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The Human Limbs: Comparison/Contrast

Human limbs are described as *pentadactyl*, meaning they have five finger-like appendages attached to the hand and to the foot.[1] Our limbs and their associated synovial joints[2], along with the many muscles, ligaments (tissue that binds bones to other bones), tendons (tissue that binds muscles to the periosteum (a fibrous membrane covering bone) and nerves give us the ability for keen dexterity (being able to hold and manipulate objects), as well as for balance and propulsion. There are a lot of similarities between our arms/hands and legs/feet, but also a lot of differences. Figures 1 through 4 illustrate the skeletal and muscular structure of the human arm (Figures 1 and 2) and leg (Figures 3 and 4) in both anterior and posterior views. These diagrams can facilitate understanding of the limbs in general, and in particular, can help us to place the five digits of each into context with the rest of the limb.

The skeletal structure of each limb is comprised of three long bones (one upper and two lower) joined in a hinge, short bones (carpals and tarsals) forming the wrist (a condyloid joint) and the ankle (a hinge joint), bones for the hand and foot (metacarpals and metatarsals), ending in numerous small bones that form the fingers and toes (phalanges). The upper limbs contain 30 bones each (Humerus, radius, ulna, 8 carpals, 5 metacarpals, and 14 phalanges), and the lower limbs also contains 30 bones each, but are a bit different (femur, tibia, fibula, patella (protective plate commonly called the kneecap), 7 tarsals, 5 metatarsals, and 14 phalanges). The joints of the limbs are primarily synovial, and the way in which muscles and tendons connect supplements joint stability in addition to providing the means for movement. While our arms and hands are required for picking up our babies, swinging tennis rackets, hailing taxis,

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[1] *Webster's Third New International Dictionary, Unabridged*. Merriam-Webster, 2002. http://unabridged.merriam-webster.com (20 Dec. 2005). Main Entry: pen·ta·dac·tyl. Etymology: *pentadactyl* from Latin *pentadactylus,* from Greek *pentadaktylos,* from *penta-* + *daktylos* finger; having five digits to the hand or foot or five fingerlike parts.

[2] Synovial joints are comprised of articulating (moving) bones capped in articulating cartilage (a dense flexible tissue that absorbs shock within joints), cushioned in a fluid-filled cavity, all of which is surrounded by a joint capsule entwined in ligament and tendon tissue.

typing papers, turning pages, feeding ourselves, folding our clothes, brushing our hair, doing hand-stands, and driving our cars, our legs and feet are primarily designed to bear the full weight of our bodies for sitting, standing, jumping and otherwise moving about (and for occasionally carrying others piggy-back, so these bones and muscles have to be able to bear the weight of anything else we are carrying). The interconnecting bones, tissues, and muscles of our limbs are thus sized and assembled to support differing roles.

Starting at the top of each limb, we can see that the large long bones (Humerus in the arm and Femur in the leg) are joined to the body by ball-and-socket, permitting a great degree of movement in any direction (X-Y-Z axis). This joint seats the bones into the shoulder and the hip, the only ball-and-socket joints in the body. The degree of motion in these joints can be limited by injury and/or body conditioning.

> Five major muscles of the shoulder (Coracobrachialis, Deltoid, Pectoralis Major, Latissimus Dorsi, and Teres Major) and their associated tendons connect from the humerus to various other bones, ensuring the ball and socket joint remains stable and seated together (lending stability to the joint ligaments), while permitting a full range of motion (the scapula (shoulder blade) and clavicle (collar bone), along with the sternum and other parts of the ribcage, act as anchoring points for the muscles of the shoulder, allowing for full rotation, extension, flexion, abduction (lift away from the body), and adduction (draw toward the body).)
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> For the hip, a similar set of large, heavy muscles (Psoas, Iliacus, Quadriceps Femoris, Gluteal, and Satorius) essentially snug the long bone ball to the socket of the pelvis, again ensuring stability and a full range of motion, permitting us to walk, run, sit down, stand up, leap, do the splits, ride a bicycle, and so forth.

