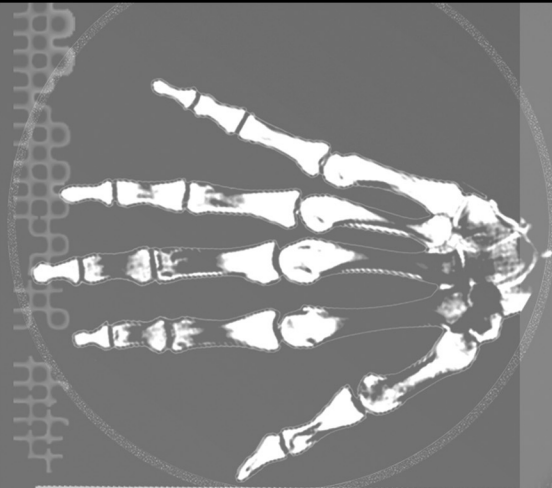


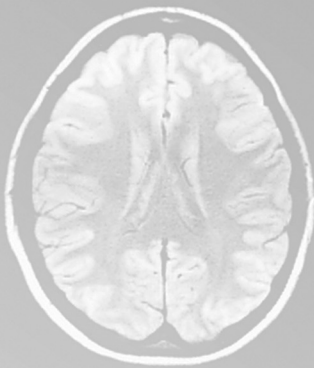
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## HUMAN ANATOMY & PHYSIOLOGY



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Dawn M. Hudson

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BACKGROUND

## The Skeletal System

The adult human skeleton consists of 206 bones. (Young children have closer to 300 bones, since some bones in the skull and other places in the body have not yet fused together.) Bones are held together by **ligaments**, which are stretchy pieces of connective tissue. The bones are **ossified**, or hardened, by calcium salts around a solid matrix. Bones do more than just support us. Bones protect our most vital organs. They provide a place for muscles to attach and move us. They also store calcium for when we need it and make red blood cells. With the exception of the hyoid bone where the tongue muscles attach, all other bones touch or articulate with other bones even if there is cartilage between them for protection. The largest bone in the human body is the femur, or thigh bone. The smallest bones in the body are the **auditory ossicles**, or ear bones, in the middle ear.



A long bone has several parts to it, including the main, long part of the bone itself, called the **diaphysis**, or the shaft. The ends of a long bone are called the **epiphyses**. Inside bone, there is dense or compact bone that is tightly packed. There is also spongy or cancellous bone toward the ends and outside, which has air spaces and resembles a porous sponge. This portion of the bone allows blood to easily flow in and out of its cavities, since this is

also the area making the red blood cells. Spongy bone forms the **marrow** of the bone. You may have noticed spongy bone when looking at chicken bones. The compact bone provides strength, and canals within it allow nutrients to get into its tightly woven spaces.

**The hyoid bone is the only bone that does not articulate with any others. Many times it is broken in cases of strangulation.**

Bones can be used to determine a person's age at death (by noting lengths of bones compared to the gender), a person's gender (by measuring various processes on the bones in addition to noting the size of the pelvic bones), a person's race (by observing facial protuberances including eyebrow ridges), and some diseases a person may have had, including bone degeneration from **osteoporosis**. It is interesting to note human body proportions that parallel the skeletal system. Did you know the length of your radius (forearm) is equal to the length of your foot? The measurement from fingertip to fingertip with your arms spread wide is the same as your height. Try it and see!

When learning bone names, there are several hints to make some of them easier to learn. The radius and ulna of the arm are easily confused since they twist over each other. If you remember that the radius is on the thumb side of the hand and that the ulna is on the little finger side of the hand, it will make them

**Urban Legends**  
**Alert: Popping**  
**knuckles will**  
**give you**  
**arthritis.**  
**Not true!**

easier to remember. Carpal bones are wrist bones. This is easy to remember since most people have heard of carpal tunnel syndrome, which is a repetitive motion injury. The tibia and fibula, two lower leg bones, are often confused. However, if you notice that the smaller of the two is the fibula, it may remind you to “tell a little fibula.” The tibia boasts a ridge, which women will relate to since they often cut their legs shaving due to the shape of this bone.

