IMPROVEMENTS IN OSTEOLOGICAL PEDAGOGY: APPLICATION OF 3D TECHNOLOGY & INTERDISCIPLINARY PRACTICE

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By

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Table of Contents

Part I: Teaching Philosophy 1

Chapter 1 – Target Students 2

Chapter 2 – Learning Objectives 5

Human or Nonhuman 5

Left or Right 6

Identification of Features 6

Limits of Knowledge 6

Student Study Methods 7

Chapter 3 – Measuring Student Abilities 11

Chapter 4 – Fundamental Components 11

PPE 11

Respect & Ethics 12

Part II: Setting Up an Osteological Course 13

Chapter 5 – Obtaining Osteological Specimens 13

Purchasing Human Bones 14

Borrowing Between Institutions 16

Osteology & Technology: 3D Scanning & Printing 16

Part III: Determining Class Structure & Organization 18

Chapter 6 – Class Structure 18

Example Course Syllabi 19

Graduates as TAs 19

Specialty Course 20

Chapter 7 - Quiz & Test Design 23

Creating Questions 24

Test Organization 25

Chapter 8 - Grading.......... 26

Part IV: Teaching Osteology 27

Chapter 9 – Course Outline 27

Vocabulary 27

Cranium.......... 27

Hyoid & Vertebrae 28

Sternum & Ribs 28

Shoulder, Arm, & HAND.......... 29

Pelvis, Leg, & Foot.......... 29

Chapter 10 – Biometrics.......... 29

Bone Composition & Function.......... 29

Bone Growth.......... 30

Biomechanics: Strength, Fragility, & Adaptation.......... 32

Chapter 11 – Variable Determination.......... 35

Sex 35

Age.......... 41

Stature 48

Chapter 12 - Pathology 49

Joint Diseases.......... 50

Infections 51

Congenital Disorders 52

Neoplasia.......... 54

Endocrine Disorders 56

Metabolic Disorders.......... 57

Other Types of Pathologies 58

Dental Caries 63

Chapter 13 – Taphonomy & Modification 66

Antemortem Trauma.......... 67

Perimortem Trauma 74

Postmortem Changes *81*
Chapter 14 – Application of Osteology in Criminal Justice **89**
<u>Part V: References</u> **91**

References *91*
Appendix *110*

Part I: Teaching Philosophy

Osteology is the study of skeletal structures &, though that may seem vague, the study of bones can be applied to a vast array of fields & careers. The primary challenge of developing educational programs is determining who can or should benefit from the intended curriculum. In this instance, we must decide which students, professionals, and/or governmental agencies need human osteology.

In my own experience, the most common majors of students who enroll in osteological courses include anthropology, criminal justice, & nursing/medicine. I have also noticed that the students who enroll in human osteology are often undergraduates in their junior or senior year &, as with many courses, the course is taken due to a specific requirement or as a general credit fulfillment. The benefit of enrollment of undergraduates in their final year(s), is that they have already decided on their major. That means they have taken the time to choose a field of interest &, generally, understanding the level of energy needed to fulfill their degree. Human osteology is not an easy course & it requires time, dedication, & discipline. On average, there are only biological anthropology majors enrolled, who are required to take the course before graduating. However, although the status quo seems to place osteology in the hidden realm of anthropology, I argue that the various courses outlined here can & should be used to bridge boundaries between the criminal justice fields, anthropological osteology, & forensic osteology. Beyond that I investigate the importance of human osteology, within both anthropological & forensic lenses, in, not just criminal justice curricula, but also in police departments & crime scene investigation units.

To conclude, I will further explore target students & constructive study methods, as well as the changing territory of how to obtain osteological teaching specimens & I will offer syllabi examples to teach courses in five different learning environments that include, at least, the basics on the foundational information of forensic osteology.

Chapter 1 – Target Students

Before designing a course, the dominant hurdle is finding students. Students are, in the simplest form, those who study. The focus often places "students" as those in college or university. I argue that "students" is a much broader term, including any individual that studies an area of interest. In this case, there is a large base of students who would benefit from osteological training. As previously stated, those at college or university, including graduate students, & professionals & those within governmental agencies, are primary targets. However, the United States is not the only country that has yet to bridge the distance between anthropological & osteological knowledge & the popular fields of criminal justice & criminology. Jobs such as criminal investigators, crime scene investigators, forensic technicians, police officers & detectives, as well as lab analysts have become increasingly popular worldwide. Yet these jobs, which will most likely encounter osteological remains, are, on a multinational average, not required or occasionally even offered osteological and/or anthropological courses. As

I’ve discussed, part of this is due to a large gap between the anthropology & criminal justice departments. However, another part, as I will discuss later, is the growing difficulty obtaining osteological specimens as well as how to use 3D technology to potentially avoid future issues. Here I will further discuss who our target students should be for osteological training.

Undergraduates who are declared biological anthropology majors at California State University, East Bay, must take human osteology. However, as mentioned, this is not the case at all schools. Schools such as the University of Maryland, the University of Albany, & the University of Cincinnati are some of the top criminal justice schools in the United States, yet none require osteology or anthropology. Even the top criminology schools in the United Kingdom, such as the universities at Stirling, Leicester, & York, do not include osteology courses for criminal justice majors, even if offered for forensic anthropology or bioarchaeology, etc. Students that pursue human osteology on their own, as opposed to course requirements, have career motives such as forensic anthropology, criminal justice, & nursing. Thus, target students for undergraduate osteology should be broadened to include, not just biological anthropological majors, but also those in majors that can reach the careers of police officers, detectives, crime scene investigators, & forensic lab technicians.

Graduate students should, & generally do, have some footing in osteology & practice handling skeletal remains. Graduate students with osteological background may help in guiding & leading the class as well as making time to study with students and/or provide access to study collection. Having graduate students with osteological background, regardless of their major, is beneficial to both the graduate & undergraduate students, as well as the professor. In this position, graduate students take on a mentor-like role with the undergraduates; providing time to tutor, useful study methods, & most importantly, challenging both the undergraduates & themselves by constantly “self-testing”, as I will discuss later. The graduate course is also designed to teach graduates osteological pedagogy in both theory & practice.

Professionals & government agencies, as mentioned previously, should also be considered students. Regardless of the educational level of the individuals in police departments, crime scene units, or forensic labs, these students should be targeted for specialized osteological training. As discussed, it is not in the practice of universities & colleges, on a worldwide scale, to include or even offer, osteological training to those training outside of the fields of forensic anthropology or bioarchaeology. Let alone not offering human osteology to those in criminology, the push from federal departments for police to have college degrees is still nominal. Various studies on higher education within police departments have shown that, on average, only 50% of individuals have some college experience while only 30% have a bachelor’s degree. While many of these studies also show the effects of higher education on issues such as authoritarian attitudes, arrest frequencies, use of force, & predilection to perform searches, they also show the correlation between college degrees & better social & ethical behavior as well as being more progressive towards minority communities. Studies have begun to urge policy changes to promote college education requirements in police departments. I will demonstrate that while promotion of college degrees is beneficial, we should be progressively adopting comprehensive forensic osteology courses for criminal justice majors as well as those with & without degrees in federal agencies (Rydberg & Terrill, 2010; Roberg & Bonn, 2004; Paoline, 2000; Henion & Terrill, 2015).

Chapter 2 – Learning Objectives

Undergraduate & graduate students should be able to identify the following from a bone, whether complete or fragmentary, while still diagnostic: 1) Determine if it is human or non-human 2) Determine the side of the body the fragment is from 3) identify diagnostic features, & 4) Know when there is not enough evidence to give a definitive answer.

Human or Nonhuman

The first & most important concept students should master is determining whether a bone or bone fragment is human. In potential crime scenes it is always imperative that the osteologist correctly identify any skeletal remains as human or nonhuman. There have been countless incidents in which animal remains are incorrectly identified as human. Teaching this concept often tests students on recalling specific shapes of human osteological remains & fragments. Students should be taught to focus on a routine of looking at the size, shape, texture, & diagnostic features of bones & fragments to determine human versus non-human. As a teacher, this includes making sure students are familiar with all ages of osteological specimens as well as deciduous dentition.

Left or Right

The second consideration the students must make is determining what side of the body the bone or fragment is from. For the complete axial components of the skeleton such as the vertebrae or hyoid, siding is considered the midline of the body. However, for appendicular bones, duplicate cranial bones, fragments, & the os coxae, the students should be able to determine what side they are from. Again, this requires identification of diagnostic features to come to an absolute answer, when possible.

Identification of Features

Thirdly, the students should be familiar enough with the features & craniometrics of the skeleton to use as a diagnostic determining tool. Features can be used to determine human versus non-human, element, & anatomical positioning. They should also be able to name specific craniometrics & features on a bone-by-bone basis.

Limits of Knowledge

Lastly is knowing when to say, “I don’t know”. This can be one of the most challenging concepts to grasp & master. There will be fragments that are nondiagnostic, both in study & in the real world. Students should try to use the fragment’s features for identification, but should be conscious of bias & assumptions. Students should be able to effectively argue their position using diagnostic features to determine the element or fragment while being open to discussion & alternative viewpoints.

Student Study Methods

There are many ways to study osteology & it is our job as educators to guide the students to the method of study that will be the most beneficial to them. Some osteological learning methods I have witnessed or used myself in the course of study are: Color-coded flashcards, drawings or sketches, charts of features, muscles, & craniometrics, self-guided testing, mnemonic devices, & sensory cues.

The number one study method for mastering osteology is self-guided testing. Students should use the teaching collection & their text resources to guide themselves through the course objectives. During this time, the students can discuss their thoughts & questions with the teacher or graduate students. As they move through the course, they should be encouraged to look at smaller fragments as well as pushed to focus on their weak points. This method is beneficial in the sense that it is both a way to acquaint graduate students with teaching pedagogy, but also to have them continually refreshing their knowledge of osteology &, potentially, associated subjects such as forensics, archaeology, & anatomy. In a similar fashion, graduate student led studying is also effective. By breaking the students into smaller groups, roughly five to six students, it is much easier for graduate students to discuss specifics or pass around bones or fragments.

Color-coded flashcards are especially helpful for straight definitions as opposed to descriptions of elemental features, soft tissues, or craniometrics. It is up to the instructor to determine the most important definitions for the students. This is variable depending on the structure of courses at your institution. For semester systems, it is easier to ask more of the students in terms of definitions, craniometrics, & non-metric features than it is during a quarter system. In the Teaching Osteology section, I go into more detail about minimum specifics. Even on a quarter system, it is possible to cover the skeleton & the vast majority diagnostic features & soft tissues. Flashcards, however, cannot replace hands-on interaction with the skeleton. I have noticed that the less time students spend working hands-on with the bones, the less information they retain.

My first introduction to studying osteology was by sketching the bones & labeling features on my own drawings. While this method is not always easy & not effective for all students, it is especially helpful for muscle memory as well as becoming intimate with the more complicated elements. For example, finding the jugular fossa on the posterior angle of the temporal bone is often challenging for new students. For some students, drawing the bone & labeling their own drawing is often all they need for it to click in their mind. This method can also help with the shape memorization of elemental fragments that is so important in osteological studying. Drawing is also helpful when studying muscle attachments, by allowing students to color-code their own sketches.

Drawing is not for all students, however, so I often suggest creating charts. I often list the features of each element & their corresponding soft tissues, craniometrics, or other important information, such as non-metric features or articulation. I started my own charts which eventually led to an abridged guide to human osteology. See Appendices for an example laboratory guide for a quarter system.

Mnemonic devices can be used but this, generally, will be on an individual basis. What makes sense to one person may or may not make sense to another. It is less helpful to force your preferred way of learning & more beneficial to use the student's strengths to their advantage. Sensory cues are often used by students without them realizing it. It is useful to point out the varying textures of the human skeleton. This improves the student's retention of the information as well as strengthens their understanding of how the human body works. For instance, I like to use the rugosities on the clavicle as an example of muscle attachments on bone. The rough texture at the attachment point is quite different from the smooth shaft. Each time they pick up a fragment, they should be able to discern between different textures to help orientate the element within the body. Without realizing it, they will have trained themselves to respond to these sensory cues.

Study Method	Description	Advantages	Disadvantages
Color-coded flashcards	Colored notecards categorized into useful groups (i.e. blue- cranium, green- axial)	Straight definition memorization	Lack of hands-on interaction with elements
Drawing/sketching	Free-handed or sketched study guides for specific bones	Creates muscle memory responses as well as a greater familiarity with elements	This method can be difficult & is not for every student

Feature & muscle charts	Charts designed to correlate craniometrics, features, & muscles	Creates a “quick guide” for students to use in the lab & in reality	Similar to color-coded flashcards, these charts lack hands-on practice
Self-guided testing	Use of whole & fragmentary	Allows for open discussion using	Students will often lose
	elements to test oneself with the help of the professor and/or graduate student(s)	fragmentary bones & allows students to focus on their own weak points	motivation in this method if not encouraged by the instructor(s)
Mnemonic devices	Acronyms, phrases, etc. used to as memory signals	Allows for individualization of methods of memorization	This tends to be quite individual & few can be used with the class as a whole

Sensory cues	Involuntary signals obtained from the senses; here, touch & sight are the two most important	Creates a stronger understanding of the skeletal system, individual bones, & fragments as well as differences in textures/shapes etc.	Since these reactions are involuntary, there is no way to regulate the outcome other than continued osteological practice

Chapter 3 – Measuring Student Abilities

As in most class settings, the general basis of measuring the student's abilities is done using quizzes & tests. Students are quizzed every other week & in addition have one midterm & one final. The quizzes, midterm, & final each contain a combination of element identification & short-answer questions. Students have one & a half minutes per question to display that they have learned the four previously discussed points.

Chapter 4 – Fundamental Components

PPE

Prior to students handling bones, it is an instructor's duty to ensure they have the proper personal protective equipment (PPE) as well as understand the importance of engaging with human remains, regardless of the discipline. First & foremost, it is imperative that all students wear gloves while handling human remains. While many labs, including my own, have casts or resin models, it is easier to have students wear gloves while handling these as well, although it is not ethically necessary. Some students also choose to wear a lab coat, though it should not be made a requirement. Lastly, students should not wear rings, bracelets, or other jewelry that could potentially damage bones, even with gloves on.

Respect & Ethics

Secondly, it should be made clear to students the expectations regarding their attitude while handling remains. These were once living, breathing humans. Students, primarily undergraduates, tend to be slightly detached due to the arbitrary nature of the skeleton for beginners. It is best to address this trend directly with the students, making it clear that human remains should be: 1) handled with respect & 2) handled with care.

Handling remains with respect goes beyond the common sense understanding to not deface or use any remains inappropriately. Respectful examination includes using bones for learning & research purposes only. Often, students displace intense feelings that emerge from handling human remains with humor, but this is not generally appropriate. Social media & imagery could potentially lead to a legal situation if a student decides to post a “selfie” with someone’s great-great grandfather. Skulls should be carefully handled with two hands, & never by the orbits or foramen magnum. Students should have ample lab space to sit down & examine bones over a flat, stable area covered in a plastic, corrugated mat. Carpet or cloth mats can be detrimental to the elements & should be avoided. Tables should be free & clear of debris; books & notebooks should be kept to a minimum.

<u>Part II: Setting Up an Osteological Course</u>

Chapter 5 – Obtaining Osteological Specimens

By far the most difficult part of teaching osteology is getting your hands on your own teaching collection. To do this, you first must decide what you need. Learning osteology requires the ability to, not only see examples of every bone, but to see multiple examples of every bone to show variation as well. Students also need access to examples of fragmented pieces as well as representation of trauma, healing, & pathology.

Aside from the elements used as teaching materials, one must also have a collection for testing. This smaller collection should be separated from your teaching material to provide fair grading standards by not allowing any student access to them prior to the exam. The first tests should have fully intact or large fragments of bone. As the class progresses, the testable fragments should get smaller. It is difficult to find a decent number of specimens that are both diagnostic as well as challenging. Students need testable materials that will force them to recognize patterns in shapes, textures, & breaks. Common testable fragments include skull fragments, such as a single occipital condyle or a sphenoidal greater wing, vertebral & pelvic fragments, individual teeth, proximal, distal & shaft portions of long bones, & singular whole elements, such as a first metacarpal (MC1) or an individual tarsal.

Purchasing Human Bones

Purchasing human bones or casts is not necessarily difficult. There are various companies that offer complete skeletons & individual bones, collections of different ages & pathologies, & additionally, high-quality casts of these as well. Some of these companies specialize in real human bones like The Bone Room, Osteology Warehouse, & Skulls Unlimited International. While others focus on realistic & medical-grade replicas like Carolina Biological, Anatomy Warehouse, & Vision Scientific.

Buying real or cast human bones can be extremely expensive. When trying to create a collection or a teaching set, the totals can quickly add up to the tens of thousands. For example, real standard human skulls run an average of $1,692 each while casts of these cost $256 each on average. For real complete skeletons, the prices skyrocket. The average price for a real, standard, complete human skeleton pushes $3,500. Full cast skeletons are much more affordable, around $550 on average. Singular bones & small sets of bones are typically economically priced & allow acquisition of articulated & disarticulated joints. However, these are primarily real bones & it can be difficult to find casts of small bones.

Additionally, bones & casts can be purchased from independent sellers as well as public & private institutions. Buying from an independent seller can be problematic & potentially risky. It is critical that you know & understand state & federal restrictions as well as the guidelines of the Native American Graves Protection & Repatriation Act (NAGPRA) & the Uniform Anatomical Gift Act (UAGA).

<u>NAGPRA</u>

NAGPRA “was enacted on November 16, 1990, to address the rights of lineal descendants, Indian tribes, & Native Hawaiian organizations to Native American cultural items, including human remains, funerary objects, sacred objects, & objects of cultural patrimony” (National Parks Service). Universities & colleges that receive federal funding may have to return any remains or artifacts to the Most Likely Descendants (MLDs) if they come under their institute’s possession.

<u>UAGA</u>

The UAGA, however, governs the sale & donation of tissue & organs on a state-by-state basis. In 2015, Georgia enacted a bill entitled the “Georgia Revised Uniform Anatomical Gift Act” which severely limits the sale or purchase of human remains. This includes shipping remains, even those from reputable or medical sources, to Georgia. Likewise, Washington, D.C. has made buying & selling human body parts completely illegal, regardless of what they will be used for. This was done by strictly defining what was included under the category of “human body parts” as well as prohibiting who could purchase biological specimens, which includes for purchases medical purposes (Section 7–1501.01. “Human body parts” defined; prohibited acts).

Buying human bones is almost always legal on a state-by-state basis. However, this is merely because the law does not explicitly state that it is illegal to do so. Because this changes on a per state basis, it is crucial that you understand the laws where you wish to purchase osteological remains from as well as the possessions laws in your own state. Questionable purchases may lead to an inquiry, which is a mess that can be easily avoided. It is preferable to know that the source is reputable and/or to know the provenience of any osteological specimens you wish to purchase.

Borrowing Between Institutions

Another option of obtaining, at least a temporary, collection is through your own institutions. California State University, East Bay, in Hayward, California has its own faunal & human osteological collection in the Anthropology department, as do most of the other CSUs. Borrowing between state institutions like CSU is possible & encouraged. However, as most researchers will find, most schools are unwilling to part with their precious specimens.

Osteology & Technology: 3D Scanning & Printing

Over the past few years, the technology of 3D scanning & printing has become more precise, less space-consuming, & much more affordable. This technology has been applied to a multitude of fields due to its many applications. The process is structurally simple. A 3D scanner is used to create a digital three-dimensional model of whatever object you choose. The most common & useful 3D scanner is a structured light scanner. This type of device uses a stand or turntable and a camera. The camera simultaneously uses bands of light to determine the surface structure of the scanned item as well as records the scan on the associated personal computer. Scanners that use a nonmoving stand require the user to rotate the objects as needed. Although turntable structured-light 3D scanners may cost a little more, they are more effective at rotating the piece without affecting the scan. It should be noted that the personal computer, mentioned above, must meet fairly rigorous specifications, particularly in regard to the graphics card & processor.

3D scanning & printing could quickly become the most efficient & cost-effective manner of obtaining an osteological collection. The benefits of owning the equipment to replicate bones pays for itself quickly. Likewise, the scanning of a bone creates a file that can be duplicated, shared, & printed numerous times over. The two most obvious benefits being that the printing of exact scans could theoretically allow all students in one room to hold & study the exact same bone or fragment at the same time &, the digital copy protects a once unique element by allowing the owner to quickly & economically create an exact laser model.

Part III: Determining Class Structure & Organization

Chapter 6 – Class Structure

For the undergraduate students, the ideal class size is as small as the university will allow. I have found in my experience that if there are any more than fifteen students in the course, multiple problems come to light. Issues can arise with too large a class size such as: a lack of one-on-one student-teacher interaction, practical assessments can become overwhelming to set up, monitor, & grade, &, of course, with a larger class you need a larger teaching collection as well as a larger testing collection. For small colleges or new teachers, this can be a challenging feat.

In addition to teaching a small undergraduate class, it is helpful & necessary to run a small graduate class concurrently. Graduate students can be led to direct & guide the undergraduates. These students should also assist with the designing, set-up, monitoring, & grading of undergraduate practicums.