At the other end of these large long bones, we find hinged joints (elbow and knee), connecting the upper part of the limb (single bone) to the lower part (two bones). Again, our muscles and other tissues connect at and around these joints, allowing for flexing and extension of the limb as well as providing additional stability. Both the elbow and knee are susceptible to injury if hyper-extended (extended beyond the limits of the hinge) or if twisted (sprained), or forced laterally. The difference in these joints is primarily related to function: the elbow is made for leaning on, propping up in bed to read, jabbing into the ribs of your friend, and the joint acts as a pivot point for lifting and carrying objects; the knee is a very heavy complex hinge-joint that also must support the full weight and motion of the body when walking, running, stooping, or kneeling. It is protected by a “cap” (patella), a bone plate in front of the joint, enabling us to kneel and bear our weight without injury. Since we don’t tend to move about on our elbows, we have no need of such a plate or cap in the arm (the “elbow” bone is actually part of the ulna).

> In the upper arm, the muscles responsible for flexing and extending the arm at the elbow joint are the biceps, brachialis, and triceps.

> In the upper leg, the muscles responsible for flexing and extending the limb at the knee are the hamstrings (biceps femoris, semimembranosus and semitendonosus muscles), the gastrocnemius (also affects foot movement), and the quadriceps femoris.

The lower part of the limbs involves two long narrow bones (Radius and Ulna in the forearm, and Tibia and Fibula in the lower leg), along with bones for the wrists (carpals) and ankles/heels (tarsals), and of course, the bones of the hands and feet (metcarpals and metatarsals) and our five fingers and toes (Phalanges). Of course, these all have associated joints, tissues, muscles and ligaments to permit their functioning.

> In the lower arm, the two bones and muscles allow a reasonable degree of twisting (pronation and supination) between the hand and the elbow. The

proximal and distal radioulnar joints make such movement possible. This movement is controlled by the pronator teres and supinator muscles.

In the lower leg, the heaviest bone (Tibia) bears the weight of our bodies and transfers the weight to our feet, while the Fibula provides for additional stability and strength. The muscles of the lower leg allow us to flex and extend these limbs, but the muscles are far more powerful than in the arm, because their purpose is for moving the weight of the body in whatever direction we want to go (whether running for a touchdown or leaping to dunk a basketball). In both limbs, the two bones are joined with smaller bones which form the wrists and ankles.

The small bones of the wrist and their respective joints, tendons, and muscles allow the hand-wrist to move in a reduced ball-and-socket motion (condyloid joint), which permits flexion, extension, adduction, and abduction. Main muscles responsible for this movement are the flexors (carpi radialis and ulnaris) and the extensors (carpi radialis longus and brevis, and carpi ulnaris). The flexor and extensor retinaculum are tough bands of fiber stretching around the carpals, encasing them and providing stability and protection. Nerves and tendons pass through this area to the hands and fingers. Add the bones, joints, and small muscles of the hands and fingers, and the result is an amazing degree of dexterity, enabling us to pen a letter in detailed calligraphy, tap out tunes on a bongo drum, wiggle our fingers, play the piano, or signal to others on the freeway. We are able to move and control our fingers and thumbs individually, and opposing thumbs give us the ability to grasp and manipulate objects with great finesse and accuracy.

Although a similar number of bones make up the foot, their shape and joinery differs a bit to support the function of weight bearing and locomotion.

Simply put, our feet (not our boots) are made for walking…and stomping, hopping, jumping, pedaling, running, sliding into home, kicking field goals, and tip-toeing through the tulips. Our ankles are actually hinge joints, and the bone and muscle structures of our feet clearly set these apart from their upper body counterparts. We don't need five toes to walk (although our toes do assist with balance, we *can* manage without them – in fact, people who lose their thumbs often opt to have surgery to harvest a great toe to create a replacement thumb.). Our feet and toes are made to flex with our weight, literally standing up to the pressure and the stress as we run along, hopping, skipping, and jumping, and they support us in body balance. In fact, the entire weight of our bodies can be concentrated on just our toes if we pivot our weight forward and push up. About the only thing we typically manipulate with our feet is wiggling our way into a pair of socks or shoes.[3] The main muscles affecting movement in the joints of the ankle, foot, and toes are the anterior tibialis, soleus, and gastrocnemius. The long tendons crossing the ankle are also protected by synovial sheaths and strong ligament tissue.

While the skeletal and muscular structure of our limbs is similar in many ways, the size of the limbs and muscles, along with articulating joints and numerous tendons and ligaments, are really suited to support two very different overall functions – that of working our way through the world (arms and hands) and walking our way through the world (legs and feet). Table 1 summarize the 31 muscles of the upper limbs and shoulder (excluding the 12 small muscles of the hand) and Table 2 summarize the 34 muscles of the hip involving thigh motion and those of the lower limbs (excluding 11 small muscles intrinsic to the foot).

