Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
1985 Volume VII: Skeletal Materials- Biomineralization

# Mathematics In You

Curriculum Unit 85.07.05
by Michael Conte, Jr.

**Abstract**

The human skeleton presents an unusual opportunity to teach mathematical skills and concepts. This paper will show the interactions of the science of Anatomy with methods of teaching mathematics. Students can learn basic skeletal anatomy as well as new concepts in mathematics, grades 5-8. The skeletal system can be the basis for teaching: scale, growth charting, tangrams (hand, teeth), graphing. ratios, proportions, percentages, geometric designs, circumference, diameter, radius, metric conversions (length, weight, mass), problem solving, addition, subtraction and measuring using the body parts as a standard.

***Introduction***

This unit has 4 sections with the first section providing a basic knowledge for the teacher on skeletons in general and includes: the appendicular and axial, growth and ossification of bones (skeletogenesis), the difference between cortical and trabecular bone, the 4 morphologic types of bones as organs and the age and sex differences in bone. In section 2 the teacher will receive background information concerning the histology and morphology (internal and external parts) of the femur along with a profile of growth and development. In section 3, the hand will be discussed. The teacher will be provided with facts on morphology, articulations and ossification sequences of the 27 bones in the hand. The final section, teeth, will allow the teacher to demonstrate for the children the names and parts of teeth, their functions and the dental formulas for deciduous and permanent teeth. All of these sections end with sample methods to illustrate a particular skill.

Children, ages 10-16, in the middle schools are going through dramatic and dynamic changes in their physical and psychological development. The various and obvious physical changes give us an opportunity to illustrate many mathematical concepts. There is a great variation in the onset and rate of physical development that children are curious about and need to know about. The areas that I chose, offer non-sensitive but essential parts of the body that are easily shown and readily available to the children. A major objective is for teachers to explore the skeleton as a basis to teach problem solving, graphing, ratios, proportions, percents, etc. The material to know is included. This unit is a resource guide and catalyst to “get you going” in presenting other aspects using your teaching expertise.

The objectives of this unit include the child being able to:

1. name and give examples of the 4 types of bones
    -long, short, irregular, flat
2. describe the 4 types of bones
    -long (femur, humerus), short (wrist, ankle), flat (cranium, scapula), irregular (vertebrae)
3. define axial and appendicular skeletons
4. describe how bones grow using the femur as an illustration
5. show age differences in skeletons
6. show sex differences in skeletons
7. list the functions of bones
    -support, protection, movement, hemopoiesis, reservoir for elements
8. list the parts of a long bone
    -diaphysis, epiphyses, articular cartilage, periosteum, medullary cavity, endosteum
9. label the major parts of the hand
    -carpus, metacarpus, phalanges
10. Label parts of the tooth
    -crown, neck, root, enamel, gum, dentine, pulp, bone
11. list the teeth found in humans
    -incisors, canines, bicuspids, molars

The objectives described above will be accomplished using scientific information, names and explanations, through integration into the mathematical curriculum area. The skills that I plan to teach using this unit include: scale, growth charting, tangrams (hand, teeth), graphing, ratios, proportions, percentages, geometric designs. circumference, diameter, radius, metric conversions (length, weight, mass), problem solving, addition, subtraction and measuring using body parts as a standard.

In the pages that follow, I will collect and put forth all the material needed to teach this unit. I would like each

section introduced using filmstrips and teacher prepared diagrams and graphs as a visual tool permanently on display while the unit is being taught.

***Overview***

The human body consists of 206 bones that provide a framework for support of the body's soft tissues and organs while also being essential for movement. Our skeleton can be divided into the axial (skull, vertebral column, sternum, and ribs) and the appendicular (upper and lower limbs) skeletons. (appendix A)

Although the number of bones are the same for both sexes, there are some obvious differences. Generally speaking, the size and weight of bones of female skeletons are smaller and lighter than the male and the pelvic area has anatomical differences. There are also growth and development changes in the skeletal system between infancy and adulthood. For example: the head becomes proportionately smaller (1/8 of its body height instead of 1/4 in an infant), the shape of the thorax changes, the pelvis becomes larger, 2 curves develop in the vertebral column, the legs become proportionately longer, the cranial capacity changes, the facial bones change and the epiphyses of the long bones become ossified except for the articular cartilage. (Anthony p. 116)

The skeletal elements, especially the long bones in the human embryo, are cartilaginous models of bones. Through the process of osteogenesis (ossification) special cells called osteoblasts form bone matrix, a mixture of protein (collagen) and mucopolysacharides. (see table below)

