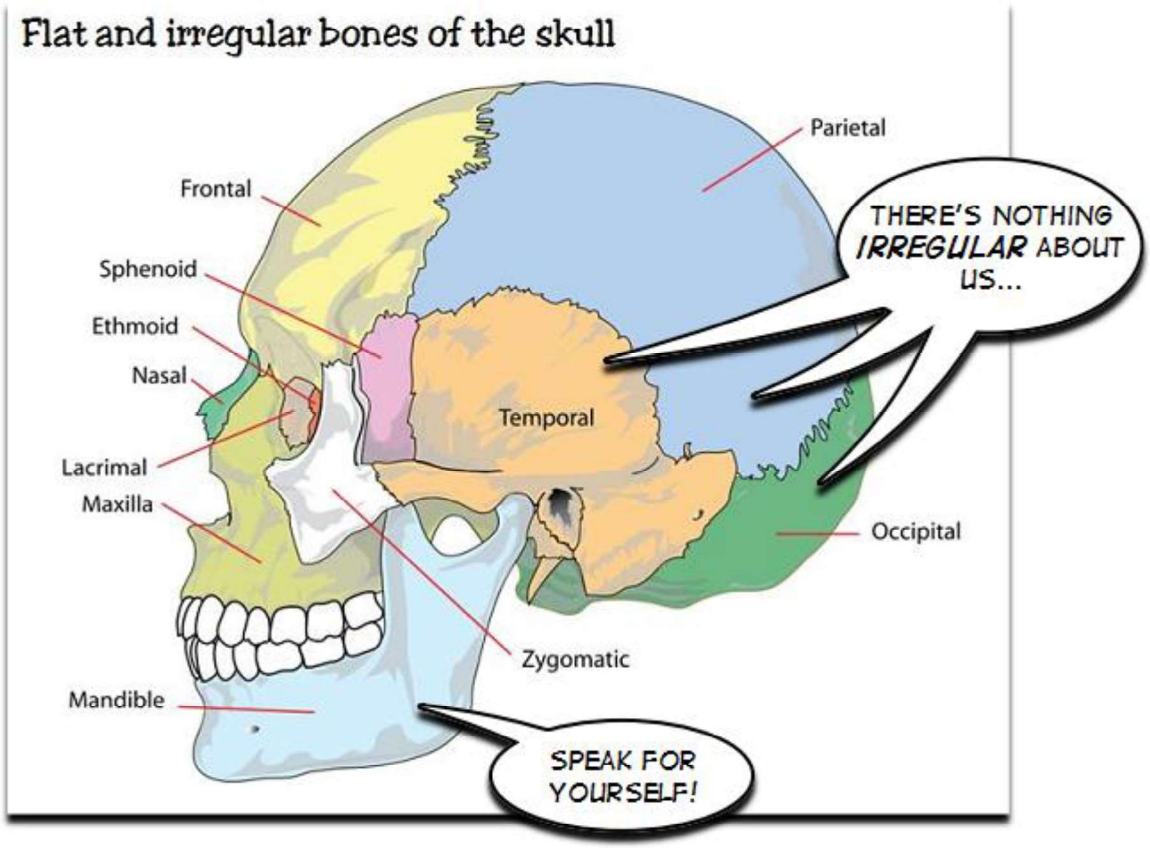
Long bones are those which are typically found within the arms and legs. These bones are like the main walls in the foundation of your home. They hold and support the majority of your body weight at any given time.

Short bones can be found in your wrists and ankles and their functions are usually to allow our bodies to move more freely.

Flat bones, like those found in your skull and pelvis, have a flattened structure (as their name implies) and can usually be found protecting the softer tissues/organs in our bodies.

Irregular bones have many different shapes. Each bone in our vertebral column, our jawbone (**mandible**), and our kneecap (**patella**) are all examples of irregular bones.

We could spend a tremendous amount of time looking at the various structures and functions for each type of bone; however, let's spend our time on the largest of the bones – the long bones.