[3] Although there is at least one armless young man I am aware of who taught himself to play a stringed instrument with his feet.

Table 1: Muscles of the Human Arm/Hand[4]

	Muscle	Origin and Insertion Points
Shoulder Motion	Trapezius	Occipital Bone, Vertebrae to Clavicle, Scapula
	Rhomboideus Major and Minor	Vertebrae to Scapula
	Levator Scapulae	Vertebrae to Scapula
	Pectoralis Minor	Ribs to Scapula
	Serratus Anterior	Ribs to Scapula
	Subclavius	First rib to Clavicle
Upper Arm Motion	Pectoralis Major	Clavicle, Sternum, Ribs to Humerus
	Latissmus Dorsi	Vertebrae to Humerus
	Deltoid	Clavicle, Scapula to Humerus
	Supraspinatus	Scapula to Humerus
	Infraspinatus	Scapula to Humerus
	Subscapularis	Scapula to Humerus
	Teres Major and Minor	Scapula to Humerus
	Coracobrachialis	Scapula to Humerus
Forearm Motion	Biceps Brachii	Scapula to Radius
	Brachialis	Humerus to Ulna
	Triceps Brachii	Scapula, Humerus to Ulna
	Anconeus	Humerus to Ulna
	Brachioradialis	Humerus to Radius
Wrist, Hand, and Finger Motions	Multiple deep and superficial muscles are responsible for the fine movements in the wrist, hand, and the fingers. In addition to these listed, there are twelve small muscles intrinsic to the hand.	
Anterior Superficial	Pronator Teres	Humerus, Ulna to Radius
	Flexor Carpi Radialis	Humerus to Second and Third Metacarpals
	Palmarus Longus	Humerus to Palmar Aponeurosis
	Flexor Carpi Ulnaris	Humerus, Ulna to Fifth Metatarsal, Pisiform
	Flexor Digitorum Superficialis	Humerus, Ulna, Radius to Second through Fifth fingers
Anterior Deep	Flexor Digitorum Profundus	Interosseous Membrane, Ulna to Second through Fifth fingers
	Flexor Pollicis Longus	Interosseous Membrane, Radius to Thumb
	Pronator Quadratus	Ulna to Radius
Posterior Superficial	Extensor Carpi Radialis Longus	Humerus to Second Metacarpal
	Extensor Carpi Radialis Brevis	Humerus to Third Metacarpal
	Extensor Digitorum Communis	Humerus to Second through Fifth fingers
	Extensor Digiti Minimi	Tendon of Extensor Digitorum Communis to Fifth finger
	Extensor Carpi Ulnaris	Humerus to Fifth Metacarpal
Posterior Deep	Supinator	Humerus to Radius
	Abductor Pollicis Longus	Radius, Ulna, Interosseous Membrane to First Metacarpal
	Extensor Pollicis Brevis	Radius, Interosseous Membrane to Thumb
	Extensor Pollicis Longus	Elna, Interosseous Membrane to Thumb
	Extensor Indicis	Ulna, Interosseous Membrane to Second Finger

[4] From Anatomy & Physiology, Second Edition, Lippincott Williams & Wilkins, 2002.

Table 2: Muscles of the Human Leg/Foot[5]