*(figure available in print form)*

Calcification of this matrix by the calcium phosphate mineral, known as Apatite, occurs almost immediately after the matrix is formed and is what make the bones hard and durable. (appendix B) The bones in our body are a composite of inorganic minerals and cellular organic materials in a fluid medium. The arrangement of the mineralized tissues produced by the cells is either compact (cortical bone) or spicular (spongy or trabecular). (see figure below)

Bone Structure (figure acquired from *Body on File* 05.003)

*(figure available in print form)*

Bones grow in thickness and are constantly internally reworked throughout our lives with heredity (genetics) and environmental factors (health and nutrition) contributing to their overall development. The bone growth and turnover are due to the combined action of osteoblasts (cells that build new bone tissue by secreting matrix and mineral deposition) and osteoclasts (cells that resorb tissue). A dynamic process, osteogenesis, normally exceeds resorption until about age 40 when the tables turn and resorption exceeds osteogenesis. The metabolic activities that modulate the bone formation and resorption system, are intimately connected to the body's hormone system, with formation also stimulated by exercise. Resorption can occur during bed rest and weightlessness.

In the human body there are 4 types of bones: long bones (femur, tibia, humerus), short bones (carpals and tarsals), flat bones (cranium and scapula) and irregular bones (vertebrae, sacrum, coccyx). The internal as well as external architecture of these bones vary and express the function each is meant to contribute to the skeleton. Aside from supporting the entire body much like that of a frame for a house, the skeleton also protects the important soft tissue and organs of the body (brain, heart, lungs) while aiding body movements through a complex system of levers made possible by muscle attachments to the bone. Two other functions of the skeletal system as a reservoir for a range of chemical elements needed for metabolism and hemopodesis,

the location (medullary cavity) for the formation of blood cells, are little known to the general public. All of the activities of bones as organs and as tissue are necessary for the proper functioning of the entire body.

Several math activities that may be used when teaching this section might be: measurement of the classbody length, weight and height, put it on a graph or chart using metric or standard units; determine the percent of bone (weight) that each child has as determined by their body weight, measure the circumference of the head (around the eyes) in relation to body height (1/8); make scale drawings based on information gathered on the children in class; use growth charts (CHCP) to graph class, determine percentiles of growth and make predictions of where the average will be in 2months, 6months time.

***Femur***

The femur, the longest, strongest and heaviest bone in the body is located in the leg and connects the lower leg with the pelvis bone. It is a long bone that is a member of the appendicular skeleton. As is the case with all long bones, it can be divided into the external morphology and internal structures. The diaphysis (see figure below) is the shaft portion of the bone. It is composed of compact bone that is well suited to support great weights while the epiphseal tissue at the end of a long bone is cancellous (spongy) in nature. The medullary cavity is the hollow part in the diaphysis which contains the marrow. Next to this marrow cavity is the endosteum which is a loosely defined area between the medullary cavity and the compact bone. The periosteum is a membrane that covers the bone except at the joints. At the joints (the only place this is found) you will find articular cartilage that acts as a cushion to absorb shock. The periosteum contains blood vessels and pre-osteoblasts, which are the source of cells vital to growth and repair of the bone.

Bone: structure (figure acquired from *Body on File* 0.5.003)

*(figure available in print form)*

The femoral head (see figure below) has a distinctive shape (morphology) distinguished by three proximal projections called the head, greater and lesser trochanters with the medial and lateral condyles located at its distal end. (In describing the bone, the teachers can point out to the children that the angle of the neck with its shaft is greater than 90°) At the end between the condyles ou will find a deep groove called the intercondylar fossa. The condyles articulate with the upper end of the tibia and patella.

Thigh and leg (figure acquired from *Body on File* 05.021)

*(figure available in print form)*

At birth, the shaft has become partially mineralized but the neck and both proximal and distal portions are mainly cartilaginous. Ossification extends from the shaft toward the cartilaginous extremities. The bone increases in length through interstitial growth of cartilage at the same time that ossification processes at secondary ossification centers located in these end parts of the bone. This process continues until around age 20 when ossification of the femur is completed (appendix B)

Sample math activities for skill and concept development would include (using chicken, turkey or human bones): measuring length and weight in metric and standard units; determining circumference, radius and diameter; measuring the angles of trochanters; determine the mass of the bones; weigh 2 different types of long bones and detail the differences in weight, length, mass, circumference, diameter and radius; enlarge the chart ratio and percent of ossification by taking the measurements off the chart.

### *The Hand*

Within the vertebrates, man may be distinguished by the organization of the bones in the hand. The form and function of the hand bones permits man to use his thumb to the fullest, in relation to the other digits. The hand is extraordinarily mobile and capable of delicate movements and manipulations.