The benefits of running a small class are more obvious. It is much easier to have one-on-one interactions with students or lead discussions in small groups. With a smaller class, less bones, fragments, & testable materials are needed to effectively run & teach the class. However, there are some other benefits that are less obvious. Smaller class sizes led to increased socialization between the students, including graduate students, & the teacher. In my experience, students group up to study &, over the course of the class, become friends & colleagues. This closeness between students creates quite a bit of competition. This also allows the teacher & any graduate student assistants to focus on the students & their strengths & weaknesses. As the class is not designed around lectures, it gives the class a free-study feel. Students can follow the course outline as well as continuously work on their areas that need improvement.

Example Course Syllabi

See Appendix B for example course syllabi for undergraduate & graduate students. Professional students should be encouraged to follow the one-week course, discussed in *Specialty Course*.

Graduates as TAs

The graduate students, as discussed previously, should be given varying degrees of responsibility in teaching the course based on experience, knowledge, ambition, & involvement with the course. The graduate students should help design the quizzes, again, by being tested themselves. They should, however, be required to take the midterm & the final exams with the undergraduates. This allows the instructor to grade the graduate students based on midterm & final grades, as well as attendance & participation.

Graduate students should have at least one human osteology course in their transcript before assisting professors with work. Under supervision, graduate students should direct student studying, design & write quizzes, as well as proctor & grade quizzes. These students should also make themselves available outside of class time to assist students with studying as well as making sure they have access to the study collection.

Specialty Course

At California State University, Criminal Justice majors are not required to take human osteology, forensic osteology, general forensics, or anatomy & physiology. While this is not the case at all institutions, there is a trend for future police officers, sheriffs, & crime scene investigators to be educated in sociology, ethics, & psychology, but not anthropology, osteology, anatomy, or forensics.

A specialty course could be designed to help combat this lack of knowledge. In a week-long seminar, a basic introduction to the entire skeleton, determinations of age, sex, & stature, different pathologies, taphonomic factors, types of modification, soft tissues, & an outline of NAGPRA & the UAGA will be covered in a series of daily lectures.

The following week-long seminar could be taught to 10-15 students/professionals using this thesis, the attached guide, & the associated 3D scans. While this will not make the attendees experts, they will be able to gain a fundamental understanding of skeletal structure as well as the appropriate forensic osteological methods of analysis. Additionally, the 3D scans included allow for the printing of a study of skull bones for each student. This is immensely important to retaining osteological & anatomical details.

<u>One Week Forensic Osteology Course: An Introduction to Basic Concepts</u>

<u>Day One:</u>

After a brief introduction by the instructor, the course should immediately begin with an introduction to the basic directional, anatomical, & osteological terminology. The next topic should be the cranium, bone-by-bone, including the most important features.

The cranium should be following by the mandible, again, focusing on the important features. This will conclude the skull as an element & time should be given for questions & review.

After the analysis of the skull, details of dentition should be covered next. Students in this specialty course will not need to know the minute details of each tooth but should be able to discern between the different teeth. This encompasses deciduous dentition as well. It is important that students can distinguish between immature & adult teeth. Lastly, the day should end with an elementary review of biometrics. It is less important that students understand the particular structures of bone, but rather the observable health or weakness of bone. Before the end of each day, a question & answer period should be allotted for clarification.

Day Two:

The second day of the seminar should begin with a short review of the previous day's topics. This should be done each day before presenting new information. After reviewing the skull, dentition, & biometrics, the vertebral column should be covered next followed by the sternum & the manubrium.

The last portion of the chest cavity is the ribs. Not much detail should be placed on the ribs, with the exception of the first, second, eleventh, & twelfth ribs. To end the day, a basic introduction to taphonomy should be covered next. The first & most important aspect is to cover the definitions anti-, peri-, & post-mortem. Once these basic descriptions have been discussed, it is useful to cover the differences between green &

dry fractures, examine types of soil discoloration, & review burned bones. More relevant however, is the inclusion of human bone modification versus animal or plant damage. A significant priority should be placed on cut marks, crushing, projectile marks, gunshot wounds, & peeling, while less emphasis should be placed on carnivore- & rodent-gnawing. As mentioned prior, it is beneficial to wrap up with a question & answer session.

Day Three:

After reviewing the two prior days, the focus shifts from the axial skeleton to the appendicular skeleton. Before starting the arm, it is preferred to begin with the shoulder girdle, including the clavicle. The rotator cuff muscles will naturally lead right into the humerus. Continue distally down the arm to cover the radius & ulna. Very limited time needs to be spent covering the carpals, metacarpals, & phalanges of the hand.

Though it may not be intuitive, it is best to discuss pathologies of both bone & teeth at this point. As one would assume, it makes the most sense to only cover the more common or important pathologies, such as osteoporosis, osteoarthritis, rickets, osteomyelitis, achondroplasia, & osteosarcoma. Lastly, it is relevant to examine the place of fractures in the frame of pathology as well as taphonomy.

Day Four:

This review should be structured as a discussion as the seminar comes to an end. Day four moves back to the axial skeleton to cover the entire pelvis. The pelvis includes two os coxae, a sacrum, & the coccyx. Although the os coxae are the most important structures of the pelvis, the sacrum & coccyx are important in the overall architecture. More detailed focus can be placed on the features of the os coxa rather than the sacrum & coccyx.

Shifting into the subject of variable determination is logical after covering the pelvis. Sexing & aging can both be done with pelvis. Sexing the skull using Walker's field method is very easy for even the most inexperienced students to master. Routine field techniques of objective age analysis using dentition & the os coxae are also useful & important tools to cover. Stature & ancestry analysis are less important to cover.

Day Five:

The final review will be the lengthiest & again should allow the students to guide the topics of focus. After the review, the final part of the appendicular skeleton can be covered; this portion covers the femur, patella, tibia, fibula, tarsals, metatarsals, & phalanges of the foot. Like the arm, the importance should be placed on the leg bones & less on the tarsals. The final topics should cover modification & the application of these tools in the fields of criminal justice & forensics. The seminar will end with a final question & answer session.

Chapter 7 - Quiz & Test Design

In measuring student abilities, I discussed quizzes & tests. Here, I will go into further detail regarding physically building the tests as well as simple grading procedures. For the quizzes, you and/or the graduate students should determine how many questions you will need. It is beneficial to create a few extra questions than there are students in the course. I will discuss this further in a bit.

Creating Questions

When creating questions, the teacher and/or the graduate students should choose bones and/or fragments as well as short-answer questions that test the undergraduates up to the teaching point in class. Elements should begin intact or largely intact for the first quiz, getting progressively more fractured &, consequently, difficult as the course goes on. As a teacher, it is imperative that you can in fact tell for sure anything asked of the students. For instance, if you have an individual deciduous lower second molar but siding is, for some reason, inconclusive, you cannot ask this of the students. In the section, “Obtaining a Collection”, I explore further how to design a testable set of bones.

Once the bones or fragments are chosen, it is quite beneficial to have the graduate students “take the reins”, so to speak. The graduate students should examine the fragments, essentially testing themselves. After reviewing the fragments with the graduate students, allow them to come up with potential questions. For general human osteology, the question for each element is a standard three-part, three-point question that asks, “Which element? What side? What feature?” So, within the allotted one minute & thirty seconds, each student must pick up the bone at their station, examine it, & answer which element it is, what side of the body it is from (left, right, or midline), & what diagnostic feature led them to this conclusion. Although, to make questions more difficult, you can use smaller fragments, and/or use non-toxic, removable, colored dots to highlight specific features. For instance, a red dot with an arrow pointing into the nutrient foramen on the femur could be used to ask specifically which feature it is. In this example, a shaft fragment of said femur with the highlighted nutrient foramen could be used in more difficult questions to require students to understand how to side shaft fragments using the highlighted feature & their osteological training.

Not all questions need to be structured this way; dentition & vocabulary questions are also used & encouraged. Loose, individual teeth make great testing materials. While dividing up points on dentition questions can be difficult, there is more than one way to do it. However, for testing teeth, questions should reflect the student's ability to determine which type of tooth it is, the side, whether it is maxillary or mandibular, & the number of the tooth. It is also a good chance to teach the proper annotation for dentition in osteology. For instance, the answer on a test for a question on an upper right third premolar would be RP$^{\underline{3}}$. Other questions can be centered around vocabulary, like defining craniometrics or other specific definitions. For example, questions that asks that students to define bregma, lambda, or apex using appropriate osteological vocabulary are encouraged. Another one of my favorite questions is to ask the student to define, using appropriate vocabulary, Frankfort Horizontal.

Test Organization

In terms of setting up the test, your first priority should be to protect the bones & second to protect the students. To protect the bones, they should be on nice flat surfaces, generally, within small, shallow boxes. This helps prevent them from rolling, sliding, or being knocked off the table or desk. Anyone touching the bones should have gloves, as per usual, including students throughout the test. To protect the students, there needs to be ample room between testing “stations” as well as between students to prevent cheating. This also helps deter “ambitious” students from trying to work on the upcoming bones, abusing the timed system. In my experience, it is best to create a ring of desks and/or tables around the outer edge of the classroom. “Stations” should be spread out evenly, skipping desks between “stations” whenever possible. If desks in the ring all face the same way, students will generally sit at the desks blocking each other from seeing their classmates’ stations.

Chapter 8 - Grading

As mentioned earlier, I generally use the standard three-part, three-point question for elements. While dividing points on dentition can be tricky, short-answer questions can easily be made three-points apiece as well. An example of grading percentages that could be used is as follows: conduct/attendance is 15%, quizzes are 30% total, the midterm exam is 25% & the final exam is 30%.

Part IV: Teaching Osteology

Chapter 9 – Course Outline

Vocabulary

Students should be able to fluently use & understand superior, anterior, posterior, inferior, medial, lateral, proximal, distal, endocranial, exocranial, sagittal, coronal, transverse, palmar & plantar. For the entire skeleton, students should know appendicular, axial, articulation, & foramen (foramina). Other important vocabulary includes skull, mandible, cranium, calvaria, calotte, splanchnocranium, & neurocranium. When covering dentition, be sure students can effectively use mesial, distal, lingual, labial, buccal, interproximal, & occlusal to describe teeth. There are many, many more words within the frame of the osteology but these are the most commonly used & should be mastered by the completion of the course.

Cranium

Regardless of whether your course runs on quarter or a semester system, it is best to start with the cranium, in the most literal sense. Before breaking the cranium down bone-by-bone, familiarize the students with the most commonly used craniometrics & Frankfort Horizontal. Proceed with the crania, going over all pertinent features, as follows: frontal, parietals, temporals, occipital, maxillae, palatine, vomer, inferior nasal conchae, ethmoid, lacrimals, nasals, zygomatics, & sphenoid. It is worth noting however, that the palatines, vomer, inferior nasal conchae, auditory ossicles (malleus, incus, & stapes), & sometimes the ethmoid, are often difficult to show separate from the whole cranium, aren't generally recovered from archaeological sites intact, & aren't generally useful for determining anything useful within in the forensic field. While students should be taught this small set of bones, less focus should be placed on siding & more on their position within the entire skull. Once the cranium is covered, is it fair to move on to the mandible & then the individual teeth. Features of the teeth should be covered as to benefit the students in terms of categorizing & siding individual teeth.

Hyoid & Vertebrae

Following the axial skeleton from the skull, next cover the hyoid & the vertebral column. It is useful to cover general features that apply to the entire vertebral column before breaking down the vertebrae into their groups. Students should cover cervical vertebrae one thru seven, paying special attention to the atlas & the axis, thoracic vertebrae one thru twelve, & lumbar vertebrae one thru five. In terms of the special diagnostic vertebrae, students should be able to specifically identify cervical vertebrae one (atlas), two (axis), & seven, thoracic vertebrae one, ten, eleven, & twelve, & lumbar vertebrae one & five. It is easier to save the sacrum until covering the os coxae.

Sternum & Ribs

The sternum should be covered next, followed by the ribs. Ribs tend to be difficult to pick out individually, apart from ribs one, two, ten, eleven, & twelve.

Students should get practice, not just handling individual ribs, but also serrating a set of ribs from at least one individual.

Shoulder, Arm, & Hand

Although it may not be intuitive, from the ribs we move on to the arm & shoulder socket. To set up the arm, it is best to start with the scapula & clavicle. This order is especially useful when covering soft tissues. From there, move on to the humerus, radius, ulna, & then cover the carpals, metacarpals, & hand phalanges.

Pelvis, Leg, & Foot

Next, the course can proceed to the sacrum, coccyx, & the os coxae. It is worth mentioning to the students the variation in the number of coccygeal vertebrae. The os coxae should be taught starting by covering the three individual bones that make up os coxae: the illium, the ishium, & the pubis. This naturally leads to the femur, patella, tibia, fibula, tarsals, metatarsals, & foot phalanges.

Chapter 10 – Biometrics

Bone Composition & Function

Bone tissue, which supports the entire body, protects vital organs, & anchors muscles, is a composite material made up of the mineral, hydroxyapatite & the protein, collagen. Hydroxyapatite is found in both the bones & the teeth, & is responsible for giving healthy elements their rigidity. Collagen, the most common protein in the body, gives bones their flexibility. Together, collagen & hydroxyapatite create a compound that is as strong as steel but as light as wood. Bones are extremely strong but can react & respond to stresses & pressures to change & adapt. Adult bone is comprised of nearly 65% hydroxyapatite, 10% collagen, 25% water, & small amounts of other elements, like magnesium, sodium, silicon, & zinc.

Bone falls into two categories, woven & lamellar. Woven bone is generally considered immature bone. Juveniles, whose bones are still growing, contain a lot of woven bone. Woven bone is also seen when a broken bone is attempting to repair itself. Alternatively, lamellar bone is regarded as mature & makes up the adult skeleton. Lamellar bone has two subcategories; cortical & trabecular. Cortical bone is what everyone pictures when they think of “bones”. Cortical bone is solid & compact, & makes up the exterior surface as well as the entirety of the shaft sections of the long bones. Unlike cortical bone, which is smooth & dense, trabecular bone is porous & netted. These two different types of lamellar bone serve two different purposes. Trabecular bone is seen at the ends of long bones or where bones are under constant pressure. The spongy matrix of trabecular bone allows it to support more weight than cortical bone, although it looks less stable. However, cortical bone is constantly under compression & tension, for instance in the femoral shaft. The dense but hollow frame of the cortical shaft allows for leverage of movement with the maximum amount of strength but the minimum amount of weight (Soluri & Agarwal, 2016; White, 2012).

Bone Growth

Bone growth, or ossification, can be broken down into two categories: primary & secondary ossification centers. Primary ossification points are the areas where bone growth starts in the prenatal development process. Ossification of the skull, which starts in the fourth month of the embryonic stage, has 110 primary centers. By the time the child becomes an adult, the skull will have 22 mature bones, after the fusion of the other 88 ossification points.

Primary Ossification

Primary ossification is divided into two subcategories: endochondral & intramembranous ossification. Endochondral ossification refers to the embryonic growth of the skull bones, or the 110 primary ossification centers. Intramembranous ossification refers to the fetal development of the long bones. The difference between endochondral & intramembranous ossification is the calcification process of cartilage. Endochondral ossification does not go through this process, whereas the intramembranous ossification does.

Secondary Ossification

Secondary ossification points occur during an individual's childhood &, sometimes, through adulthood, as cartilage goes through the process of ossification. This is most easily seen in the long bones. Long bones are divided into three sections: the epiphysis, the diaphysis, & the metaphysis. The epiphyses of the long bones are at the proximal & distal ends. The diaphysis is also known as the shaft; for example, the dense, hollow, lamellar bone of the femoral shaft. The metaphyses are the meeting points of the diaphysis & the epiphyses. Between the metaphysis & the epiphysis is the epiphyseal plate, or the growth plate, where the addition of new bone lengthens the shaft.

The shaft also grows in width through appositional growth, as well as through mechanotransduction, as I will explore in Bone Strength & Fragility. This happens through a process known as modeling or remodeling, wherein old bone is resorbed &

new bone cells create an outer layer of fresh bone (Soluri & Agarwal, 2016; White, 2012).

Biomechanics: Strength, Fragility, & Adaptation

The constant pressures on bone require them to be very metabolically active as they adapt to their surroundings. In the 19th century, German doctor Julius Wolff determined the mechanotransduction properties of bone & hypothesized that bone would react & remodel in the face of external stresses. Today, we call this Wolff's Law, which states that as stress is applied to bone, the bone will remodel & rebuild to adapt to, & eventually, resist against repetitive tension or compression.

In the 1960s, American doctor Harold Frost refined Wolff's Law with a model called the *Mechanostat*. He determined that "mechanical elastic deformation of bone" is a lifelong process caused by muscles & other changes to bone, like breaks. The elastic deformation of the bone is measured in strain in regard to disuse, overload, fracture, & constant adaptation. This model, which was first displayed in the Utah Paradigm of Skeletal Physiology, is primarily important in combating bone loss in such instances as severe fracture, osteoarthritis, & osteoporosis. This has led others, such as Charles H. Turner, to focus specifically on the mechanotransductor pathway method to use pharmacotherapy to restore bone loss.

There are two basic models of biomechanics; the load-displacement curve & the stress-strain curve. In the load-displacement model, the y-axis represents the force applied to the bone & the x-axis represents the displacement, or dislocation, of the bone. The load-displacement curve provides a variety of information: bone integrity, stiffness, brittleness, & the point of fracture. Likewise, this model can also show the changes to the bone depending on varying circumstances. For instance, “osteopetrotic bone is brittle & thus displays reduced work to failure” because the bone does not have the capability to be displaced the same way a healthy bone would. Furthermore, the pliable nature of juvenile elements raises the amount of displacement needed before the bone will break, “resulting in increased work to failure” & potential deformation of the bone. The stress-strain curve measures the rigidity of the bone & the amount of energy necessary to cause the bone to fracture. The trajectory of the stress-strain curve is known as Young’s modulus.

Together, these two models can tell the osteologist the durability & the stiffness of the bone in question. Where an element falls within the load-displacement curve & stress-strain curve determines how healthy the bone is. When placed together, Young’s modulus & the ultimate strain are inversely correlated along the y-axis. The x-axis displays the bone mineral density (BMD) which is displayed as a fraction of the mineral volume of bone. As previously discussed in Bone Composition & Function, there are average percentages of the different components of bone. Changes to this ratio could have serious consequences in terms of the strength & fragility of the bone. The higher the hydroxyapatite, or mineral content, the more brittle the bone becomes. Alternatively, collagen, while less significant to the strength or fragility of the bone, improves the durability of the bone.

Many researchers, like Turner, set out to prove that, German physicist Dr. Claus Mattheck's theory on the biomechanics of trees, could also be applied to bone. If Mattheck's theory applied to bone biomechanics as well, then it is expected that stress on bone will cause growth & adaptation in the area the stress is directly affecting. Alternatively, lack of stress or disuse can cause bone to become less dense. In the early 2000s, it was determined in multiple experiments that bone does in fact react greater to higher strains & in the specific area that it is needed. "The improvement in bone structure is evidenced by a 64% increase in bone strength & a 100-fold increase in fatigue life, yet the improvement in areal BMD was only a modest 5-8%". This shows that stress greatly increases the strength & life span of the bone while keeping the bone mineral density, or heaviness, to a minimum.

Bone Adaptation

Bone adaptation follows three central rules: 1) It is stimulated by dynamic loading, 2) it occurs during short intervals of time, & 3) it is more reactive to novel loading. Firstly, bone adapts, as Wolff determined, when stress is applied. However, stress loads fall into two different categories, & bones react differently between the two types of loading. Dynamic loading is constantly varying in the force being applied to the bone, whereas static loading applies a steady, constant pressure. Bone adapts more readily to dynamic loading, as opposed to static. Secondly, bone responds quickly to short intervals of loading. In fact, continued dynamic loading can hit a point of saturation where the bone will begin to resist adaptation &, eventually, will decrease additional remodeling. Thirdly, bone adaptation is more respondent to unique stress situations than habitual or methodical loading. This is because the bone cells react strongly to new & uncommon stresses (Turner, 1998; Turner, 2002; Turner, 2006; Bonfield & Li, 1966).

Chapter 11 – Variable Determination

Sex

Determining sex of skeletal remains is one of the most important aspects of forensic anthropology. The pelvis has been regarded as the most sexually dimorphic bone in the body. However, the pelvis does not always survive. Many osteologists & forensic anthropologists have historically considered the skull to be the second most useful element in determining an individual's sex. However, there is a growing trend to use biometric or osteometric statistical measurements to analyze univariate & multivariate qualities of postcranial elements. If multiple postcranial bones are available, it is more effective to metrically evaluate the sex for a higher rate of accuracy than just cranial analysis alone.

<u>Pelvis</u>

Estimating sex using the pelvis can be done visually, without the use of metrics, & if done correctly, sex can be determined with high accuracy. The greater sciatic notch of the ilium is one highly variable feature. Males tend to have narrow, deep notches, while females have wide, broad notches. On the pubis, the most sexually diagnostic element of the pelvis, three features can be visually evaluated to estimate sex using Phenice's Technique: 1) the ventral arc, 2) the subpubic concavity, & 3) the medial aspect of the ischiopubic ramus. The ventral arc & subpubic concavity are almost never seen in males. The anterior surface of the pubis in males is flat & generally smooth, whereas in females, the ventral arc creates a distinct lipped edge. On the posterior side of the pubis, a concavity is seen on females on the inferior aspect of the ischiopubic ramus. Again, this feature is absent in males, whose ishiopubic ramus has a straight, almost linear inferior angle. Lastly, the medial inferior border of the ischiopubic tends to have a sharp ridge in females, which is smooth & dull in males (Phenice, 1969; Lovell, 1989; White, 2012).

