Osteoware Software Manual
Volume II: Pathology Module

Developed by the Repatriation Osteology Lab, Smithsonian Institution

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Preface

Documentation of pathological changes is one of the most complex data entry tasks, and this is reflected in the large number of data entry screens in the Paleopathology Module of Osteoware™. Given this complexity and the need for numerous photographic examples, the manual for this module warranted its own volume. The Pathology Module also has the most changes from the Standards1, and these changes are indicated at the beginning of each chapter. Nonetheless, the Standards scoring system for pathological changes has held up remarkably well during the documentation of tens of thousands of lesions in the Repatriation Osteology Lab, Smithsonian Institution, and we are indebted to the groundbreaking work of the Standards editors and contributors.

The Literature Cited section has been kept to a minimum by extensive reference to several well-known paleopathology sources (e.g., Aufderheide and Rodríguez-Martín, 1998; Ortner, 2003). Without the work of these and other leading researchers in systematizing descriptions, categorizing lesions, and reviewing the literature, the refinements made in scoring lesions and the writing of this manual would have been infinitely more difficult.

While a full list of acknowledgements is given in the preface to Volume 1, we thank the following individuals here for their help with specific aspects of the Paleopathology Volume: David Hunt, Smithsonian Institution; Lenore Barbian, Edinboro University of Pennsylvania; and Brian Spatola and Franklin Damann, National Museum of Health and Medicine. Special thanks goes to Donald Ortner, Smithsonian Institution. In addition to contributing some of the photographs, Don was very generous with his time in answering questions posed by various authors on specific points of paleopathology. Needless to say, any inaccuracies are the fault of the authors and editors. The editors of this volume would like to thank all the authors for their patience in responding to our comments and their toleration of the changes needed to ensure a continuity in style and voice.

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1 As in volume 1, the Standards is used throughout this volume to refer to Buikstra and Ubelaker, 1994.
Contributors

J. Christopher Dudar, Ph.D., Repatriation Osteology Lab, National Museum of Natural History (NMNH)
Chris Dudar received his PhD in Physical Anthropology in 1999 from McMaster University, Canada. After completing a SSHRC postdoc at the University of Florida involving historic records research on the Navajo reservation, he became a contract osteologist in the NMNH Repatriation Osteology Laboratory in 2002, and has served as the RO Lab Director since 2008. Chris has excavated and directed several historic cemetery relocation projects and has research interests in paleopathology, kinship, and mortuary studies.

Erica B. Jones, M.A., Repatriation Osteology Lab, NMNH
Erica Jones received her M.A. in Anthropology in 1992 from The George Washington University. She has been a staff member of the Repatriation Osteology Laboratory since 1993, where she collects osteological data, helps oversee laboratory organization, and works with the Lab Director to coordinate database management. She has acted as the osteologist for several CRM projects and is a member of the national Disaster Mortuary Operational Response Team (DMORT). Her primary area of research expertise is dental anthropology.

Marilyn R. London, M.A., Department of Anthropology, University of Maryland.
Marilyn London received her M.A. in Biological Anthropology at the University of New Mexico in 1979. She has contracted professionally with the Department of Anthropology at the Smithsonian Institution for more than 16 years, working in Public Information, Collections Management, and the Repatriation Osteology Laboratory. She is currently a Lecturer in the Department of Anthropology, University of Maryland; a Fellow of the American Academy of Forensic Sciences, Physical Anthropology Section; and a forensic anthropologist for the U.S. Department of Health and Human Services DMORT disaster response team.

Gwyn Madden, Ph.D., Grand Valley State University
Gwyn Madden received her Ph.D. in Physical Anthropology in 2004 from the University of Nevada. From 2005 to 2006, Gwyn worked as a contract osteologist with the Repatriation Osteology Laboratory, NMNH. Since 2006, she has been an assistant professor in the Department of Anthropology, Grand Valley State University. Gwyn specializes in the study of mummified human remains, having worked on remains from the American Southwest, California, Mexico, Chile, and Peru.

Dawn Mulhern, Ph.D., Fort Lewis College
Dawn Mulhern received her Ph.D. in Anthropology in 1996 from the University of Colorado at Boulder. From 1998 to 2005, Dawn was a contract osteologist with the Repatriation Osteology Laboratory, NMNH. Currently, she is Associate Professor of Anthropology at Fort Lewis College in Durango, Colorado, where she also serves as the Native American Graves Protection and Repatriation Act (NAGPRA) Coordinator for the college. Dawn is also a forensic anthropologist for the
national Disaster Mortuary Operational Response Team (DMORT) and serves as a consultant for local law enforcement agencies.

Claire O’Brien, M.S., Repatriation Osteology Lab, NMNH
Claire O’Brien received her M.S. in Forensic Archaeological Science from University College, London in 2002. Claire has been a contract osteologist for the Smithsonian Office of Repatriation since October 2008. Her research interests include taphonomy, reassociations of commingled remains, and human identification. She has also served as a forensic expert for the International Commission on Missing Persons.

Stephen D. Ousley, Ph.D., Mercyhurst College
Stephen Ousley received his Ph.D. degree in physical anthropology at the University of Tennessee. He was director of the Repatriation Osteology Lab from 1998 to 2007. Currently he is an Assistant Professor in the Applied Forensic Science and Anthropology Departments at Mercyhurst College. In addition to programming Osteoware, he developed the Fordisc software program for forensic discriminant function analysis in collaboration with Dr. Richard Jantz, University of Tennessee: [http://web.utk.edu/~fac/fordisc.html](http://web.utk.edu/~fac/fordisc.html)

Cynthia A. Wilczak, Ph.D., San Francisco State University
Cynthia Wilczak received her Ph.D. in Anthropology from Cornell University in 1998. She was a contract osteologist for Office of Repatriation, NMNH from 2003 to 2007. Currently she is an Assistant Professor of Anthropology at San Francisco State University, teaching classes that include paleopathology, bioarchaeology, and statistics. She has served as a forensic consultant for local law enforcement and has research interests in paleopathology and skeletal responses to mechanical stress.
Chapter 1: The Pathology Module Main Screen (Side/Aspect/Section)
by J. Christopher Dudar

Thorough description is one of the most important elements for differential diagnosis in paleopathology (Ortner, 2003). Additionally, understanding the cells and tissues involved and the processes and morphological features associated with normal and diseased bone will enable the researcher to identify abnormalities accurately, as well as provide the necessary terminology to describe them, thus greatly contributing to their documentation. It is not within the scope of this manual to provide this in-depth background knowledge. The reader is instead referred to a number of excellent books on the subject: Aufderheide and Rodríguez-Martín, 1998; Resnick 2002; Ortner, 2003; Mann and Hunt, 2005; Roberts and Manchester, 2007; Chhem and Brothwell, 2008; Pinhasi and Mays, 2008; Waldron, 2008.

When abnormally appearing bone is determined to have been formed antemortem (as opposed to postmortem taphonomic alteration; see Chapter 4, Volume I), the investigator has four potential sources of information to identify its cause: 1) gross morphological analysis, 2) radiographic appearance, 3) microscopic examination, and 4) chemical/molecular analysis. Only the first two are nondestructive; thus, they are the most common types of analyses performed on human skeletal remains. At a minimum, the observation of the overall gross appearance of the pathological bone should be documented. Whenever possible, radiographic images (see Chapter 12, Volume I) should be taken for all lesions because some processes affecting the internal structure of the bone will not be visible to the naked eye. Ortner (2003) maintains that an unknown number of pathological conditions will be missed if every bone in the skeleton is not radiographed. However, he also acknowledges that investigations are conducted within time and budget constraints, which may preclude full radiography.

The Osteoware Pathology Module is designed to provide an intuitive graphic user interface (GUI) and flexible framework for categorizing and documenting complex pathological observations into the Structured Query Language (SQL) database, thus allowing for subsequent analyses within and between skeletal samples. When the Pathology Module is opened from the Osteoware Home Screen, the default page is the Pathology Module Main Screen (also called the Side/Aspect/Section data entry screen). Other data entry screens are available within the Pathology Module for recording the process and/or type of bone abnormality such as, Bone Loss, Trauma, or Abnormal Bone Formation (see tabs in screenshot, Figure 1.1). Some of these screens contain contextually driven options (e.g., Vertebral Anomalies), meaning the skeletal element in the Pathology Module Main Screen must be selected in order to have the appropriate data entry choices available to you.
Selecting the Bone Involved

**BONE DROP-DOWN MENU:**
When the Pathology button on the Osteoware Home Screen is clicked, the default Pathology Module Main Screen is displayed. In the screen-shot (Figure 1.1), a skeletal element has not yet been selected in the blue selection box of the Bone drop-down menu (opened by clicking the arrow to the right of the box).

The Bone drop-down menu contains an alphabetical list of skeletal element choices beginning with 1st metacarpal and proceeding through Zygomatic (Figure 1.2). Scroll through the list to familiarize yourself with the options. Note that several anatomical regions are available, such as Limb Upper; Limb Lower; and Skeleton, Appendicular.

While the list is open and before any bone has been selected, you can type the first letter of the desired element, for example, ‘v’ for vertebrae, and the list will jump to those bones beginning with that letter. Scroll to, highlight, and click on the desired element to select it (Figure 1.3). Only after this choice has been made will you be able to proceed with other data entry into the module.

![Figure 1.2 The Bone drop-down menu.](image)

![Figure 1.3 Vertebral element selections.](image)
THE JOINT BUTTON: If the pathological condition affects the surfaces of multiple elements of a joint complex, click on the button and a Joint window opens within the Pathology Module Main Screen (Figure 1.4). The Joint window has a selection box similar to the Bone selection box described earlier. By clicking on the Joint drop-down button (to the right of the Joint window, with a black arrow), a list of all the joint choices are presented in anatomical order beginning with the default TMJ (Temporomandibular Joint) and ending with Ankle. Scroll within the list and highlight the desired joint, then click to select.

The bones composing that joint complex now appear in the Joint menu with check boxes beside them. If the pathological condition only affects some of these bones, then uncheck the bone(s) not affected. In Figure 1.5, Proximal Radius Articular Surface has been deselected from the elbow joint surface choices.

The effective use of the Joint menu allows you to complete, with a single data capture event, the entry of a shared pathological condition (such as arthritis) that is observed on multiple bones of a joint. Each selected bone will have a separate record in the database with identical pathology codes (OBS) and description field (Figure 1.6), so an accurate and thorough description detailing any differences in the condition observed on multiple bones is necessary.
Selecting the Side/Aspect/Section

After a bone or joint complex has been selected and before entering the specific observations of a pathological condition (such as porosity and eburnation in the Arthritis data entry screen), some basic observations of where the condition occurs will need to be selected.

Choose the appropriate radio button to indicate if the Right, Left, or Both sides of a bone (antimeres) are affected, whether it is a Midline element, or is of Unknown side (Figure 1.7). Radio buttons only allow a single choice to be made.

After Side has been entered, select all the affected bone aspects from the Aspect menu. The check boxes allow multiple selections to be made (Figure 1.8).

After the Side and Aspect have been entered, select the Section of the bone or bones affected (Figure 1.9). Again, select as many choices from the Section menu as is appropriate to the lesion using the check boxes.