Joints between the bones are filled with synovial fluid or have cartilage (gristle) to allow the bones to freely move around one another and not grind down. A common urban legend is that popping your knuckles will give you arthritis. This is not true! So far, no studies have proven that popping knuckles causes arthritis—or makes your joints larger, for that matter. When you “pop” your knuckles, you are actually compressing air found in the joint cavity along with the synovial fluid. It takes a period of time before the air comes out of the solution for you to be able to pop your knuckles again.

We should really learn to appreciate our bones because, in nature, having bones is actually a rarity. If you look at all the animals on Earth, 97% of them are invertebrates and lack true bones! Arthropods such as insects are the most abundant invertebrates; they have an exoskeleton instead of bones.



## Student Lab: Calcium and Bone Strength

How true is it that calcium (such as that found in milk and dairy products) is good for your bones? This lab will answer that question along with other questions you may have about bones and bone strength and the factors that might have an influence on them. You will also be given an opportunity to choose a liquid to test on the bone to see if it affects its strength.

### Materials

- Goggles
- 3 fresh (non-cooked) chicken bones (legs)
- Vinegar (acetic acid)
- Gloves
- Water
- Graduated cylinder
- Aprons
- Protractor
- Jars with lids (3 for every set of lab partners)
- Student chosen liquids
- Bleach

### Special Safety Considerations

Put on goggles, gloves, and an apron for working with acetic acid and to protect against possible salmonella contamination from handling raw chicken. Be careful handling bones; if they break, they can splinter and puncture your skin.

### Procedure

1. Obtain three jars for you and your lab partner. Depending on the size of the chicken legs and the size of the jars, place equal volumes of water, acetic acid, or a liquid of your choice into each of the jars—enough to cover the chicken bone fully. For example, in Jar A (the control) there will be one chicken leg and “X” amount of water. In Jar B, there will be one chicken leg and “X” amount (identical in volume to the water) of acetic acid. In Jar C, there will be one chicken lag and “X” amount (identical in volume to the water) of the liquid you chose.

2. Measure the bend of chicken leg A with a protractor. If the leg does not bend at all, record zero degrees. Repeat for chicken legs B and C.
  - a. Degree of bend in chicken leg A \_\_\_\_\_
  - b. Degree of bend in chicken leg B \_\_\_\_\_
  - c. Degree of bend in chicken leg C \_\_\_\_\_
  
3. Place chicken leg A into the premeasured water in Jar A. Place chicken leg B into the premeasured acetic acid in Jar B. Place chicken leg C into the premeasured student-chosen liquid in Jar C.
  
4. Predict what will happen to the chicken legs in the jars after they have been sitting for five days.
  - a. Chicken leg A will \_\_\_\_\_.
  - b. Chicken leg B will \_\_\_\_\_.
  - c. Chicken leg C will \_\_\_\_\_.
  
5. Each day over the next school week, and after the weekend (note that the chart skips the days you are not at school), measure the degree of bend of each of the chicken legs and record your data in the chart.

DEGREE OF BEND IN CHICKEN LEG BONE

Degree of bend as measured with a protractor	Day 1	Day 2	Day 3	Day 4	Day 5	Day 8
Leg "A" (Control) in water						
Leg "B" (Experimental) in acetic acid						
Leg "C" (Experimental) in _____						

## Conclusions

1. What liquid did you and your partner choose to soak chicken bone C in?
2. Why did you choose that particular liquid?
3. Compare and contrast the three bones placed in the various liquids.
4. Why do you think the liquids had the effect they did on the bones?
5. Were you correct in your predictions in the lab? Why or why not?

## Lab Extension

1. Research the chemical components (organic and other) that make up the chicken leg bone. Show the chemical equation for what is happening in this experiment for both the acetic acid and the liquid you chose to use.
2. Obtain a chicken foot from the butcher at a grocery store. You should be able to pull on the tendons of the foot, which will move the toes of the chicken. This is similar to the way our tendons connect our muscles and bones together.



MATH CONNECTION

## Making Height Estimations from Bones

Anthropologists can estimate the height of an individual by measuring that person's bones. The femur is most commonly used, but if it is unavailable other bones, such as the humerus, radius, or tibia, can be used with a different formula to make the same prediction.

### Materials

- Tape measure or string
- Ruler or meter stick

### Procedure

1. Measure the length of your femur in centimeters using either a tape measure or a string. (Measure from the top of the leg where it goes into the pelvis to the knee.) Hold the tape measure or string up against a ruler or a meter stick to get the measurement in centimeters.