The pelvis, which includes both os coxae, the sacrum, & the coccyx, has sexually dimorphic characteristics that can be analyzed, when available. When viewing the pubic cavity inferiorly, females tend to have a wide opening, free of potential obstructions of the birth canal. Males, alternatively, have a heart shaped opening with protrusion of the ischial tuberosities & the coccyx into the pubic cavity. When viewed anteriorly, the male pubic concavity is narrow & the iliac fossae incline superiorly. In this same view, the female pubic cavity is much wider than the males & the iliac fossae are much more horizontally angled, creating wider hips & a shallow pelvic bowl.

Similar to the sciatic notch, the subpubic angle is acute in males & obtuse in females. Inversely, males tend to have wider pubic angles than females. From the lateral view, male obturator foramina look like vertically-orientated ovals. The female obturator foramina look compressed & slightly triangular.

Cranium

The cranium, when present, is often considered the second-best indicator of sex when the pelvis is unavailable. Although this is disputed by some, Dr. Phillip L.

Walker's qualitative grading method for skulls has an accuracy rate around 86%. Walker's system requires the osteologist to objectively classify each of five features of the skull, while in Frankfort Horizontal, on a scale of one to five, where one is more feminine & five is more masculine. A grade of three signifies an inability to discern feminine or masculine aspects. However, assignments of two & four reflect an uncertainty; two is a probable female & four is probable male. The five features analyzed in this method are 1) the nuchal crest of the occipital, 2) the mastoid processes of the temporals, 3) the supraorbital margins of the frontal, 4) the glabella of the frontal, & 5) the mental eminence of the mandible. Once the osteologist has graded each feature available, the mean total will give the sex estimation.

The nuchal crest, attachment site of many neck & upper back muscles, should be viewed laterally. In females, the nuchal crest is less pronounced due to leaner muscle structure. In males, the nuchal crest tends to protrude posteriorly. The mastoid processes are also neck muscle attachment sites which tend to pull the bone posteriorly more in males than in females. A good, if unofficial, method for grading the size of the mastoid processes is to place the skull on a smooth, flat surface. If the mastoids are large enough to lift the skull up off the table, it is most likely a male. However, if the mastoids are small then the skull will rest on the occipital condyles around the foramen magnum; this situation generally dictates a female skull. Next, determine the value for the supraorbital margins. When viewed laterally, female supraorbital margins are sharp & point posteriorly, while males tend to have blunt, rounded margins. In this same view, the glabella of the frontal can be graded as well. In males, the glabella protrudes just anterior to the nasion of the nasal bones. This is nearly absent in females, as the glabella tends to be almost smooth. Lastly, the mental eminence of the mandible, a triangular portion of the jaw which defines the size of the chin in life, can be graded as the other features. As assumed, females tend to have slight eminences & overall smaller mandibles. Male jaws are often larger in comparison with more pronounced mental eminences. Although not included in Walker's qualification method, the gonial angles of the mandible are also fair indicators of sex. Men tend to have large, flared, & generally 90° gonial angles. This produces strong, square jaws in life. Inversely, females have slender angles that are fairly rounded (White, 2012; Walker, 2008).

The skull and/or pelvis may not always be available for sex determination analysis in all situations. It is possible to use postcranial elements to determine sex, however, these techniques usually require laboratory metrics as opposed to the qualitative style of field procedures. Naturally, the more postcranial elements & features examined, the higher the accuracy percentage.

<u>Scapula</u>

The scapula may have as high as a "95% correct sex determination using only three parameters" including the maximum distance between the acromion & coracoid process, the maximum length of the coracoid process, & the anteroposterior length of the glenoid fossa (Di Vella, 1994). Measurement of the anatomical height, or the maximum length, of the scapula can also be used for sex determination, though this method has its restrictions. Delimitation points of scapular height can determine sex with nearly 97%

accuracy. Male scapulae have a minimum length of 14 cm & female scapulae have a maximum height of 17 cm. However, scapular measurements that fall in between these demarcation points can only be sexed with 29% accuracy (Dwight, 1894; Dabbs 2009). Lastly, the scapular breadth can be used to gauge sex with roughly 85% accuracy. Female scapulae average out at 9.5 cm wide & men at nearly 11 cm (Moore, 2016; Spradley, 2011). Less exact visual assessments of the scapula can be made using the suprascapular notch & the angle of the scapular spine. Male scapulae tend to have deep notches while female notches are shallow. Furthermore, male & female scapulae vary in the obvious aspects of overall size & shape, including the angle of the spine to the vertex of the superior angle, which is larger in males than in females.

Humerus

The humerus is multivariate with an accuracy rate of over 85%. The two features of the humerus with the highest accuracy are the vertical humeral head diameter & the epicondylar breadth. The vertical humeral head is measured from the lateral-most to the medial-most points along a true line. Males average at 4.7 cm & females at 4.1 cm. The epicondylar breadth is measured from the lateral-most portion of the lateral epicondyle to the medial-most part of the medial epicondyle. The average female epicondylar breadth is 5.5 cm while the mean male breadth is almost a centimeter more at 6.4 cm. According to numerous studies, the presence of a supratrochlear foramen just anterior to the trochlea of the distal humerus could indicate a female. The average percentage of females with the foramen is 23%, while only about 16% of males show presence of this trait (Ndou et al. 2012, Erdogmus et al. 2014).

Femur

Like many of the other long bones, the average overall length of the bone can sometimes be used in sex determination due to the correlation between height & long bone length. Out of all the components of the radius, the maximal length is the most accurate at 85%. Female radii generally average out at 24 cm while male radii have an average length of nearly 27 cm. However, leg bones are much more accurate for sex determination, with tibial & femoral features having accuracy greater than 86%. This is not including the respective lengths of these elements, whose accuracy falls below 80% for both the tibia & the femur. The best tibial feature for determining sex is the breadth of the proximal epiphysis, which is measured from the lateral-most point of the tibial plateau to the medial-most point of the plateau. Females have an average maximum breadth of 7 cm & males average out at 8cm.

The femur, however, has two features that should be used concurrently when establishing sex. The femoral epicondylar breadth, at 89% accuracy independently, & the maximal diameter of the head, at 86% accuracy independently, are the most precise femoral traits. It is worth noting though that other studies have shown these precision rates to be lower in non-White populations. The femoral epicondylar breadth, measured from the lateral epicondyle to the medial epicondyle, has a sectioning point of 7.7 cm, with females at an average of 7.2 cm & males at an average of 8.2 cm. The vertical diameter of the femoral head averages at 4.1 cm in females & 4.6 cm in males, with a demarcation position at 4.3 cm. Lastly, the triangle formed by the lateral-most point of the femoral head plate & the apices of the greater & lesser trochanters on the posterior proximal end has been found to be sexually dimorphic. The differences in size are directly correlated to sex in most cases. Muscular insertion points, like those on the proximal end of the femur & the distal end of the humerus, create greater variances between the sexes. This method of measuring the proximal end of the femur is over 87% accurate (Işcan, 2005; Purkait, 2005).

Age

Age estimation attempts to determine the age of the individual at death. There are several methods for estimating age such as dental formation & eruption, dental attrition, epiphyseal plate growth, long bone length, sternal rib ends, suture closures, & the pubic symphysis & auricular surface of the os coxae. While each method has its own benefits & disadvantages, it is most effective to use multiple techniques as well as comparing dental & elemental development & growth (Bassed, 2012).

Tooth Formation

Tooth formation begins in utero & continues through the development of permanent teeth. While eruption charts are useful, radiographs can allow a more profound inspection of the predetermined structure of tooth formation. Demirjian, et. al developed a system for classifying & scoring seven teeth from the left mandible in which the use of comparative radiographic images, detailed illustrations, & exacting, descriptive stages allows for chronological aging with over 90% accuracy. However, this aging method is only useful for subadults (Demirjian, 1973; Maber, 2006).

Tooth Eruption

If radiographic analysis is unavailable, tooth eruption patterns are also used to age subadults. Eruption charts are available from multiple different reputable, reviewed sources; most of these charts agree on the specific years of childhood & adolescence in which teeth erupt. By the second year of life, the majority of the deciduous teeth will have emerged. Around seven, permanent teeth begin to emerge, starting with the incisors. By eleven, the permanent canines & premolars are emerging. & the permanent molars come in at the intervals of six years, twelve years, & eighteen years.

Considering that not all individuals fall within these patterns, it is beneficial to compare multiple methods of aging dentition as well as other available correlative data (Ubelaker, 1999; White, 2012).

Dental Wear

Once an individual has all of their permanent teeth fully formed & erupted, these methods are no longer applicable for aging. However, dental wear patterns are one way to age adults upon completion of eruption. Dental wear patterns or attrition charts, such as Brothwell's dental wear chart, attempt to estimate age based on the amount of dentine exposed on the occlusal surface of the tooth. However, there are numerous issues with systems such as this. The primary issue is that exact chronological age is not achievable. Brothwell's age ranges are 17-25, 25-35, 35-45, 45+. While an age estimation of 25-35 may be sufficient in some cases, the 45+ age range leads into the issue of aging elderly individuals. The second concern, as just mentioned, is the uncertainty in aging during senescence. As individuals age, especially as seen in archaeological sites, tooth loss is somewhat common; thus in combination with potentially severe wear, aging older individuals with any sort of exactness is unfeasible. The third & final dilemma is the lack of cultural or individual variety. Various diets, lifestyles, beliefs, & other behaviors can impact dental wear & health. These variations cause differences in the way tooth loss occurs, whether it is through attrition, erosion, or abrasion (Koçani, 2012; Scheuer, 2002; Brothwell, 1965).

Epiphyseal Fusion

The epiphyseal plate is the area at the proximal & distal ends of long bones that allows for growth during childhood. These plates contain a layer of cartilage that goes through the process of ossification during development to continually add new layers of bone. Mature bones that are no longer growing have fused epiphyseal plates in which bone has replaced all the cartilage. The predictable rates at which these plates fuse can help osteologists estimate individual age. Long bone fusion, which occurs between 18-25 years of age, is the most accurate for aging. The fusion rates of other elements, including the scapula & the ischium, are much more variable & thus, provide less accuracy. Proper aging using this technique requires appropriate differentiation between separate, fusing, & fully fused epiphyses (Scheuer, 2002; Stevenson, 1924).

Long Bone Length

Long bone length used in age determination attempts to find chronological age based on the interrelationship between the overall size of the element & the age of the individual. However, these measurements, including the length of the diaphysis, the length of the entire long bone, & the maximal vertical diameter of the femoral head, are generally only useful for subadults up to approximately 23 years of age. Nevertheless, long bones are still useful in age determination, especially the femur. The use of radiographs, or even more precise, microradiographs, for the study of the internal tissue structure can predict adult & elderly ages as well as give more exact ranges. It has been noted, however, that additional factors, such as illness, cultural influences, variation, & population-specific data, skew analysis, even through the use of regression formulae. The most common problem seen with most age estimation methods is a direct correlation between old age & ambiguous categories. As bones age, the predictability of their microbiology & architecture becomes less definite & thus, accuracy decreases as the chronological age of the individual increases, regardless of the intensity of the element destruction (Rissech, 2008; Watanabe, 1998; Jantz & Jantz, 1999; Schmeling, 2007; Franklin, 2010).

Ribs

Analysis of the ribs has become increasingly popular for age estimation. This method, developed by M. Y. Işcan, scores three multivariate factors of the sternal end of the ribs allowing for increasingly accurate aging in senescence. Though, like many other aging techniques, this method tends to overestimate ages. The benefit of this method is that numerous rib analysis tends to support the same result as the singular analysis of the right fourth rib, which is less work on the osteologist than other techniques & provides up to 75% accuracy (Franklin, 2010; Işcan, 1984; Wolff, 2012; Meena & Rani, 2014).

Cranial Suture Fusion

Just as epiphyseal plates fuse during development, the separate bony plates that make up the cranium fuse at the suture lines as an individual ages. Young individuals have space for growth between the plates. Once the skull matures, the sutures begin to close in a very specifically timed pattern, beginning endocranially & moving to the ectocranium. Generally, it is only vault sutures that are analyzed, with the exception of the four palatine sutures, to estimate age. There are multiple different scoring techniques used to age, & when possible, multiple variables & methods should be used & compared. As with other biological estimations, variation exists across populations & time, & non-specific data should be treated with apprehension. It should also be noted that suture fusion or union can result in complete erasure of the suture; this will be discussed further in the congenital disorder section of “Pathology”.

Comparing multiple methods of the cranial suture closure age estimation will lead one to a basic set of structured limits. As previously noted, it is safe to say that sutures close from the endocranium to the ectocranium in a constant, distinguishable pattern. The “lapsed union” phenomena has been addressed by multiple authors, which states that suture closure may decelerate with age, with endocranial activity terminating around middle age, causing incomplete closure, even in completely healthy individuals. Sex can also cause differences in suture closure times & should be taken into consideration. Due to the potential of previously discussed variation, it is safest, & more prevalently accepted, to use decade age ranges for age estimation. Lastly, correct age estimation becomes more difficult as an individual ages, & as such, older estimation should be done so with greater conservation (Krogman, 1962; Bedford et al., 1993; Key, Aiello, & Molleson, 1994; Meindl & Lovejoy, 1985; Todd & Lyon, 1925).

Pubic Symphysis

A common method of adult age estimation is the morphology & texture of the pubic symphysis. The pubic symphysis is the meeting point of the left & right os coxae of the pelvis. In life, the two sides have a layer of cartilage in between them & are held together by the pubic ligaments. It is important to understand this because the two faces of the pubic symphysis never actually touch. However, throughout the course of an individual's life, the faces change shape & texture. Young individuals have well defined pubic symphyseal faces with deep ridges. As individuals age, the ridges erode & become less visible. The overall outline of the face may also change shape.

In the 1920s, T. W. Todd developed a ten-phase chart for age estimation of the pubic symphyseal face in adults. While many others have expanded on & improved upon Todd's method, the Suchey-Brooks method has since proved to have high accuracy from 18-30 years old, dropping exponentially as the individual's true age increases. This is partly due to the unpredictability of changes as an individual ages. Different factors can contribute to more severe degradation such as childbirth or injury. The Suchey-Brooks system encompasses six phases that include strict characterization for each, including sketches. While Todd's method was based solely on a moderately sized sample of White males, Suchey-Brook's method utilized a sample of over 1,000 males & females (Todd, 1921; Brooks & Suchey, 1990; Gilbert & McKern, 1973; Cox, 2010; Brooks, 1955; Franklin, 2010).

Auricular Surface

Similarly to the pubic symphysis, the auricular surface of the os coxae is also used. The auricular surface, like the symphyseal plates, is separated from directly articulating with the sacrum by cartilage & the joint is held together by large ligaments. The erosion to this kidney bean-shaped portion of the ilium can be used to estimate age at time of death. The auricular surface is considered a more reliable indicator of age than the Suchey-Brooks method for the pubic symphysis. This method uses Lovejoy's eight-phase system to place individuals within an age range. As with multiple types of age estimation, unpredictability often causes higher percentages of overestimation in individuals over the age of sixty.

The surface of the iliosacral articulation is undulated with highly visible striae. As the individual ages, the surface loses ridge detail, becomes more porous, & begins to lip up around the perimeter of the joint. This method also uses features such as microporosity, granularity, & transverse organization. It has been recently suggested however, that some of the phase requirements for the Lovejoy method may occur independently of each other & therefore, atypical of the model (Hens, 2008; Schmitt, 2004; Buckberry & Chamberlain, 2002; Lovejoy, 1985; Franklin, 2010; White, 2012; Klepinger, 2006).

Stature

Long Bone Length

When estimating stature, it is common to use long bones due to their direct correlation to an individual's living height. While height estimation began very differently, most methods today rely on specific formulae to determine living stature within a degree of error. As with all other estimations & calculations, populations & genders vary in stature across the world. It is also important to note that stature may be lost with age &, some have found, that taller individuals have a greater amount of soft tissue to account for.

Various methods have been developed with the use of varying populations. Trotter & Gleser's 1952 version was used until Trotter spoke at a seminar in 1968 about improvements to the system. Since then, more precision has been added to known populations & genders.

FORDISC & Owsley's Method

The debate about the difference between biological stature & forensic stature has led to other methods of linear regression models being formulated as well as using greater numbers of sources of osteological data. The most extensive, although far from perfect, is FORDISC 3.0, a collective software used for establishing a probable biological profile. Unlike the methods of Trotter & Gleser (1952), Trotter (1970), & Owsley (1995), FORDISC establishes stature from cranial fragments only. The benefit of FORDISC is the extensive inventory of collections used as reference within the software.

FORDISC contains the cranial data of W. W. Howell's lifelong work as well as the Forensic Anthropology Data Bank (FDB), which is partnered with over 30 institutions, including medical examiners' offices, universities, & the C. A. Pound Human Identification Laboratory. The FDB currently reports to having almost 3,400 total individuals with the sex & ancestry known of over 2,400 of those.

Owsley's regression model is often considered next best when lack of funding or other issues prevent the use of FORDISC. To counter the errors in Trotter & Gleser's 1952 measurements, Owsley's method, using left elements only, measured the femur, tibia, ulna, humerus, & radius of males & females in Black & White populations, when available. Further expansions have focused on damaged, as opposed to intact, elements, particularly in the use of the distal or proximal ends of long bones as well as foot measurements. This is especially helpful in specific forensic cases as well as bombings & mass killings (Trotter & Gleser, 1952; Trotter, 1970; Owsley, 1995; Özaslan, 2003; Krishan, 2006; Brandt, 2009).

Chapter 12 - Pathology

While the vast majority of diseases do not leave their marks on bone, many different types of congenital, metabolic, & infectious diseases are clearly visible on affected elements. Archaeologically, this helps understand the population as a whole; what diseases affected them & how they handled them within a socio-cultural perspective. It is worth noting that fractures can be categorized as both a pathology as well as a human modification depending on the cause & effect on the bone.

Joint Diseases

The most common pathology among humans is arthritis. Arthritis can be broken down into two different categories, rheumatoid arthritis (RA) & osteoarthritis (OA). It is important to know their similarities & differences, though we do not currently have the capability to macroscopically determine which arthritis an individual is exhibiting. Further research in this area could help expand knowledge about archaeological populations & the presence of RA, an autoimmune disorder. OA, while the same as RA in the sense that both can cause severe joint inflammation & pain as well as constant degradation of the joint cartilage, is caused by normal use during the aging process. Historically & presently, knee joints are the most commonly effected.

The two most common pieces of osteological evidence of arthritis are very specific & clear to determine. First, many arthritic specimens show signs of polishing, also known as eburnation; this gives the bone surface a smooth & shiny appearance which is caused by complete obliteration of cartilage in life. Secondly, & most commonly, is the formation of osteophytes, also known as “bone spurs”, which causes sharp, bony projections & deformation around the outer edges of the element. If osteophyte growth is severe, total fusion of joints is possible, especially in the vertebral column.

Additional joint diseases include TMD, Forestier’s Disease, Charcot’s Joint, septic arthritis, & cysts. TMD, often misreferred to as TMJ, is a condition that affects the temporomandibular joint of the mandibular fossa. Forestier’s Disease is a type of Diffuse Idiopathic Skeletal Hyperostosis (DISH), which most often affects the spine by causing the spinal tendons to calcify. A multitude of factors can cause DISH, such as genetics, environment, diet, & overuse. Neurotrophic arthropathy, also known as Charcot's Joint, is a degenerative, reabsorption of joint bones, often due to diabetes. While OA & RA are incurable, septic arthritis is curable but also life-threatening. Septic arthritis is not truly a type of arthritis, but instead an infection of the fluids within a joint. Cysts can also form within joints, often leaving lesions easily visible macroscopically (White, 2012; Ubelaker, 1999; Rogers, 1990; Soluri & Agarwal, 2016; Twigger, 2007; Gray, 1977; Mayo Clinic, 2017; ABTA, 2014).

Infections

Various types of infections can lead to bone degeneration & deformation. Bacterium, viruses, & fungi can enter the bloodstream, lymphatic system, respiratory system, or immune system & effect the overall quality of the bone. Many infections cause affected bones to show signs of localized swelling & inflammation as well as porosity, apertures, anamorphosis, & overall enlargement of the entire bone.

Infections of the skeletal system are, in general, labelled osteomyelitis, or the inflammation of bone. All types of infections that affect bones cause osteomyelitis. The most common of these, however, are mycobacterium, which causes tuberculosis, & pyogenic bacterium, such as staph infections & salmonella. Other types of infectious diseases include Bechterew's Disease, syphilis, & Hansen's Disease. Bechterew's Disease, known medically as ankylosing spondylitis, causes spine deformation, particularly in young men. Syphilis is a bacterium-caused STD which can be cured of, but when left untreated, can cause soreness, rashes, &, eventually, deformation. When left untreated, syphilis can reach its tertiary state which can affect the central nervous system, cause the growth of soft, gummatous tumors, & abdominal aortic aneurysms (AAA).