After the Side, Aspect, and Section menu selections are completed, specific observations can be entered in one or more of the remaining pathology data entry screens by selecting the appropriate tab along the top of the Pathology Module Main Screen (Figure 1.10). Each of these data entry screens is discussed in detail in separate chapters.
The ‘Other Pathology’ Check Box
If the observations of the pathological condition are not appropriate for any of the pathology data entry screens, then select [Other Pathology NOT in system (describe in Comments)] and provide a detailed description. The Other Pathology check box should only be used as a last resort.

Description
The pathology description field allows detailed qualitative descriptions of the physical appearance of the lesions to be recorded within the database. Viewing all lesions under at least 5 X, or better yet 10 X, power magnification will allow for greater accuracy and detail in the description. A metric assessment (using calipers) of the extent of the abnormal area should also be included, i.e., measure and report the size of the affected area and depth/height. Taking at least one measurement from an established landmark, in addition to general descriptions of the anatomical location (anterior, medial, proximal, etc.), is useful for complete documentation. For example, the first sentence of a description may begin like this:

A circular, well-defined lytic lesion on the lateral aspect of the midshaft of the right humerus measures 25 mm in diameter and 5 mm deep. It is located 55 mm distal to the proximal articular surface . . .

In the case of cranial pathological conditions, triangulate the lesion from a minimum of two landmarks whenever possible. For example:

A circular, smooth-surfaced bone deposit with slightly undercut margins is located on the left side of the frontal bone, 40 mm from bregma and 60 mm from nasion. It measures 12 mm in diameter and is raised 3 mm above the surface of the surrounding bone. The shape, size, sharp demarcation, and dense, ivory-like texture are consistent with a button osteoma/hamartoma . . .

As discussed at the beginning of this chapter, understanding the physiological processes and morphological features associated with normal and pathological bone will enable accurate descriptions of lesions. Notes on differential diagnoses can also be entered into the description field. The level of detail will vary, but in cases of less common conditions or more difficult diagnoses, inclusion of references and explicit criteria used in reaching a conclusion will increase the value of the data collected.

Save/Exit/Clearall
If you have made errors in selecting radio buttons and/or check boxes on any of the pathology data entry screens, press [Clear all] to completely remove these entries. Alternatively, individual check boxes can be deselected one at a time, and individual radio buttons can be cleared by clicking on the radio button itself (note that a dotted line appears around the button label when selected) and pressing Delete on the keyboard.
When you have thoroughly documented the pathological condition in the data entry screens and the description field, click **Save**. The **Save and Keep Path** button acts in the same way as Save. To end a pathology data entry session, click **Exit**, or use the **X** at the top right corner of the Pathology Module window.

**Check Data Entry**

After you have completed entering the pathological conditions, press the **Check** button to view all pathology entries for that catalogue number. Click on any record and the skeletal element will appear in the Bone window and information entered for each data record will be displayed (Figure 1.11). The text in the description field is active, so you can directly edit the text on this screen or on the Side/Aspect/Section data entry screen.

You may also right-click on any pathology record in order to view the text version of the entered pathology codes. A turquoise box in the upper left of the Check Data Entry screen is a reminder of this function.

![Figure 1.11 The Check Data Entry screen. The turquoise box gives text descriptions of the codes.](image)

**NOTE:** You can go back and edit the text description of any pathology record, but you will NOT be able to revise selected check boxes or radio buttons once saved. To edit check boxes or radio buttons, delete the entire record by selecting it in the Check Data Entry screen (Figure 1.11) and then pressing the Ctrl and Delete keys. Confirm your deletion when prompted by the pop-up box (Figure 1.12). Remember to copy the Description before deleting the record in order to paste it to the new entry.

![Figure 1.12 Confirmation box for deletion of pathology records.](image)
Chapter 2: Size, Shape, and Bone-Specific Abnormality
by Gwyn Madden

Anomalies affecting the size and shape of bone include conditions that are genetic, nutritional, behavioral, infectious, traumatic, or developmental. They range from the common accessory facet on the sacrum to the rare case of pseudohypoparathyroidism. This module could be considered a “catchall” for those abnormalities that do not fit well in more easily defined categories, such as trauma or abnormal bone loss; however, overlap with other categories is possible. For example, flaring metaphyses may be described as a shape abnormality as well as abnormal bone formation. A few general references to aid in identification and description of this broad range of abnormalities are Aufderheide and Rodríguez-Martín (1998), Ortner (2003), and Mann and Hunt (2005).

Changes from the Standards in this module are minor, consisting of additional categories:

- The addition of gigantism to Skeleton, Total.
- Several common bone-specific anomalies have been added: precondylar tubercles, paracondylar tubercles or processes, asymmetry of the occipital condyles/foramen magnum, vastus notch/bipartite patella, innominate/sacral facets, and squatting facets.
- While some of the anomalies in this section can be classified as non-metric traits rather than pathological conditions, note that the cranial non-metric traits classified as being of “primary importance” in the Standards are scored under a separate module from pathological conditions.

Data Entry

To enter a pathological change, select a bone from the drop-down menu on the Pathology Module Main Screen along with the side, aspect, and section (see Chapter 1). Depending on the bone selected, the choices on the Size/Shape/Bone-Specific Abnormality data entry screen will present different options to reflect pathological changes that occur in specific areas of the skeleton (Figure 2.1). Some bone-specific abnormalities always occur in the same location, and in these cases, the standard aspect and section to select is indicated in the following descriptions.

Figure 2.1 Example of a Bone-Specific data entry screen.
Size Abnormalities: Cranium

HYDROCEPHALY: Hydrocephaly can result from trauma, infection, or tumors, but it is most commonly considered a congenital disorder (Figure 2.2). According to Aufderheide and Rodríguez-Martín (1994: 57), several characteristics should be noted in determining the diagnosis of hydrocephaly: enlargement of the head; thinning of the skull bones; bulging fontanelles; widely separated sutures, often showing wormian bones; atrophy of the supraorbital ridges; and flattening of the cranial base.

Select Cranium from the Bone drop-down menu and Circumferential for the aspect on the Pathology Module Main Screen. Hydrocephaly can then be selected from the Size/Shape/Bone-Specific Abnormality data entry screen (Figure 2.1). Comments should be entered in the description field regarding the extent of the shape change and any other associated features of hydrocephaly.

ACROMEGALY: Excess production of growth hormone after epiphyseal fusion results in acromegaly. It can co-occur with gigantism when the hormonal imbalance begins in childhood and continues into adulthood (Figure 2.3). The changes associated with acromegaly noted by Aufderheide and Rodríguez-Martín (1998) include: thickening of all bones; elongated, prognathic mandible; prominence of the nose and facial bones; beaded costochondral junctions; wide ribs and enlarged vertebrae; a subperiosteal bone envelope; tufted digits; degenerative joint changes; and an enlarged or eroded sella turcica.

Depending on the skeletal elements present, select either Cranium or Total, Skeleton from the Bone drop-down menu and Circumferential for the aspect on the Pathology Module Main Screen. Acromegaly can then be selected from the Abnormal Size/Shape/Bone-Specific abnormality data entry screen. Radiographs should be taken and any thickening of the bones recorded in the description along with details about any other associated features of acromegaly.
acromegaly. Measurements are recorded as usual in the Craniometrics and Postcranial Metrics Modules, but they should be labeled as pathological in the comments.

**MICROCEPHALY:** Microcephaly is defined as a cranial circumference below 46 cm or a cranial capacity of less than 1000cc (Aufderheide and Rodríguez-Martín, 1998; Mann and Hunt, 2005). The condition is relatively rare and is the result of deficient brain growth. True microcephaly is not caused by early suture closure; therefore, accurate diagnosis depends on the lack of fusion of the sutures and a small vault circumference (Figure 2.4). Because facial growth is not as severely affected, the face is large relative to the cranial vault and the frontal and parietals slope posteriorly. The sloping forehead and irregular growth reductions help distinguish microcephaly from the proportionate reductions in head size seen in pituitary dwarfism.

Select Cranium from the Bone dropdown menu and Circumferential for the aspect on the Pathology Module Side/Aspect/Section data entry screen. Microcephaly can then be selected from the Abnormal Size/Shape/Bone-Specific Abnormality data entry screen. Cranial circumference measurements and a discussion of suture closure should be entered into the description field. Other cranial measurements should be entered in the Craniometrics Module as usual, but they should be labeled as pathological in the comments.

*Figure 2.4 Microcephalic cranium compared to an average-sized female from the same archaeological site. a) anterior; b) left lateral; c) superior (photos by C. Wilczak).*
Abnormalities of Size: Postcranial
Small size may affect the entire skeleton or specific skeletal regions. The affected region determines the selections from the Bone drop-down menu. For example, to record a case of shortened metacarpals, as seen in pseudohypoparathyroidism (Figure 2.5), select Hand from the Bone drop-down menu, Circumferential for the aspect, and all sections on the Pathology Module Main Screen. Abnormally small size can then be selected from the Size/Shape/Bone-Specific Abnormality data entry screen. As this is a relatively rare finding, detailed observations should be recorded in the description field. Measurements should be entered on the Postcranial Metrics Module as usual, but they should be labeled as pathological in the comments.

Abnormalities of Size: Total Skeleton
When the entire skeleton is of abnormal size as in dwarfism or gigantism, select Skeleton, Total from the Bone drop-down menu, then select the appropriate pathological condition (Figure 2.6). In these cases, it is extremely important to make extensive notes in the description field. Affected bones present should be part of the description because Skeleton, Total was selected, but all elements may not be present.

Figure 2.5 Abnormally small 4th and 5th metacarpals, likely resulting from pseudohypoparathyroidism (radiograph by S. Pelot).

Figure 2.6 Data entry screen for size abnormalities affecting the entire skeleton.
ACHONDROPLASTIC DWARFISM: Achondroplasia is an autosomal dominant trait that may be inherited, but most cases result from a spontaneous mutation. In this form of dwarfism, cartilage growth and ossification are depressed at the growth plates, resulting in shortened limbs (Figure 2.7). Long bones will appear abnormally thick because periosteal growth is not affected. Growth reductions are diminished in the axial skeleton due to the more numerous growth centers of the vertebral column and the primarily intramembranous growth of the skull, so the trunk and skull appear abnormally large in proportion to the limbs. Other skeletal changes associated with achondroplasia include: frontal bossing, a depressed nasal bridge (midface hypoplasia), lordosis, widening of the metaphyses, and thickened ribs (Aufderheide and Rodríguez-Martín, 1998: 358-360).

Depending on the bones present, select Skeleton, Total or an individual bone from the Bone dropdown menu, Circumferential for the aspect, and all sections on the Pathology Module Main Screen. Achondroplasia can then be selected from the Size/Shape/Bone-Specific Abnormality data entry screen. Details should be recorded in the description field regarding the differential proportions of the limbs and axial skeleton. Measurements should be entered into the Postcranial Metrics Module as usual, but they should be labeled as pathological in the comments.

Figure 2.7 Achondroplastic dwarfism. a) left femur, tibiae, and humerus, showing shortened diaphyses and flared metaphyses; b) depressed nasal bridge in left lateral view (photos courtesy of D.J. Ortner, Smithsonian Institution).
PROPORTIONAL DWARFISM: Proportional or pituitary dwarfism is caused by congenital or acquired defects in pituitary growth hormone production or genetic abnormalities in hormone receptors. Both intramembranous and endochondral bone growth are diminished so the affected individual is short-statured but of normal proportions (Figure 2.8), differentiating this type of dwarfism from other forms (Aufderheide and Rodríguez-Martín, 1998).