Femur length: \_\_\_\_\_ cm

2. To predict your height, use the formula below, which is based on your gender.

a. Male:  $(2.32 \times \text{length of femur in cm}) + 65.53 \text{ cm} \pm 3.94 \text{ cm}$

b. Female:  $(2.47 \times \text{length of femur in cm}) + 54.10 \text{ cm} \pm 3.72 \text{ cm}$

3. What is your actual height in centimeters?

Height in inches: \_\_\_\_\_  $2.54 \text{ cm} =$  \_\_\_\_\_ cm

4. How close was the predicted value to your actual height? (Be sure to add or subtract the error value at the end before calculating.) \_\_\_\_\_ cm

5. Measure the length of your humerus by using the length of the arm from the shoulder joint to the medial epicondyle of the elbow.

Humerus length: \_\_\_\_\_ cm

6. To predict your height, use the formula below, which is based on your gender.
  - a. Male:  $(2.97 \times \text{length of humerus}) + 73.5 \text{ cm} \pm 3.94 \text{ cm}$
  - b. Female:  $(3.14 \times \text{length of humerus}) + 65 \text{ cm} \pm 3.72 \text{ cm}$
7. How close was the predicted value to your actual height? (Be sure to add or subtract the error value at the end before calculating.) \_\_\_\_\_ cm
8. Measure the length of your radius by using the length of the arm from the wrist bone on the thumb side of the forearm to the elbow.  
  
Radius length: \_\_\_\_\_ cm
9. To predict your height, use the formula below, which is based on your gender.
  - a. Male:  $(3.7 \times \text{length of radius}) + 80.5 \text{ cm} \pm 3.94 \text{ cm}$
  - b. Female:  $(3.9 \times \text{length of radius}) + 73.41 \text{ cm} \pm 3.72 \text{ cm}$
10. How close was the predicted value to your actual height? (Be sure to add or subtract the error value at the end before calculating.) \_\_\_\_\_ cm
11. Measure the length of your tibia by using the length of the leg from the knee to the ankle.
  - a. Tibia length: \_\_\_\_\_ cm
12. To predict your height, use the formula below, which is based on your gender.
  - a. Male:  $(2.4 \times \text{length of tibia}) + 81.79 \text{ cm} \pm 3.94 \text{ cm}$
  - b. Female:  $(2.5 \times \text{length of tibia}) + 72.64 \text{ cm} \pm 3.72 \text{ cm}$
13. How close was the predicted value to your actual height? (Be sure to add or subtract the error value at the end before calculating.) \_\_\_\_\_ cm

## Conclusions

1. An anthropologist finds a 46-cm tibia in a shallow grave in a remote area. There was a missing person's report for a young lady (5 feet, 5 inches tall) one week ago. Could this bone possibly belong to her? Why or why not?
  
2. Which of the methods for determining your own height (measuring your femur, tibia, humerus, or radius) was the most accurate?
  
3. Why do you think that this method led to the closest measurement?
  
4. Compare your data to that of ten other people in the class. Which methods did your classmates find the most accurate for determining height? Did their findings agree with yours? Why do you believe this is so?

## Extension

Gravity has an effect on our bodies other than to cause us to have weight on Earth. The vertebrae in our backs have discs between them that cushion and aid the gliding effects of the bones over one another in the back. Since these discs are not solid structures, they may change or degenerate over time. This is the reason why some people become shorter as they age. During the course of a day, however, even a young person can have different heights depending on the compression of the spinal column.

1. Measure your height just before you go to bed in the evening.

Height in cm: \_\_\_\_\_

2. Measure your height just as you rise the next morning and have not moved other than to stand next to the bed to be measured.

Height in cm: \_\_\_\_\_

3. Did you notice a difference in your height? Explain.

4. Was the difference more or less significant than you expected?

5. Compare the data you collected to the data of ten of your classmates. Input all the before, after, and difference values into a spreadsheet and then construct a graph that best fits the data.

6. Compare this data to that of someone who is about 20 years older than you. If possible, also compare this data to that of someone who is 40 or more years older than you. Also compare the data of tall people to the data of shorter people. Are there any differences?