White, Black, & Folkens also explain the effect of periostitis on bone. Periostitis is different from osteomyelitis in the sense that, while the latter affects the entirety of the bone, including the medullary cavity, periostitis only affects the external surface of the bone. Periostitis is not itself an infectious disease, but instead, it is a common manifestation of various infections when the periosteum (the tissue layer over bone) incurs damage. Periostitis can cause localized erosion to the cortical bone such as in cases of chronic shin splints in athletes (Ubelaker, 1999; White, 2012; Rosenberg & Khurana, 2016; Twigger, 2007; Gray, 1977; Mayo Clinic, 2017; ABTA, 2014; Brothwell, 1965).

Congenital Disorders

Congenital disorders occur either in utero or right around the time of birth. Many congenital disorders are inherited, such as achondroplasia & mucopolysaccharidoses disorders (most of which are also metabolic). Other congenital disorders occur due to a combination of genetic & environmental factors, such as spina bifida & cleft palate. Talipes equinovarus (CTEV) & femoral deficiency (CFD) are both congenital disorders that may or may not have genetic factors; disorders like these still evade doctors as to their cause. Polio is a congenital disorder that is caused by a virus & is therefore both congenital & infectious.

Achondroplasia, also known as dwarfism, is the most common type of skeletal dysplasia. The most common skeletal symptom of achondroplasia is shortened long bones. Mucopolysaccharidoses disorders are part of a unique set of inherited, congenital metabolic syndromes. These include Hurler's Syndrome, Hunter's Syndrome, Sanfilippo Syndrome, & Morquio Syndrome. This group of syndromes is characterized by the body's inability to create skin, tissues, cartilage, tendons, &, of course, bone. Osteogenesis imperfecta & osteopetrosis are also genetic congenital disorders but are rather rare. Osteogenesis imperfecta, also known as Brittle Bone Disease or OI, manifests in one of four types & affects the collagen structure of bone. Conversely, osteopetrosis, also called Marble Bone Disease or osteosclerosis fragilis generalisata, has three different forms that affect the overall density of bone. Both cases, however, increase the risk of fracture & deformation.

While some congenital disorders have known causes, others, such as spina bifida & cleft palate, are still not fully understood. Spina bifida is often used as an umbrella term for each of the three different types. Spina bifida occulta is the least severe form of the disorder which causes slight spaces between the vertebrae. It is possible that spina bifida occulta may not actually have any osteological signs. Meningocele & myelomeningocele are the other two types of spina bifida, which are rarer & more severe, respectively. Meningocele, like spina bifida occulta, may not have any osteological signs due to the relative mildness & its focus on soft tissues. Myelomeningocele is the most severe form of the disorder & is often called spina bifida in everyday speech. Myelomeningocele causes an opening along the lower vertebrae, causing them to protrude outwardly. This often causes deformation of the spine & feet, as well as the appearance of Wolff's Law in the pelvis. Like spina bifida, the cause of cleft palates are not completely known. It is accepted that environmental & dietary factors play a large role, as the majority of cases are seen in undeveloped or developing countries. Cleft palates are separated into two parts, cleft lip (CL) & cleft palate (CP), & are recognizable as moderate to severe deformation of the maxillae and/or the palates. Talipes equinovarus, also known as club foot, & congenital femoral deficiency (CFD) are both congenital disorders that are not considered to have heritable factors. Club foot can cause a shortening of the femur as well as contortion of the foot. CFD causes deformation to the knee and/or hip joints causing weakness & imbalance. Lastly, polio or poliomyelitis, caused by the poliovirus, often causes coxa valga, or the widening of the femoral-acetabular joint. Coxa valga creates an angle of greater than 135° from the shaft to the apex of the femoral head (Gray, 1977; White, 2012; Ubelaker, 1999; Mayo Clinic, 2017; ABTA, 2014).

Neoplasia

Quite simply, neoplasia is the abnormal growth of tissue. Neoplastic conditions are those in which the individual suffers from malignant and/or benign tumors, which can leave their mark on the skeleton. Malignant neoplasia, commonly referred to as cancer, are tumors that grow rapidly, can infect other parts of the body, & effectively cause damage to nearby soft tissues as well as osseous tissue. Malignant sarcomas commonly affect bone or the surrounding tissues & thus are easily visible on both green

& dry bone. Many of the sarcomas look the same in the sense that they can form lytic lesions, blastic lesions, or, sometimes, a combination of both.

The most common type of bone-affecting cancer is osteosarcoma, which begins in the metaphyses of the long bones during the early years of growth. This can look very similar to chondrosarcoma, which are tumors that invade the cartilage present in the pelvis & joints of older individuals. Paget's Disease, commonly misidentified as late onset osteosarcoma or chondrosarcoma, is specifically characterized by an expedited rate of bone destruction & regrowth affecting the pelvis & legs, but it is also known to affect the skull & spine. Similarly, Ewing's Sarcoma is a rare form of bone disease that affects the appendages & pelvis of young children. Lastly, fibrosarcoma & rhabdomyosarcoma, which can be fairly difficult to identify in skeletal remains, affect the fibrous tissues & the muscles, respectively, leaving their marks on bone.

Other non-sarcoma cancers can still affect the bone, specifically the quality of the bone. Multiple myeloma, or Kahler's Disease, is one such cancer that attacks the bone marrow via the white blood cells & results in an overall weakening of the bones. Alternatively, leontiasis ossea, sometimes called "lion face", is marked by severe bony overgrowth in the skull & mandible. Lastly, nasopharyngeal carcinoma, a type of skin or organ-lining tissue cancer, can mimic leprosy. This type of carcinoma eats away at the nasal & sphenoid bones (Ubelaker, 1999; Brothwell, 1965; White, 2012; Mayo Clinic, 2017; ABTA, 2014; Krygler & Lewis, 2009; Chowdhuri, 1969; PRO, 2014; NCI, 2016)

Endocrine Disorders

The endocrine system of the human body is responsible for releasing hormones into the bloodstream via the different glands. Disorders that affect the hormone levels in the body can cause issues with growth & development as well as mineral metabolism of bone. All endocrine disorders can also be congenital as well. Conditions such as hyperparathyroidism & hypothyroidism can affect the overall quality of the bone whereas disorders such as pituitary dwarfism & acromegaly tend to only affect the growth & development of the bone.

Conditions such as these tend to cause the release of either too much or too little of the necessary growth hormones. Hypothyroidism, which is caused by an underactive thyroid, can lead to delayed skeletal development in children as well as the discontinuation of bone reabsorption & remodeling in older age, if left untreated.

Comparatively, hyperparathyroidism affects the smaller parathyroid glands, just posterior to the thyroid, causing an overproduction of hormones. However, similar to hypothyroidism, bones can become weak & brittle in those with hyperparathyroidism. Both conditions have also been associated with joint pain & the onset of OA.

Whereas hyperparathyroidism & hypothyroidism can affect bone mass & quality, pituitary dwarfism & acromegaly tend to affect the overall rate of development. Both pituitary dwarfism & acromegaly are caused by issues with the pituitary gland, however the latter is caused by an underactive gland & the former by an overproduction of hormones during childhood. Pituitary dwarfs have shortened limbs & a disproportionately large cranium. Conversely, acromegaly causes the hands, feet, & cranium of those affected to grow abnormally large. Acromegaly is often referred to as gigantism due to the proportionally acute growth of the limbs & torso (Mayo Clinic, 2017; White, 2012; Brothwell, 1965; Ubelaker, 1999; Gray, 1977; Harvey, 2002; Potluková, 2013).

Metabolic Disorders

Various metabolic conditions can leave macroscopically visible traces. Metabolic disorders can either arise independently, such as when an individual is missing essential vitamins, or in response to other factors, such as endocrine disorders, liver or pancreatic disease, or eating disorders. Conditions such as these generally lower the individual's BMD or bone mineral density. For the vast majority of these conditions, the bones become weak & brittle from a lack of healthy bone growth. This leads to deformation & fracture of bone in life.

Many of the metabolic issues revolve around various deficiencies. Some of these disorders include calcium, vitamin D, & vitamin C deficiencies. Other conditions come about due to overall poor nutrition, such as in cases of anorexia or in undeveloped countries. Many of the deficiency conditions can be congenital if the mother has poor nutrition during pregnancy.

Hyper- & hypocalcemia are conditions that are related to too much calcium & too little calcium, respectively. As the calcium levels in the bloodstream become unstable, the new bone growth is weak & characterized by lytic lesions. It has been noted that hypercalcemia can come about due to childhood leukemia. Rickets & osteomalacia both result from a lack of vitamin D. Rickets is associated with soft, deformed bones in children, & while osteomalacia also creates weak bones, it only occurs in adults as a consequence of the aging process & poor nutrition.

Osteopenia is a classic disorder associated with anorexia. This disease creates bones with an overall lowered BMD by resorbing old bone faster than the new bone is formed. This gives the bone a porous appearance with a brittle structure subject to frequent breaks. Paget’s Disease also causes issues with the regeneration of healthy bone. As previously mentioned, Paget’s Disease is often confused with osteosarcoma, due to the similarities in bone degradation. Due to the bone cell’s inability to regenerate properly, the new bone is soft & pliable. This commonly leads to deformities, especially in the skull, pelvis, & spine. Lastly, scurvy, sometimes called scorbus, is a nearly eradicated disease caused by a lack of vitamin C. Many undeveloped & developing countries have issues providing proper nutrition to their people; conditions like these often affect children the worst. Scurvy prevents the bone from developing properly. This often results in distinctive blastic cysts on the frontal squama & on the frontal bone portion of the orbits (Mayo Clinic, 2017; White, 2012; Ubelaker, 1999; Brothwell, 1965; Lee, 2007; Walters & De Swiet, 2002; Viswanathan, 2014; Selby, 2013).

Other Types of Pathologies

There are various other types of pathologies that can cause damage to the skeletal system. As mentioned before, fractures can be considered a pathology due to the changes to structure of the bone during fracture & any subsequent healing. Other pathologic conditions that are skeletally visible include suture closure issues, chromosomal syndromes, various anemias, & other genetic disorders.

Healed Fractures

As previously discussed, osteomyelitis is any inflammation of bone. This inflammation initiates the response of bone growth. Bone fractures, when improperly set or provoke infections, fall within the realm of pathologies. However, even when properly set, fractures are often easy to spot & will be discussed further in modification & trauma. Nonetheless, fractures that heal improperly still go through the normal bone healing process, infections & disorders notwithstanding. The normal healing process begins with osteomyelitis at the fracture site. Like any other injury to the body, the reactionary response is inflammatory. However, at a fracture site, this inflammation is necessary to begin the healing process. New osteoblasts continue to form & cartilage begins to bridge the gap. Once this process begins, cartilage will advance in the path of least resistance to connect the two (or potentially more) ends of the improperly set bones.

The cartilage continues through the normal ossification process, culminating in deformed bones in severe fractures &, as states, fractures that are either set improperly or left to heal naturally. The injury site is clearly visible by a “knotted” appearance due to irregular remodeling (Agarwal & Soluri, 2016; White, 2012; Väänänen, 1996; Brothwell, 1965; Klepinger, 2006; Ubelaker, 1999).

Suture Closure

The closure pattern of sutures generally follows a normal, patterned course. Issues with the timing and/or pattern of the suture closures falls into two categories: craniosynostosis or delayed closure. Craniosynostosis refers to any condition that causes premature suture closing. In 1851, H.R. Virchow postulated the ways in which premature suture closure happens & the consequences of such instances. All forms of craniosynostosis cause microcephaly, in which the brain cause is significantly smaller than average. Microcephalic individuals have impeded brain development & thus suffer from learning disabilities. Virchow observed five types of craniosynostosis, depending on which sutures fused prematurely: trigonocephaly, scaphocephaly, brachycephaly, & anterior & posterior plagiocephaly. Delayed suture closure, unlike craniosynostosis, is not necessarily abnormal & generally does not cause developmental issues. The most common result of these delayed closures is the appearance of Wormian bones. While Wormian bones are also associated with types I & IV of osteogenesis imperfect, they are more commonly a benign sign (Soluri & Agarwal, 2016; Cohen, 1988; Key, 1994; White, 2012; Meindl & Lovejoy, 1985; Todd & Lyon, 1925; Alden, 1999; Gray, 1977; Brothwell, 1965).

Chromosomal Disorders

While there are many types of chromosomal disorders, few have such an extreme impact on the skeleton as Turner’s Syndrome. This syndrome begins with a chromosomal disorder. Turner’s Syndrome only affects biological females, causing them to be born with only one X chromosome. While this does not directly affect the skeletal system, Turner's Syndrome causes delayed puberty as well as cardiovascular & endocrine system issues. Because of this delayed growth, those with Turner's Syndrome tend to maintain a childlike appearance, even into adulthood. This includes stunted growth & shortened limbs (Soluri & Agarwal, 2016; Mayo Clinic, 2017).

Anemic Diseases

Anemic disorders are those that are defined by affecting the body's red blood cells. However, anemia in which the individual has nutritional lack of iron is specifically known as iron deficiency anemia. This lack of iron stops the body from making healthy red blood cells that can effectively carry oxygen throughout the body. Iron deficient anemia is common, both presently as well as historically, due to its connection to malnutrition & parasitic activity. Various authors have attributed this type of anemia to the archaeological presence of porotic hyperostosis. Porotic hyperostosis (PH) is characterized by destructive lesion growth "that usually presents in the cranial bones as porous & spongy bone surfaces" (Soluri & Agarwal, 2016). Porotic hyperostosis that occurs specifically in the orbits is known as cribra orbitalia, while lesions of the endocranium are known as cribra cranii. More recently, biological anthropologists have been questioning the assumed attribution of anemia in cases of porotic hyperostosis. It should also be noted that while sickle cell anemia & thalassemia are potentially more likely causes of porotic hyperostosis, they are both quite rare in comparison to iron deficiency anemia (Walker, 2009; Mayo Clinic, 2017; Mushrif, 2000; Ortner, 2003; Soluri & Agarwal, 2016; Brothwell, 1965; Ubelaker, 1999).

Genetic Disorders

Many types of heritable genetic disorders, while generally rare, can leave severe evidence on an individual's bones. Two of these rare genetic disorders cause heterotopic ossification, or growth of bone tissue in abnormal areas of the body. This generally leads to ossification of the connective, muscle, nervous, & epithelial tissues implicating organs, tendons, & ligaments. These two diseases are fibrodysplasia ossificans progressive (FOP) & progressive heterotopic ossification (HO). FOP's most common sign is the congenital appearance of deformation of the bones attached to the first metatarsal. As the disease progresses, the ossification moves to the cervical vertebrae, scapulae, & the appendicular skeleton. Alternatively, HO begins in the skin & fat tissues. The primary stages of the disease only affect the outer skin layers. As the disease progresses, muscle tissue & joints are commonly ossified. In both FOP & HO, the disease may cause total immobility; hyperostosis cranialis interna, though also a genetic ossification disease, does not affect mobility. Hyperostosis cranialis interna is a genetic disease that causes thickening of the calvaria, particularly near the basilar region & the occipital condyles. This expansion of the bones often causes cochleovestibular nerve compression syndrome (CNCS), which results in palsy of the facial nerves &, regularly, the sense of smell. Similarly, hyperostosis frontalias interna, causes an accumulation of bone on the vertical & horizontal endocranial portions of the frontal bone (NLM, 2017; White, 2012; Kaplan, 2013; Kaplan, 1994; Kaplan, 2008; Manni, 1990; Waterval, 2010; Waterval, 2012; Schwaber & Hall, 1992; Klepinger, 2006).

Dental Disease

Dental diseases are commonly seen historically as well as in current populations. White, Black, & Folkens discuss the categories of dental disease determined by J. R. Lukacs in 2006; the four categories are developmental, degenerative, genetic, & infectious, though there is a distinction drawn at dental wear. Dental wear is only viewed as pathological if it causes symptoms that fall into one of Lukacs' four categories. Common dental diseases include dental caries, periodontal disease, enamel hypoplasia, dental fluorosis, hypodontia, severe attrition, as well as dental calculus.

<u>Dental Caries</u>

Dental caries, more commonly known as cavities, are areas of the teeth that are going through demineralization & deterioration due to an overproduction of acid in the mouth. This overproduction of acid correlates to what types of food are ingested. It has been noted that populations with diets higher in carbohydrates are more likely to incur dental caries. If left untreated, dental caries can cause permanent damage to, not just the enamel, but to the dentin as well (White, 2012; Soluri & Agarwal, 2016; Brothwell, 1965).

<u>Periodontal Disease</u>

Periodontal disease, a leading cause of tooth loss, is an infection of both the soft tissues of the mouth as well as the alveolar bone. As this disease progresses, the bone surrounding the teeth is resorbed & fails to properly remodel. In the severity of the disease, the bone resorbs until the teeth fall out. This degenerative disease is caused by a variety of factors such as calculus build-up, severe attrition, & genetic predisposition, as well as reduced tissue resistance caused by malnutrition and/or eating disorders (White, 2012; Brothwell, 1965).

Hypoplasia

Enamel hypoplasia creates horizontal lines on the teeth which "indicate [that] the individual suffered stress (nutritional or health problems) while the tooth was being formed in early childhood" (Soluri & Agarwal, 2016). The lines are areas of the tooth that have incurred demineralization & thus have less enamel than the surrounding areas. Hypoplasia is an interesting developmental disease that affects amelogenesis, the crown-to-root formation of enamel. This creates many clues to, not just recognizing hypoplasia, but also to help also ascertain when the individual experienced the cause of the disease. Because enamel formation begins at the crown, tooth eruption ages can help gauge ages affected. Teeth that have already been formed, regardless of eruption, are not affected. However, if the enamel is still being constructed, the development of the remainder of the tooth may be affected. Enamel hypoplasia can also be an indication of the length of time the individual was affected for (White, 2012; Soluri & Agarwal, 2016; Brothwell, 1965).

Dental Fluorosis

One of the most commonly misidentified & still somewhat misunderstood diseases is dental fluorosis. Fluoride, a mineral found in ground & natural water, has been shown to help reduce dental caries by protecting the teeth against acid. However, various studies have noted the effects of excess fluoride in drinking water. Long term exposure to, even low levels of, fluoride cause enamel hypomineralization, which weakens enamel during development. These weakened areas of enamel create a blotchy, irregular surface. In mild circumstances, the teeth seem to have white patches. As the exposure continues, the teeth become increasingly weak as the body is unable to maintain a healthy tooth exterior. This eventually leads to excessive dental caries, tooth decay, & tooth loss. Early stages of dental fluorosis have been notably mistaken for hypoplasia (Pendrys, 1990; Pendrys, 1996; Breslow, 2002; Aoba & Fejerskov, 2002).

Hypodontia

Hypodontia is a rare developmental disease in which one or more of the teeth fail to form. This can occur in the deciduous or permanent tooth formation stages. There are two other forms of hypodontia, anodontia & microdontia. Anodontia, which is the rarest form, refers to a total lack of tooth formation, in either or both types of dentition. Microdontia, which causes incomplete formation of teeth, often results in small, pointed or rounded lateral incisors. Microdontia often occurs in addition to general hypodontia. This developmental disease has genetic & environmental factors that are still not completely understood. The prevalence of some form of hypodontia is roughly 5% in permanent dentition & some studies have noted higher instances in females than males. Hypodontia is associated with other conditions such as malocclusion, misplacement on teeth, & slowed dental growth (Daugaard-Jensen, 1997; Jeong, 2015; Gill, 2011).

Dental Attrition

Dental attrition, within normal, non-pathological circumstances, is the wear that occurs between the two surfaces of the maxillary & mandibular teeth during regular chewing. However, should the wear become severe enough, it may cause damage to the dentin, dental caries, & other inflammatory conditions, such as abscesses. Severe wear is seen more in prehistoric populations in which teeth were commonly used as tools, dental health was non-existent, &, as many studies have suggested, grit/sand in food was more prevalent & is likely a contributing factor to intense dental erosion (White, 2012; Ubelaker, 1999).

Dental Calculus

Lastly, dental calculus is the most common pathology. Calculus occurs when plaque becomes mineralized on the tooth's exterior. However, dental calculus build-up leads to other issues such as calcification &, as previously mentioned, periodontal disease. Calcification occurs when the calculus growth becomes severe enough to cause permanent damage. Often, severe calcification will gradually push the gums away as the build-up continues down the root. Historically, dental calculus & associated dental caries occur more often in agricultural societies as opposed to hunter gatherers (White, 2012; Brothwell, 1965).

Chapter 13 – Taphonomy & Modification

Taphonomy is specifically the "study of the processes that operate between the time of death of the organism" & when the remains are collected & analyzed (White, 2012). The time frame for these changes can be broken down into three categories:

antemortem, perimortem, & postmortem. Antemortem changes happen while the individual is still alive. These are not technically taphonomic changes because they occur prior to death. Antemortem pathologies, including fractures, generally show some to complete healing. Perimortem changes, however, occur just around the time of death & could be potentially related to the cause. Because these occur so close to the time of death, there are generally no signs of healing, but the bones still react as fresh bones. Postmortem changes occur after the individual is already deceased.