Select Skeleton/Total from the Bone drop-down menu, Circumferential for the aspect, and all sections on the Pathology Module Main Screen. Proportional Dwarfism can then be selected from the Size/Shape/Bone-Specific Abnormality data entry screen. Size of the limbs relative to the axial skeleton should be discussed in the description field. Measurements should be entered on the Postcranial Metrics data entry screen as usual, but they should be labeled as pathological in the comments.

Figure 2.8 Comparison of an abnormally small female and an average-sized female from the same archeological site. a) mandibles; b) femora; c) radii; d) sacra (photos by C. Wilczak).
GIGANTISM: Gigantism differs from acromegaly in both the timing of occurrence and the characteristic skeletal changes. Gigantism affects individuals in childhood and is most commonly caused by benign tumors of the pituitary. Excess growth is seen at the cartilaginous growth plate, and the period before fusion of the growth plate is extended. Height is approximately . . . three or more standard deviations greater than the population’s mean value . . . which in western countries today is roughly equal to a total body height greater than 213 cm (7 feet)” (Aufderheide and Rodríguez-Martín, 1998: 327). Bones are abnormally elongated but of normal proportions (Figure 2.9). Because of the increased weight and muscular weakness, gigantism is also associated with degenerative changes of the joints and spine, kyphoscoliosis, and tarsal deformities (Aufderheide and Rodríguez-Martín, 1998).

Select Skeleton/Total from the drop-down menu, Circumferential for the aspect, and all sections on the Pathology Module Main Screen. Gigantism can then be selected from the Size/Shape/Bone-Specific Abnormality data entry screen. Measurements should be entered on the Postcranial Metrics Module as usual, but labeled as pathological in the description.

Figure 2.9 Reported case of gigantism with an estimated age of late 20s to early 30s. a) cranium; b) right humerus showing delayed epiphyseal union; c) degenerative changes of the L4-L5 superior endplates (from Figures 1, 3 & 5 of Mulhern (2005); reproduced by permission from the author).
Abnormalities of Shape: Cranium

PREMATURE SUTURE CLOSURE: Abnormalities of cranial shape are most commonly caused by early closure of the cranial sutures (craniosynostoses). When a suture closes early, the brain will continue to grow and the cranial vault will expand in the direction of the open sutures (Fig 2.10 and 2.11). Artificial cranial modification also causes abnormal shape, but is not a pathological change, and it should be entered in the Cranial Deformation Module.

To enter craniosynostosis into the database, select Cranium from the Bone drop-down menu. Circumferential is usually chosen for aspect on the Pathology Data Entry Home Screen because most cases of craniosynostosis involve the entire cranium. Once these choices have been made, the Size/Shape/Bone-Specific Abnormality data entry screen will display the appropriate selections (Figure 2.10). The shape change should be identified as barely discernible or clearly present. When it can be determined, early suture fusion can also be described as partial or complete.

Figure 2.10 Premature sagittal suture closure. a) partial closure, barely discernible shape change; b) complete closure, barely discernible shape change; c & d) complete closure, clearly discernible shape changes from right lateral and superior views (photos by J. Beck).
Abnormalities of Shape: Long Bones

Several specific shape abnormalities can be selected in the data entry screen for long bones such as bowing and flared metaphyses (Figure 2.12). For abnormalities of shape that do not fall under one of these categories, “Other” should be checked and a detailed description should be provided.

Bowed (Abnormal Curvature): True shaft bowing (Figure 2.13) should be distinguished from pseudobowing due to non-circumferential bone deposition, e.g., the “saber shin” of syphilis or yaws. Bowing may affect multiple skeletal elements, and if so, Upper Limb, Lower Limb, or Skeleton, Total can be selected from the Bone drop-down menu. If only one bone or a set of paired bones is affected, a single bone can be selected. Bowing can then be selected from the Size/Shape/Bone- Specific Abnormality data entry screen. The severity of bowing (slight, moderate, severe) and differential diagnoses should be addressed in the description field.

Angulated: Data may need to be entered into multiple modules for angulated bones. Radiographs are necessary to detect potential fractures, and the appropriate selections should also be made on the Trauma data entry screen when present. For example, the tibia in

Figure 2.11 Complete sagittal suture closure, partial coronal and lambdoidal suture closure, and clearly discernible shape changes. a) lateral; b) superior; c) posterior (photos by J. Beck).

Figure 2.12 Long Bone Shape Abnormalities data entry screen.
Figure 2.14 would also be entered as a pathological fracture. Other associated entries may include abnormal bone formation or ankylosis. When the cause of the angulation is unclear or it is likely congenital, it would only be entered as abnormal shape. *Circumferential* is the usual choice of aspect, but the section will vary depending on the location of angulation on the shaft. The degree of angulation should be noted in the description.

**FLARING METAPHYSES:** Flaring at the metaphyses is one developmental shape change (Figure 2.15). Instead of following normal growth in which bone is removed from the external aspect of the metaphysis and added endosteally, bone builds on the external aspect of the metaphysis, giving it a flared appearance (Buikstra and Ubelaker, 1994). Long bones can be selected individually from the Bone drop-down menu or as Limb, Upper and Limb, Lower. Select *Circumferential* for aspect and the proximal and distal 1/3 sections on the Pathology Module Main Screen. *Flaring metaphyses* can then be selected from the Size/Shape/Bone-Specific Abnormality data entry screen and the shape change can be discussed in the pathology description. For subadults, metaphyseal width measurements should be entered in the Postcranial Metrics Module as usual, but they should be labeled as pathological in the comments.
UNIFORM WIDENING: Uniform widening refers to a change in the shape of the tubular bones, and it is frequently associated with infection (Buikstra and Ubelaker, 1994). As the infectious process progresses, abnormal bone may be deposited, giving the tubular bone a uniformly thickened appearance (Figure 2.16). Bone may become infected through a number of circumstances, including surgery and trauma (Ortner, 2003). Surgery may leave behind identifiable markers such as cut marks or hardware, while trauma in the form of fractures can be observed through radiography. Other pathways of infections, such as a hematogenous route, may not be identifiable with incomplete remains.

Select the affected bone or skeletal region from the Bone drop-down menu, Circumferential for the aspect, and all of the sections on the Pathology Module Main Screen. The skeletal changes of uniformly widened elements should be specified in the description, including any abnormal bone loss, abnormal bone formation, and observations regarding fractures or cut marks. The appropriate selections should also be made in the corresponding data entry screens for each type of pathological change observed.

FUSIFORM (SPINDLE-SHAPED): Fusiform is defined in long bones as a thickened shaft with tapering at one or both ends (Figure 2.17). Infectious processes are thought to cause the change in shape, and the shaft may show abnormal bone formation in association with the fusiform shape (Buikstra and Ubelaker, 1994).

Figure 2.16 Uniform widening of a right ulna. a) medial aspect; b) anterior aspect. Note the appropriate selections should also be made on the Abnormal Bone Formation data entry screen (photo by C. Wilczak).

Figure 2.17 Fusiform shape. a) juvenile humerus with tapering at the proximal end; b) adult femur with tapering at both ends (photos by C. Wilczak).
Select the affected bone or skeletal region from the Bone drop-down menu and *Circumferential* for the aspect on the Pathology Module Main Screen. The shape change should be included in the description with measurements of the extent of bone affected and the distances from the epiphyses. The appropriate selections should also be made in the Abnormal Bone Formation data entry screen.

**Bone-Specific Abnormalities**

When entering a bone-specific abnormality, the bone must first be selected from the drop-down menu and the applicable selections will appear in the Size/Shape/Bone-Specific Abnormality data entry screen (Figure 2.18). When vertebral elements are selected, an extensive list of abnormalities are displayed separately on the Vertebral Anomalies data entry screen (Chapter 8). The remaining non-vertebral abnormalities are described here.

**Bone-Specific Abnormalities: Occipital**

ASYMMETRY OF THE OCCIPITAL CONDYLES AND FORAMEN MAGNUM: This asymmetry is shown in Figure 2.19. Select *Occipital* from the drop-down menu, *Midline* for the side, and *Medial* for the aspect on the Pathology Module Main Screen. Asymmetry of the occipital condyles and/or the foramen magnum can then be selected from the Size/Shape/Bone-Specific Abnormality data entry screen. The degree of asymmetry should be discussed in detail in the description.
PARACONDYLAR TUBERCLE OR PROCESS: Bony prominences lateral to the posterior end of the occipital condyles can be unilateral or bilateral and may or may not be symmetrical in size and appearance (Barnes, 1994:88). The terms tubercle or process are alternatively used depending on the degree of expression. A true process is relatively conical in shape, projects inferiorly, and lacks signs of rugosity (Figure 2.20). Often paracondylar tubercles or processes are found in association with other anomalies of the vertebral column (Barnes 1994). The presence of other anomalies may be mentioned in the description, but they should also be entered separately under the Vertebral Anomalies data entry screen (Chapter 8).

Select Occipital from the Bone drop-down menu. Side can be Right, Left or both, and the aspect is Medial on the Pathology Module Home Screen. Paracondylar tubercle/process can then be selected from the Size/Shape/Bone-Specific Abnormality data entry screen (Figure 2.18). Trait expression should be discussed in the description section, including diameters and height measurements. When an articular facet for the paracondylar process is present on C1, it should also be recorded under Vertebral Anomalies.

PRECONDYLAR TUBERCLE: A precondylar tubercle is a protrusion of bone into the foramen magnum from its most anterior point (Figure 2.21). It has been classified by some researchers as a cranial border shift of the first cervical vertebra (Barnes 1994). A more detailed discussion of vertebral border shifting is given in Chapter 8.

Select Occipital from the Bone drop-down menu. Side is Midline and the aspect is Medial on the Pathology Module Home Screen. Precondylar tubercle can then be selected from the Size/Shape/
Bone-Specific Abnormality data entry screen (Figure 2.18). Indicate the degree of expression in the description, including measurements.

Bone-Specific Abnormalities: Postcranium

ACCESSORY SACROILIAC FACETS: These accessory facets are an additional area of articulation between the sacrum and ilium. In the case shown in Figure 2.22, the anomaly should be entered for both the Ilium (or Innominate can be selected) and Sacrum using the Bone drop-down menu. Side can be right, left, or both and the aspect is medial on the Pathology Module Main Screen. Accessory sacroiliac facets can then be selected from the Size/Shape/Bone-Specific Abnormality data entry screen. The location of the facet should be indicated in the description, using measurements from standard points on the ilium and/or sacrum. The size of the facet should also be taken and entered into the comments section. In addition to creating a separate entry for the sacrum, note in the description if there is an associated facet on the sacrum for the ilium and vice versa.

VASTUS NOTCH AND BIPARTITE PATELLA: The vastus notch and bipartite patella were once considered variants of the same condition; however, they are now thought to be two separate anomalies arising through different processes (Anderson, 2002; Mann and Hunt, 2005). The bipartite patella results from the formation of a separate ossification center, the “patellula” (Mann and Hunt, 2005), while the vastus notch is a morphological variation of the vastus lateralis insertion (Anderson, 2002).
Both notches and bipartite ossicles are located on the superiolateral aspect of the patella, but they differ in appearance (Figures 2.23 and 2.24). According to Mann and Hunt (2005: 196), “A bipartite patella has a porous, roughened central area surrounded by smooth-bordered cortical bone for attachment of an accessory (bipartite) bone. A vastus notch, on the other hand, is a smooth-surfaced, depressed or flattened area with no accompanying porosity.”