	Muscle	Origin and Insertion Points
Hip/Thigh/Knee Motion	Iliopsoas	First Thoracic and all Lumbar Vertebrae and Iliacus to Femur
	Gluteus Maximus	Ilium, Sacrum, Coccyx to Femur and Iliotibial Band
	Gluteus Medius	Ilium to Femur
	Gluteus Minimus	Ilium to Femur
	Tensor Fasciae Latae	Iliac Crest/Spine to Iliotibial Band
	Piriformis	Sacrum to Femur
	Obturator Internus	Obturator Membrane (inner surface) to Femur
	Obturator Externus	Obturator Membrane (outer surface) to Femur
	Gemellus Superior	Ischial Spine to Femur
	Gemellus Inferior	Ischial Tubercle to Femur
	Quadratus Femoris	Ischial Tubercle to Femur
	Adductor Magnus	Pubis, Ischial Tubercle to Femur
	Adductor Longus	Pubis to Femur
	Adductor Brevis	Pubis to Femur
	Pectineus	Pubis to Femur
	Gracilis	Pubis, Pubic Arch to Tibia
Anterior Compartment	Sartorius	Iliac Spine to Tibia
	Quadraceps Femoris	Ilium, Femur to Tibia
Hamstring Group	Biceps Femoris	Ischial Tubercle to Fibula, Tibia
	Semitendonosis	Ischial Tubercle to Tibia
	Semimembranosus	Ishical Tubercle to Tibia
Foot/Toe Motion	**In addition to these listed, there are eleven muscles intrinsic to the foot.**	
Anterior Compartment	Tibialis Anterior	Tibia, Interosseous Membrane to Tarsals and First Metatarsal
	Extensor Hallucis Longus	Fibula, Interosseous Membrane to Great Toe
	Extensor Digitorum Longus	Tibia, Fibula, Interosseous Membrane to Second through Fifth Toes
	Peroneuous Tertius	Fibula, Interosseous Membrane to Fifth Metatarsal
Lateral Compartment	Peroneus Longus	Fibula to First Metatarsal, Medial Cuneiform
	Peroneus Brevis	Fibula to Fifth Metatarsal
Posterior Compartment	Gastrocnemius	Femur to Calcaneus
	Soleus	Fibula, Tibia to Calcaneus
	Plantaris	Femur to Calcaneus
	Popleteus	Femur to Tibia
	Flexor Hallicus Longus	Fibula to Great Toe
	Flexor Digitorum Longus	Tibia to Second Through Fifth toes
	Tibialis Posterior	Tibia, Fibula to five Tarsals and Second through Fourth Metatarsals

[5] From Anatomy & Physiology, Second Edition, Lippincott Williams & Wilkins, 2002.

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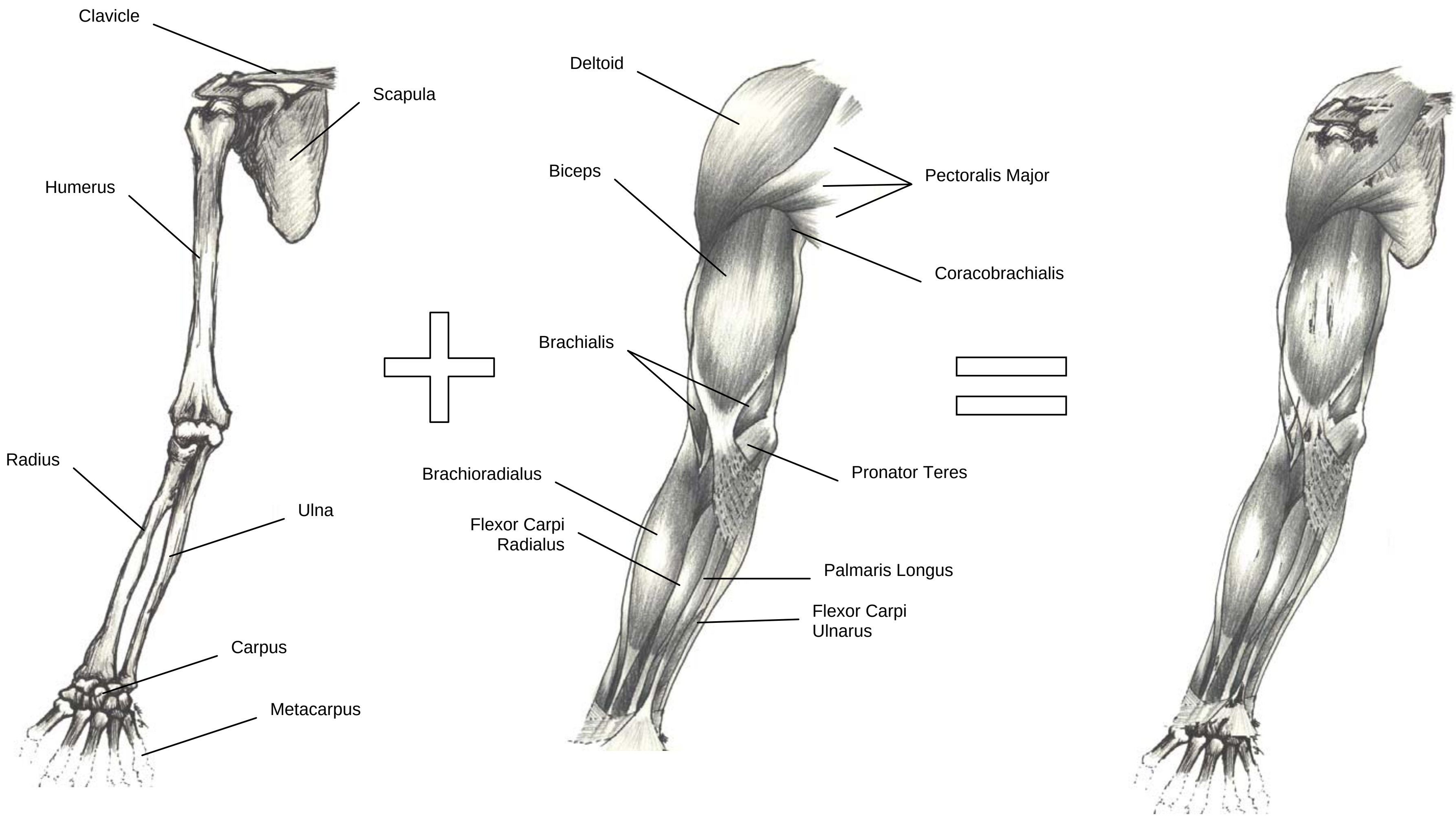