The hand contains a total of 27 bones divided into 3 groups: the carpals, metacarpals and phalanges. (see figure below) The carpals consist of 8 irregular bones in two rows (4 each) called the proximal and distal rows. The distal row acts as anchors for the metacarpals, 5 long bones articulating with the distal row at its base, while joining with the three sets of phalanges-proximal, middle,distal(l2 bones), The thumb has only 2 phalanges.

Hands (figure acquired from *Body on File* 05.019)

*(figure available in print form)*

The bones of the carpus are cartilaginous at birth. Ossification commences in each of the 8 bones a few months later, the process as outlined for the femur, and is almost complete by age 10. The ossification sequence is: Capitate, Hamate in the first year; Triquetral in the second; Lunate in the third to fourth, Trapezium, Trapezoid and Scaphoid in the fifth to sixth years; and finally the Pisiform in the ninth to tenth years. (The specific names and times of each part of the hand and their approximate ossification timetables are given so that teachers can have an appropriate initial reference to satisfy student inquiry.)

### *Metacarpus.*

The second set of bones in the hand, the metacarpals, are 5 bones each having a shaft, distal head, and proximal base. (see preceding figure) Each metacarpal articulates with the distinctively shaped bones of the phalanges in addition to the carpals. Ossification of the 2nd to 5th metacarpals begin at 2 sites (shaft and distal epiphyses). with the epiphyseal centers appearing in the second to third years. Similarly located epiphyseal centers of the thumb metacarpal appears in the second year. All metacarpal epiphysos close, the bones completely ossified at around 18 years for men, 16 for women.

### *Phalanges*

The final group of bones in the hand are the phalanges. They are a set of 5, all having concave facets at their proximal end for articulation with the metacarpals. The middle phalanges have double concave facets for articulation between the proximal and distal phalanges. The distal phalanges are only facetted at their proximal ends, the tips are flat. This articulation is very important to us as human beings, for as stated earlier, the use of our hands is a major distinction which raises us above other creatures on earth. The hand’s movements allow us to grasp, handle, manipulate, and mold our environment to suit our needs. A interesting experiment that teachers might try is to tape the thumb to the index finger and have the children perform simple tasks. This activity is fun for the children yet has amazing results. Some tasks they might perform would be: button a shirt, tie a shoe, write their name, zip up a coat, fasten a belt, eat a sandwich, open a bag of potato chips, etc.

Ossification in each bone of the phalanges begins in the shaft, except for the distal set where it commences at the distal end. The approximate timetable for the onset in each set is:

distal 7th to 9th week (post natal), proximal, 9th week and middle 12th week. The epiphyseal

centers join at puberty. In the thumb, the last phalange shows the first ossifying nucleus in the hand.

Sample math activities that the teacher might use would be: measure the circumferences of the wrist and ankle and make a comparison ratio: make charts of the fingers of the children in the class, length, hand spans: make a chart describing the different periods of time that the bones in the hand ossify; produce ratios of the hand parts in regards to length and age; make ratios about finger parts-metacarpals to phalanges; make a tangram of the hand and have the children assemble it.

***The Teeth***

The first set of teeth developed in the human mouth are deciduous, in that they fall out as the adult teeth formed below in the gum take their place. The teeth have begun forming in utero but do not begin to break through the gum into the oral cavity until 1/2 to 1 years in age, with the process completed around 2 to 3 years of age. The first teeth to appear are usually the 2 lower middle incisors, the last molars erupt during early adulthood between 16-22 years of age. The calcification of the permanent or adult teeth takes place within the gum and bone tissue of the jaw, normally until the last molar is in place. (see figure below)

Teeth: 2 (figure acquired from *Body on File* 05.012)

*(figure available in print form)*

The first adult teeth are called molars and come in about age 6. (The jaw is now large enough to accept them.) By age 12 all of the deciduous teeth have been replaced and by the age of 20 all of the adult teeth are in place. A third set of molars, known also as the wisdom teeth, erupt only if the jaw has room. If there is not sufficient room for them to come into the mouth they might have to be removed by a dentist.

The teeth in the adult are: the incisors, wedge shaped teeth that are use for cutting; the canines, tearing teeth; bicuspids, double canines; and molars, that are used to grind food. The dental formula for adults is lower 2-1-2-3/upper 2-1-2-3. (see figure below) In man the teeth are small relative to weight and size. Over the millions of years of primate development the proportions of the face have changed radically, probably in response to functional needs. Man’s teeth are small since we now use implements (tools) for activities which we may in the past have used teeth.