Select *Patella* from the Bone drop-down menu and both the *Lateral* and *Superior* surface for the aspect on the Pathology Module Home Screen. Vastus notch or bipartite patella can then be selected from the Size/Shape/Bone-Specific Abnormality data entry screen. In the comments section, describe the margins of the area involved and, in the case of the bipartite patella, note if the associated accessory bone is present.

*Figure 2.23 Bipartite patella with preserved “patellula” (os patella). (photo by J. Beck)*

*Figure 2.24 Vastus notch on the superiolateral aspect of the patella. a) lateral; b) posterior (photo by J. Beck).*
SQUATTING FACETS: Discussions of pressure facets, including the previously covered sacroiliac facets, are not included in many texts that describe skeletal pathology as they are generally classified as non-metric trait variation. Squatting facets are associated with hyperflexion of the knee and hyperdorsiflexion of the foot in a squatting posture with genetic factors contributing to their expression (Boulle, 2001). Due to the probable mix of genetic and environmental causality and the current lack of a postcranial non-metrics module, squatting facets are recorded in Osteoware as a pathological change. The anterior margin of the distal tibia and superior aspect of the talar neck are the most common locations for squatting facets (Figure 2.25), and they can be entered into the database using Bone-specific check boxes. Mann and Hunt (2005: 191) suggest scoring a tibial squatting facet as “present whenever there is a break in the continuity of the anterior margin of the distal tibia”, and Boulle (2001) discusses variation in the presentation of talar squatting and pressure facets. Facets or articular extensions associated with a squatting posture have also been described at other location such as the femoral condyles, tibial plateau, calcaneus, and distal metatarsals (Larsen, 1997; Mann and Hunt, 2005).

Select Tibia and/or talus from the Bone drop-down menu. For the tibia, select Ventral/Anterior for the aspect and Distal epiphysis/articular surface for the section on the Pathology Module Main Screen. For the talus, the aspect is Superior surface. In both cases, squatting facet can then be selected from the Size/Shape/Bone-Specific Abnormality data entry screen. Measure and record the description of the squatting facets and discuss the presence or absence of matching facets on the opposing element. Squatting facets or articular extensions on bones other than the tibia and talus can be recorded using the Other Pathology, NOT in the System check box on the Pathology Module Home Screen.

Figure 2.25 Squatting facets. a) anterior aspect of the distal tibia; b) articulating facet on the superior aspect of the talus (photos by J. Beck).
Chapter 3: Abnormal Bone Loss
by Dawn M. Mulhern

Abnormal bone loss can result from increased osteoclastic activity and/or decreased osteoblastic activity. Such activity can produce focal lesions (osteolysis) or diffuse bone loss (osteopenia, osteoporosis). Focal bone loss accompanied by reactive bone is indicative of a slower process, whereas focal bone loss with no reactive bone is indicative of a more rapid process (Ortner, 2003). Abnormal bone loss can be associated with many different pathological processes including: trauma, infection, tumors, endocrine disorders, hematopoietic diseases, and metabolic disorders. Identifying the type and pattern of bone loss within the skeleton is important for narrowing down the range of possible causative factors. Note that a discussion of the porosity associated with some hematopoietic and metabolic disorders (e.g., anemia, scurvy) is outside the scope of this chapter because it is scored separately. Absence of bone where the bone never formed, e.g., an epidermal inclusion cyst, is rare but does occur. These cases should be scored using the Other Pathology, NOT in System check box on the Pathology Module Main Screen (Chapt 1, pp. 6).

Osteoware Bone Loss data entry has added a few descriptions to the Standards protocol:

- Lytic lesions at muscle/ligament attachment sites are scored in a separate category under the Enthesal Defects heading.
- Selections for moth-eaten and permeated destruction have been added to the Bony Response to Local Bone Loss heading.

Data Entry

Abnormal bone loss data entry does not include vault changes attributed to porotic hyperostosis or the articular changes of arthritis, which follows the protocol established in the Standards. Documenting external porosity elsewhere on the skeleton can be problematic because it is not always clear if the porosity results from osteoclast activity or if it is a feature of abnormal bone formation. Therefore, Osteoware has expanded the porotic hyperostosis module to include data entry for porosity at skeletal locations other than the vault and orbits (Chapter 6).

Figure 3.1 Bone Loss data entry screen.

1Photographs by J. Beck and radiographs by S. Pelot unless otherwise indicated.
Abnormal Bone Loss: Location

Abnormal bone loss can be scored at one or more of the following surfaces: 1) periosteal, subchondral surface, or external table; 2) cortex, trabeculae or diploë; 3) endosteal surface or inner table, or; 4) at muscle/ligament attachments (entheses). The fourth category is intended for lytic enthesal defects and is not found in the Standards. More than one location can be chosen for a single entry.

Extent of Involvement

The extent of involvement is scored as less than 1/3, 1/3 to 2/3, or more than 2/3 of the area. Note that the extent of involvement is relative to the aspect and section first selected on the Pathology Module Main Screen. For example, if the medial aspect of the middle 1/3 of the diaphysis was selected, the extent refers to that portion of the bone involved and not the entire bone.

Number of Foci

Abnormal bone loss is either focal or diffuse. Lesions resulting from focal bone loss may be visible on the external surface but may require radiographic analysis if contained within the bone. An isolated lesion is unifocal. This includes cases of single, coalescing lesions comprised of several destructive foci. Multifocal lesions are scored as: 2, 3-5, 6-10, or more than 10 in number.

Size of Focal Bone Loss

The size of the lesions is scored as <1 cm, 1-5 cm, or > 5 cm. Rather than recording various combinations of mixed sizes as in the Standards, in Osteoware the largest lesion size is selected using the radio button with any smaller sizes indicated in the description.

Figure 3.2  a) Multifocal lesions on the cranium with circumscription and sclerotic reaction. b) Close-up of the large lesion on the right side of the occipital.
Bony response to local bone loss refers to the marginal definition of a lytic lesion. Lesions may exhibit localized destruction with well-defined borders that may or may not show sclerosis. Ideally, these two conditions should be distinguished through radiographic analysis. The descriptions of these phases follow Ragsdale (1993).

**Localized Destruction, Circumscription, Sclerotic Reaction:** Figures 3.2 and 3.3 illustrate radiographs and photographs of localized destruction, circumscription, and sclerotic reaction. Bone loss with marginal sclerosis generally indicates a slower process.

**Localized Destruction, Boundaries Well-Defined But No Sclerosis:** Lesions with localized destruction and well-defined margins but no sclerosis appear “punched-out” as illustrated in Figure 3.4.

*Figure 3.3* Radiographs of individual from Figure 3.2. a) sclerotic margins of multifocal cranial lesions; b) sclerotic margins of the multifocal lesions are seen even more clearly in the sternum. Only the largest lesion on the left side of the sternal body was visible externally.

*Figure 3.4* Photo (a) and radiograph (b) of inferior surface of T8 showing localized destruction with well-defined margins but no sclerosis.
LOCALIZED DESTRUCTION, MARGINS NOT SHARPLY DEFINED: Examples of lesions with poorly defined margins are illustrated in Figure 3.5. Lesions with poorly defined margins result from an infiltrative process and are generally attributed to pathological conditions with greater biologic activity such as osteomyelitis or osteosarcoma (Ragsdale, 1993).

MOTHEATEN AND PERMEATED DESTRUCTION: Ragsdale (1993) also describes two specific patterns of bone loss: “moth-eaten” and “permeated destruction.” Multifocal sites of bone loss in cortical or cancellous bone may progress from localized destruction with well-defined boundaries and no sclerosis into a moth-eaten pattern (Figure 3.6). In cortical bone, destruction on the endosteal surface initially appears as scalloped marrow cavity borders on radiographs but the process may extend to complete perforation of the cortex (Figure 3.7). Examples of lesions with a moth-eaten appearance include: metastatic carcinoma, osteomyelitis (particularly the granulomatous type), and rapidly progressing osteopenia. Although lesions are scored based on their number and the characteristics of their borders, it may be useful in some instances to use “moth-eaten” as an additional descriptive term. Illustrations of these variants (adapted from Ragsdale) are provided in the Standards, although they are not included in their scoring for abnormal bone loss.

Permeated destruction results from osteoclastic tunneling that increases Haversian canal size, thereby increasing blood flow (Ragsdale, 1993). On radiographs, it appears as numerous, small, lucent streaks in cortical bone that become oval lucencies over time. Permeated destruction can be caused by a variety of neoplasms (e.g., primary round cell sarcomas and

Figure 3.5 Radiographs of the distal right femur show localized destruction without sharply defined margins. a) anterioposterior (A-P); b) mediolateral (M-L).

Figure 3.6 Tibia with moth-eaten bone loss, showing cortical scalloping and cancellous lesions.
lymphomas) as well as hyperparathyroidism, infection, and mechanical problems. Cancellous trabeculae can exhibit a similar type of hollowing as a result of primary hyperparathyroidism. While moth-eaten destruction has been observed and recorded in the Smithsonian database, permeated destruction has not and may be very rare in archaeological bone or may simply be too difficult to recognize.

**Diffuse Bone Loss**

Diffuse bone loss indicative of osteopenia should be identified through radiographic analysis. Osteoware uses the term osteopenia, rather than osteoporosis, because it applies to general losses in bone tissue quantity with or without changes in quality and without specifying the mechanism of loss (Ortner, 2003). Radiographs are required to determine if a decrease in bone mass is accompanied by cortical thinning as shown for the right upper limb in Figure 3.8.

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Figure 3.7 Left scapula with multifocal, moth eaten destruction, including perforation of the cortex. Known case of metastatic carcinoma from the Terry Collection, NMNH.

Figure 3.8 Long bones of the upper limb illustrating diffuse bone loss (osteopenia) with cortical thinning on the right side.
Structural Collapse

Structural collapse may result from focal or diffuse bone loss. An example is shown in Figure 3.9.

Entheseal Defects

Entheseal defects may be found at sites of a muscle or ligament attachment (Figure 3.10). If these defects result from osteoclastic activity, the location is scored “at muscle or ligament attachment site” and recorded under the Enthesal Defects heading as “lytic lesions.” Lesions should be measured and characterized in the description field. In future versions of Osteoware, we hope to provide a separate data entry page to record enthesal changes in more detail.

Figure 3.9 Structural collapse of the lower spine resulting from tuberculosis (photo courtesy of D.J. Ortner, Smithsonian Institution).

Figure 3.10 Clavicles exhibiting bilateral lytic lesions at the costoclavicular (rhomboid) ligament enthesis.
Abnormal bone formation results from pathological processes that stimulate osteoblastic activity. It includes external bone formation, or periostitis, as well as bone formation on the endosteal surface, improper osteoid formation, and disorders in mineralization (Ortner, 2003). A vast range of disease processes can result in abnormal bone formation including infections, trauma, neoplasms, and endocrine disorders, so complete descriptions by anatomical location, distribution, and morphology of the proliferative bone is essential to differential diagnosis. However, even with careful observation and description, determining the specific etiology may not be possible. Disorders that are characterized by bone loss and bone formation should be scored in both modules.