Figure 1: Right Arm, Anterior View

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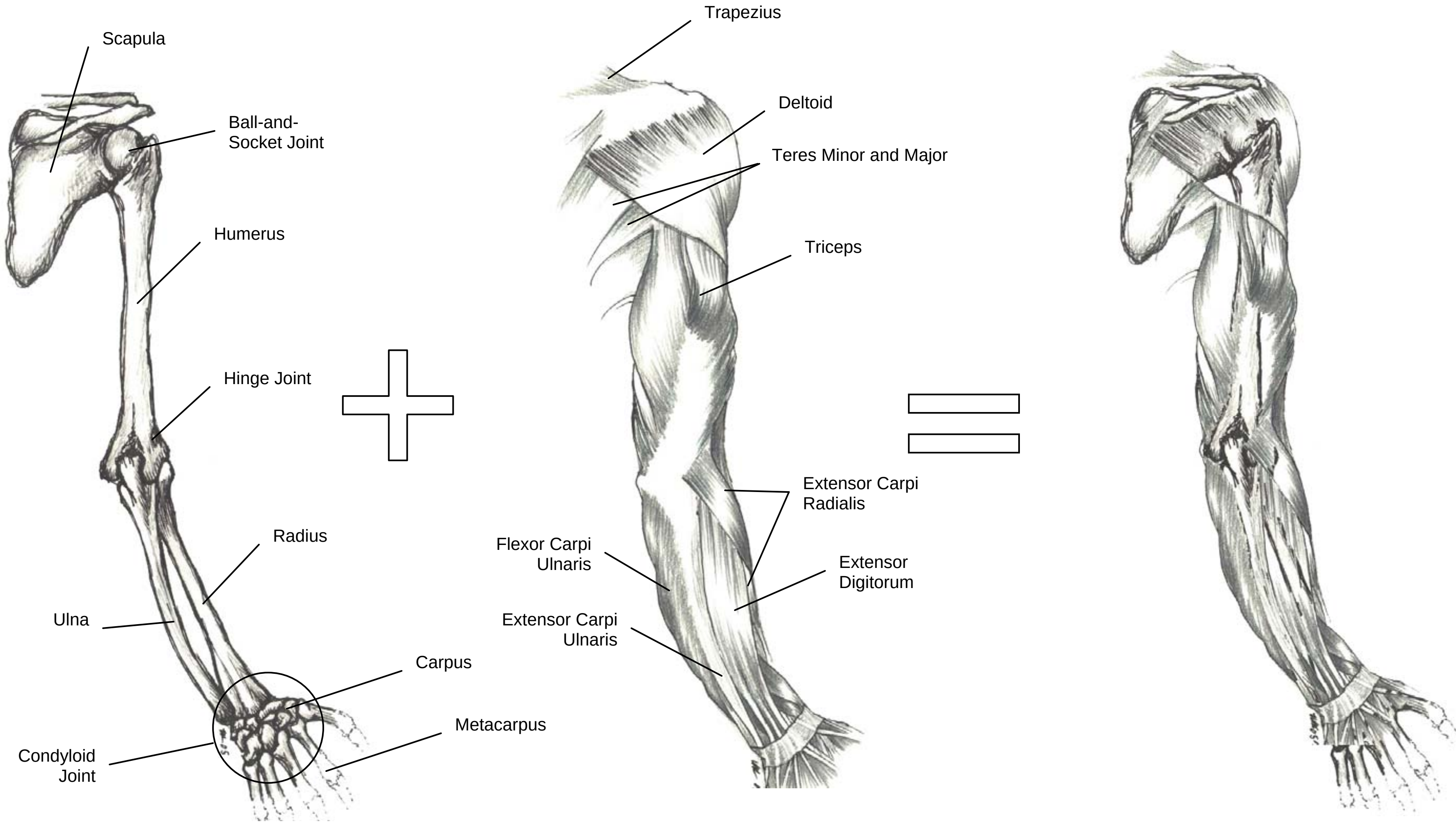