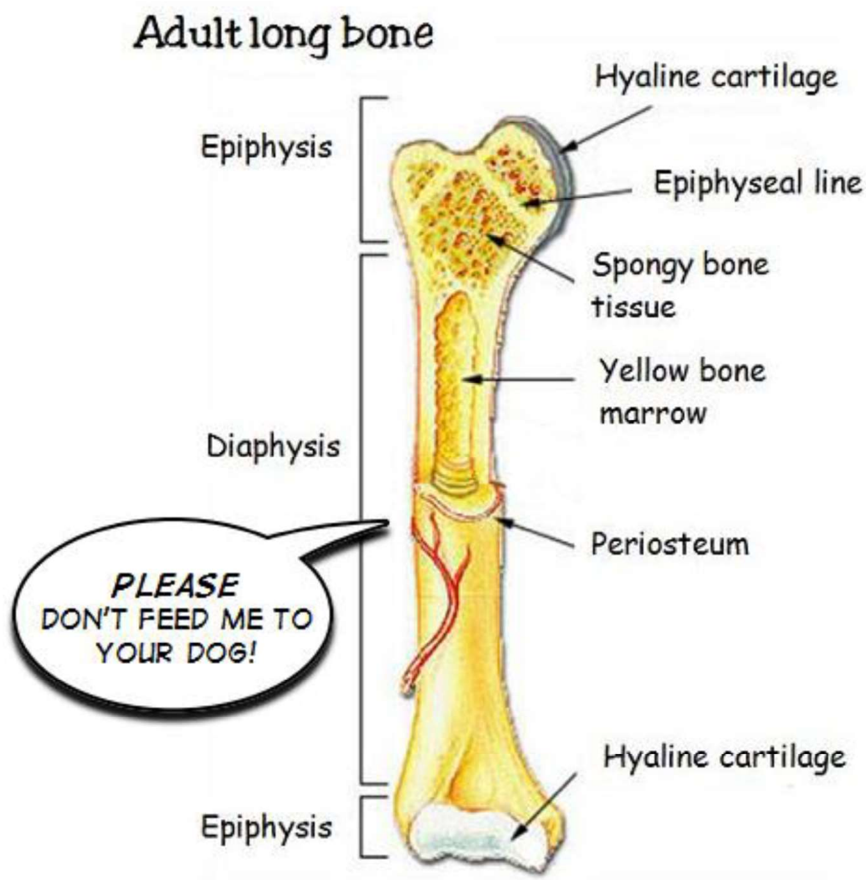
The following chart will tell you each of the long bones in the body and their general location:

Long bones within the human body:

Long Bone	Location
Humerus	Upper arm
Radius	Lateral bone in the lower arm
Ulna	Medial bone in the lower arm
Femur	Upper leg
Tibia	Medial bone in the lower leg
Fibula	Lateral bone in the lower leg
Phalanges	Fingers and toes
Metacarpals	Between the fingers and the short bones of the wrists
Metatarsals	Between the toes and the short bones of the ankles

Like most bones of the skeleton, the long bones are composed of **compact bone tissue** and **spongy bone tissue**. Compact bone tissue is the hard outer layer, while the spongy bone tissue is the porous, highly vascular inner portion. The structure of the long bones includes a long shaft called a **diaphysis** capped on both ends with an enlarged rounded end called an **epiphysis**.

The epiphysis is made up of spongy bone tissue and is filled with **red bone marrow**. It is within the red bone marrow that **hematopoiesis** (the formation of blood cells) takes place. A thin layer of compact bone tissue surrounds and protects each epiphysis.



The diaphysis is made up mostly of compact bone tissue which gives it considerable strength. A hollow area can be found within the diaphysis which is filled with **yellow bone marrow.** This type of marrow serves as a storehouse for fat which can be converted into energy if needed.

Even though our bones are covered in a protective layer of compact bone tissue, it is still a living organ! This means the bones must have a way of receiving nutrients from the blood and removing waste from their cells. This is accomplished through the **periosteum**, which covers our bones and allows for the transfer of nutrients and waste in addition to providing areas of attachment for tendons.

How are bones formed and how do they grow?

This is another one of those questions we could spend all day talking about. To make things a little simpler we are going to look at a basic model for bone development also known as **ossification**.