Modifications to the human skeleton can be divided into the different taphonomic groups: antemortem, perimortem, & postmortem. Antemortem changes, as previously mentioned, generally show complete healing. Bone fractures, cultural modifications, amputations, & other pathologies are included in the antemortem time frame. Perimortem alterations are nearly always related to trauma & are therefore extremely useful to the forensic osteologist. Postmortem changes, often referred to as psuedopathologies, encompass animal marks, dry bone fractures, physical/biological alterations, & human modifications.

Antemortem Trauma

Antemortem pathology is any trauma that occurred during the individual's life & shows some signs of healing. While this trauma generally is not the cause of death, antemortem pathologies can help identify individuals as well as determine more about an individual's life. Common antemortem alterations seen archaeologically as well as forensically are cranial deformations, amputations, & dislocations. As discussed in Pathologies, cranial deformation can be caused by disorders such as craniosynostosis.

However, cultural deformations such as cranium wrapping & trephination can cause antemortem damage that the individual may survive with their entire life.

Cranial Deformation

Artificial cranial deformation has been reported in various parts of the world over the span of many cultures. There are five different types of cranial deformation: 1) vertico-occipital, 2) lambdoid, 3) frontal, 4) fronto-occipital, & 5) circular (Ubelaker, 1999; Stewart, 1973). Vertico-occipital flattening is the easiest & most common type of cranial deformation, which produces a depression on the occipital bone. Archaeologically, this is seen in infants that have been strapped to a cradleboard. However, in recent times, vertico-occipital deformation is common in infants left on their backs for extended periods of time. Lambdoid deformation, though less common, is a less extensive form of vertico-occipital flattening. This type of deformation occurs anterior to the occipital planum, just along the intersection of the sagittal & lambdoid sutures. Frontal deformation occurs when pressure is applied to the frontal squama. The use of tumplines, both archaeologically & currently, can produce this type of deformation. Fronto-occipital flattening is often seen archaeologically as a cultural norm in some civilizations. This combines either types 1 & 3 or 2 & 3 of the types of deformation (Ubelaker, 1999). Lastly, circular deformation produces flattening around the circumference of the skull producing a cone shape. This is occasionally caused by the force applied to the infant's cranium during passage through the birth canal. This type of deformation can be fixed if altered during the child's early years (White, 2012; Ubelaker, 1999; Stewart, 1973; Brothwell, 1965).

Trephination

Trephination is the cultural & medical practice of cutting or drilling into in the cranial vault bones. The most common reasons behind this practice was to leave pain caused by brain swelling or attempting to perform a biopsy. Antemortem trephination scars are healing or completely healed. However, in the cases where trephination leads to death, it is categorized as perimortem trauma. Nonetheless, many individuals survived trephination procedures & show distinct marks of the procedure as well as various levels of regrowth (White, 2012; Ubelaker, 1999; Brothwell, 1965).

Amputation

Amputation, or the complete or partial removal of the appendicular body, produces hypervascularity in the affected area. The most common effect of amputation is a reduction in bone density, otherwise known as atrophy. The severity of atrophy is dependent on where the amputation occurred, what type of tool was used, additional factors, such as sclerosis or infection, & the amount of healing between procedure & the individual's death (Krogman, 1962; Sevastikoglou, 1969).

Whereas a fracture causes a break in the actual bone, dislocations affect the joint. If the dislocation is reset properly, there will likely be no osteological evidence of the trauma. However, in some instances, the joint is not properly repositioned & degradation of bones begins. Changes in morphology & articulation points occur the longer the bone is out of the joint socket (Lovell, 1997; Ubelaker, 1999; White, 2012).

Fractures

Fractures can be caused by four different factors, according to Nancy C. Lovell's 1997 article. Fractures can be caused by direct trauma, indirect trauma, stress, or pathology (Lovell, 1997). Within these causal categories, force applications can be divided into three subcategories: shearing, compression, & tension (Johnson, 1985). Shearing results in a shifting motion that slides the parts in opposite directions. Compression, as will be discussed further in crush fractures, is force applied to both sides of the element. Lastly, tension is any motion that pulls in opposite directions (Lovell, 1997; Johnson, 1985).

Direct trauma occurs at the site of impact whereas indirect trauma occurs adjacent to the impact site. Stress fractures, sometimes referred to as fatigue fractures, are caused by repetitive force. As discussed previously, shin splints suffered by athletes can commonly result in a tibial stress fracture due to repeated pressures. Lastly, certain pathologies may create an environment more open to bone fracture. Pathologies such as osteogenesis imperfecta & metabolic conditions weaken elemental chemical make-up leading to increased risks of fracture (Johnson, 1985; Lovell, 1997).

Direct trauma fractures occur due to exact force in a specific location. Fractures that often occur during direct trauma are crush, transverse, comminuted, & penetrating (Lovell, 1997). Crush fractures occur frequently in trabecular bone. This type of fracture can be broken down into three categories: compression, depression, or pressure (Lovell, 1997; Johnson, 1985).

Compression fractures, within crush fractures as well as in the broader sense of the term, occur when both sides of the bone are subjected to tension until the point of break. Alternatively, depression fractures only occur on one side of the bone & may cause indentations or led to complete rupture. Pressure crush fractures occur in bone that is still developing. This is often seen in conjunction with cultural alterations such as in cranial deformation or “the alteration of the normal contour of the skull by applying external forces” (Ubelaker, 1999) & foot binding practices (Ubelaker, 1999; White, 2012; Johnson, 1985; Lovell, 1997).

Transverse fractures resulting from direct force are commonly referred to as a “clean break”. These fractures occur when “force [is] applied in a line perpendicular to [the] long axis of the bone” (Lovell, 1997). Transverse fractures occur in one single break perpendicular to the longest axis of the bone. Transverse fractures are always complete, meaning that they always break the bone through & can often lead to displacement (Lovell, 1997; Radiopaedia, 2017).

Comminuted fractures result from crushing force in long bone diaphysis. These fractures differ from crush fractures to trabecular bone in that they cause the cortical bone to break into at least two pieces. Commonly, “high velocity bullets & blunt force trauma to the cranium […] cause comminuted fractures” (Lovell, 1997).

Lastly, penetrating fractures can cause complete or impartial break of the bone by a severe piercing force in one specific area. Penetrating fractures have an extremely large base of causes. In archaeological sites, penetrating fractures are often produced by projectiles, such as arrowheads, or cutting tools, such as knives or axes. In current forensic cases, penetrating fractures are often seen in sharp force trauma to the skull as well as stab wounds. Penetrating fractures also include puncture wounds such as gun shots (Brothwell, 1965; Lovell, 1997; Johnson, 1985; Glaister, 1921).

Indirect trauma, which occurs away from the point of impact, can result in spiral, oblique, greenstick, impaction, burst, & avulsion fractures. Spiral, oblique, & greenstick fractures occur more frequently than impaction, burst, or avulsion fractures, due to their causes (Lovell, 1997).

Spiral fractures are caused by high intensity, “rotational & downward loading stress on the longitudinal axis” of the bone (Lovell, 1997). Spiral fractures occur when one end of the bone is in a fixed or immoveable & the other end is forcefully twisted. “Accidental spiral fractures of the tibia are common in preschool children who fall short distances onto an extended leg & are often called "toddler's fractures" (Lukefahr, 2008). However, instances of spiral fractures in individuals younger than two years of age may represent abuse due to the amount of force needed to force a fracture (Lovell, 1997; Klepinger, 2006; Lukefahr, 2008).

Similar to & often confused with spiral fractures are oblique fractures. Transverse fractures split the bone perpendicularly to the longest axis, whereas oblique breaks fracture the bone at an angle. Like transverse fractures, oblique fractures are fairly common but oblique breaks require rotational force as well as direct impact to the site. It has been noted that, when "well healed, this break is easily confused with a spiral line" (Lovell, 1997).

The last of the most common types of indirect trauma are greenstick fractures. As discussed in Chapter 4, fresh bone is a living organism that is constantly regenerating cells & remodeling. Fractures to fresh bone occur when the energy needed to break the bone reaches the "work to failure" limit (Turner, 2006). As discussed, fresh bones will bend with some ductility until the force of displacement causes fracture. Greenstick fractures are those that are specific to fresh bone. Lovell identified two common causes of greenstick fractures: angular force & compression. Greenstick fracture caused by angular force could result from a variety of reasons, such as overly ductile bone or failure to reach the minimum point of fracture. This angular force causes deformation & incomplete fracture. The bone will bend until the point of fracture is reached. In greenstick fractures, the bone will bow & may potentially create an incomplete fracture on the convex edge. Compressive greenstick fractures, as the name implies, incur compression force as opposed to angular force. Like angular greenstick fractures, compressive greenstick fractures may occur is excessively flexible bone or when there is not enough force applied to fracture the bone. In most instances, this causes a "localized bulging on the bone" (Lovell, 1997) & is often seen in infant bones during childbirth as well as the limb bones of the elderly (Lovell, 1997; Turner, 2006).

Impaction fractures, though less common than compressive greenstick fractures, occur due to the same type of force. Impaction fractures result from severe compression on both ends of the bone & causes one or both ends to break. Impaction fractures are often jagged, unlike the "clean break" of a transverse fracture & are "often seen in the proximal humerus as the result of a fall onto an outstretched hand" (Lovell, 1997).

Burst fractures also occur due to compression. However, unlike greenstick & impaction fractures, burst fractures are only seen in the vertebrae & result in the deterioration of the trabecular bone of the vertebral body. It is uncommon to see burst fractures in the general population, & it is even more rare when burst fractures occur for reasons other than senescence. As individuals age, constant compression & degeneration of the vertebrae cause "the intervertebral disc [to rupture] through the vertebral end plate" (Lovell, 1997).

Lastly, "an avulsion fracture is caused when a joint capsule, ligament, or tendon is strained & pulls away from its attachment to the bone, tearing a piece of the bone with it" (Lovell, 1997). This often results in a transverse fracture to the bone but is specifically connected to the spraining of a muscle, tendon, or ligament. While this is a common injury in athletes, due to overextension of the joints, occurrence in younger individuals may be a sign of abuse. While uncommon, there are numerous sites where avulsion fractures may occur such as the rotator cuff, the patellar tendon, or any of the attachment sites of the hip rotator cuff muscles (Lovell, 1997; Radiopaedia, 2017; Klepinger, 2006).

Perimortem Trauma

Perimortem changes to the skeleton are the most useful to the forensic osteologist. These pathologies, which occur near the time of death, are almost always related to the cause of death. Trauma analysis of recovered skeletons attempts to determine the type of injury present as well the device used to cause damage.

Forensic Trauma: Blunt Force, Sharp Force, Gunshot, Dismemberment, & Hyoid Fracture

While fractures often occur due to falls, pathologies, or other injuries, they may often point to signs of homicide, suicide, or interpersonal violence. Blunt force trauma, particularly to the cranium, sharp force trauma, gunshot wounds (GSW), dismemberment, & hyoid fractures are the most common sources of forensic osteological evidence.

Blunt Force Trauma

Blunt force trauma, while potentially mild to the skeleton, can cause severe internal damage to the soft tissues leading to death. Blunt force trauma results in a depression caused by compression force & perpendicular fracture lines "radiating toward the point of impact, & oppositely to the point of distension" (Glaister, 1921). Depending on the amount of force used, "concentric extocranially directed heaving fractures [may] develop perpendicular to the radiating fractures" (Klepinger, 2006).

Using the biomechanics of bone, LeFort & Moritz "identified areas of buttressing in the face" & vault, respectively (Berryman & Haun, 1996). Facial & cranial buttress systems surround fragile bones by thick, solid bones. This allows the thicker bones to absorb the force from blows, sparing the delicate bones of the face. Various instruments are used to inflict blunt force trauma such as baseball bats, hammers, pipes, or clubs. This type of trauma can cause internal or external beveling, depending on the amount of force applied to the blow. In rare cases, trauma from a blunt instrument can imitate a gunshot wound (Quatrehomme, 2015).

One rule used in studies of blows to the head is the Hat Brim Line Rule. Ehrlich & Maxeiner determined the hat brim line to be about a three-centimeter-wide ring that runs above the eyebrows & ears & across the occipital protuberance (Ehrlich & Maxeiner, 2002; Kremer, 2008). These studies have shown that it is possible to use the Hat Brim Line (HBL) to determine if an individual suffered an accidental fall or a violent blow. Accidental falls tend to occur at or below the HBL & generally affect the right side of the cranium. Alternatively, blows to the head or purposeful pushes frequently occur above the HBL, affect the left side of the cranium, & are more likely to have associated wounds to the soft tissues of the scalp. Various studies have also used CT scans to determine homicidal trauma from a fall (Gruspier, 1999; Glaister, 1921; Soluri & Agarwal, 2016; Klepinger, 2006; White, 2012; Brothwell, 1965; Kremer, 2008; Ehrlich & Maxeiner, 2002; Fleming-Farrell, 2013; Jordana, 2013; Lovell, 1997; Berryman & Haun, 1996; Quatrehomme, 2015).

Sharp Force Trauma

Sharp force trauma is caused by acute damage to the soft tissue that may impact the skeleton. In archaeological specimens, this may include sword or axe cuts; in more recent forensic cases, knives or blades generally cause sharp force trauma. It is easy to overlook stab wounds as they often look like a small notch, however, “absence of sharp instrument stigmata on the skeleton does not mean that sharp injury was not the cause of death" (Klepinger, 2006). The most common sharp trauma injuries are seen in the chest, including the ribs, sternum, & clavicles. Sharp force injuries are also seen in the cranium, though the blade used is generally wider & longer than used in chest trauma.

While cuts can be seen with standard macroscopic analysis, "scanning electron microscopy (SEM) has become the method of choice for analyzing such cut marks" because it produces "a high-resolution magnified image of the surface of the element of interest" (Thompson & Inglis, 2009). Such advances in technology, including 3D scanning, can answer specific questions such as "the position of the victim in relation to the attacker, the handedness of the attacker", the specific weapon used, & whether the wounds are self-inflicted or homicidal (Thompson & Inglis, 2009). Due to the pliable nature of fresh bone in relation to dry bone, cut marks may cause a sliver of bone to bend away from the element, particularly in the ribs (Soluri & Agarwal, 2016; Klepinger, 2006; Ubelaker, 1999; Thompson & Inglis, 2009).

Penetrating Gunshot Wounds

Gunshot wounds (GSW), particularly to the skull, have similar attributes to blunt force trauma. Like blunt force trauma to the skull, GSWs generally create radiating & concentric fractures around the area of impact. This occurs in both types of trauma by compressing the convex side of the skull. Simple macroscopic analysis is enough to differentiate a GSW from blunt force trauma. GSWs leave a circular aperture & are much more forceful than when hit with a blunt object. Because of this difference in force, GSWs cause internal beveling. Internal beveling, which occurs at the entrance wound, causes the bone to fracture outwardly in the inner table of the bone. This causes the endocranial plate to have a wider opening than the initial GSW to the ectocranial table. There may or may not be an exit wound, however when present, they are generally much larger than the entrance wound & “the external table of [the cranial] bone [will exhibit] a ragged, cone-shaped external bevel” (Smith, 2003). Not all GSWs follow the same patterns, however. Variations in gun type, bullet category, & range of fire can, not only be mistaken for blunt trauma, but often require radiographic imaging to determine cause of death. More importantly, understanding differences between “acute angle & tangential shots”, which “can produce very irregular patterns, such as the “keyhole” wound”, may lead to determining if the death was suicide or homicide (Klepinger, 2006). Understanding bone biomechanics & effects of trauma is useful both archaeologically as well as forensically (Berryman & Haun, 1996; Klepinger, 2006; Gruspier, 1999; Ubelaker, 1999; Soluri & Agarwal, 2016; Glaister, 1921; Smith, 2003; Denton, 2006).

Dismemberment

Signs of dismemberment can often tell the forensic anthropologist if the trauma occurred peri- or postmortem, what type of weapon was used, &, in some cases, the reason behind why the crime occurred. “Soft tissues will show vital reactions, & demonstrable hemorrhages will be present if the person was alive when the dismemberment took place”, however, this evidence will be missing in instances of postmortem trauma (Gruspier, 1999). Rainwater developed a three-type classification system for dismemberment based on the earlier works of Reichs (1998) & Häkkänen-

Nyholm (2009). The three different types of dismemberment trauma are: “disarticulation around the joints, transection of bone via chopping, & transection of bone via sawing” (Rainwater, 2015). The use of sharp instruments show signs similar to sharp force trauma, such as stabbing. How & where the body was dissected can help infer the movie behind the crime and/or potential information about the perpetrator. Klepinger defines the three most common motives of dismemberment as attempts to obstruct forensic analysis, efforts to fit remains into certain storage containers, & mutilation for lustful or impassioned reasons (Klepinger, 2006). A common feature associated with dismemberment are false start kerfs. These notches are incomplete cuts to the bone, often adjacent to complete transection points, caused by a deliberate change in the position of the cutting implement or, more frequently, the “jump” of power saws &, sometimes, hand saws. False start kerfs & complete kerfs of dismembered bodies can be microscopically & macroscopically analyzed to “broadly characterize the tool used”, whether it be a straight or serrated knife, axe, or saw (Klepinger, 2006). In multiple cases, this has been imperative to determining the murder weapon (Gruspier, 1999; Klepinger, 2006; Rainwater, 2015).

Hyoid Fracture

While still under the general category of fractures, hyoid breaks are particularly interesting to forensic osteologists. This fragile bone is “suspended from the tip of the styloid processes of the temporal bone by ligamentous bands, the stylo-hyoid ligaments” & can easily be deformed, broken, or separated from the attachment points (Gray, 1977). Deformation is more common in children due to the pliability of their bones. However, damage to the cricoid and/or thyroid cartilages is also possible by not visible osteologically. Hyoid fractures & associated cartilage damage is generally indicative of hanging, ligature & manual strangulation, or throttling. Various studies have reported that actual fracture of the hyoid bone is partially dependent on the type of trauma to the throat. Ubelaker (1992) reported that the hyoid bone fractured in 34% of manual strangulation cases. However, ligature strangulation caused fracture in only 11% of cases & in hanging cases, the fracture only occurred in 8% of instances. Pollanen (1999) determined that fracture of the hyoid bone is directly connected to "age & status of fusion […] of the hyoid synchondroses". While absence of a fracture may not rule out strangulation or throttling, presence of a fracture should be thoroughly evaluated for potential interpersonal violence (Gray, 1977; Ubelaker, 1992; Klepinger, 2006; Pollanen, 1999; Lovell, 1997; Soluri & Agarwal, 2016).

<u>Blast Trauma</u>

In the last 70 years, mass killings via explosion have become increasingly common. Terrorism & the use of improvised devices & car bombs has led to an increasing number of forensic anthropologists called to separate individuals in these mass murders. Explosions cause damage in a radius known the blast wave. The burst begins at the site of ignition & explodes through the materials of the bomb "at speeds often as high as 6-8 km/sec" (Christensen, 2012). Damage to the skeleton is caused by two different factors in blast trauma: 1) the force of the explosion and/or 2) impact from blast projectiles. It goes without saying that the extent of the damage is directly correlated to the size of the explosive. Most explosions apply a variety of forces to the body "including compression, shearing, & bending; these patterns appear to be more r&om in appearance than those typically associated with projectile or blunt force injury events" (Christensen, 2012). In instances of mass fatalities, forensic anthropologists may not have skeletonized remains but are necessary to develop biological profiles & a minimum number of individuals. Micro- & macroscopic analysis as well as the appearance of butterfly fractures, particularly in the ribs, can be used to determine blast trauma as opposed to low-speed forces (Saul & Saul, 2003; Christensen, 2012; Christensen & Smith, 2013; Pechníková, 2015).

Postmortem Changes

The postmortem interval includes any changes that occur after the death of the individual. Taphonomic changes incur no healing & are caused by obvious & distinguishable marks. The time since death & the burial environment(s) are important to the forensic anthropologist for a number of reasons. Stephen Nawrocki explains that the burial location is part of an ecosystem that requires "a holistic approach that blends biology, geology, & environmental science" in order to produce the most complete picture of the individual's life, death, & subsequent burial (Nawrocki, 2016). Proper analysis of human remains can help determine if the individual is within the archaeological or forensic time frame, the presence of human modification, number of burial sites, animal or plant damage, environmental effects, & postmortem fracturing. Forensically, remains older than 50 years are of little importance due to the presumed death of the criminal (Sorg, 2012; Knight & Lauder, 1969; White, 2012; Klepinger, 2006; Gruspier, 1999; Nawrocki, 2016).

Determining time since death can be a complicated & difficult process. Multiple factors must be taken into account before making any analysis. The first & primary consideration is that taphonomic process occur more slowly when the individual is buried as opposed to exposed to the elements. Thus, skeletonization occurs more quickly & there is a greater likelihood of scavenging when remains are left unburied. This requires the forensic anthropologist to consider "information about ecological processes of decomposition, consumption, dispersal, & assimilation involving plants, animals, & microorganisms that become associated with the decomposing body" for the most thorough analysis (Sorg, 2012).