7. Present your findings to the class.



EXPLORE

## Exploring Bone Names

Many students find it difficult to memorize the many different names of bones, joints, movement types, cranial bones, and bony processes. The following game, which is similar to bingo, is an easy (and fun) way to review. Choose 24 bone names, joint types, movements, cranial bones, processes, and so forth from a list provided by your teacher. Everyone's card will be different; in fact, some will not even have all the same words on them, much less in the same spot on the game board. The center spot, just as in bingo, will be the "free space" designated by the skull. Your teacher will have a cup filled with the words that have been written for you to choose from. Your teacher will call out either the common name for that particular bone, point to it on a diagram or skeleton, or give its definition. It is then up to you to cover that word if you have it. For example, if your teacher calls out the clue "collar bone," you must then cover the word *clavicle*. Another example would be the clue "knee cap," which is referring to the *patella*. Yell out "bones!" (instead of yelling "bingo!") when you have covered five in a row either across, up and down, or diagonally.


### Extension

To make the game more difficult to play, the student who wins and shouts out "bones!" must call out the definition of each of the words covered on his or her card (or point out the bones on a skeleton).

### Variation

To make it more interesting, the game can be played so that the winning combination is a shape or a letter formed on the board. For instance, the winning shape may be a large "picture frame" (all 16 spaces around the outside of the card covered), the letter "T" in any direction, the letter "I" in any direction, a small "picture frame" (the 8 spaces around the free space), or any other variation.

# B O N E S



BACKGROUND

## The Muscular System

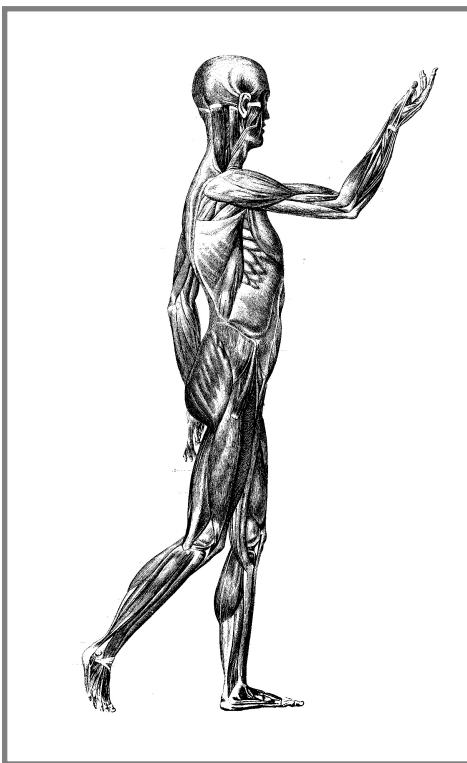
Did you know that scientists are still trying to agree on how many muscles are in the human body? One estimate is that there are anywhere from 656 to 850 muscles in the body. You may have heard it takes 43 muscles to make a frown, whereas it only takes 17 muscles to smile. When learning about the muscular system, there are many natural connections that can be made to physics and simple machines. Muscles act as levers when they pull on the tendons, which in turn pull on our bones. Basically, we are like marionettes as our muscles contract to pull and move our bones. To test this, wrap your hand around the top of your wrist so that your fingers end up on the bottom side of the wrist. Squeeze gently on the tendons and ligaments—making your fingers curl up as you do so. Our stretchy tendons and ligaments are what make us more or less limber or “double jointed” than others. But being “double jointed” is a misconception. It really means having stretchy tendons and ligaments—not double joints! By stretching to limber up your tendons and ligaments, you are actually making small tears in the muscle. As the muscle repairs itself, you gain some flexibility due to the muscle being a bit longer. This is also the reason why you might feel stiff after you have worked out.

**Being “double jointed” really means having stretchy tendons and ligaments—not double joints!**

The longest muscle in the body is the sartorius, which helps you to flex the hip and knee (in addition to doing the dance “the twist”). Another interesting

muscle, the soleus, lies on the side of the leg adjacent to the calf or gastrocnemius muscle. The soleus, when dissected away from the bone, resembles a filet of sole (fish). Many muscles (as with many bones) receive their names from their action, the bones above which they lay, their insertions, or even their general description. The tensor fascia latae muscle lies on the side of the thigh and helps to abduct the thigh. A good way to remember this muscle (which might sound like a good cup of cappuccino) is to picture lying on your side in front of a warm fire with a cappuccino sitting on the side of your leg. The more outrageous the mental picture, the easier it will be for you when it comes time to remember the names of hundreds of muscles.