Before we are born, the main bone-building cells during our development are known as **osteoblasts**. These cells absorb the mineral calcium from the blood supplied by the mother (primarily through the digestion of milk and dairy products as well as through leafy greens and other foods) and begin creating bone tissue. As the tissue is being generated, more osteoblasts become integrated into the new tissue (much like gravel being added to concrete) and mature into **osteocytes** which help to maintain and support the ever growing layers of skeletal tissue. While this is occurring, another type of cell within the skeletal tissue known as the **osteoclasts** secrete proteins that act to destroy the bone.

Why would you want your newly-formed bone to be destroyed?

If you remember, the largest bones in your body, *the long bones,* have a hollow interior shaft that acts as a storehouse for fat. There has to be a way to hollow out that bone! This is where the osteoclasts get to work. These cells break down the calcium-rich tissue inside the diaphysis until a hollow opening exists within the bone. The osteoclasts continue to break down the inside of your bones until a specific thickness is achieved (which is determined by your DNA but we'll get into that another day). At this point, the osteoblasts continue to form new bone tissue at the same rate as the osteoclasts are destroying it! This keeps the thickness of your bones relatively stable throughout your life while constantly providing new and fresh tissues to be formed. Cool, huh?

Throughout childhood, your number of osteoblasts outnumbers the osteoclasts. This is a good thing as it allows your body to continually grow! However, the number of osteoblasts becomes much lower as we age. This creates a series of potential problems for our bones as we get older.

In addition to its cooperation with the osteoblasts, the osteoclasts also perform a couple of other very important functions as well. When you do not have enough calcium within your body, the osteoclasts work to destroy parts of your bones to release some of its calcium into your blood supply. And, whenever you break a bone, it is the osteoclasts which help to repair the break!

That explains how your long bones become hollow. But how to they become "long"?

Your long bones continue to lengthen from birth through adolescence. This lengthening is achieved by the activity of two cartilage plates, called **epiphyseal plates** (also known as the **growth plates**), and are located where the diaphysis meets the epiphyses on both of its ends. The growth plates continually produce new cartilage and push these cells towards the end of the epiphyses where they eventually become transformed into bone.

These "plates" continue to provide new cartilage until we reach our adult height (normally before the age of 25). As new cells develop on these areas the length of the shaft (diaphysis) increases at both ends and the ends of each bone (epiphyses) moves farther apart. After we reach our adult height, the epiphyseal plates stop developing new cartilage between the epiphysis and diaphysis and the existing cartilage eventually is transformed into bone. All that remains of the growth plate at this time is a small line of cells in the epiphysis area known as the epiphyseal line.

Let's take a brief look at some of the other bones within your body...

Skull

The skull contains a total of 22 different bones; eight of these are flat bones which are joined together to protect your brain and sense organs while the remaining 14 bones give your face its shape and helps to hold your teeth in place.

Vertebrae

Vertebrae are the small irregular bones within your vertebral column (backbone or spine) which help you move your head and chest while encasing and protecting your **spinal cord** (a large bundle of nerve fibers). Your "backbone" curves in four different areas:

Cervical (neck) curvature

Thoracic (chest) curvature

Lumbar (small of the back) curvature

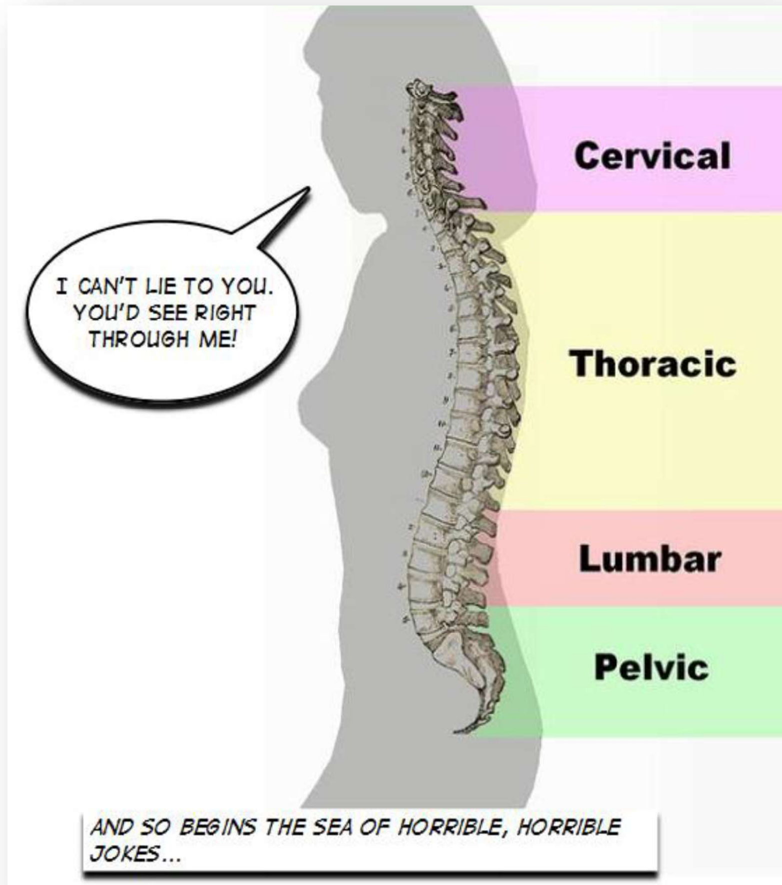
Pelvic curvature

Cervical (neck) curvature

Contains seven vertebrae and is found within the neck

Thoracic (chest) curvature

Contains twelve vertebrae and is attached to the ribs



Lumbar (small of the back) curvature

Contains five vertebrae and supports a significant amount of the human body's weight