Stages of Death

As soon as the body enters the postmortem interval, the skin will lose its blush & the internal temperature begins to drop; these are the stages of pallor & algor mortis, respectively. While pallor mortis sets in regardless, algor mortis is much more dependent on the temperature of the environment. Colder temperatures slow decomposition & will delay the onset of the consecutive stages if kept at or below 32° Fahrenheit. Rigor mortis, also called cadaveric rigidity, refers to the third stage of death in which "a limited contraction of the muscle takes place", forcing the remains into a stiff, immoveable body due to the loss of adenosine triphosphate (ATP) (Glaister, 1921; Klepinger, 2006). The onset & duration of rigor mortis is dependent on four factors at the time of death: 1) the age of the individual, 2) the muscular condition of the individual, 3) the temperature of the environment prior to algor mortis, & 4) the manner of death (Glaister, 1921). Young individuals, whose muscles have yet to fully mature, are less susceptible to & generally sustain a shorter period of time of rigor mortis. Muscular condition at death also impacts the severity & duration of rigor mortis. The more muscular the individual, the slower the onset of rigor mortis & the longer the duration of the stage. These rules are true unless the remains are exposed to temperatures above 160° Fahrenheit. In high temperatures, the body goes through a phenomenon known as "heat stiffening" in which the muscles become stiffer than normal rigor mortis. However, as previously mentioned, cold temperatures can delay the start of rigor mortis if kept frozen. Regardless, once the remains reach temperatures above 50° Fahrenheit, rigor mortis will begin quickly & pass quickly. Lastly, the way in which the individual died or was killed will have an impact on the period of rigor mortis. If the individual exerted muscular energy prior to death, such as during a struggle, convulsion, or due to a pathology, the rigor mortis stage will have an early onset & a short duration period.

After rigor mortis, the body enters lavor mortis. Once the heart ceases to pump blood throughout the body, it begins to pool at the body's lowest point. The remains take on a dark blue or purple color with "bruising" characteristics where the coagulated blood has settled. From this stage on, the remains begin to decay in the putrefaction process which continues into decomposition, & then to skeletonization.

Decay of the remains follow a five-stage process: 1) fresh, 2) bloat, 3) active decay, 4) advanced decay, & 5) dry (Klepinger, 2006). The duration & severity is dependent on how or if the remains were buried. Depending on environment temperature & element exposure, insect activity will begin within the first couple of hours & may need the expertise of a forensic entomologist (Klepinger, 2006). Insect development is dependent on the ecosystem in which the remains are left. While most insects have patterned stages of development, the presence of some drugs can alter their maturation times (Klepinger, 2006; Glaister, 1921).

Human Modification

Alterations made to the skeleton after death can sometimes point to the presence of human involvement. There is a wide variety of ways that humans modify bones which can describe both the individual & the modifier. Cut marks, fractures, burial placement, cremation, & ritual practices can be distinguished from modifications made by alternate processes.

As previously discussed, disarticulation of the body after death can lead to small, unintentional cuts to the bone. However, dismemberment is not the only cause of cut marks. Defleshing often leads to slight, parallel lines in the bone in attempts to remove soft tissues (White, 2012). Fractures can be difficult to determine if the time frame of their occurrence was perimortem or postmortem. GSWs, sharp force trauma, & blunt force trauma are all fairly recognizable within the realm of perimortem damage. In some instances, fracture & tension on fresh bones can cause peeling on the ends of the affected element. Where & how the body was buried can also cause fracture. This can occur during forceful positioning or dropping the remains from a height (White, 2012; Klepinger, 2006).

Cremation of human remains is a practice that dates back as far 40,000 BP, according to the most recent dating of the Mungo Lady of Australia, discovered in 1969 (Bowler, 2003; Snoeck & Schulting, 2013). The analysis of the cremation & burial of remains requires a trained forensic anthropologist. Sites of cremation can be evidence of archaeological burial practices. However, the cremation of remains is common in homicide cases in an attempt to destroy potential evidence as well as prevent the identification of the victim (Skinner, 1999). The primary change caused to the bone during cremation is shrinkage. Studies have shown that, when subjected to temperatures greater than 1,400° Fahrenheit, total shrinkage can reach 25% (Klepinger, 2006). Similarly, calcined bone will begin to occur in temperatures over 1,300° Fahrenheit (Alunni, 2014). Death and/or cremation by pyre is uncommon in modern forensic studies & in these cases, it is difficult to determine the cause of death. It is rare for cremation to completely destroy the skeleton & severe burning requires adding fuel, manual breakage, & long duration period (Fairgrieve, 2008; Skinner, 1999; Alunni, 2014). Crematoriums run at an average of 1,700°, requiring the calcined remains to be pulverized afterwards (Skinner, 1999; Alunni, 2014; Klepinger, 2006; Fairgrieve, 2008; Van Deest, 2012).

Fairgrieve suggests that all fatal fires are of forensic importance until fully investigated. Modern cases of homicide may occasionally include covert bonfires;

however, intentional arson is more common. Instances of house fires should be investigated for cause as well as the circumstances of the fire. In 2007, arson accounted for 9% of fire deaths in Canada & 25% of all of British Columbia's fires were considered incendiary (Wijayasinghe, 2011). In some instances, such as when the perpetrator has time to properly dispose of the body, Fairgrieve argues that burial is likely to follow cremation. This method of disposal can be done in a number of ways. The body may be burned in one location, moved, & buried in another location. However, some cases involve shallow fire pits in which the remains are burned & subsequently buried in the same place (Fairgrieve, 2008; Skinner, 1999; White, 2012; Klepinger, 2006; Van Deest, 2012).

Ritual practices & desecration of burials often taken place months to years after death. Historically, burials & human remains have been pillaged for a variety of reasons. Trophy gathering, or the practice by the perpetrator of removing parts of the body to keep, is a practice still seen today (Klepinger, 2006). Other ritual practices are cult or religion related & involve painting certain elements or using crania as bowls (Klepinger, 2006). Burials are desecrated worldwide to sell mortuary items as well as in order to move the body to a new location (Ubelaker, 1999; Klepinger, 2006).

Plant, Soil, & Animal Modification

Whether remains have been buried or left exposed to the elements, plant & animal activity begins soon after decomposition begins. Scavengers, such as dogs, wolves, coyotes, vultures, cats, raccoons, & various rodents, greatly affect bone assemblages by removing portions to other areas, damaging bones, & creating pseudopathological signs.

Large carnivores often remove portions of the body to other locations & crush the trabecular areas of bone in order to obtain marrow (White, 2012). Carnivore's create four types of bone trauma: 1) punctures, 2) pits, 3) furrows, & 4) scores (Blumenschine, 1996). Carnivore puncture marks are created by teeth penetrating the bone, whereas pits do not fully pierce the affected element. While scores may be singular, they are generally shallow cut marks. However, furrows are much deeper & occur "from attempts to access the marrow" (Klepinger, 2006). These types of trauma can be differentiated from intentional cut marks or other pathologies by their patterns & more irregular profile (Bell, 1996; Blumenschine, 1996; Klepinger, 2006; White, 2012).

Rodent gnawing can mimic large carnivore damage by relocating remains as well as producing parallel scoring marks (Klepinger, 2006). However, the repetitive gnawing produces a "distinctive, fan-shaped pattern of regular, shallow, parallel or subparallel, flat-bottomed grooves" that can conclude the damage as rodent as opposed to human or carnivore inflicted (White, 2012). The movement & burrowing of rodents can also cause bioturbation, disrupting the original burial placement. Insects, such as dermestid & tenebrionid beetles, can create burrow patterns & furrows in bones (Rajendran & Parveen, 2005; Ubelaker, 1999). However, the presence of certain animal or insect activity can give more information about the environment(s) in which the individual's body was during the postmortem interval (Ubelaker, 1999; Rajendran & Pareveen, 2005; Klepinger, 2006; White, 2012).

Plants & soils can also greatly impact the preservation & subsequent recovery of human remains. When left untouched, plant roots can destroy bones & produce a vast network of grooves on the skeleton. As the roots move into the ground in search of water, they produce acids which crave the bones with shallow, white grooves (Nawrocki, 1995). Soil taphonomy is broken into two categories: macro- & micro-alterations. Macroalterations of soil taphonomy include ground freeze/thaw cycles, or cryoturbation, as well as large-scale ground movement (Jaggers & Rogers, 2009). High moisture environments can also be connected to chemical leaching from remains which increases "dissolution & the loss of bone material" & fractures (Jaggers & Rogers, 2009). Earthquakes & ground shifting can also alter the placement of burials or, in some instances, completely destroy the remains & any potential evidence. Soil pH, whether acidic or alkaline, can completely alter how bones are preserved or destroyed. More acidic environments can erode the outer layer of bone; however, more alkaline environment may lead to better preservation of the skeleton (White, 2012). Factors such as these should be thoroughly investigated to preserve as much of the remains as possible, as well as any pertinent evidence (White, 2012; Klepinger, 2006; Jaggers & Rogers, 2009; Nawrocki, 1995).

Fractures

Postmortem fractures are common for the variety of reasons discussed above as well as during excavation & recovery. It is imperative to know & understand the morphological differences between peri- & postmortem fractures. Though the length of time remains stay in the perimortem interval after death vary depending on environment, burial, & animal & insect activity, it is possible to determine if fractures occurred while in the green or dry state. Forensic taphonomic studies have shown that fresh bones are much more resistant to fracture by having a higher moisture content & being more pliable than dry bones. Trauma to dry bones causes severe fragmentation, the presence of bone flakes, & 90° fracture angles (Jordana, 2013). Likewise, fresh bones, with higher moisture content, absorb energy more readily than dry bones, creating radiating & concentric fractures Jordana, 2013). While fractures can be separated into peri- or postmortem, proper crime scene investigation, excavation, & recovery of remains can avoid unnecessary damage & potential loss of evidence (White, 2012; Jordana, 2013).

Chapter 14 – Application of Osteology in Criminal Justice

The idea of including anthropological perspectives in criminology is not a new one. Cesare Lombroso, often called the father of criminal anthropology, attempted to use the physical human body to explain & profile criminals (Lombroso, 1895). Lombroso used the theory of social evolution derived from Charles Darwin's Origin of Species. Lombroso resisted the theory that criminal actions were part of general human nature & instead concluded that criminals were inherently lawless with distinguishable physical defects (Lombroso, 1895). Similar areas of study, such as phrenology, incorrectly attempt to connect the physical body to the psychological nature of humans. While psychology is immensely important to understanding the criminal mind, I argue biological anthropology should be just as important. Most criminal justice or criminology schools require sociology and/or psychology courses. However, as previously mentioned, forensic anthropology is either not required or omitted entirely, despite the important skills included. Forensic osteologists have to be able to distinguish human from non-human, biological characteristics, & trauma. These same skills should be taught in the fields of criminology & criminal justice. Forensic osteological training provides law enforcement with the skills needed to appropriately identify potential burials, determine human vs. nonhuman, & recognized signs of trauma. Competence in this field can prevent scene contamination, assist in biological identification, & promote recognition & understanding of the types of trauma. Despite the advantages, anthropology & its associated fields are underutilized in current criminal justice education (Lombroso, 1895).

Part V: References

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Appendix

Osteological Guidebook

To be used concurrently with this thesis, the scans, & the associated teaching materials.

PART ONE: Necessary Vocabulary

Skeleton

- Axial – Consisting of the skull with the hyoid, vertebral column to the coccyx, & the ribs
- Appendicular – Consisting of the shoulder (includes clavicle & scapula), arms to fingers, pelvis, & legs to toes
- Articulation – Where bones meet via a joint at articulation points
- Foramen – Opening in bone for passage of soft tissues

Skull

- Skull – Entire head & jaw
- Mandible – Lower jaw
- Cranium – Skull without the mandible
- Calvaria (calvarium) – Cranium without the face or skull without the face or mandible

- Calotte – Calvaria without the base or skull without the face, mandible, or base
- Splanchnocranium – Facial skeleton
- Neurocranium - Braincase

Directions & Planes of Reference

- Superior – Towards the head, upwards (faunal: cranial)
- Inferior – Away from the head, downwards, opposite of superior (faunal: caudal)
- Anterior – Towards the front, forward (faunal: ventral)
- Posterior – Towards the rear, backward (faunal: dorsal)
- Medial – Towards the midline, middle
- Lateral – Away from the midline, outside, opposite of medial
- Proximal – Towards the axial skeleton, opposite of distal
- Distal – Away from the axial skeleton, opposite of proximal
- Endocranial – Inside cranial vault
- Ectocranial – Outside cranial vault
- Sagittal – Midline plane along the anterior/posterior line, line of symmetry

- Coronal – Perpendicular plane to sagittal plane along lateral (side to side) line
- Transverse – Horizontal plane along the superior/inferior line
- Palmar – Palm side of hand
- Plantar – Sole side of foot
- Volar – Same as palmar & plantar
- Dorsal – Opposite palmar & plantar
- Mesial – Teeth, towards midline of body
- Distal – Teeth, away from midline, opposite of mesial
- Lingual – Teeth, side the tongue touches
- Labial – Teeth, side the lips touch, opposite of lingual (incisors, canines)
- Buccal – Teeth, side the cheeks touch, opposite of lingual (premolars, molars)
- Interproximal – Teeth, where teeth touch each other
- Occlusal – Teeth, biting surface

Motions

- Flexion - Bending movement that decreases the angle between body parts
- Extension – Straightening movement that increases the angle between body parts

- Abduction – Movement of a body part away from the sagittal plane
- Adduction – Movement of a body part towards the sagittal plane
- Rotation – Movement of a body part around an axis
- Opposition – Movement of body parts coming together
- Pronation – Movement of the forearm that rotates the palm from anterior facing to posterior facing
- Supination – Movement of the forearm that rotates the palm from posterior facing to anterior facing
- Eversion – Pronation of the foot
- Inversion – Supination of the foot

Craniometrics	**Associated Landmarks**
Prosthion	Alveolar process
Nasospinale	Nasal aperture
Rhinion	Internasal suture
Nasion	Nasal & frontal intersection
Glabella	Frontonasal suture
Metopian	Metopic midline
Bregma	Coronal & sagittal intersection
Apex	Poria plane
Vertex	Frankfurt horizontal
Obelion	Parietal foramina
Lambda	Sagittal & lambdoidal suture

Opisthocranion	Occipital midline
Opisthion	Posterior foramen magnum
Basion	Anterior foramen magnum
Sphenobasion	Basilar midline
Orbitale	Orbital margin
Pterion	Frontal, parietal, temporal, sphenoid
Porion	External acoustic meatus

PART TWO: Osteological Chart

Area	Landmarks	Veins/ Arteries/ Nerves/ Vessels	Muscle Attachments/ Ligaments/ Tendons	Craniometrics/ features
Frontal				
	Frontal eminences			
	Temporal lines		Temporalis	
	Zygomatic processes			
	Superciliary arches			
	Supraorbital margins			
	Supraorbital notches or foramina	Supraorbital vessels		

	Metopic suture			
	Meningeal grooves	Middle meningeal arteries		
	Sagittal sulcus	Superior sagittal sinus		
	Frontal crest			
	Foramen cecum			
	Arachnoid foveae	Arachnoid		
	Pars orbitalis			
	Lacrimal fossae	Lacrimal glands		
	Ethmoidal notch			
	Frontal sinuses			
Parietals				
	Frontal angle			Bregma
	Sphenoidal angle			Pterion
	Occipital angle			Lambda
	Mastoid angle			Asterion
	Parietal eminence			
	Superior temporal lines		Temporal fascia	
	Inferior temporal lines		Temporalis	
	Parietal foramen			
	Parietal striae			
	Meningeal grooves	Middle meningeal arteries		

Area	Landmarks	Veins/ Arteries/ Nerves/ Vessels	Muscle Attachments/ Ligaments/ Tendons	Craniometrics/ features
	Sagittal sulcus	Superior sagittal sinus		
	Arachnoid foveae	Arachnoid		
	Sigmoid (transverse) sulcus	Sigmoid (transverse) sinus		
Temporal				
	Petrous pyramid			Temporal & occipital lobes*
	External acoustic meatus			Ear canal
	Zygomatic process		Masseter	
	Suprameatal crest			
	Supramastoid crest		Temporalis	
	Parietal notch			
	Mastoid process		Sternocleidomastoideus, splenius capitis, & longissimus capitis	
	Mastoid foramen	Occipital artery		
	Mastoid notch or digastric groove		Digastric	
	Occipital sulcus (groove)	Occipital artery		
	Temporomadibular articular surface			

Area	Landmarks	Veins/ Arteries/ Nerves/ Vessels	Muscle Attachments/ Ligaments/ Tendons	Craniometrics/ features
	Mandibular fossa			
	Postglenoid process			
	Entoglenoid process			
	Styloid process		Stylohyoid ligament	
	Stylomastoid foramen	Facial nerve & stylomastoid artery		
	Vaginal process			
	Jugular fossa	Internal jugular vein		
	Carotid canal	Internal carotid artery		
	Middle meningeal grooves			
	Internal acoustic meatus	Facial & acoustic nerves & internal auditory artery		
	Sigmoid sulcus	Sigmoid sinus		
Occipital				
	Foramen magnum	Brainstem		
	External occipital protuberance			
	Superior nuchal line		Nuchal	

	Inferior nuchal line		Nuchal	
	External occipital crest		Nuchal ligament	
	Occipital condyles			Atlas articulation
	Condylar foramina (canals)	Emissary vein		
	Hypoglossal canals	Hypoglossal nerves		
	Jugular processes			
	Jugular notch			

Area	**Landmarks**	**Veins/ Arteries/ Nerves/ Vessels**	**Muscle Attachments/ Ligaments/ Tendons**	**Craniometrics/ features**
	Cruciform eminence			Cerebral (2) & cerebellar (2) fossae
	Cerebral fossae			Occipital lobes*
	Cerebellar fossae			Cerebellar lobes*
	Internal occipital protuberance			
	Sagittal (occipital) sulcus	Sagittal sulcus		
	Internal occipital crest			
	Occipitomarginal sulcus*			**Is not always present*

	Transverse sulci	Transverse sinuses		
	Groove for the medulla oblongata			
Maxillae				
	Alveolar process			
	Alveoli			
	Canine jugum			
	Zygomatic process			
	Infraorbital foramen	Infraorbital nerve & vessels		
	Canine fossa			
	Anterior nasal spine			
	Infraorbital sulcus (groove)			
	Infraorbital canal			

Area	**Landmarks**	**Veins/ Arteries/ Nerves/ Vessels**	**Muscle Attachments/ Ligaments/ Tendons**	**Craniometrics/ features**
	Maxillary sinus			
	Frontal process			
	Anterior lacrimal crest			
	Lacrimal groove			
	Lacrimal canal	Nasolacrimal duct		
	Palatine process			
	Incisive foramen			

	Incisive canal	Greater palatine artery & nasopalatine nerve		
	Premaxillary suture			
	Greater palatine groove	Greater palatine vessels & nerve		
	Maxillary tuber			
	Nasoalveolar clivus			
Palatine				
	Greater palatine foramen	Greater palatine vessels & nerve		
	Pterygopalatine canal			
	Posterior nasal spine			
	Lesser palatine foramina	Lesser palatine nerves		
	Perpendicular plate			
	Pyramidal process			
	Conchal crest			
Vomer				
	Wings (alae)			
	Perpendicular plate			
	Posterior border			

Area	Landmarks	Veins/ Arteries/ Nerves/ Vessels	Muscle Attachments/ Ligaments/ Tendons	Craniometrics/ features
	Nasopalatine groove	Nasopalatine nerves & vessels		

Inferior Nasal Conchae				
	Maxillary process			
	Lamina			
	Lacrimal fossa			
	Ethmoidal process			
Ethmoid				
	Cribiform plate	Olfactory nerves		
	Cristagalli	Olfactory bulbs & falx cerebri (of the dura mater)		
	Labyrinths (lateral masses)			
	Perpendicular plate			
Lacrimals				
	Posterior lacrimal crest			
	Lacrimal groove (sulcus)			
Nasals				
	Nasal foramen			
Zygomatics				
	Frontal process			
	Temporal process			
	Maxillary process			
	Zygomaticofacial foramen	Zygomaticofacial nerve & vessels		
	Masseteric origin	Masseter		
	Zygomaticoorbital foramina			

Area	Landmarks	Veins/ Arteries/ Nerves/ Vessels	Muscle Attachments/ Ligaments/ Tendons	Craniometrics/ features
	Zygomaticotemporal foramen	Zygomaticotemporal nerve		
Sphenoid				
	Optic canals	Ophthalmic artery & optic nerve		
	Sella turcica			
	Hypophyseal fossa	Pituitary gland		
	Dorsum sellae			
	Posterior clinoid processes			
	Clivus			
	Sphenoidal crest			
	Sphenoidal rostrum			
	Sphenoidal sinuses			
	Greater wings			
	Superior orbital fissures			
	Foramen rotundum	Maxillary nerves		
	Foramen ovale	Mandibular nerves & accessory meningeal arteries		
	Foramen spinosum	Middle meningeal vessels		
	Infratemporal crests			
	Orbital surfaces			
	Lesser wings			

	Anterior clinoid processes	Tentorium cerebelli		
	Angular spine	Pterygospinous ligament		
	Pterygoid processes			

