Bone

Let's get back in construction mode. For your new body to acquire proper mobility and stability, it will require a structural compound which, when shaped and linked together, will provide leverage for muscles and space within your tissues. In other words, you're going to need some bones.

Types of Bone

Our blueprints call for 206 bones to comprise your skeleton. Approximately 175 will be involved with voluntary motion. We'll build you as planned, but it's not unusual for a person to have an extra or a missing rib, vertebra, phalanx or other bone.

Your bones will be built into several types—long, short, flat, irregular and sesamoid (4.1). Your femurs and humeri are examples of long bones, while the cube-shaped bones of your hands and feet are short bones. Flat bones include your sternum and ilium; irregular bones include the bones of your face and the vertebrae. A bone embedded in tendon, such as your patella, is a sesamoid bone.

The skeleton is divided into two sections: the axial skeleton and the appendicular skeleton. The axial skeleton is the skeleton's center and includes the cranium, vertebral column, ribs, sternum and hyoid. The appendicular ("appendages") skeleton is composed of the arms and legs, pectoral girdle (scapulae and clavicles) and pelvic girdle (hips). These skeletal divisions will help our conversation on gait and posture.

Functions of Bone

Your bones will serve many roles—mechanical and metabolic. We'll focus here on the ones involved chiefly with movement and support.

Operating as a unified skeleton, your bones will form a portion of the structural framework that supports your body and serve as spacers for surrounding tissues. In doing so, they will help to maintain your shape. Do a few jumping jacks (4.2) and—thanks to your rigid bones—you won't flatten out like a crepe with your first bounce (4.3).

They also must be able to bear the weight of your body and more. You may not notice it when standing, but continue doing jumping jacks and you'll feel how each body part endures the load and momentum of the portions above it. Tolerating this type of compressive force is what bones were designed for and, when joined with fascia's resistance to tensile forces, your body becomes a unique and dynamically balanced organism.

Many of your body's tissues and structures will need a mooring. For this, your bones support your tissues by...
offering reliable attachment sites to muscles (via tendons), fasciae and organs (4.4).

Interestingly, notice that all five of the above-mentioned mechanical tasks can be seen in the poles of a circus tent. They form the tent’s framework; create space between the tent’s top, bottom and sides; hold its shape; carry its weight; and give its sheets, wires and banners a place to attach.)

Finally, bones will serve as levers for motion. Your muscles use the rigidity of bones in the same way you use the leverage offered by a screwdriver, nutcracker or scissors. The muscle contracts, the bone (acting as a lever) is pulled and movement occurs at that part of your body. Without the stiffness of your bones, your mobility would dwindle to a slither (4.5).

Since this is a rather impressive list of functions your bones will need to perform, let’s go to the lab and figure out how we’ll devise their structure.

Let’s Build a Bone

Structure of Bone

The physical requirements of your bones will be nothing short of amazing to be strong and yet light as wood! You might assume that the relative toughness of a bone must be equally redundant, simply just cells dealing with some stress.

Recipe for Building a Bone

1 part (10%) of bone **bone cells** - a combination of osteoblasts, osteocytes and osteoclasts. These are specialized connective tissue cells found only in bone. Osteoblasts build-up bone tissue by secreting collagen into the surrounding extracellular matrix. When they become trapped in their own secretion, osteoblasts become osteocytes. As the primary cells in bone tissue, osteocytes maintain daily metabolism by exchanging nutrients and waste with the blood. Osteoclasts are huge cells that break down and clear away extracellular matrix.

4 parts (organic material) comprised of collagen fibers, that provide a maximum, but essential, amount of tensile strength to your bone. More importantly, its woven, stringy arrangement traps minerals used for stiffness and density.

6 parts (inorganic material) which is mostly mineral salts made of calcium phosphate. This solidifying agent is an insoluble compound that impregnates the extracellular matrix giving bone—the hardest type of connective tissue—its rigidity.

2 parts (20%) water. Even in the densest part of your anatomy, water is still a critical component. (Please keep in mind that all of these ingredient percentages will differ with age, activity level and other individual characteristics.)

Here, of course, we’re building you from scratch, but in “real life” your compression tissues (bones and cartilage) develop in utero and then throughout infancy and into adulthood. The weight and stress experienced by these tissues as you mature is what mediates and directs their growth.
Major Parts of a Bone

A bone light machine works its magic on your developing bone (4.6). Let's examine compact bone, the densely packed type of bone tissue that makes up the bulk of the diaphysis (shaft) of long bones such as the femur (4.7). As a bone's thinnest outer layer, it provides protection and resists the stress produced by weight and movement, not coincidentally, three times skin to a tree trunk when magnified seven thousand times (4.8).

Other portions of a bone's insides are comprised of spongy bone tissue. Its arrangement might appear haphazard, but its little beams (trabeculae) act like a house for resisting stress and transferring force. Once your femur is up and running (literally), this porous design will rearrange itself along lines of stress to maximize its supportive capabilities.

Persisting in the membrane on the outside surface of the femur is part of the tensile network of fascia described on page 41.