Teeth: 1 (figure acquired from *Body on File* 05.011)

*(figure available in print form)*

The 32 teeth that we have, each of which is a separate organ, are not bone but composed of three special mineralized tissues: enamel, dentine and cementum. Those tissues are organic matrices mineralized with calcium phosphate as bone but the structures are built around a central canal called the pulp cavity. This cavity functions as the site of the transference of nutrients as blood vessels and nerves are concentrated here. The three tissues labeled in the previous figure (F) are dentine and cementum quite like bone in texture and mineralized level and enamel. Enamel at 99% mineral is the hardest and most mineralized tissue in the body.

The cells of the pulp cavity, below the dentine, exchange material with the bloodstream to keep the tooth viable. Below the gumline the dentine in the tooth root is surrounded by cementum, the mineralized tissue that holds the tooth in place. (Ligaments attach from cementum into the jaw bones.) Above the gum line enamel covers the tooth and protects it. Enamel, is what one sees and where we brush, has no cells and

cannot be repaired or regenerated if it decays.. It is this reason why there is a need for preventive measures. A sound enamel produced through good nutrition during the growth period (through the age of 20) is aided by the addition of fluoride. This fluoride, which can only be absorbed by growing teeth, is beneficial when supplied at 1 part per million as in our local water supply.

Activities that can enhance your mathematics skill and concept work might be: compare the ratio of mineralized tissue in teeth to that in bone; plot on a graph, years of age vs growth of teeth; measure teeth, length, weight in metric and standard, make a tangram of the mouth and have the children assemble the teeth in their correct order, make comparisons between the different teeth (ratio).

***Problem Solving Activities*** **(Sample Problems)**

1. If bones weigh 20% of our total body weight, what is the weight of bones in a person weighing 80 pounds?
2. Harry weighs 150 pounds and loses 3O pounds on a crash diet. What percent of his new weight is bone material?
3. The femur is a long bone in the body that has a hollow cavity which holds marrow. If a bone weighs 10 pounds and is 25% lighter because it is hollow, how much would it weigh if it were solid?
4. An infant has a ratio of 1-4 skull size (height) to the rest of his body. If a baby is 40 inches long, what is the length of its head?
5. A sample of human bone is about 1/3 organic material. If the total weight of bones equal 30 pounds, what is the weight of inorganic material?

## Lesson Plan #1

***Objective The child will be able to construct ratios using the hand as data.***

***Materials paper, pencil. ruler. tape measure (metric, standard)***

***Procedure***

1. Teach the section of the unit on the hand to the children detailing and explaining the parts of the hand and showing diagrams of how they look.
2. Discuss what ratios are and how they are formed. (use the textbook)
3. Review how to measure objects using a tape measure in metric and standard 1/2, 1/4, 1/8, cm,

mm.
4. Have the children measure their fingers and put the appropriate measurements in the table.
5. Have the children make ratios using the information gathered to develop problems for their classmates.

| | Index | Middle | Ring | Pinky |
|---|---|---|---|---|
| Proximal | | | | |
| Middle Distal | | | | |

(Index) *middle* distal. = (Middle) *middle* distal Leave out the value of the distal middle

## *Lesson Plan #2*

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***Objective The child will be able to (using examples of cortical and trabecular bone found in the long bones) measure circumference, diameter, length, and weight of long bones.***

***Materials long bones (chicken, turkey), paper, pencils, ruler, tape measure***

***Procedure***

1. Teach overview and femur sections of the unit. Note: cortical and trabecular bone charts and diagrams in the unit.
2. Discuss concepts and skills relating to circumference. (use the textbook)
3. Review measuring procedures for weight, length, diameter, circumference.
4. Cut a few long bones so that children can look at trabecular and cortical bone.
5. Have the children measure the bones (length, etc.) and put them on a graph.
6. Have the children draw diagrams of the bones and label the parts they may want to draw cross sections.

## *Lesson Plan #3*

***Objective The child will be able to fill in a growth chart (CHCP) and perform mathematical computations using this data.***

***Materials paper, pencils, scales, growth charts, yardsticks***

***Procedure***

1. Teach the overview sections to the class.
2. Review measuring techniques for weight and height.
3. Teach the class how to plot the growth chart and use this information to perform computations.
4. Have the class measure each other and themselves.

***Computations to perform:***

1. If bones weigh 20% of our total body weight, what is the weight of bones in my body?
2. Human bone is 1/3 organic material. What is the total weight of inorganic material in my bones? (use answer from above)
3. If my femur weighs 10 lbs. and is hollow and weighs 25% lighter than solid bone: what would it weigh if it were solid?
4. Our body height is in a 1-8 ratio with the circumference of our head at adulthood. What is your growth ratio?