Area	**Landmarks**	**Veins/ Arteries/ Nerves/ Vessels**	**Muscle Attachments/ Ligaments/ Tendons**	**Craniometrics/ features**
	Lateral pterygoid plate			
	Medial pterygoid plate		Medial pterygoideus	
	Pterygoid fossae			
	Pterygoid Hamulus			
	Pterygoid canals			
Mandible				
	Alveolar portion			Alveoli
	Mental foramen	Mental vessels & nerve		
	Oblique line			
	Extramolar sulcus		Buccinator	
	Mylohyoid line		Mylohyoid	
	Submandibular fossa	Submandibular gland		
	Sublingual fossa	Sublingual gland		
	Mandibular torus			

	Mandibular symphysis			
	Mental spines		Genioglossus & geniohyoid	
	Digastric fossae		Digastric	
	Mental protuberance			
	Ramus			
	Mandibular condyle			
	Condylar neck		Lateral pterygoideus	
	Coronoid process		Temporalis	

Area	**Landmarks**	**Veins/ Arteries/ Nerves/ Vessels**	**Muscle Attachments/ Ligaments/ Tendons**	**Craniometrics/ features**
	Mandibular notch			
	Gonial angle		Masseter	
	Masseteric tuberosity		Masseter	
	Masseteric fossa			
	Endocoronoid ridge			
	Mandibular foramen	Alveolar vessels & inferior alveolar nerve		Mandibular canal
	Lingula		Sphenomandibular ligament	
	Mylohyoid groove	Mylohyoid vessels & nerve		

	Pterygoid tuberosities		Medial pterygoideus	
Hyoid & Vertebrae				
Hyoid				
	Greater horns		Lateral thyrohyoid ligament	
	Lesser horns		Stylohyoid ligament	
Vertebral anatomy				
	Vertebral foramen	Spinal cord		
	Vertebral body	Basivertebral vein		
	Vertebral arch	Spinal cord		
	Pedicle			
	Lamina			
	Spinous process		Interspinatous & suprapinatous ligaments	
	Transverse process			
	Superior articular facet			

Area	Landmarks	Veins/ Arteries/ Nerves/ Vessels	Muscle Attachments/ Ligaments/ Tendons	Craniometrics/ features
	Inferior articular facet			
Cervical vertebrae (N=7)				
	Uncinate processes			

	Vertebral foramina			
	Transverse processes			
	Transverse foramina	Vertebral arteries		
	Lateral portion (3)			
	Posterior tubercle of the transverse process			
	Anterior tubercle of the transverse process			
	Intertubercular lamina			
	Spinous processes			
	Articular facets (2)			
	Superior			
	Inferior			
Special Cervical Vertebrae				
	Atlas C1			
	Axis C2			Dens or odontoid process

Area	**Landmarks**	**Veins/ Arteries/ Nerves/ Vessels**	**Muscle Attachments/ Ligaments/ Tendons**	**Craniometrics/ features**

	Seventh cervical vertebra C7			
Thoracic Vertebrae (N=12)				
	Costal facets (4)			
	Transverse costal facets			T1-T10
	Superior costal demi facets			T2-T9
	Inferior costal demi facets			T1-T8
	Costal facets			T1, T10-T12
	Vertebral foramina			
	Transverse processes			
	Aortic impression			T5-T10
	Spinous processes			
	Articular facets (2)			
	Superior			
	Inferior			
	Intervertebral notches (2)	Spinal nerves		
	Superior			
	Inferior			
	Intervertebral foramina			
Special Thoracic Vertebrae				
	First thoracic vertebra T1			

Area	Landmarks	Veins/ Arteries/ Nerves/ Vessels	Muscle Attachments/ Ligaments/ Tendons	Craniometrics/ features
	Tenth thoracic vertebra T10			
	Eleventh thoracic vertebra T11			
	Twelfth thoracic vertebra T12			
Lumbar Vertebrae (N=5)				
	Vertebral foramina			
	Spinous processes			
	Transverse processes			
	Articular facets (2)			
	Superior			
	Inferior			
	Mammillary process			
	Accessory process			
Sternum & Ribs				
Sternum				
	Manubrium			
	Clavicular notches			
	Jugular notch			

	Costal notches			
	Corpus sterni			
	Sternal angle			
	Lines of fusion			
	Xiphoid process			
Ribs				
	Head			

Area	Landmarks	Veins/ Arteries/ Nerves/ Vessels	Muscle Attachments/ Ligaments/ Tendons	Craniometrics/ features
	Crest for rib head			
	Neck			
	Crest for rib neck			
	Tubercle			
	Costal angle			
	Shaft			
	Coastal groove	Intercostal artery, vein, & nerve		
	Sternal end			
	Cranial end			
	Caudal end			
Special Ribs				
	First rib	Subclavian vein, subclavian artery, & brachial plexus	Anterior scalene	
	Second rib		Serratus anterior	

Area	**Landmarks**	**Veins/ Arteries/ Nerves/ Vessels**	**Muscle Attachments/ Ligaments/ Tendons**	**Craniometrics/ features**
	Tenth rib			Single articular surface
	Eleventh rib			“floating”
	Twelfth rib			“floating”
Clavicle & Scapula				
Clavicle				
	Sternal end			
	Acromial end			
	Costoclavicular tuberosity		Costoclavicular ligament	
	Subclavian sulcus		Subclavius	
	Conoid tubercle		Conoid ligament	
	Trapezoid line		Trapezoid ligament	
	Nutrient foramen			
	Superior surface			
	Rugosity for		Trapezius	
	Rugosity for		Deltoideus	
	Rugosity for		Pectoralis major	
Scapula				
	Superior border			
	Scapular notch	Suprascapular nerve		
	Coracoid process		Biceps brachii, pectoralis minor, coracobrachialis, & coracoid tendon	

	Subscapular fossa		Subscapularis	
	Oblique ridges			
	Lateral border		Teres minor & teres major	
	Glenoid fossa			
	Supraglenoid tubercle		Biceps brachii	
	Infraglenoid tubercle		Triceps brachii	
	Scapular neck			
	Medial border		Serratus anterior, rhomboid major, & rhomboid minor	
	Scapular spine		Deltoid & trapezius	
	Acromion process		Deltoid & trapezius	Clavicular facet
	Supraspinous fossa		Supraspinatus	
	Infraspinous fossa		Infraspinatus	
	Superior angle		Levator scapulae	
	Inferior angle		Latissimus dorsi	
Humerus, Radius, & Ulna				
Humerus				
	Humeral head			

Area	Landmarks	Veins/ Arteries/ Nerves/ Vessels	Muscle Attachments/ Ligaments/ Tendons	Craniometrics/ features

	Anatomical neck	Joint capsule		
	Surgical neck			
	Lesser tubercle		Subscapularis	
	Greater tubercle		Supraspinatus, infraspinatus, & teres minor	
	Intertubercular groove		Biceps brachii & transverse humeral ligament	
	Crest of the greater tubercle		Pectoralis major	
	Crest of the lesser tubercle		Teres major, latissimus dorsi, & medial rotators & abductors	
	Humeral shaft			
	Anteromedial surface			
	Anterolateral surface			
	Posterior surface			
	Medial border			
	Lateral border			
	Deltoid tuberosity		Deltoideus	
	Crest for		Triceps brachii	
	Radial sulcus	Radial nerve		
	Nutrient foramen	Nutrient arteries		
	Olecranon fossa			
	Coronoid fossa			
	Radial fossa			
	Capitulum			
	Trochlea			

Area	Landmarks	Veins/ Arteries/ Nerves/ Vessels	Muscle Attachments/ Ligaments/ Tendons	Craniometrics/ features
	Lateral epicondyle		Radial collateral ligament, supinator, & extensors	
	Medial epicondyle		Ulnar collateral ligament, pronator teres, & flexors	
	Medial supracondylar crest			
	Lateral supracondylar crest		Brachioradialis	
Radius				
	Radial head			
	Radial neck			
	Radial tuberosity		Biceps brachii	
	Anterior surface		Pronator quadrutus	
	Posterior surface			
	Lateral surface			
	Interosseous border	Interosseous membrane		
	Anterior border			
	Posterior border			
	Nutrient foramen			
	Anterior oblique line			

	Posterior oblique line			
	Pronator tuberosity		Pronator teres	
	Ulnar notch			
	Carpal articular surface			
	Styloid process			
	Suprastyloid crest		Brachioradialis	
	Dorsal tubercle		Extrinsic extensor muscles	

Area	**Landmarks**	**Veins/ Arteries/ Nerves/ Vessels**	**Muscle Attachments/ Ligaments/ Tendons**	**Craniometrics/ features**
	Groove for		Extensor muscle tendons	
	Groove for		Extensor pollicis longus	
	Groove for		Extensor carpi radialis	
Ulna				
	Olecranon		Triceps brachii	
	Trochlear notch			
	Guiding ridge			
	Coronoid process			
	Ulnar tuberosity		Brachialis	
	Radial notch			
	Ulnar shaft			
	Anterior surface			

	Posterior surface			
	Medial surface			
	Interosseous border			
	Anterior border			
	Posterior border			
	Longitudinal crest			
	Nutrient foramen			
	Supinator crest		Supinator	
	Pronator ridge		Pronator quadrutus	
	Ulnar head			
	Ulnar styloid process		Ulnar collateral ligament	
	Groove for		Extensor carpi ulnaris	
	Articular circumference			
Carpals				
Scaphoid				

Area	Landmarks	Veins/ Arteries/ Nerves/ Vessels	Muscle Attachments/ Ligaments/ Tendons	Craniometrics/ features
	Scaphoid tubercle		Flexor retinaculum	
	Facet for			Capitate
	Facet for			Lunate
	Radial facet			
	Facet for			Trapezoid

	Facet for			Trapezium
The scaphoid is shaped like a snail. Hold the scaphoid in your hand with the convex side of the "shell" pointing towards yourself. The "head" of the snail will point in the direction of its side. E.g. the "head" points to the left, therefore it is a left scaphoid.				
Lunate				
	Facet for			Radius
	Facet for			Scaphoid
	Facet for			Capitate
	Facet for			Triquetral
	Facet for			Hamate
Hold the lunate so that the side in which the articulating groove is the deepest is facing you. The groove leans in the direction of its side. E.g. the groove leans to the right, therefore it is a right lunate.				
Triquetral				
	Facet for			Hamate
	Facet for			Lunate
	Facet for			Pisiform
Place your index finger on the pisiform facet & place your thumb on the lunate facet. The direction in which the hamate facet is facing gives you the side. E.g. the hamate facet is facing right, therefore it is a right triquetral.				
Pisiform				
	Pisiform body		Flexor retinaculum	
	Facet for			Triquetral
	Pisiform groove			
No siding method				
Trapezium				
	Trapezial ridge		Flexor retinaculum	
	Trapezial groove		Tendon of the flexor	
	Facet for		Carpi radialis	MC1
	Facet for			MC2
	Facet for			Trapezoid

Area	Landmarks	Veins/ Arteries/ Nerves/ Vessels	Muscle Attachments/ Ligaments/ Tendons	Craniometrics/ features
	Facet for scaphoid			
Hold with the MC1 facet facing away from yourself & down. Put your thumb over your curved fingers. The direction of the ridge between the facets will tell the side it's from. E.g. the ridge is pointing left, therefore it is a left trapezium.				
Trapezoid				
	Double facet for			MC2
	Facet for			Capitate
	Non-articular palmer surface			
	Facet for			Trapezium
	Facet for			Scaphoid
	Non-articular dorsal surface			
Hold the trapezoid so that the bone resembles a boot or a shoe. The "zipper" on the side of the bone always faces laterally towards the sign that it's from.				
Capitate				
	Head			
	Base			
	Facet for			Scaphoid
	Facet for			Lunate
	Facet for			MC3
	Facet for			MC2
	Facet for			Trapezoid
	Non-articular palmer surface			
	Non-articular dorsal surface			
	Facet for			Hamate
Face the head up & away while facing the hamate facet(s) toward yourself. The side of the bone the facet(s) are on gives the side.				
Hamate				
	Facet for			MC4

	Facet for			MC5
	Facet for			Triquetral
	Facet for			Capitate
	Facet for			Lunate
	"Hook"		Flexor retinaculum	

Area	Landmarks	Veins/ Arteries/ Nerves/ Vessels	Muscle Attachments/ Ligaments/ Tendons	Craniometrics/ features
With the hook pointing upwards, the hamate resembles a thumbs-up. The thumbs-up always lines up with the second knuckles & the hamate looks like the side it is from.				
Ribs				
See Rib Chart				
Sacrum, Coccyx, & Os Coxae				
Sacrum				
	Base			
	Sacral plateau			L5
	Sacral promontory			
	Alae or "wings"			
	Sacral canal			
	Pelvic surface			
	Transverse ridges			
	Auricular surface			
	Sacral tuberosity		Sacroiliac ligaments	
	Lateral part			

	Anterior (pelvic) sacral foramina	Anterior divisions of the sacral nerves & lateral sacral arteries		
	Superior articular facets			
	Superior articular processes			
	Dorsal surface			
	Dorsal wall			
	Posterior (dorsal) sacral foramina	Posterior divisions of the sacral nerves		
	Intervertebral foramina			
	Sacral spine			

Area	**Landmarks**	**Veins/ Arteries/ Nerves/ Vessels**	**Muscle Attachments/ Ligaments/ Tendons**	**Craniometrics/ features**
	Intermediate sacral crest			
	Lateral sacral crest			
	Sacral hiatus			
	Sacral cornua			
	Apex of the sacrum			
	Facet for			Coccyx
Coccyx				
	Coccygeal cornua			
	Transverse processes			

Os Coxae				
	Ilium (2)			
	Body			
	Ala			
	Ischium (2)			
	Body			
	Rami			
	Pubis (2)			
	Body			
	Rami			
	Acetabulum			
	Acetabular margin			
	Acetabular fossa		Ligamentum teres	
	Acetabular notch			
	Lunate surface			
	Supraacetabular groove			
	Gluteal surface			
	Gluteal lines (3)		Gluteus minimus, gluteus medius, & gluteus maximus	

Area	Landmarks	Veins/ Arteries/ Nerves/ Vessels	Muscle Attachments/ Ligaments/ Tendons	Craniometrics/ features
	Inferior gluteal line			
	Anterior gluteal line			
	Posterior gluteal line			
	Sacropelvic surface (2)			

	Auricular surface			Cranial & caudal limbs
	Iliac tuberosity		Sacroiliac ligaments	
	Spina limitans			
	Iliac pillar			
	Tuberculum of			Iliac crest
	Iliac crest (3)		Abdominal muscles	
	Outer lip		External oblique	
	Inner lip		Transversus abdominis	
	Intermediate zone		Internal oblique	
	Anterior superior iliac spine		Saratorius muscle & inguinal ligament	
	Anterior inferior iliac spine		Rectus femoris muscle & iliofemoral ligament	
	Posterior superior iliac spine		Gluteus maximus	
	Posterior inferior iliac spine		Sacrotuberous ligament	
	Preauricular sulcus			
	Greater sciatic notch		Piriformis	
	Ischial spine		Sacrospinous ligament	

Area	**Landmarks**	**Veins/ Arteries/ Nerves/ Vessels**	**Muscle Attachments/ Ligaments/ Tendons**	**Craniometrics/ features**
	Lesser sciatic notch		Obturator internus	

	Ischial tuberosity		Semitendinosus, semimembranosus, biceps femoris, & quadratus femoris	
	Iliac fossa			
	Arcuate line			
	Pectineal line		Pectineus	
	Iliopubic eminence			
	Pubic crest		Rectus abdominis	
	Superior pubic ramus			
	Ischiopubic ramus			
	Pubic tubercle		Inguinal ligament	
	Symphyseal surface		Pubic ligaments	Pubic symphysis
	Obturator foramen	Obturator membrane		
	Obturator crest		Pubofemoral ligament	
	Anterior obturator tubercle			
	Posterior obturator tubercle			
	Obturator groove	Obturator vessels & nerve		Obturator canal
Pelvis				
	Pelvic surface			
	Pelvic cavity			
	Pubic arch			
	Greater pelvis			
	Lesser pelvis			
	Linea terminalis			Separates greater &

Area	Landmarks	Veins/ Arteries/ Nerves/ Vessels	Muscle Attachments/ Ligaments/ Tendons	Craniometrics/ features
				lesser pelvises
	Iliopectineal line			
	Pelvic inlet			
	Pelvic outlet			
Leg				
Femur				
	Femoral head			Articulates with acetabulum
	Fovea capitis		Ligamentus teres	
	Femoral neck			
	Greater trochanter		Gluteus minimus & gluteus medius	
	Intertrochanteric line	Joint capsule	Iliofemoral ligament	
	Trochanteric fossa		Tendon of obturator externus, superior gemelli, inferior gemelli, obturator internus, & piriformis	
	Obturator externus groove		Tendon of obturator externus	
	Lesser trochanter		Iliopsoas tendon	
	Intertrochanteric crest		Quadratus femoris	Quadrate tubercle
	Gluteal tuberosity		Gluteus maximus	
	Spiral line		Vastus medialis	
	Pectineal line		Pectineus	

	Femoral shaft			
	Linea aspera		Vastus, longus, brevis, & magnus	
	Medial lip of the linea aspera		Adductor magnus & adductor longus	

Area	**Landmarks**	**Veins/ Arteries/ Nerves/ Vessels**	**Muscle Attachments/ Ligaments/ Tendons**	**Craniometrics/ features**
	Lateral lip of the linea aspera		Vastus lateralis & biceps femoris	
	Nutrient foramen			
	Medial supracondylar line			
	Lateral supracondylar line			
	Popliteal surface			
	Lateral condyle			
	Lateral epicondyle		Lateral collateral ligament & gastrocnemius	
	Popliteal groove		Tendon of the popliteus muscle	
	Medial condyle			
	Medial epicondyle		Medial collateral ligament	
	Adductor tubercle		Adductor magnus	
	Impression for the lateral head			

	of the gastrocnemius			
	Impression for the popliteus			
	Intercondylar fossa		Anterior & posterior cruciate ligaments	
	Intercondylar line			
	Patellar surface			
	Patellar lip			
Siding a femur: The trochanters & the linea aspera are posterior. The patellar lip will be higher on the lateral side. The fovea capitis is posterior inferior.				
Patella				

Area	Landmarks	Veins/ Arteries/ Nerves/ Vessels	Muscle Attachments/ Ligaments/ Tendons	Craniometrics/ features
	Apex			
	Lateral articular facet			
	Medial articular facet			
	Base			
Siding a patella: The medial facet is the largest. Hold the patella so that the apex (pointed end) is away from you. The bone will "lean" towards the side it is from.				
Tibia				
	Tibial plateau	Medial & lateral menisci		
	Medial condyle			
	Lateral condyle			
	Intercondylar eminence			

	Medial intercondylar tubercle			
	Lateral intercondylar tubercle		Anterior & posterior cruciate ligaments	
	Anterior intercondylar area		Anterior cruciate ligament	
	Superior fibular articular facet			
	Groove for			Semimembranosus
	Tibial tuberosity		Patellar ligament & quadriceps femoris	
	Shaft			
	Medial surface			
	Posterior surface			Popliteal surface
	Lateral surface			Interosseous
	Medial border		Deep transverse fascia	
	Anterior border			

Area	**Landmarks**	**Veins/ Arteries/ Nerves/ Vessels**	**Muscle Attachments/ Ligaments/ Tendons**	**Craniometrics/ features**
	Interosseous border	Interosseous membrane		
	Soleal (popliteal) line		Popliteus muscle, popliteus fascia, & soleus muscle	
	Nutrient foramen			

	Vertical line		Tibialis posterior & flexor digitorum longus	
	Medial malleolus			Anterior & posterior colliculus
	Intercollicular groove		Deltoid ligament	
	Anterior groove			
	Fibular notch		Tibiofibular ligament	
	Distal fibular articular surface			
	Posterior (malleolar) groove		Tendons of the tibialis posterior & flexor digitorum longus muscle	
	Groove for			Flexor halluces longus
	Talar articular surface			
Fibula				
	Fibular head		Biceps femoris muscle & lateral collateral ligament	
	Styloid process			
	Proximal fibular articular surface			
	Fibular neck			
	Shaft			

Area	Landmarks	Veins/ Arteries/ Nerves/ Vessels	Muscle Attachments/ Ligaments/ Tendons	Craniometrics/ features
	Anterior border			
	Lateral surface			
	Posterior border			
	Posterior surface			
	Medial crest		Tibialis posterior & flexor halluces longus	
	Posteromedial border		Tibialis posterior, soleus, & flexor halluces longus	
	Medial surface			
	Interosseous border		Interosseous membrane	
	Surface for		Interosseous membrane	
	Nutrient foramen			
	Triangular subcutaneous area			
	Lateral malleolus			
	Malleolar articular surface			
	Malleolar fossa		Transverse tibiofibular & posterior talofibular ligaments	

Area	Landmarks	Veins/ Arteries/ Nerves/ Vessels	Muscle Attachments/ Ligaments/ Tendons	Craniometrics/ features
	Fibular groove		Tendons of the fibularis (peroneus) longus & fibularis (peroneus) brevis	
Foot				
Tarsals				
	Head			
	Body			
	Trochlea			

Area	Landmarks	Veins/ Arteries/ Nerves/ Vessels	Muscle Attachments/ Ligaments/ Tendons	Craniometrics/ features
	Neck			
	Groove for		Flexor halluces longus	
	Subtalar facets (3)			
	Anterior subtalar			
	Medial subtalar			
	Posterior subtalar			
	Sulcus tali			
Calcaneus				
	Calcaneal tuberosity		Calcaneal tendon (Achilles)	
	Lateral & medial processes		Intrinsic	
	Sustentacular tali			

	Sustentacular sulcus		Tendon of the flexor halucis longus	
	Fibular tubercle		Tendons of the fibularis (peroneus) longus & brevis	
	Groove for		Fibularis (peroneus) longus	
	Facet for			Talus
	Facet for			Cuboid
Cuboid				
	Cuboid tuberosity			
	Groove for		Tendon for the fibularis longus	
	Facet for			Calcaneus
	Facet for			Lateral cuneiform
	Facet for			MT4
	Facet for			MT5
Navicular				
Area	**Landmarks**	**Veins/ Arteries/ Nerves/ Vessels**	**Muscle Attachments/ Ligaments/ Tendons**	**Craniometrics/ features**
	Tubercle		Tibialis posterior	
	Facet for			Talus
	Facet for			Medial cuneiform
	Facet for			Lateral cuneiform
	Facet for			Intermediate cuneiform
Medial Cuneiform				
	Facet for			Navicular

	Facet for			Intermediate cuneiform
	Facet for			MT1
	Facet for			MT2
Intermediate Cuneiform				
	Facet for			Navicular
	Facet for			Medial cuneiform
	Facet for			Lateral cuneiform
	Facet for			MT2
Lateral Cuneiform				
	Facet for			Navicular
	Facet for			Cuboid
	Facet for			Intermediate cuneiform
	Facet for			MT2
	Facet for			MT3
	Facet for			MT4

Rib Chart

Rib	**Facets**	**Shaft**	**Features**	**General Appearance**
1	Unifaceted		Scalene tubercle, subclavian vein, subclavian artery	
2			Tuberosity for serratus anterior	

3		Thicker, rounded		
4		Thicker, rounded		Tighter curve, flatter superior
5		Thicker, rounded	Inferior costal groove	Tighter curve, flatter superior
6		Thicker, rounded	Inferior costal groove	Gradual shallow curve, rounded superior
7			Inferior costal groove	Gradual shallow curve, rounded superior
8				Gradual shallow curve, rounded superior
9			Superior crest	Gradual shallow curve
10	Unifaceted		Superior crest	Gradual shallow curve
11	Unifaceted		Sharp superior crest	Pointed sternal end
12	Unifaceted		Sharp superior crest	Pointed sternal end

PART THREE: Dentition Chart

Dentition chart & associated legends.