Figure 2: Right Arm, Posterior View

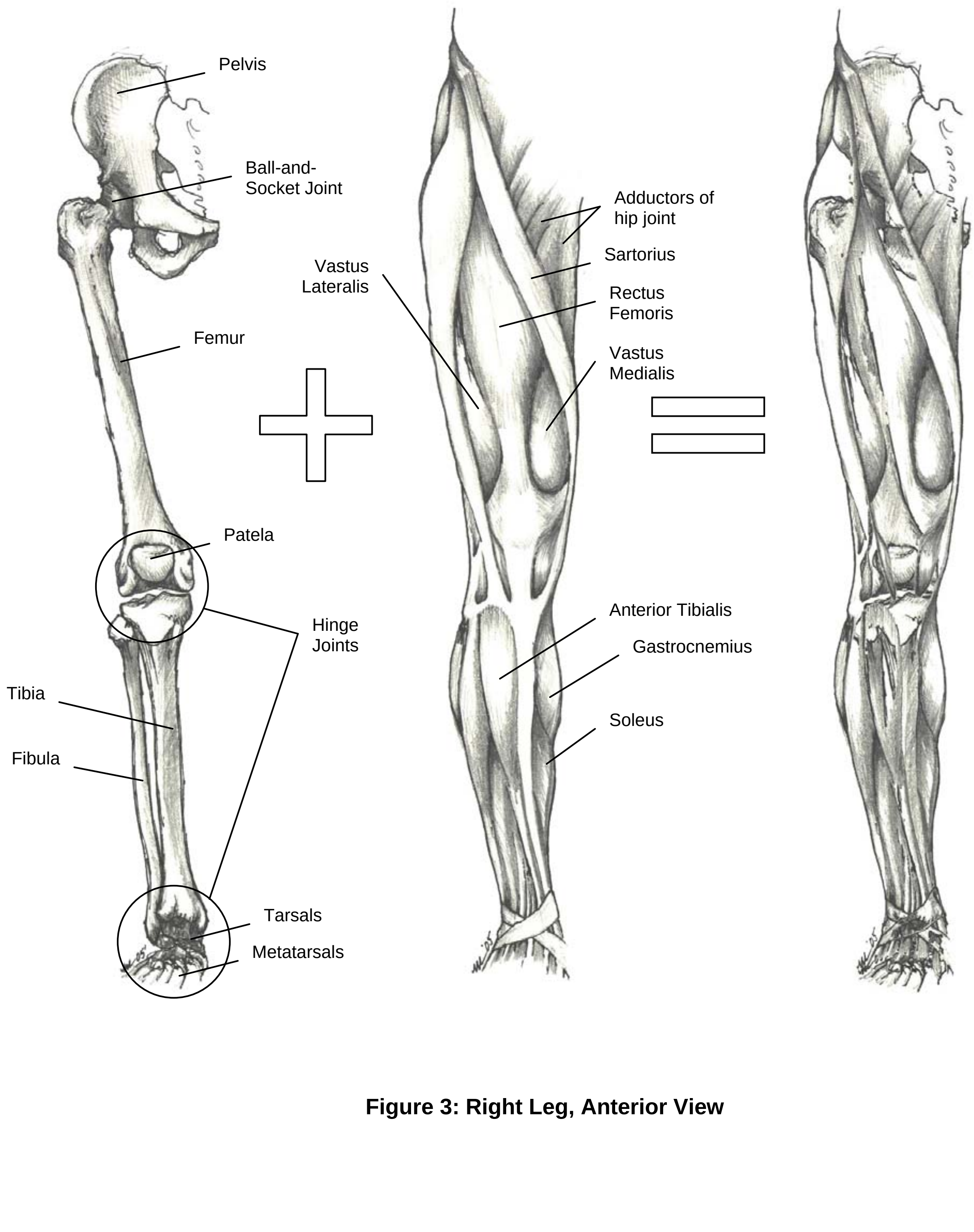

Figure 3: Right Leg, Anterior View