Epicondylitis is a common muscular disorder usually known as “tennis elbow.” It is a result of repeated strain on the forearm, and it causes the muscle and tissue to swell. It can be caused from playing tennis, but other things can cause it, too. Often, school bus drivers without automatic bus door openers develop this disorder from constantly using their forearms to open and close the bus doors.





## Summary: Pulling Anatomy and Physiology Together

Construct a graphic organizer or a visual representation of how one system in anatomy is related to every other system through physiology. This visual representation could be a PowerPoint presentation, a large poster, or an original idea as long as connections are made between the systems. You will first need to work with your teacher to determine which system will be your primary focus and then branch out from there. Some systems may be a bit more difficult to relate to others, but you will find a relationship regardless!

The systems to be included are:

1. the integumentary system
2. the skeletal system
3. the muscular system
4. the nervous system
5. the endocrine system
6. the digestive system
7. the cardiovascular system
8. the immune system
9. the respiratory system
11. the urinary/excretory system
12. the reproductive system

5. surface area
6. It will need more plasma membrane.
7. The volume also increases.
8. a direct relationship
9. It decreases—meaning the cell has less surface area to feed itself.
10. The cell needs more food or oxygen than the plasma membrane can diffuse, and it also makes more waste (due to the increased volume inside) than can be exported.
11. the smallest cell—1 mm.
12. the smallest cell
13. It could divide.
14. the volume
15. larger
16. This might be difficult for students to grasp, but for any increase in the surface area, the amount is squared and the increase in volume is cubed. Using the variable  $x$  to represent any length value, we would say surface area equals  $x^2$  and volume equals  $x^3$ . When we double the length of  $x$  or make  $x = 2$  in this case, then  $(x^2) = 4 (2 \cdot 2)$  and the volume is  $(2^3) = 8$ . Students should notice that the volume is cubed and not tripled. Continuing this pattern, when  $x = 3$ ,  $(3^2) = 9$  and  $(3^3) = 27$ .

**Exploration Activity:**  
**Surface-Area-to-Volume Ratio**

*Materials:*

- A computer with Excel will be helpful for graphing and doing mathematical computations

Students will plug in their own values for these two situations, but the answers in the end will all be the same. As the surface area goes up, the volume goes up also, but in a greater amount.

## The Integumentary System

### Student Lab: Dermatoglyphics

*Materials:*

- Pencil
- Clear tape
- Sheet of paper

Decide how students will record cumulative data and communicate this to the class. Have students calculate percentages by dividing the total number of each type of fingerprint by the grand total of fingerprints taken.

If the data matches the human population as a whole, you should find that 60 percent are loops (left or right), 35 percent are whorls, and 5 percent are arches. This can vary depending on genetics. For example, in Australia, there are more people who have arches.

## The Skeletal System

### Student Lab: Calcium and Bone Strength

*Materials:*

- Fresh (non-cooked) chicken leg bones
- Goggles
- Aprons
- Gloves
- Acetic acid (10 percent solution) or vinegar
- Jars with lids
- Various liquids suggested by students
- Protractors
- Water
- 10 percent bleach water
- Graduated cylinder

If possible, conduct this lab on a Monday so that you will have a full school week in addition to the added

weekend to note measurements as the bones begin to change. Change the chart if you are unable to do this or wish to carry out the experiment for a longer period of time. If you would like to do an impressive demonstration for your students, use a turkey leg bone in acetic acid. Since it is longer than the chicken legs, you should be able to actually tie it into a knot once the acetic acid has had long enough to work on it!

Teacher preparation: Chicken will have to be stripped off the bones without cooking it, if possible. Tissue will be more viable if it is not cooked, and it will be able to more easily take up calcium from milk or other liquids students may choose to soak them in. Students could help do this, but caution them about using sharp knives or scalpels.

Students may soak their bones in any liquid (within reason) that they choose. They will also need to give their reasoning as to why they are choosing that particular liquid. Some ideas are as follows: milk, vitamin water, orange juice, calcium-enriched orange juice, syrup, diluted hydrochloric acid, bleach, hydrogen peroxide, calcium-enriched bottled water, honey, soapy water, ammonia, diluted nitric acid, and sodium hydroxide. Proper precautions should be taken when using strong acids or bases.