Wolff's Law

Your bones are constantly being remodeled—breaking down old tissue and replacing it with new. At this very moment, probably 3% of your total bone mass is being recycled. But this occurs at different rates throughout the body. For instance, the distal end of your femur is turned new every four months, but to completely replace portions of your femoral shaft will require your entire adulthood.

How do your bones know when and how to be remodeled? From the messages you send them: exercise and they will become stronger; rest yourself on the coach all winter and don't be surprised when they weaken.

When stressed, many materials will diminish under the strain, but not bone. Wolff's Law, utilizing the piezoelectric effect, states that bone tissue, when put under stress, will thicken and form a stronger, osseous matrix. Conversely, when stress is removed, bone will rip down and reabsorb unused material. "Use it or lose it," for real.

You might not have noticed, but this physiological law is evident in your client, Tony. His tibial tuberosity and other prominent bony landmarks, for instance, have enlarged due to the tensile (pulling) demands of his tendons. Too much of a good thing, however, has occurred in his neck. The excessive pressure he's placed on his displaced cervical vertebrae (seen through an X-ray, right) has fostered the growth of small bone spurs, unhealthy buildups of calcium on the bony surfaces.
Stacked and Compressed?

Let's clear up two common misconceptions about your bones. The first belief is that your skeleton is a tower of stacked and balanced building blocks. The problem with this concept is that bones can't actually maintain vertical assemblage, let alone hold themselves together. Their articular ends are not squared off, but include rounded and uneven surfaces. This explains why a classroom skeleton hangs from a hook or sits on a stand and is fastened together with bolts and wires. Bones don't stack because they can't (below).

If this is true, how then does your skeleton bear weight and form a structural framework? A hint—it receives help from surrounding fascial tissues. This leads to the second fallacy, which is that the body is basically a compression structure comprised of stacked units that bear weight down on the parts below. The theory goes like this: The head sits on the neck; they press down on the trunk; the head, neck and trunk all rest on the pelvis and so forth to the feet. Yes, your feet take the brunt of the body's pressures and strains, yet these do not pass from head to toe only through your bones.

It turns out that the body is less like a brick wall and more like a Tensegrity toy (above). This ingenious device demonstrates how dowel rods (bones) and rubber bands (fasciae) can combine their qualities of tension and compression to produce a dynamic framework (below; right). This teamwork occurs in the body as well, with the placement of the bones balanced by the tensile forces of the fasciae (and their enveloped muscle bellies).

Without fascial support, bones collapse.

† You can purchase your own toy at www.tensegriteach.com.

* Based on a design by Tom Flemons. Check out his website (www.intensiondesigns.com) for more products and discussion about tensegrity.

Your lower appendage (as well as the rest of you) is like a giant Tensegrity contraption.
Cartilage

Your newly fabricated femur (page 38) will ultimately be placed end-to-end with your tibia to form your knee (tibiofemoral) joint. To prevent these surfaces from grinding away on each other, we'll need to attach some bumpers onto the end of your bones.

Of course, not just any old fender will do. We need to furnish your joints with a material that will provide a smooth, low-friction surface for movement, endure tremendous loading—almost the entire weight of your body will pass through the knee—and be resilient enough to return to its original shape after being compressed. By blending the properties of rubber and soft plastic into an organic, living tissue, we'll get precisely what the body demands—cartilage.

As a dense web of collagen and elastin fibers embedded in a gelatinous—not watery—ground substance, cartilage can endure significantly more stress than dense connective tissues such as ligaments or tendons. Unfortunately, it has a poor blood supply, which limits its ability to heal after an injury.

We have three types of cartilage to choose from:

- **Fibrocartilage**, the toughest form, has a composition that affords great tensile strength (being pulled and stretched). It's a perfect material for intervertebral discs, menisci of the knee (4.9), labra of the shoulders and acetabula of the hips.

- **Elastic cartilage** is the most pliable type. It is best for maintaining the shape of structures such as your external ears (4.10), eustachian tubes and epiglottis (the flap that covers your trachea when swallowing).

- **Hyaline cartilage**, also known as articular cartilage, is the most abundant form in the body and is found in the majority of joints involved with motion. Located on bones' articulating surfaces, hyaline cartilage forms the load-bearing surfaces of joints. (It's the shiny, opaque stuff at the ends of chicken bones.) It may only be 1–7 mm thick, but thanks to its supportive yet flexible composition, it can reduce friction and absorb shock. You guessed it: it's the most suitable cartilage for the articulating end of your femur at the knee joint (4.11).

4.9 A disc (above, left) and a meniscus (above, right), examples of fibrocartilage.

4.10 Elastic cartilage holds the ear in shape.

4.11 Hyaline cartilage at the end of the femur.

But how should we attach the hyaline cartilage? Glue? Nails? The body lends some insight. If we recall that bone and cartilage are both connective tissues—albeit very dense ones—they could fuse together to form an incredibly strong bond. And that's what occurs, with cartilage actually calcifying as it anchors itself into bone tissue (4.12).

4.12 A cross section of hyaline cartilage and bone.