Maxillary Legend:

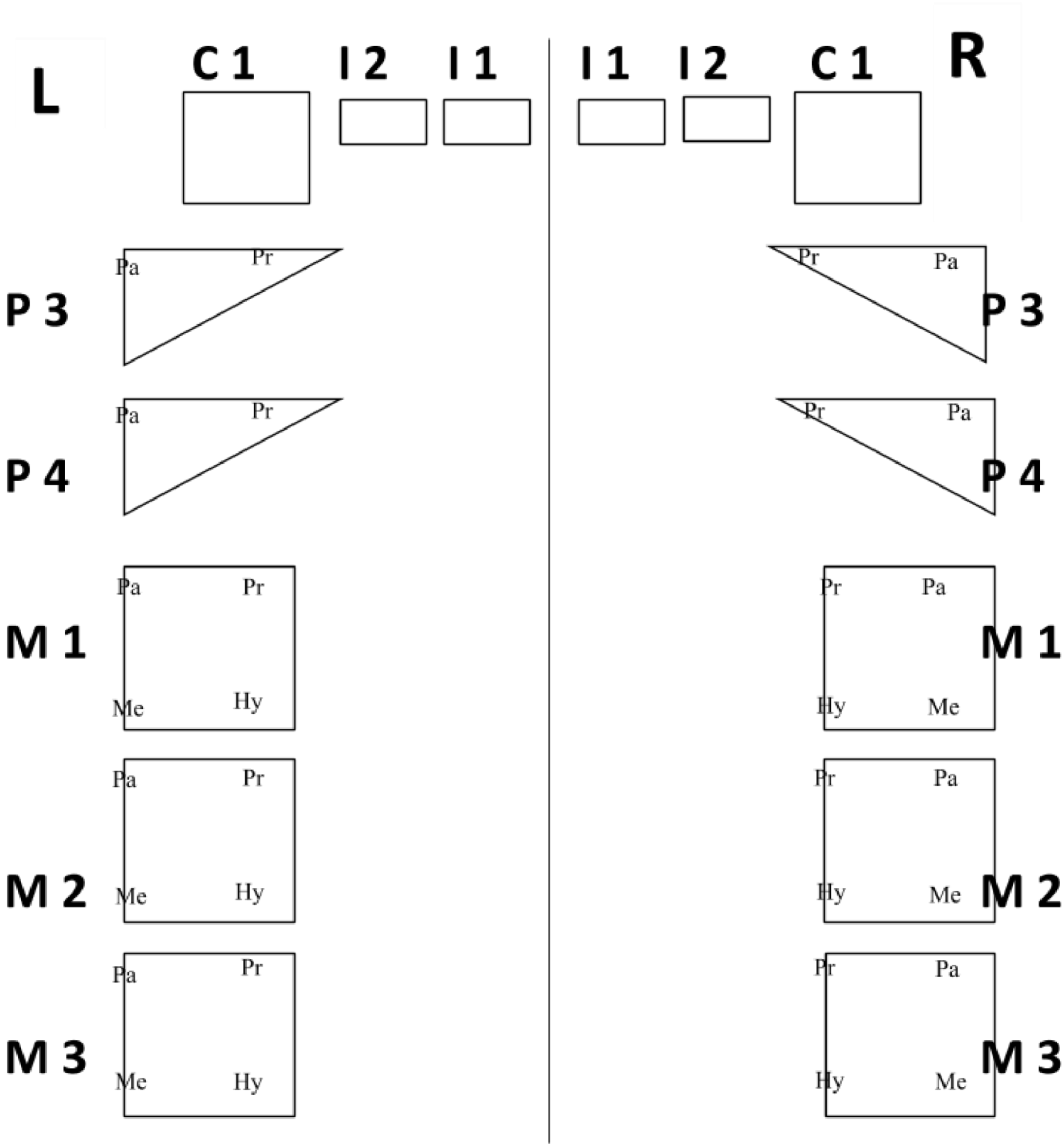
- Pr = Protocone (Mesiolingual)
- Pa = Paracone (Mesiobuccal)
- Me = Metacone (Distobuccal)
- Hy = Hypocone (Distolingual) Mandibular

  Legend:

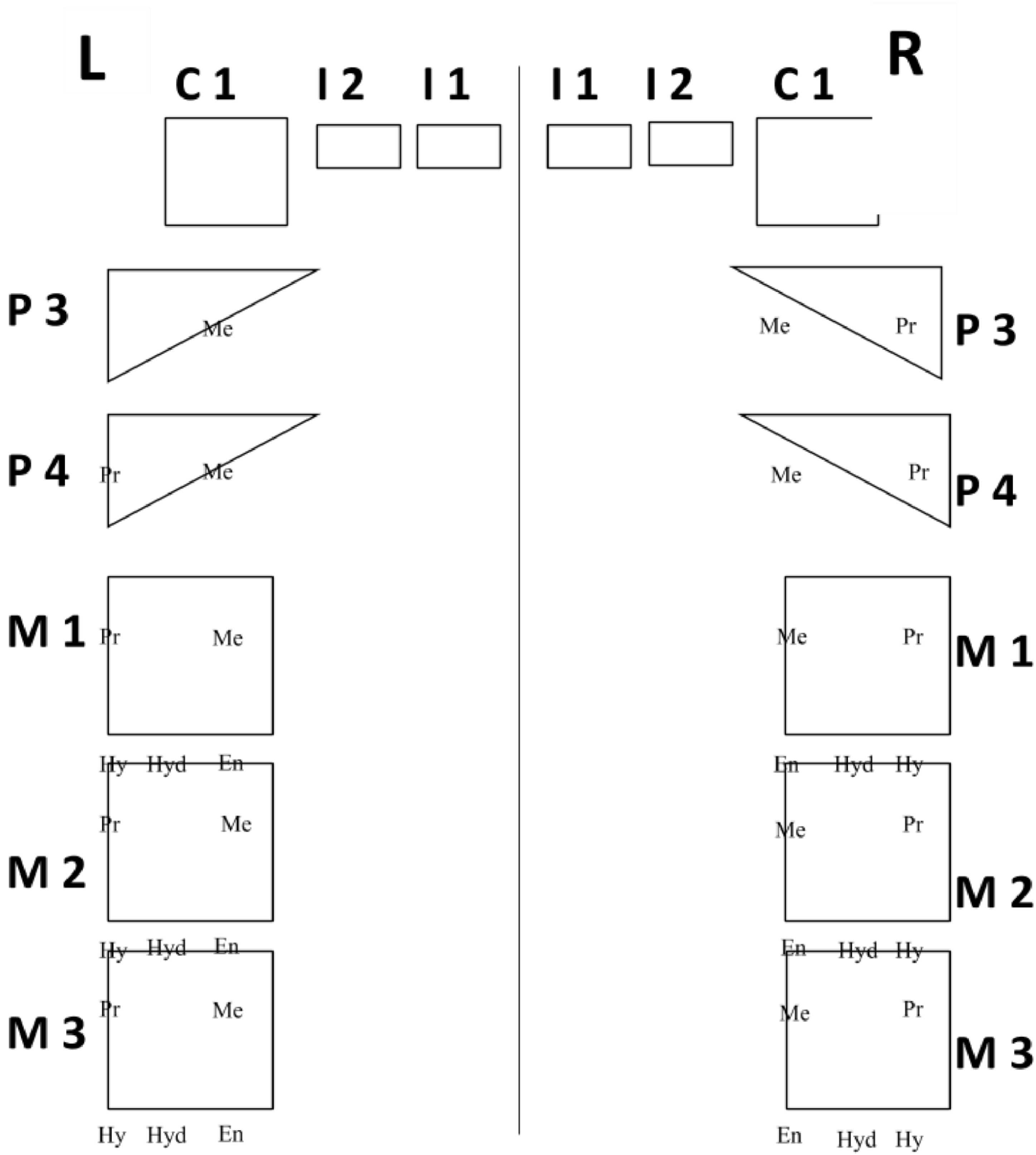
- Me = Metaconid (Mesiolingual)
- Pr = Protoconid (Mesiobuccal)
- Hy = Hypoconid (Distobuccal)
- Hyd = Hypoconulid (Disto)
- En = Entoconid (Distolingual)

Dentition - Upper teeth angle up lateromedially, bottom teeth angle down mediolaterally

Maxillary - Buccal & lingual cusps of Ps are nearly equal; buccal side of Ms tends to wear slower lending to more height over the lingual side



Mandibular – Buccal cusps of Ps dominates the lingual side in size & height; Lingual side of the Ms tends to wear slower lending to more height over the buccal side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PART FOUR: Example Syllabi

Human Osteology Syllabus (Graduate Quarter Class)

Course Overview

Human osteology is, very simply, the study of human bones. While this may seem short-sighted, human osteology actually encompasses a wide range of techniques, methods, & disciplines. Osteology, & the associated fields, are useful in many areas of study, including criminal justice, forensic anthropology, nursing & medicine, paleoarchaeology, & epidemiology.

Bones can tell us a lot, including information about human biological variation & human populations, as well as precise forensic evidence. Osteologists may use their training in forensic crime labs, archaeological sites, & centers for pathological disease research, as well as many other settings.

Learning Outcomes

- Students will learn the appropriate anatomical & directional terminology required to discuss osteology.
- Students will learn each element in the adult human skeleton.
- Students will learn craniometrics and/or features for each element in the adult skeleton.
- Students will learn how to properly discern between human & non-human bones.
- Students will learn how to appropriately handle human remains with respect & care.
- Students will learn how to critically analyze diagnostic features of intact & fragmented bones to determine vital information.
- Students will learn peer-reviewed methods of age, sex, & stature determinations.

- Students will learn how to identify osteological pathologies and/or pathological conditions that affect bones.
- Students will learn the differences between anti-, peri-, & post-mortem changes to the human skeleton, & how to recognize them.
- Students will learn about bone modifications by bioturbation, humans, & physical factors.
- Students will learn fields & careers that use real world applications of human osteology.
- Students will learn osteological teaching pedagogy.
- Students will contribute to teaching & instructing the classes.
- Students will act as mentors & guides to the undergraduates.
- Students will learn how to design, set-up, proctor, & grade practical exams.

Required Text

Human Osteology, Third Edition, *White, Black, & Folkens: 2012* The

Human Bone Manual, First Edition, *White & Folkens: 2005*

Course Schedule

Week	**Subject**	**Areas of Focus**
One	Overview, Terminology, & Skull	WBF 1, 2, 4 MT 1, 2, 3 OG P1
Two	Skull & Intro to Biometrics	WBF 3, 4 MT 3, 4 OG P1, P2
Three	Skull, Dentition, & Pathology	WBF 4, 5, 19 MT 3, 6 OG P1, P2, P3
Four	Hyoid, Vertebrae, Ribs, & Modification	WBF 6, 7, 20 MT 3, 8 OG P1-3
Five	Review & Midterm	
Six	Shoulder Girdle, Humerus, Radius, & Ulna	WBF 8, 9 MT 3 OG P1-3

Seven	Carpals, Metacarpals, & Taphonomy	WBF 10, 20 MT 3, 7, 8 OG P1-3
Eight	Pelvis & Variable Determination	WBF 11, 18 MT 3, 5 OG P1-3
Nine	Femur, Tibia, Fibula, Tarsals, Metatarsals, & Forensic Case 3 Studies	WBF 12, 13, 23 3, 9 OG P1-
Ten	Review & Final	

Exam Schedule *Design & Grade Only

Week	**Subject**	**Type**
Two	Skeleton overview, terminology, & the skull*	Quiz
Four	Through ribs*	Quiz
Five	Through ribs	Midterm
Seven	Through the hand*	Quiz
Nine	Through the foot*	Quiz
Ten	Cumulative	Final

Human Osteology Syllabus (Graduate Semester Class)

Course Overview

Human osteology is, very simply, the study of human bones. While this may seem short-sighted, human osteology actually encompasses a wide range of techniques, methods, & disciplines. Osteology, & the associated fields, are useful in many areas of study, including criminal justice, forensic anthropology, nursing & medicine, paleoarchaeology, & epidemiology.

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Learning Outcomes

- Students will learn the appropriate anatomical & directional terminology required to discuss osteology.
- Students will learn each element in the adult human skeleton.
- Students will learn craniometrics and/or features for each element in the adult skeleton.
- Students will learn how to properly discern between human & non-human bones.
- Students will learn how to appropriately handle human remains with respect & care.
- Students will learn how to critically analyze diagnostic features of intact & fragmented bones to determine vital information.
- Students will learn peer-reviewed methods of age, sex, & stature determinations.
- Students will learn how to identify osteological pathologies and/or pathological conditions that affect bones.
- Students will learn the differences between anti-, peri-, & post-mortem changes to the human skeleton, & how to recognize them.
- Students will learn about bone modifications by bioturbation, humans, & physical factors.

- Students will learn fields & careers that use real world applications of human osteology.
- Students will learn osteological teaching pedagogy.
- Students will contribute to teaching & instructing the classes.
- Students will act as mentors & guides to the undergraduates.
- Students will learn how to design, set-up, proctor, & grade practical exams.

Required Text

Human Osteology, Third Edition, *White, Black, & Folkens: 2012*

The Human Bone Manual, First Edition, *White & Folkens: 2005*

Course Schedule

Week	**Subject**	**Areas of Focus**
One	Overview & terminology	WBF 1, 2 MT 1, 2, 3 OG P1
Two	Skull & Intro to Biometrics	WBF 3, 4 MT 3, 4 OG P1, P2
Three	Skull, Dentition, & Biometrics	WBF 3, 4, 5 MT 3, 4 OG P1, P2, P3
Four	Dentition & Pathology	WBF 5, 19 MT 3, 6 OG P1-3
Five	Hyoid, Vertebrae, & Pathology	WBF 6, 19 MT 3, 6 OG P1-3
Six	Vertebrae & Ribs	WBF 6, 7 MT 3 OG P1-3
Seven	Review & Midterm	
Eight	Clavicle, Scapula, & Modification	WBF 8, 20 MT 3, 8 OG P1-3

Nine	Humerus, Radius, Ulna, Modification, & Taphonomy	WBF 9, 20 MT 3, 7, 8 OG P1-3
Ten	Carpals, Metacarpals, & Taphonomy	WBF 10, 20 MT 3, 7 OG P1-3
Eleven	Pelvis & Variable Determination	WBF 11, 18 MT 3, 5 OG P1-3
Twelve	Pelvis & Variable Determination	WBF 11, 18 MT 3, 5 OG P1-3
Thirteen	Femur, Tibia, Fibula, & Forensic Application	WBF 12, 15 MT 3, 9 OG P1-3
Fourteen	Tarsals, Metatarsals, & Forensic Case Studies	WBF 13, 23, 24 MT 3, 9 OG P1-3
Fifteen	Review & Final	

Exam Schedule *Design & Grade Only

Week	**Subject**	**Type**
Two	Skeleton overview, terminology, & the skull*	Quiz
Four	Through dentition*	Quiz
Seven	Through ribs	Midterm
Nine	Through the arm*	Quiz
Eleven	Through the pelvis*	Quiz
Thirteen	Through the leg*	Quiz

Fifteen	Cumulative	Final

Human Osteology Syllabus (Undergraduate Quarter Class)

Course Overview

Human osteology is, very simply, the study of human bones. While this may seem short-sighted, human osteology actually encompasses a wide range of techniques, methods, & disciplines. Osteology, & the associated fields, are useful in many areas of study, including criminal justice, forensic anthropology, nursing & medicine, paleoarchaeology, & epidemiology.

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Learning Outcomes

- Students will learn the appropriate anatomical & directional terminology required to discuss osteology.
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- Students will learn craniometrics and/or features for each element in the adult skeleton.
- Students will learn how to properly discern between human & non-human bones.
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- Students will learn how to critically analyze diagnostic features of intact & fragmented bones to determine vital information.
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Required Text

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The Human Bone Manual, First Edition, *White & Folkens: 2005*

Course Schedule

Week	Subject	Areas of Focus
One	Overview, Terminology, & Skull	WBF 1, 2, 4 MT 1, 2, 3 OG P1
Two	Skull & Intro to Biometrics	WBF 3, 4 MT 3, 4 OG P1, P2
Three	Skull, Dentition, & Pathology	WBF 4, 5, 19 MT 3, 6 OG P1, P2, P3
Four	Hyoid, Vertebrae, Ribs, & Modification	WBF 6, 7, 20 MT 3, 8 OG P1-3
Five	Review & Midterm	
Six	Shoulder Girdle, Humerus, Radius, & Ulna	WBF 8, 9 MT 3 OG P1-3

Seven	Carpals, Metacarpals, & Taphonomy	WBF 10, 20 MT 3, 7, 8 OG P1-3
Eight	Pelvis & Variable Determination	WBF 11, 18 MT 3, 5 OG P1-3
Nine	Femur, Tibia, Fibula, Tarsals, Metatarsals, & Forensic Case Studies	WBF 12, 13, 23, 24 MT 3, 9 OG P1-3
Ten	Review & Final	

Exam Schedule

Week	**Subject**	**Type**
Two	Skeleton overview, terminology, & the skull	Quiz
Four	Through ribs	Quiz
Five	Through ribs	Midterm
Seven	Through the hand	Quiz
Nine	Through the foot	Quiz
Ten	Cumulative	Final

Human Osteology Syllabus (Undergraduate Semester Course)

Course Overview

Human osteology is, very simply, the study of human bones. While this may seem short-sighted, human osteology actually encompasses a wide range of techniques, methods, & disciplines. Osteology, & the associated fields, are useful in many areas of study, including criminal justice, forensic anthropology, nursing & medicine, paleoarchaeology, & epidemiology.

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Course Schedule

Week	Subject	Areas of Focus
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Two	Skull & Intro to Biometrics	WBF 3, 4 MT 3, 4 OG P1, P2
Three	Skull, Dentition, & Biometrics	WBF 3, 4, 5 MT 3, 4 OG P1, P2, P3
Four	Dentition & Pathology	WBF 5, 19 MT 3, 6 OG P1-3
Five	Hyoid, Vertebrae, & Pathology	WBF 6, 19 MT 3, 6 OG P1-3
Six	Vertebrae & Ribs	WBF 6, 7 MT 3 OG P1-3
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Fifteen	Review & Final	

Exam Schedule

Week	Subject	Type
Two	Skeleton overview, terminology, & the skull	Quiz
Four	Through dentition	Quiz
Seven	Through ribs	Midterm
Nine	Through the arm	Quiz
Eleven	Through the pelvis	Quiz
Thirteen	Through the leg	Quiz
Fifteen	Cumulative	Final