Special Safety Considerations: Goggles, gloves, and aprons should be worn to prevent acid from splashing up into the eyes or irritating the skin. Additionally, salmonella can be found in raw chicken, so any lab surfaces that come into contact with the chicken should be thoroughly wiped down with a 10 percent solution of bleach water. The bone, if it breaks, can splinter and puncture skin.

Chart answers will vary by student, but students should notice that the chicken bone in water never bends much (if at all) and hovers around the zero degree mark. The chicken bone in acetic acid (vinegar) will become more and more flexible the longer it soaks until it reaches a stopping point. The results for student liquids will vary.

Lab Extension: The vinegar is an acid that dissolves the calcium phosphate in the bones. Without the calcium, the bones become weaker and softer. Equations from student-chosen liquids will vary according to the liquids students have chosen.

### **Math Connection: Making Height Estimations from Bones**

#### **Procedure**

1–13. Answers will vary depending on student bone measurements and height.

#### **Conclusions**

1. The first step is to change the height of 5 feet, 5 inches into a metric measurement (65 inches  $2.54 = 165$  centimeters). Most likely, the bone does not belong to the missing woman because the bone would have belonged to someone very tall. The bone is probably from a male who was about 192 centimeters tall (75.59 inches or just over 6 feet, 3.5 inches tall) or from a female who was about 188 centimeters tall (74.01 inches or just over 6 feet, 2 inches tall).
2. Answers will vary.
3. Answers will vary.
4. Some possible sources of error include measuring the bones incorrectly, making mathematical errors, and so forth.

#### **Extension**

1–7. Answers will vary.

### **Exploration Activity: Exploring Bone Names**

Put bone names up on an overhead, a computer screen projector, a blackboard, and so forth. Possible names could include any of the 206 you wish your students to know in addition to the types of joints (including ball and socket, hinge, saddle, gliding, pivot, and so forth), and the bone or suture names of the cranium (including temporal, occipital, vomer, sagittal, and so forth). Cut out the names you chose

from a sheet of paper and place them into a cup from which to draw.

Note: The most important thing to remember is that the name drawn from the cup should not exactly match the clue given. If so, it would not be a helpful review. If the word drawn is *femur*, then the clue “thigh bone” should be called out, or it should be pointed to on a skeleton or on a skeleton diagram.

Prizes for the winners could include extra credit, free homework passes, recognition on a poster or during announcements, and so forth.

Other applications: This board may be adapted and used to review any of the systems in anatomy, including the muscular system, the nervous system, and the endocrine system.

## The Muscular System

### Student Lab: Exploring the Muscular System

#### Materials:

- Rubber bands measuring 11 cm in length and 1–2 mm in width
- Chair
- Toothpicks
- Newspaper
- Tissue paper
- Construction paper (papers to be folded)
- Bobby pins, hair pins, or paperclips
- Plastic knives
- Empty paper towel rolls
- Empty wrapping paper rolls
- Paper fasteners
- Long balloons
- Tape or rubber bands
- Mirror
- Exercise mat (if possible)
- Tennis ball
- Stopwatch
- Bowl of ice or cold water (optional)

1. Students should be able to see many of the facial muscles by doing this activity and look pretty silly while doing it, too!
2. Muscles act as levers. In this activity, there is not enough room for the lever to operate since the fulcrum is too close.
3. Once again, there is not enough room for the lever to operate.
4. The thigh muscles are not strong enough by themselves to overcome gravity.
5. The muscle does not have much of an angle, so it is like a short handle on a screwdriver that does not allow much leverage. To make it more difficult, the person holding his or her fists together should bend the arms. That way, the angle is decreased, which will make it harder to separate the hands since the force cannot overcome the angle.
6. Both events described will be difficult as long as the toothpick is kept at the first finger joint, because this does not allow enough leverage to break it. If the toothpick is moved down near the lower joints of the fingers, there will easily be enough leverage to break the toothpick.
7. Human muscles simply cannot be strong enough to overcome the folding of a sheet of paper that many times. This is a matter of thickness versus muscle size. Surprisingly to the students, it does not matter if they are trying to fold a newspaper this many times or a small, thin piece of tissue paper. The result is the same.
8. Students will have trouble doing this because their tendons will not be flexible enough to allow this movement.
9. Even when we try to remain perfectly still, our muscle groups are maintaining balance and posture, and slight contractions are always occurring. It becomes even more obvious as