In Osteoware, recording of abnormal bone formation has undergone a few important changes from the Standards (Figure 4.1):

- A compact/remodeled selection has been added to the Periosteal Surface heading.
- Selections have been added under a new Surface Appearance heading to describe external cortical texture.
- “Other” has been added as a selection under ossified tissue.

Data Entry

Two general categories of abnormal bone formation can be scored: surface bone formation (periosteal or endosteal) or abnormal matrix formation. If significant bone loss and formation co-occur, both should be scored. The Abnormal Bone Type and Surface Appearance headings refer specifically to periosteal surface reactions. They are left blank when scoring bone formation on the Endosteal Surface or Abnormal Matrix formation.

The presence of porosity only, without obvious additions of new bone, should be entered into the Porosity and Vascular Channels

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Chapter 4: Abnormal Bone Formation
by Cynthia A. Wilczak and Erica B. Jones

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1 Photographs by C. Wilczak unless otherwise indicated
data entry screen (Chapter 6). However, when porosity is merely a feature of proliferative bone, it should only be scored as Abnormal Bone Formation.

**Extent of Involvement**

The extent of involvement should be indicated for all types of bone formation. Note that it is relative to the Aspect and Section first selected on the Pathology Module Main Screen. For example, if the medial aspect of the middle 1/3 of the diaphysis was selected, the extent refers to that portion of the bone involved and not the entire bone.

**Periosteal Surface**

The Periosteal Surface heading is used to describe the general category of externally visible abnormal bone. Classification of abnormal bone as either woven or sclerotic as specified in the Standards is not always possible, so the compact/remodeled category was added. Multiple categories can be selected.

**WOVEN BONE:** Poorly organized bone with a porous or trabeculated appearance that is appositionally deposited on the periosteal surface is scored as woven bone (Figure 4.2). It may be only loosely adhered to the underlying cortical bone, particularly in children. Woven bone indicates the lesion was active at the time of death.

**COMPACT / REMODELED:** Abnormal bone that does not have the less organized porous or trabeculated appearance of woven bone is scored as compact/remodeled (Figure 4.3). It should be selected along with woven bone if the edges have begun to integrate with the surrounding normal surface, which is indicative of healing (Figure 4.4).
SCLEROTIC REACTION: Bone sclerosis is increased mineralization of the bone matrix, resulting in greater than normal bone density. Ideally, it is diagnosed radiographically, but sclerosis may be scored when there is an extremely dense, ivory-like texture, similar to that seen in many button osteomas/hamartomas (Figure 4.5).

Ortner (2003, personal communication) uses the term bone sclerosis in a more restrictive sense to describe the dense bone associated with reparative processes at the margins of a destructive lesion or the subchondral sclerosis associated with osteoarthritis. In this usage, sclerosis is an inappropriate descriptor of periostotic bone. The term sclerosis has been retained from the Standards, but it is recommended that it be used sparingly as most periostotic “sclerotic” bone is more properly classified as compact.

Productive Reaction Type
Following the Standards, productive reaction types are adapted from a subset of those described by Ragsdale (1993) and Ragsdale et al. (1981). Distinguishing among the types often requires radiographs. If radiographs are not available or insufficient and the reaction type cannot be distinguished based on the external morphology, this section should be left blank. The lesion will then only be recorded as abnormal bone of the Periosteal Surface (woven, compact/remodeled, sclerotic) and descriptors of Surface Appearance can be selected.

Most abnormal bone formation can be described as either solid or lamellated. Shell formations may be encountered, but much less frequently. Cauliflower, parallel-spiculated, and sunburst patterns are associated with tumor formation and are rarely observed in an archaeological context.
SOLID AND LAMELLATED: Solid and lamellated (single or multiple lamellae) reactions occur when bone is added to the surface of the original cortex. Radiographs are normally needed to distinguish between these selections in intact bone, but lamellae may be visible in a cross section (Figure 4.6).

SHELL-TYPE REACTIONS: The outer surface can be a smooth, lobulated, or ridged shell (Figure 4.7). They are enlargements of the bone contour, resulting from destruction of the original cortex and replacement by the new shell formation (Ragsdale et al., 1981). This contrasts with contour changes resulting from appositional bone deposits on the intact original cortex, which are classified as either solid or lamellated.

Shell formation occurs over rapidly enlarging solid or cystic masses and differential diagnoses include various tumors and cysts. Proliferation in chronic osteomyelitis begins primarily as a solid or lamellated reaction and the new bone “shell” (involucrum) forming around necrotic bone should be scored by choosing the appropriate check boxes under the specific structures heading and not scored as a shell-type reaction.

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Figure 4.6 Lamellated periosteal bone formation is clearly visible in this femoral cross section (photo courtesy of D.J. Ortner, Smithsonian Institution).

Figure 4.7 Shell-type reaction of the left proximal femur (photos courtesy of D.J. Ortner, Smithsonian Institution).
PARALLEL/SPICULATED AND SUNBURST REACTIONS: Parallel, spiculated reactions have a “hair-on-end” appearance and are normally associated with osteosarcoma and other types of rapidly-growing tumors. When the spicules are distinct and divergent, this pattern is described as a sunburst (Figure 4.8).

CAULIFLOWER:
The cauliflower-type proliferative reaction is not a category included in the Ragsdale classification, but it was part of the Standards. In this usage, the term is restricted to a subset of parallel/spiculated reactions arising from slower growth than the sunburst form, resulting in a coarsely textured, multilobate surface (Figure 4.9). It should not be used to describe shell-type reactions with a superficially lobulated appearance.

Surface Appearance
The Surface Appearance (periosteal) heading contains selections that describe the gross features of abnormal bone. Only categories that apply to at least 10% of the total surface area of the proliferative bone should be selected. If less than 10% of the bone presents a particular feature, it can be noted in the description. For example: "Very slight porosity is present at the margins of the lesion." If more than two of the categories (excluding vascular impressions) can describe the surface appearance, it should be classified as “other/irregular”.

Figure 4.8 Sunburst pattern in osteosarcoma of the mandible (photo courtesy of the National Museum of Health and Medicine).

Figure 4.9 Cauliflower type bone formation (photo courtesy of D.J. Ortner, Smithsonian Institution).
POROUS: Periosteal surface porosity is only scored under abnormal bone formation when there is evidence of bone apposition or remodeling affecting the normal bone contour (Figure 4.10). “Pure” porosity without excess bone formation should be scored under the Porosity and Vascular Channels data entry screen. This does not necessarily mean that the pores formed in the absence of a proliferative reaction because very thin appositional layers of porous bone may not be visible grossly. However, often this distinction cannot be made without sectioning and microscopic examination, which is not practical in many analyses for a variety of reasons.

STRIATED: Striated bone is the thin, ridged bone that is often seen on the tibia, although it does occur quite frequently on other long bones (Figure 4.11). It is associated with the healing phases of periostitis. Porosity often accompanies striated bone when the ridges are still well defined. In later healing phases, the ridges become less sharply defined, but any visible striations should be scored as abnormal bone formation.

UNDULATING SURFACE: Undulating describes the wavy appearance of the bone surface that may be the only evidence of bone remodeling in the later stages of healing.
**VASCULAR IMPRESSIONS:** Vascular impressions are only scored as a secondary feature to a primary surface description such as striated, smooth, or porous bone (Figure 4.13). The impressions should be carefully examined, preferably under magnification, to differentiate them from taphonomic artifacts such as root damage.

**PITTED:** It is not unusual to see porosity and pitting used synonymously in the paleopathological literature. According to Stedman’s Medical Dictionary, 24th ed.: “a pore is a hole, perforation or foramen” and a pit is “a natural depression; dimple; pockmark or indent.” To be scored in Osteoware, a pore must be narrow and deep, while a pit would be wider than it is deep, i.e., an indentation. Osteolytic pits associated with substantial reactive bone should be scored under both Bone Loss and Formation. However, in advanced reparative phases, without active lytic reactions (Figure 4.14), the lesion should only be scored as abnormal bone formation.

**SMOOTH:** Smooth-surfaced bone is normally solid and clearly defined as is seen in plaque-like formations (Figure 4.15). The lesion may be of any shape, but it does not show significant pitting, porosity, or other surface irregularities.

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*Figure 4.13* Vascular impressions of the tibial shaft on remodeled, compact bone. Porosity and slight striations are also present.

*Figure 4.14* Severe pitting of the ischial tuberosity.

*Figure 4.15* Smooth, abnormal bone formation within the maxillary sinus. The central, elongated structures and the peripheral deposits would also be scored as nodular (photo by J.C. Dudar).
NODULAR BONE: Like smooth bone, nodular bone is generally solid. It consists of distinct structures that range in appearance from rounded spheres to more flattened or elongated deposits. It may describe the primary appearance of abnormal bone, or it may be present as peripheral reactive bone secondary to the main lesion (Figure 4.16).

OTHER/IRREGULAR: The selections under Surface Appearance are designed to cover the most common variants of abnormal bone. However, some will have an overall appearance that does not easily fit into any one or two of the above categories. They should be scored as other/irregular and recorded in more detail in the description field.
Endosteal Surface

In intact bone, deposition on the endosteal surface can only be observed on radiographs or CT scans. With shaft breakage, endosteal narrowing may be scored, but determining the extent, severity, and presence of lamellae would still require radiographs. Even with radiographs, care must be exercised in interpreting narrowing with no visible lamellae. Overexposure and the angle of bone to the plane of the film may obscure lamellae that are present. As the wording implies, medullary cavity narrowing with no visible lamellae does not mean lamellae are absent, just that they are not visible.

Abnormal Matrix

Abnormal matrix formation is associated with various metabolic or endocrine disturbances such as rickets, Paget’s disease, osteoporosis, and generalized hyperostosis (Ortner, 2003), but it may also be seen in some infectious processes such as treponemal disease. It can be observed radiographically or in a bone cross section. As emphasized in the Standards, abnormalities in the formation of the matrix should be distinguished from cases were appositional bone is added to the normal, underlying cortex.

DEPOSITION OF WOVEN BONE: This selection is made when normal cortex or trabecular bone is replaced by poorly organized, woven bone (Figure 4.19).
EXTENSIONS OF CANCELLOUS BONE: Cancellous bone extensions into the cortex are difficult to clearly define, but an example is shown in Figure 4.20. When cortical bone is not completely replaced, recognition depends on the relative thickness of the remaining cortex and the dense cancellous bone on the endosteal border.

TRABECULAR COARSENING: Coarsened trabeculae are often associated with osteoporosis, but thickening may also occur with inflammation and infection. It may be systemic or localized. Although the example in the illustration shows externally visible trabeculae (Figure 4.21), radiographs would be necessary to completely describe this condition.

Ossified Tissue

Ossification of soft tissue is primarily distinguished by the location of the ossified tissue within a muscle (Figure 4.22), ligament (Figure 4.23), or cartilage (Figure 4.24). Detached ossified masses may be cartilaginous, as in the ossification of the cricoid cartilage, but nearly any tissue can ossify. Soft tissue ossifications not included in the selections can be scored as “other” and can include ossified lymph tissue (Figure 4.25) or calcifications of the extraosseous hydatid cysts of echinococcosis.