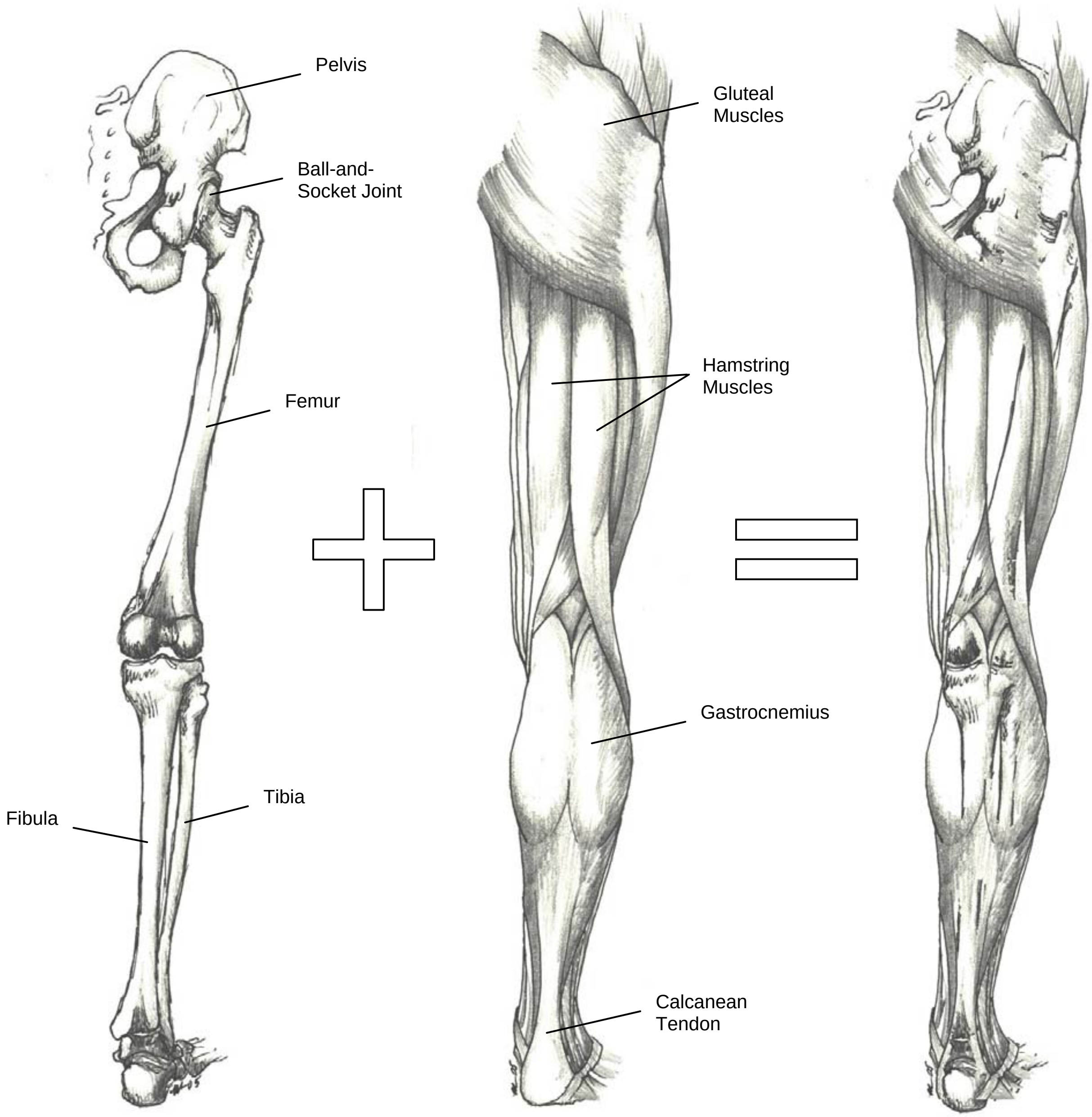

Figure 4: Right Leg, Posterior View

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