# Resources

***Filmstrips Filmstrips can be found in the New Haven Public School System through the Audio-Visual Department***
Eye Gate Media Incorporated

1. *The Teeth* B 556-D Filmstrip-cas.

2. *The Skeleton* B 556-E Filmstrip-cas.

***National Geographic Society***

1. *The Human Body II: Support and Movement of Bones and Muscles* 04277 Filmstrip-cas.

*Diagrams* (For display in the classroom. These can be found in the books listed in the bibliography and made into charts.)

***Overview:***
1. *Skeleton Body on File* 05.001

2. *Ossification-Long bone* Francis *Human Anatomy* p.30

3. *Bone/Cartilage Body on File* 05.003

4. Growth Charts CHCP

***Femur:***
1. *Long Pane Parts* Anthony *Anatomy and Physiology* p. 83

2. *Femur-diagram* Anthony Anatomy and Physiology p.112

3. *Femur-diagram* Francis *Human Anatomy p* .67-8

4. *Thigh Body on File* 05.022

5. *Bone:Structure Body on File* 05.002

***Hand:***
1. *Hand Parts Body on File* 05.019

2. *Hand Parts diagram* Anthony *Anatomy and Physiology* p.107

3. *Hand Parts-diagram* Frazer *Human Skeleton* p.89

***Teeth:***
1. *Deciduous Teeth Body on File* 05.012

2. Permanent Teeth *Body on File* O5.O11

3. *Tooth Structure* Asimov *The Human Body* p.82

## Bibliography (Student's)


Bateman, Walter L., *How Man Began* , Chicago: Benefic Press, 1975.

An easy book for children to read. Particularly useful are pages 28 and 40 where head size is measured and discussed in charts.

Goldsmith, Ilse. *Anatomy for Children* . New York: Sterling Publishing Company, 1978.

A very good book for children to get brief basic facts about the human body, illustrations are adequate.

Klein, Aaron. *You and Your Body: A Book of Experiments to Perform on Yourself* , Garden City, New York: Doubleday and Company, Inc., 1977.

This book gives very short summaries of the parts of the body with simple experiments children can perform.

Tully, Marianne and Mary Alice. *Facts About the Human Body* . New York: Franklin Watts, 1977.

An excellent book for children. It is a series of questions and answers about the body:

Wilson, Hon. *How the Body Works* . New York: Larousse and Co. Inc., 1978.

A good book for children to use with bright illustrations and language appropriate for grades 5-7.

Zim, Herbert. *Bones* . New York: William Morrow and Co., 1969.

A children's book with very simple pictures and vocabulary. a good first book to use.


## Bibliography (Teacher's)


Anthony, Catherine Parker, et al. *Textbook of Anatomy and Physiology* . St. Louis: The C. V. Mosby Co., 1979.

A very Simple to read teacher resource, explanations are clear and the illustrations are good.

Asimov, lsaac. *The Human Body Its Structure and Operation* . Houghton Mifflin Company, 1963.

A resource book to aid in gaining knowledge and a reference for teeth.

Crescimbeni, Joseph. *Treasury of Classroom Artihmetic Activities* . West Nyack, New York: Parker Publishing Company, Inc., 1969.

A book on activities in mathematics.

Breathnach, A. S., editor. *Frazer's Anatomy of The Human Skeleton* . Boston: Little, Brown and Company, 1965.

Very technical resource with pictures that are hard to decipher, only for advanced readers with a science

background.

Lasker, Gabriel Ward. *The Evolution of Man* . New York: Holt, Rinehart and Winston Inc., 1962.

A very technical book. Chapter 19 gives fairly good examples on *Growth Patterns in the Individual* .

Lenihan, John. *Human Engineering* . New York: George Braziller, 1975.

This book talks about the human body from a mechanical engineer's viewpoint. Very interesting reading.

Loomis, Andrew, *Figure Drawing for All Its Worth* . Viking Press, 1973.

A good art book to show children parts of the body.

Schider, Fritz. *An Atlas of Anatomy for Artists* . Dover Publishing Company, 1957.

An art book depicting the parts of the body.

Swan, Ruth, editor. *The Human Body on File* . New York: Facts on File, Inc., 1-98-3:

This is *the* resource to use for diagrams. A must!! The illustrations are clear and labeled well.

Walker, Warren. *Vertebrate Dissection* . W.B. Saunders Company, 1975.

A teacher's reference book that can be used to find information relating to different vertebrate creatures.

Appendix A

*(figure available in print form)*

Appendix B

*(figure available in print form)*

Appendix C

*(figure available in print form)*