Notes on Enthesophytes: Exostoses at the entheses (muscle attachments) can be crudely scored within the Osteoware system. In general, the authors of this volume have only recorded larger enthesophytes (> 2 mm). This may be useful in diagnoses of certain disorders, such as DISH, but has limited value in more sophisticated analyses of enthesial morphology. In future versions of Osteoware, we hope to provide a separate data entry page to record enthesal changes in more detail.
Figure 4.23 Ossification of the transverse acetabular ligament (photo by J. Beck).

Figure 4.24 Ossification of the 1st costal cartilage.

Figure 4.25 Other: Irregular ossified lymph node tissue, probable tuberculosis (scrofula).
Specific structures

Specific structures of abnormal bone are well-known to the osteologist and can be referenced in many paleopathology or osteology texts.

**BUTTON OSTEOMA / HAMARTOMA:**

In the case of button osteoma (Figure 4.26), further classification is not necessary for Bone Type or Surface Appearance, unless the form is atypical or other abnormal bone formation is associated with the lesion. However, the size and location should be recorded in the description field.

**STELLATE SCARS:** Because of the cyclical nature of stellate scarring/caries sicca, the lesions may be characterized as either primarily bone loss or primarily bone formation (Figure 4.27). However, to ensure that searches of the database recover all cases of probable treponemal infection, all stellate-type lesions should be scored under Abnormal Bone Formation, regardless of whether bone loss is scored or not.

**SEQUESTRUM, INVOLUCRUM, AND CLOACA** refer respectively to necrotic bone; the new bone surrounding the necrotic bone; and the openings of the involucrum where drainage occurs and the necrotic bone is extruded (Figure 4.28).
Chapter 5: Trauma
by Claire O’Brien and J. Christopher Dudar

Trauma is one of the most frequently encountered pathological conditions in archaeologically recovered human remains. It is the role of the anthropologist to document traumatic injuries that are present on the bone, estimate when they occurred, and consider the mechanisms involved in their creation (Galloway et al., 1999: 5).

Trauma can affect the skeleton in four ways: 1) partial or complete break in bone; 2) abnormal displacement or dislocation of joints; 3) disruption in nerve and/or blood supply affecting healing and/or normal development; and 4) an artificially induced abnormal shape or contour of the bone (Ortner, 2003: 119-129). Evidence of trauma incurred during subadult years may be obliterated as an individual ages, or other pathological processes may obscure the evidence of trauma. Therefore, it is likely that trauma prevalence will be underestimated in skeletal samples.

The Osteoware Trauma data entry screen has added a few selections to the Standards protocol (described as Fractures and Dislocations):

- A selection of “other” has been added to the Fracture Type heading.
- Selections for deformation and traumatic enthesopathy have been added to the Trauma Complications heading.

Data Entry
Fractures are first classified by Fracture Type and secondarily by Fracture Characteristics in the Osteoware Trauma menu (Figure 5.1). Fractures involving the vertebral body or classified as spondylolysis should be recorded on the Vertebrae pathology data entry screen; however, all other vertebral fractures are recorded in the Trauma section. Postmortem breakage is documented in the Taphonomy Module.

Fracture Type
The Fracture Type list prompts the user to classify fractures by the

Figure 5.1 Trauma data entry screen.
pattern resulting from different biomechanical forces involved in the injury (Figure 5.2). A comprehensive discussion of these fracture types by anatomical region or specific skeletal elements can be found in Galloway (1999). Note that it is not possible to choose and enter data on more than one fracture type at a time. If there is more than one fracture on a bone, e.g., both a simple and a compression fracture, record the traumas as two separate entries.

PARTIAL (GREENSTICK/BOWED): Incomplete bending fractures (or infractions) occur in children due to the higher elastic potential of their bones. As seen in Figure 5.3, fracture lines can be obliterated during growth so that deformation is the only remaining sign of an earlier trauma.

SIMPLE (TRANSVERSE/OBLIQUE): Transverse fractures run at approximately right angles to the long axis of the bone. Oblique fractures run diagonal to the long axis of the bone, usually at 45 degrees (Figure 5.4).

Figure 5.3 This probable greenstick fracture has been obliterated, leaving no observable fracture line or callus, but the shaft is significantly deformed compared to its antimere (radiograph by J. Hinton; photo by J. Beck).

Figure 5.4 Simple fracture of the femur with advanced healing and deformation due to poor alignment. Note the callus bridging the fractured ends in the cross section (photo by J.C. Dudar).
COMMINUTED/BUTTERFLY: In a comminuted fracture, more than two fragments are generated (Figure 5.5). Specific types of comminuted fractures include butterfly and segmental fractures (Figure 5.8).

SPIRAL: A spiral fracture is scored when the fracture line curls around the longitudinal aspect of the bone.

COMPRESSION: In a compression fracture, bone is forcefully pressed against another bone or object causing an inward crushing with partial or complete fracture lines (Figure 5.6).

DEPRESSED SKULL FRACTURE: Depressed skull fractures are the result of an impact, usually from a blunt object, that causes inward displacement of bone (Ralston, 1967:43; Galloway, 1999:51). If the displacement is limited to the ectocranial surface, select Depressed skull fracture, outer table only. Superficial cranial...
depressions can be caused by factors other than trauma, such as a cyst of the scalp (Don Ortner, personal communication); therefore, radiating fractures or other indicators of trauma are needed to confirm that the depression is of traumatic origin when only the inner table is involved. When the displacement involves both the inner and outer tables of the vault, select *Depressed skull fracture, outer and inner table*. In the case of multiple fractures (Figure 5.7), the relative timing of the impacts can often be determined because the fracture lines produced by later impacts will be arrested at the point of intersection with the fracture lines from earlier impacts (Madea and Staak, 1988: 321).

**OTHER:** If none of the fracture types accurately describe the trauma, e.g., a Salter-Harris or stress fracture, select *Other*. Fractures caused by sharp force trauma and high velocity projectiles should also be recorded as *Other* for Fracture Type, and the appropriate Trauma Characteristics can be selected.

### Trauma Characteristics

The Trauma Characteristics menu includes specific observations regarding the qualitative appearance of the traumatic condition and may indicate what sort of implement or force was involved in its creation. Check boxes are provided so all characteristics that apply can be selected.

**BLUNT ROUND and BLUNT OVAL:** The general shape of blunt force trauma fractures can give some clues to the implement used and/or the angle of impact. The two most common shapes, round or oval (Figure 5.7), can be selected from the Trauma Characteristics menu. Other shapes should be detailed in the description.

Figure 5.7 Two depressed fractures on the frontal bone with radiating linear fractures originating from the points of impact. Note that the superior impact occurred first, as the circular fracture line is uninterrupted (photo by J.C. Dudar).

Figure 5.8 Segmental fracture of the left tibia. The tibia is fractured in three locations, twice in the proximal third and once at the distal end of the diaphysis. The left fibula exhibits a simple fracture on the proximal third of the diaphysis (photo by J. Beck).
EDGED/SHARP FORCE TRAUMA: Bone fractures resulting from edged weapons display a straight incised fracture that is often V-shaped in cross section (Stewart 1979; Figure 5.9). Cutmarks on the skull (Figure 5.12) are the most convincing evidence of perimortem trauma associated with scalping and are documented as sharp force trauma (Ortner 2003: 167). Cut marks likely produced as a result of postmortem dismemberment should be recorded in the Taphonomy Module, and not in Trauma. Trephination, or surgical removal of a portion of the vault, is scored under trauma (Figure 5.13).

Figure 5.9 a) Sharp force trauma to the frontal bone; b) Note the linear fracture and beveled nature of the wound in cross section (photos by J.C. Dudar).

Figure 5.10 A deep line of demarcation, cut marks, and a sloughed off outer table indicate that this female survived a probable scalping for up to several months. Scalping should be recorded as “Edged/Sharp Force Trauma” (photo by J.C. Dudar).

Figure 5.11 This trephination used a sharp edged instrument and would be recorded in the Fracture Characteristic as Edged/Sharp Force Trauma. Note the incomplete trephination cut mark to the right (photo by J.C. Dudar).
PROJECTILE ENTRY: A projectile entry site is usually associated with inward beveling, in which the external defect is larger than the internal defect (Berryman and Haun, 1996; Figure 5.13). When documenting bullet wounds, radiodense bullet fragments (also known as bullet splatter or bullet wipe) may be observed on a radiograph (Figure 5.12). View multiple aspects of the x-rays (medial-lateral, anterior-posterior, superior-inferior) to confirm the presence of lead fragments and eliminate the possibility of radiodense artifacts such as those due to dust particles on the x-ray film. In the absence of observable bullet splatter, the use of an x-ray fluorescence detector (XRF) for elemental analysis may establish the trace presence of lead.

PROJECTILE EXIT: If the projectile has enough velocity to both enter and exit the bone, the projectile exit wound can demonstrate outward
beveling, in which the internal defect is smaller than the external defect (Berryman and Haun, 1996).

**PROJECTILE EMBEDDED**: A low velocity projectile may only partially perforates the skeletal element and remain embedded in the bone (Figures 5.13c).

**RADIATING / STELLATE**: A projectile entrance wound or blunt force trauma of sufficient force can produce fractures lines that radiate away from the point of impact (Berryman and Haun, 1996; Figures 5.7, 5.13a).

**OTHER (PATHOLOGICAL, ETC.):** If a Trauma Characteristic is observed that is not listed above, select ‘Other’, and provide detailed observations in the description. This includes pathological fractures resulting from trauma to a bone weakened by conditions such as osteopenia, osteomalacia, or certain neoplasms (Figure 5.14).

### Timing of Fractures
Analysis of skeletal trauma includes determining when the individual sustained the injury in relationship to time of death. This is divided into: 1) antemortem or before death; 2) perimortem or around the time of death; and 3) postmortem or after death. Antemortem and perimortem fractures are documented in the Trauma data entry screen in the Timing of Fractures menu.

**PERIMORTEM FRACTURES**: The distinction between perimortem fractures and postmortem breakage is based on the condition of the tissue when the fracture occurred. Bone in the living or recently deceased contains a degree of moisture plus collagen for flexibility. Fractures present in collagenated bone will have sharp margins and characteristics such as concentric circular and radiating fractures. Decomposition degrades the collagen in bone and may reduce moisture content. Postmortem fractures (or breakage) will reflect the drier, more brittle nature of the bone by having more jagged edges, fracture edges that are less stained and lighter in color than the surrounding bone, little to no beveling, and a lack of radiating fractures (Mann and Hunt, 2004: 235).

**Figure 5.14 Pathological fractures of the proximal right femur associated with severe osteomalacia a) posteriomedial and b) in cross section (photo courtesy of D.J. Ortner, Smithsonian Institution).**
If the fracture appears to have occurred at or near the time of death, they are scored as: 1) Clearly *perimortem* or 2) Ambiguous; possibly postmortem. If any evidence of healing is present, neither option should be selected, and the fracture should be documented as an antemortem fracture.

**Fracture Healing (Antemortem)**

Antemortem fractures are classified by the extent of healing that has occurred. Since the healing process begins immediately after injury, this is an indicator of how long the individual survived after the trauma was incurred. Radiographs of the affected bone should be considered whenever possible.