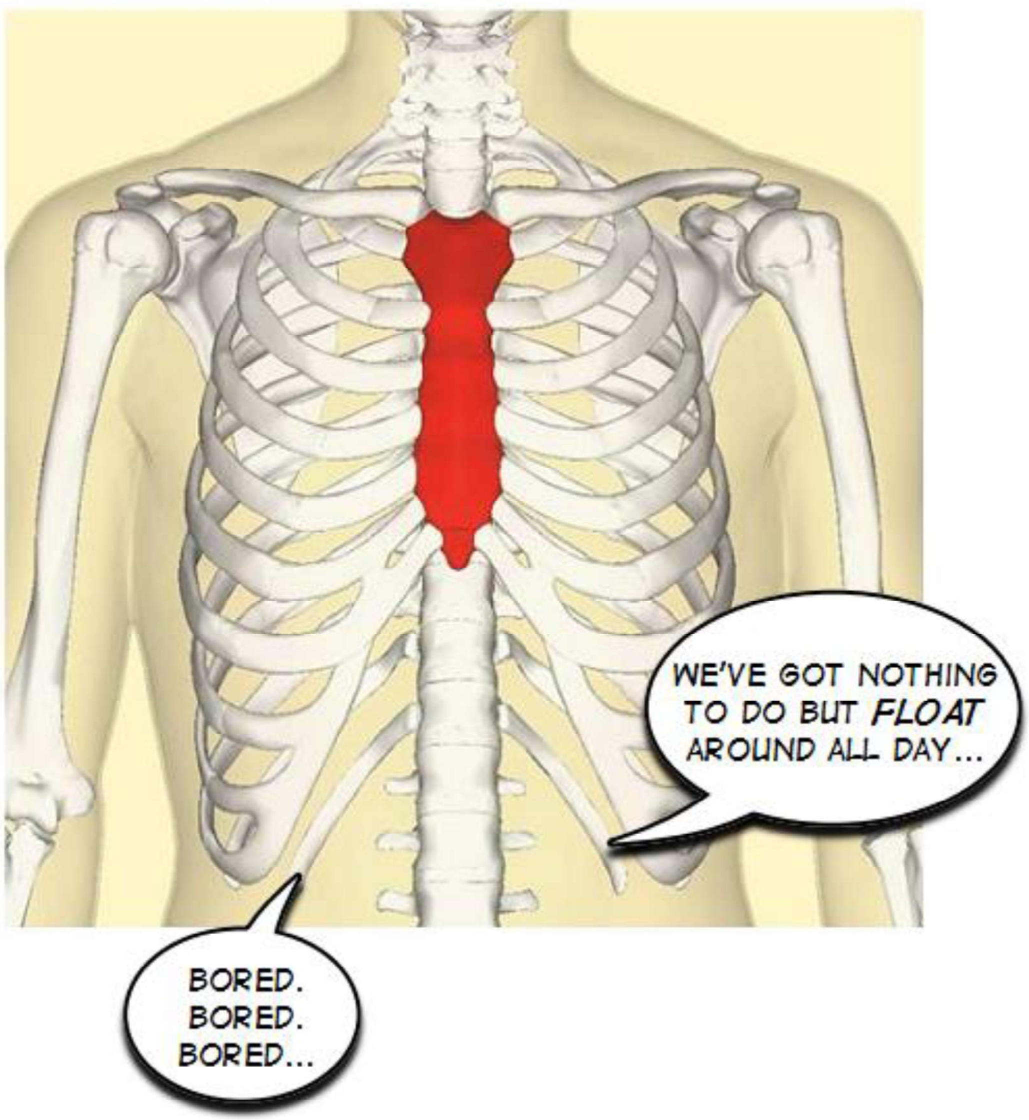
Pelvic curvature

The pelvic curvature contains five vertebrae which are fused together and is known as the **sacrum**. The sacrum is attached to our **pelvis** (hipbones) and four more fused vertebrae which make up the **coccyx** (tailbone).

Ribs

Twelve pairs of ribs attach to the thoracic curvature of the spine and make up what is called the **rib cage**. The rib cage is responsible for protecting most of the organs within the axial skeleton and plays an important role in the act of breathing. The first seven pairs of ribs are attached to the **sternum** (breastbone) in the front (anterior) of our body. The eighth, ninth, and tenth pairs of ribs are attached to the seventh pair of ribs and are called **false ribs**. The last two pairs of ribs are not attached to the ribcage at all and are known as **floating ribs.**

Sternum (red) and Ribs



What about the structures that holds bones together?

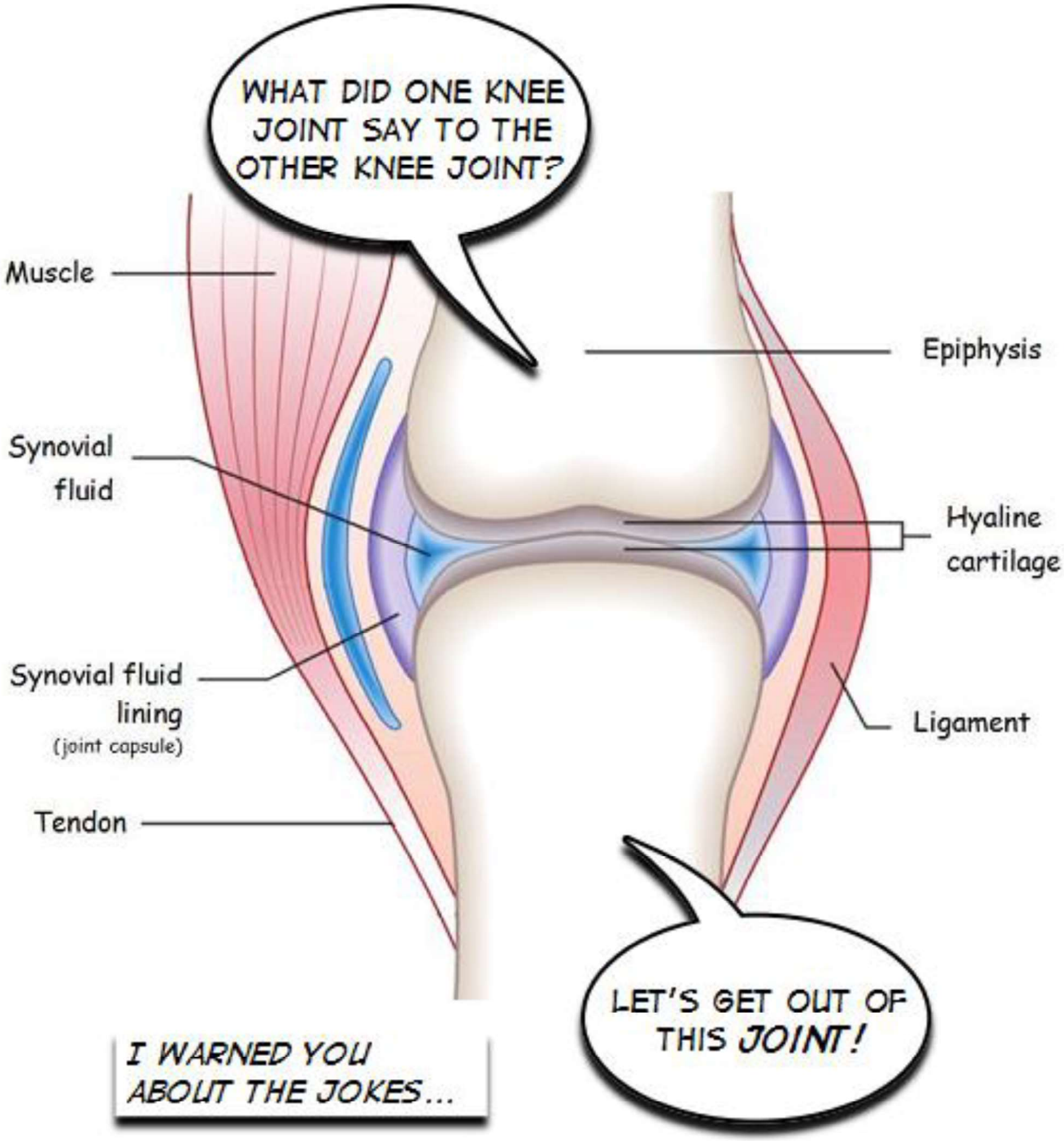
Every area in the human body that holds two bones together is known as an **articulation** (joint). The ends of bones that are connected to other bones through a joint (like the knee or elbow) tend to be covered with a type of cartilage called **hyaline**. This smooth connective tissue is very slippery and allows tissues to move/slide over each easily. However, not all joints allow bones to move at all! There are three different types of joints in the human body:

Fibrous, Cartilaginous, and Synovial

Fibrous joints do not allow any movement to exist at all between the two bones. These are very rigid connections. The joints between the eight flat bones of the skull are examples of fibrous joints. I don't believe you would want the bones of your skull to start moving around!

Cartilaginous joints are made up of either hyaline cartilage or fibro-cartilage and provide little if any movement at all. The rigid connections between the ribs and the sternum are cartilaginous joints which do not allow any movement; however, our vertebrae are separated by disks of fibro-cartilage which allow slight movement under pressure and are still classified as cartilaginous joints.

Synovial joints include all freely moving joints in the human body such as those found in the shoulders, knees, elbows, wrists, etc. Within this type of joint a hyaline layer of cartilage covers the ends of the connecting bones allowing the bones to move more freely against each other. In addition, a synovial joint is entirely contained within a sealed fluid-filled "pocket." This fluid is known as **synovial fluid** and helps to lubricate the cartilage between the bones.


WHAT DID ONE KNEE JOINT SAY TO THE OTHER KNEE JOINT?
Muscle
Epiphysis
Synovial fluid
Hyaline cartilage
Synovial fluid lining
(joint capsule)
Ligament
Tendon
LET'S GET OUT OF THIS JOINT!
I WARNED YOU ABOUT THE JOKES...

Anatomy & Physiology - Connections

How the following body systems affect the skeletal system		How the skeletal system affects the following body systems	
Integumentary	Production of vitamin D needed for calcium and phosphorus absorption	Provides framework for muscle and integumentary systems	**Integumentary**

Match the following vocabulary terms with their correct definition:

appendicular skeleton
articulation
axial skeleton
cartilaginous joints
cervical (neck) curvature
coccyx
compact bone tissue
diaphysis
epiphyseal plates
epiphysis
extremities
false ribs
fibrous joints
flat bones
floating ribs
hematopoiesis
hyaline
irregular bones
ligaments
long bones
lumbar curvature
mandible
ossification
osteoblasts
osteoclasts
osteocytes
patella
pelvic curvature
pelvis
periosteum
red bone marrow
rib cage
sacrum
short bones
spinal cord
spongy bone tissue
sternum
synovial fluid
synovial joints
tendons
thoracic (chest) curvature
vertebrae
vertebral column
yellow bone marrow

1) ______________ 8th-10th pairs of ribs which are attached to the seventh pair of ribs

2) ______________ a large bundle of nerve fibers protected within the vertebral column

3) ______________ a section of the spinal cord which contains five vertebrae and carries most of the weight of the human body

4) ______________ a section of the spinal cord which contains twelve vertebrae and is attached to the ribs