Clinical researchers recognize several distinct phases of fracture repair beginning with the initial hematoma, formation of granulation tissue, mineralization of the primary fibrous callus, transition to lamellar callus, and culminating in the obliteration of the fracture line (Ralston, 1967; McKibbin, 1978; Barbian and Sledzik, 2008). As the first two stages do not leave evidence on the bone, only the last three are recorded in Osteoware. The fracture margins should be viewed under magnification (10x minimum) and described in the comments.

The three stages of bone formation scored in Osteoware are:

- Callus formation, woven bone. The initial observable response to trauma is the presence of new bone formation (woven bone) and/or surfaces of the fracture eroded by osteoclasts (Barbian and Sledzik, 2008; Figures 5.6 and 5.15).
- Callus formation, remodeled bone (Figure 5.17).
- Healing, obliteration of fracture (Figures 5.4, 5.16, and 5.19).
Trauma Complications
More than one box can be checked if multiple conditions apply under the Trauma Complications menu. Note that several of the conditions (infections, arthritis, enthesopathy) can also be scored on other data entry screens. They should only be scored under Trauma when they are unambiguously related to a bone fracture or dislocation.

NON-UNION: Failure of a fracture to regain bone continuity is scored as non-union and includes the formation of a pseudarthrosis (Figure 5.17).

TISSUE NECROSIS: Necrosis is tissue death, which can lead to the formation of sequestrum and/or involucrum.

INFECTION: The most common evidence of infection secondary to trauma are the formation of cloaca and reactive bone deposits beyond the fracture callus.

TRAUMATIC ARTHRITIS: Premature degeneration of a joint can result when trauma disrupts the cartilage and subchondral bone (Figure 5.21).

JOINT FUSION: Fusion is associated with fractures of a joint where the callus formation results in ankylosis of two or more bones (Figure 5.18).

TRAUMATIC MYOSITIS OSSIFICANS: Traumatic injury to the bone can be accompanied by myositis ossificans (Figure 5.19), where bone ossifies directly in the muscle, often in association with the hematoma (Ortner 2003: 134).
DEFORMATION: Bone that is misshapen or angulated due to trauma is scored as deformation (Figure 6.18, 6.20).

TRAUMATIC ENTHESOPATHY: Inflammation and ossification at the origin or insertion of ligaments and tendons into bone (entheses) can occur in association with trauma. Traumatic enthesopathies are often a response to changes in muscle orientation when there is severe deformation due to fracture or dislocations.

Dislocations
Dislocation involves the displacement or misalignment of the articular surfaces of a joint. It is most often caused by trauma; however, certain congenital conditions can make an individual predisposed to dislocation. In archaeological specimens, dislocation can only be considered present when there is significant remodeling of
the articular surfaces. For this reason, temporary dislocations or chronic subluxations can not be definitively diagnosed in skeletal remains. Dislocation can occur at most joints, but the hip and shoulder are most vulnerable (Ortner 2001: 59).

If evidence of dislocation is present, select Traumatic, Congenital, or Ambiguous from the Dislocation Menu. Traumatic dislocations may be characterized by the formation of a new joint surface and/or joint degeneration. Congenital dislocations may exhibit anomalies such as the shallow acetabulum and flattened femoral head seen in congenital hip dysplasia.
Chapter 6: Porosity and Channel Formation

by Cynthia Wilczak

In the *Standards*, porosity was scored on the cranial vault and orbits (cribra orbitalia) under the category of porotic hyperostosis based on the assumption that most cranial porosity resulted from the hyperplastic response of blood-forming cells to iron-deficiency anemia. Our understanding of porous orbital and ectocranial lesions has since changed in fundamental ways. Not only has the etiology of porotic hyperostosis been questioned (Walker et al., 2009), but it has become more widely recognized that cranial or orbital porosity can result from processes other than marrow hypertrophy such as generalized inflammation, traumatic subperiosteal hematomas, osteoporosis, rickets, and scurvy (Ortner and Mays, 1998; Ortner et al., 1999; Wapler et al., 2004; Wilczak and Jeney, 2008; Wilczak and Hopkins, 2010). In the case of rickets or scurvy, porosity is frequently seen at locations other than the cranium, and the Ostoeware database allows more flexibility in scoring porosity throughout the skeleton. It is important to distinguish between porosity of the cortical bone and the porosity of poorly organized woven bone, which is scored as abnormal bone formation.

The changes in this module from the *Standards* protocol are (Figure 6.1):

- Scoring for channel formations has been added to record serpentine impressions or deeper channel structures on the orbits, endocranium, or other cranial locations.
- Diploic hyperostosis is scored separately to enable description of porosity without evidence of marrow proliferation.
- Porosity can be scored on any bone.
- Degree of porosity is scored by specific pore size.
- Estimates of pore density per cm² have been added.
- “Other features” that often co-occur with ectocranial porosity have been added, such as pitting and striations.

It should also be noted that the terms pitting and porosity, which have often been used interchangeably in the literature, are used in a very specific way in the database.

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1 All photographs by the author unless otherwise noted.
Following the definitions in Stedman’s Medical Dictionary, 24th ed.: 1) a pit is a “depression, dimple, pockmark or indentation; and 2) a pore is a “hole, perforation or foramen.”

**Data Entry**

Any bone can be selected from the drop-down menu in the Porosis and Channel Formation data entry screen, enabling scoring of non-cranial locations such as the scapula (Figure 6.2). This data entry screen should only be used when there is no clear indication of appositional bone formation. When porosity is clearly related to the deposition of woven bone layers on the cortical surface, the lesions should be scored as abnormal bone formation.

**Degree of Porosity: Pore Size and Density**

**PORE SIZE:** Three different size categories can be scored: pinpoint; between pinpoint and 0.5 mm; and > 0.5 mm (Figure 6.3). Pinpoint porosity is usually just visible without magnification, whereas clear visibility of individual pores becomes much easier in the pinpoint to 0.5 mm range. Multiple pore size categories can be selected, but each should only be used when at least 10% of the pores fall within a given size range. Coalesced porosity is utilized when pores have obviously merged or overlap in their contours (Figure 6.3d). Only one obliteration of the walls between pores is necessary for “coalesced” to be chosen.

**Figure 6.2** Example of porous bone at a non-cranial location.

**Figure 6.3** a) Infant sphenoid with pinpoint porosity and clearly visible porosity; b) Cranial vault porosity, most falls within the pinpoint to 0.5 mm range, although pinpoint porosity is also present; c) Porosity of the left orbit of pinpoint to 0.5 mm and >0.5 mm; d) Porosity along the lambdoid suture shows pores that have coalesced (arrows).

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*Volume II: Paleopathology*
PORE DENSITY: An estimate of pore density is made based on the approximate numbers of pores per square cm. Only one category is selected based on the highest density of porosity in the affected area. If coalescence is present, the maximum density should always be selected. Care should be exercised in counting pores since very small pores may be visible under low magnification that are a normal feature of non-articular bone. Figure 6.4 shows a close-up of porous bone that illustrates the normal background porosity versus pores counted as abnormal.

Active versus Healing Porosity

The categories of active and healing porosity have been retained from the Standards, although Jacobi and Danforth (2002) have suggested that there is high interobserver in scoring the degree of healing. Mixed active and healing lesions are indicated by checking both categories. Most lesions will be mixed, although examples of pure active and pure healing lesions are shown in Figure 6.5.

Location of Ectocranial Porosity

Selections under this category are only made in cases of ectocranial porosity and should be skipped when scoring postcranial bone porosity. If only one bone in the cranium is affected (for example, the parietals), it can be specifically chosen from the drop-down bone menu on the Pathology Module Home Screen. More commonly, multiple bones are affected and Cranium can be selected. The orbits and the superior vault (parietals, superior frontal and occipital squama) have separate entries while “other” is used for any location outside these two areas. Examples of “other” locations include the greater wing of

Figure 6.4 Moderate pore density within a 1 cm square area of the vault. The “background” porosity consists of extremely small pores generally not visible without magnification. In this enlarged view, only the circled pinpoint pores are counted.

Figure 6.5 Porosity of the orbit a) shows an active lesion with sharp edged pores and no evidence of healing compared to b) where healing is advanced.
the sphenoid (Figure 6.3a) and the basicranium (Figure 6.6). When multiple locations are affected and *Cranium* is the selected bone, it is important to list the affected sites in the description field. This will facilitate searching for specific types of porosity cases in the database. For example, sphenoid porosity has been associated with vitamin C deficiencies (Ortner, 2003), and potential cases could be located through a search of “sphenoid” within the cranial porosity descriptions.

**Diploic Hyperostosis**

Diploic hyperostosis is scored as possible, definite, or absent. This category is only relevant for orbital or superior vault porosity and should be skipped in all other cases. Examples of possible and definite diploic hyperostosis are shown in Figure 6.7. This category is only used when there is evidence of marrow proliferation. When excess bone clearly originates through appositional additions to the ectocranial surface, the lesion should be scored under abnormal bone formation.

![Figure 6.6 Abnormal porosity. (a) Infant pars basilaris; (b) inferior sphenoid.](image)

![Figure 6.7 a) Definite diploic hypertrophy was scored for the occipital squama due to the clearly raised surface in association with enlarging and coalesced pores that suggest marrow hyperplasia. b) The right parietal was scored as possible diploic hypertrophy. Healing is advanced but there is some evidence of prior pore coalescence and pore enlargement. Although difficult to see in the photograph, the porous area was also slightly raised.](image)
Other Features
The Other Features menu was added to include observations frequently associated with cranial vault porosity (Figure 6.8), and they are only scored for the superior vault. As noted in the introduction to this section, pitting is used in a very specific sense to denote rounded, shallow depressions best described as indentations or dimples. Undulations or irregular thickening of the vault is scored separately, although it may result from extensive and repeated pit formation followed by cycles of healing.

Figure 6.8 Other features often associated with ectocranial porosity. a) large, shallow indentations or “pits”; b) Extensive irregularity (including pitting) and uneven thickening, resulting in an undulating surface. This is most clearly seen when looking down the posterior aspect; c) striations of the right and left parietal; d) rounded thickening along the sagittal suture.
Channel Formation

Channels are often vascular impressions, but they can include any elongate or serpentine lesion, even if the etiology is unclear. Only channels on the cranium are scored, and this includes the channels described as serpens endocranial symmetrca by Hershkovitz et al. (2002).

CHANNEL LOCATION: Channels are most commonly seen on the orbits and endocranial surface. Any other cranial location is marked as “other.”

CHANNEL APPEARANCE: Very fine and shallow channels are typical of increased vascularity. Deeper channels are most frequently seen on the endocranial surface, although severe hypervascularity may occasionally result in fairly deep channels at other locations such as the orbits (Figure 6.9). Deep channels are further subdivided into those that have sharp, nearly 90 degree angles at the margins with a flattened surface between the channels and those that have a more rounded pattern both at the edges and on the surfaces between channels (Figure 6.10). The two types of deep channels may differ in their etiologies or they may represent different stages of the healing process.

Figure 6.9 Channels scored on the superior orbital surface. a) fine, shallow channels along the posterior edge of coalesced porosity; b) deep channels with sharp edges and flattened interchannel surface.