5) ______________ a type of connective tissue proper which connects bones to other bones

6)	______________	a type of connective tissue proper which connects muscles to bones
7)	______________	all freely moving joints in the human body such as those found in the shoulders, knees, elbows, wrists, etc.
8)	______________	arms and legs
9)	______________	bones having many different shapes; examples include the jawbone and kneecap
10)	______________	bones which are responsible for protecting the head, neck, and trunk of the body
11)	______________	breastbone; attaches the first seven pairs of ribs
12)	______________	cells found within the center of a bone which secrete proteins that destroy bone tissue
13)	______________	enlarged rounded end of a long bone
14)	______________	five vertebrae which are fused together forming one part of the pelvic curvature
15)	______________	flattened bones found in the skull and pelvis which typically protect softer tissues/organs
16)	______________	fluid found within a sealed pocket containing a synovial joint; helps to lubricate the fibro-cartilage between the bones
17)	______________	form of connective tissue which is very smooth and allows tissues to move/slide over each easily
18)	______________	found in wrists and ankles; allows the body to move more freely
19)	______________	found within spongy bone tissue of long bones; site of blood cell production
20)	______________	hard outer layer of bones
21)	______________	hipbones
22)	______________	jawbone

23)	______________	joints which are made up of either hyaline cartilage or fibro-cartilage and provide little if any movement
24)	______________	joints which do not allow any movement to exist at all between the two bones
25)	______________	joints; an area in the human body that holds two bones together
26)	______________	kneecap
27)	______________	last two pairs of ribs which are unattached to any other structures
28)	______________	long shaft of a long bone
29)	______________	mature osteoblasts; assist in the maintenance and support of growing skeletal tissue
30)	______________	permeable covering over bones which allows for nutrient/waste transfer and sites for attachment by tendons
31)	______________	porous, highly vascular inner portion of bones
32)	______________	process of bone development
33)	______________	small bones of the backbone
34)	______________	storehouse for fat; found in the long hollow area within the diaphysis of long bones
35)	______________	tailbones; four fused vertebrae found within the pelvic curvature
36)	______________	the backbone or spine
37)	______________	the lower skeleton containing the pelvis and all of the extremities
38)	______________	the lowest section of the spinal cord which contains the sacrum, pelvis, and coccyx
39)	______________	the main bone-building cells during human development
40)	______________	the process of blood formation
41)	______________	those which are typically found within the arms and legs

42)	____________	top section of the spinal cord which contains seven vertebrae within the neck
43)	____________	twelve pairs of ribs attach to the thoracic curvature of the spine
44)	____________	two cartilage plates found where the diaphysis meets the epiphyses on both of its ends; areas where new cells continue to grow thereby lengthening the long bones

Choose the correct answer from the following questions:

1) The most important minerals stored in bones are:

A) calcium and iron
B) calcium and potassium
C) sodium and potassium
D) calcium and phosphorus
E) sodium and phosphorus

2) Which of these are bone-forming cells:

A) osteocytes
B) osteoclasts
C) periosteum
D) red bone marrow
E) osteoblasts

3) The scientific term used to describe the formation of bone is:

A) osteoarthritis
B) epiphysis
C) osteoporosis
D) ossification
E) articulation

4) The axial skeleton contains which combination of the following bones:

1. skull
2. arms and legs
3. ribs and sternum
4. vertebrae
5. pelvis

A) 1, 2, 3, 5   B) 1, 3, 4   C) 1, 3, 4, 5   D) 2, 5   E) 2, 3, 4, 5

5) Which of these bones is NOT a long bone found in the leg:

A) femur
B) fibula
C) radius
D) tibia
E) patella

6) Fingers and toes are referred to as:

A) tarsals
B) carpals
C) metatarsals
D) metacarpals
E) phalanges

Application Question:

While playing on her swing set, 10-year-old Sally falls and breaks her right leg. At the emergency room, the doctor tells her parents that the proximal end of the tibia where the epiphysis meets the diaphysis is fractured. Sally's leg is put into a cast and eventually heals. During a doctor's visit eight years later, Sally learns that her right leg is 2 cm shorter than her left. The doctor tells her this is likely because of her accident. What might account for this difference in length?