Figure 6.10 The two types of deep channels. a) flattened interchannel surfaces; b) rounded interchannel surfaces.
Chapter 7: Pathological Condition of the Vertebrae
by Dawn M. Mulhern and Erica B. Jones

This module includes a wide range of observations related to vertebral pathology, including activity- and age-related structures, abnormalities associated with various diseases and congenital conditions, and specific types of vertebral fractures.

Minor changes have been made to the vertebral pathology section of the Standards protocol (Figure 7.1):

‣ Porosity associated with vertebral osteophytes is scored.
‣ The distinction between sacral clefting and spina bifida has been clarified.
‣ Characteristics of vertebral body fractures has been added.
‣ Abnormal shape of the spinal column is scored.

Vertebral Pathologies (Miscellaneous)

SCHMORL’S DEPRESSIONS result when intervertebral disc pressure (Figure 7.2) leads to herniation through the annulus fibrosus of the vertebral end plate (Ortner, 2003). The specific vertebra(e) and end plates affected, the morphology of the defects (depression only, remodeling/ nodules present, etc.), and the extent of the depressions (e.g., affecting the end plate and posterior annulus fibrosus) should be specified in the description.

Figure 7.2 Schmorl’s depression. a) no healing; b) with healing (photos by J.C. Dudar).
SPONDYLOLISTHESIS
The displacement of one vertebral body in relation to the one inferior to it is called spondylolisthesis (Figure 7.3). It most commonly occurs as a complication of spondylolysis (see Figure 7.9, pp. 64), but it can arise as a consequence of congenital neural arch defects, non-spondylolytic fractures (pathological and traumatic), or severe degenerative disease (Merbs, 1985). While the association with spondylolysis is so common that cases due to other factors have been called atypical or pseudospondylolisthesis, the two conditions do occur separately, thus they are scored separately in Osteoware. In dry bone, the presence of osteophytes and/or eburnation can indicate spondylolisthesis, but rearticulation of the affected vertebrae is necessary to confirm the displacement. The specific evidence for this condition should be discussed in the description, and when spondylolysis and spondylolisthesis co-occur, both conditions should be checked on the data entry screen.

Vertebral Osteophytes
Although the intervertebral joints are not synovial, degeneration of the intervertebral discs can result in arthritic-like changes, including marginal osteophyte formation and marginal or end-plate porosity (scored separately). As described in the Standards, osteophytes, which are typically age- or activity-related defects, are characterized by “shelflike” protrusions. In some cases, fusion may occur between vertebrae. The following degrees of expression can be recorded for vertebral osteophytes: barely discernible vertebral osteophytes, vertebral osteophytes with elevated rim, curved spicules, and osteophytes with fusion of spicules (Figure 7.4). Select all degrees of expression present. A detailed description should indicate which vertebrae are affected and the distribution of any variation in the degree of expression.
Porosities around Margins of Vertebral Osteophytes
Vertebral osteophytes may be associated with porosity. The location of the porosity is scored as porosity along the margins of the vertebral body and/or within the end plates (Figure 7.5).

Figure 7.4 Vertebral osteophytes. a) barely discernible; b) elevated rim; c) curved spicules; d) osteophytes with fused spicules and compression fracture of the vertebral bodies would both be scored (Photos by J.C. Dudar).

Figure 7.5 Porosity around Margins of Osteophytes. a) at the margins of the vertebral body; b) within the endplates (Photos by J.C. Dudar).
Syndesmophytes

Syndesmophytes result from ligamentous ossification (Figures 7.6 and 7.7). In the vertebral column, they are most commonly associated with spondyloarthopathies (a class of inflammatory diseases of the connective tissues and joints with axial involvement), such as ankylosing spondylitis (AS). They are also associated with diffuse idiopathic skeletal hyperostosis (DISH) where ossification occurs in the anterior longitudinal ligament. The primary syndesmophytes of AS and DISH differ in location; those in AS include the margins of the vertebral body endplates, whereas those found in DISH are non-marginal and restricted to the anteriolateral aspect of the vertebral bodies (Auferheide and Rodríguez-Martín, 1998; Wheeless, n.d.). The ligamentous ossification in DISH may also be accompanied by localized osteophytosis (Resnick et al., 1978).

It should be noted that the Standards uses the term “syndesmophytes” to describe the ossification of intervertebral discs in AS and the term “enthesophytes” to describe the ossification of the anterior or posterior longitudinal ligaments in DISH. However, in the orthopaedic medical literature, soft tissue ossifications associated with ligaments are called syndesmophytes, whereas enthesophytes describe ossifications associated with tendons. Therefore, the primary vertebral ossifications characterizing DISH and AS can both be classified as syndesmophytes (see Wheeless n.d.; Belanger and Rowe, 2001).

The maximum degree of expression should be recorded as: barely discernible syndesmophytes, syndesmophytes with elevated rim, extended spicules, or syndesmophytes with fusion of spicules.
Cleft Sacrum and Spina Bifida

Barnes (1994) notes that in most cases, cleft neural arches of the sacrum lack myelodysplasia (neural tube defect) and are likely due to a developmental defect within the paraxial mesoderm developmental field. In the clinical literature, many researchers stress the need to distinguish between common nonfusion of vertebral arches that does not involve abnormalities of the nervous system and "spina bifida occulta," a term that should be used only when significant clinical abnormalities are present (Laurence et al., 1968; Ozonoff, 1988; Schmidt and Freyschmidt, 1993; Modic et al., 1994; Soonawala et al., 1998; Renton, 2003; Kumar and Burton, 2008). Unfortunately, it is not always possible to distinguish between these conditions based on dry bone. Therefore, scoring in Osteoware is based on the conservative approach of scoring nonunion of the sacral arches as a partial or complete cleft (Figure 7.8 a, b). Comments should indicate the width and extent of the cleft. As suggested by Barnes (1994), if additional skeletal evidence for spina bifida is present such as an enlarged canal with edges of a bony cleft that are pushed outward (Mulhern et al., 2009), it can be scored as spina bifida (Figure 7.6 c, d) with a description indicating the nature of the evidence for this condition. Cleft neural arches for other vertebrae should be scored as ununited components on the Vertebral Anomalies data entry screen. Note that the sacral hiatus, which involves nonfusion of the fourth and fifth sacral neural arches, is considered normal and should not be scored.

Figure 7.8 Nonfusion of the sacral neural arch. Complete cleft (a and b). Spina bifida with an enlarged spinal canal (c and d). Note the edges of the cleft are pushed outward (Photos by C. Wilczak).
**Spondylolysis**

Separation of the posterior vertebra most commonly occurs at pars interarticularis (Figure 7.9) and sometimes at the pedicles. There are three options for scoring: 1) the fracture may be complete, with the elements still separated; 2) the fracture may exhibit some healing resulting in partial or complete reattachment; or 3) a partial fracture could be present, where the elements were never completely separated. Distinguishing between options “2” and “3” may not be possible in some cases, but displacement is suggestive of option 2. In the description, the location of the separation (e.g., at pars interarticularis) should be noted as well as whether the condition is unilateral or bilateral and whether any associated spondylolisthesis is present (scored with a separate check box).

![Figure 7.9 Spondylolysis with complete bilateral separation of neural arch at pars interarticularis seen in a) inferior view for the affected vertebra and a superior view of the vertebra below. Note the extensive porosity and resorption of the vertebral bodies and the marginal osteophytes. Rearticulated vertebrae in b) lateral and c) anterior view confirms the presence of spondylolisthesis (photos by J.C. Dudar).](image-url)
Vertebral Body Fractures

Several types of vertebral body fractures, including those resulting from trauma or osteopenia/osteoporosis are included in this section. Compression fractures resulting from trauma (nonpathological) should be radiographed to confirm the fracture and identify any healing (Figure 7.10). Single end-plate depressions may or may not involve wedging; these options provide further descriptions of the fractures. Biconcave bodies with or without wedging due to bone loss (osteopenia/osteoporosis) should be distinguished from congenitally wedged vertebrae through radiographic analysis (Figures 7.11 and 7.12). Congenitally wedged vertebrae are scored on the Vertebral Anomalies data entry screen (Chapter 8).

Figure 7.10  Non-pathological/traumatic compression fracture (photo by J.C. Dudar).

Figure 7.11  Single endplate fracture with wedging (photo by J.C. Dudar).

Figure 7.12  Biconcave vertebral bodies with no wedging (photo by J.C. Dudar).
Abnormal Shape of the Spinal Column

The shape of the spinal column may be affected by a number of conditions listed under Vertebral Pathology (i.e., compression fractures or osteoporosis) as well as other diseases and congenital conditions. The two major shape abnormalities are scoliosis, resulting from vertebrae with decreased lateral body height, and kyphosis, or anterior-posterior displacement resulting from vertebrae with decreased anterior body height (Figures 7.13 and 7.14). Scoliosis is scored according to the angle of the deformation—with the lateral extent toward the anatomical left or right. The type of scoliosis or kyphosis is also scored as either angular, in cases where only one or a few vertebrae have caused the deformation, or gradual, in cases where there is a decrease in body height affecting a number of vertebrae, as seen in osteoporosis.

Figure 7.13 Scoliosis of the vertebral column (photo by J. Beck).

Figure 7.14 Kyphosis. a) angulated due to tuberculosis (photo courtesy of D. Ortner, Smithsonian Institution); b) gradual due to DISH (photo by J. Beck).
Chapter 8: Vertebral Anomalies
by Cynthia A. Wilczak and Marilyn R. London

The Vertebral Anomalies data entry screen lists the most common variants of morphology (Figure 8.1). Most of the developmental defects are abnormalities in identity expressed as a partial or complete “shift” in the transition point between vertebral types, e.g., when T12 has characteristics of L1 (lumbarization). These boundaries are specified during development and segmentation of the somites, the fetal precursors of the vertebrae and associated tissues. The occipital/cervical boundary can also be involved because the first four somites give rise to portions of the occipital bone. Other defects include failures in the normal fusion of ossification centers or failures in segmentation of the somites. Great strides have been made in identifying the genes and signaling pathways involved in vertebral segmentation, specification of segment identity, and somatogenesis, but a full discussion is beyond the scope of this chapter. The reader is instead referred to several excellent reviews of vertebral development (Pilbeam, 2004; Alexander et al., 2009; Iimura and Pourquié, 2007).

The Standards pathology coding did not include most of the conditions scored on the vertebral anomalies data entry screen. Cranial and caudal shifts in vertebral borders were listed as a single entry in the supplemental list of postcranial, non-metric traits. While many are not pathological in the strict sense of causing disease or disability, they can be associated with more severe congenital conditions, such as Klippel-Feil syndrome, and even in isolation some may have clinical consequences (Barnes, 1994; Fernandes and Costa, 2007). Vertebral anomalies are relatively common and both genetic and environmental factors can contribute to their expression (Usher and Christensen, 2000). Placing them in the Pathology Module rather than including them as non-metric variants reflects their complex etiology and facilitates more detailed data collection. Development of the vertebral anomalies list was primarily based on Barnes’ 1994 publication, Developmental Defects of the Axial Skeleton.

![Figure 8.1 Vertebral Anomalies data entry screen.](image)
Data Entry
Vertebral anomalies are scored on a context-dependent data entry screen that is only available after an appropriate bone is selected from the drop-down menu. Individual vertebrae, a vertebral region, or the entire vertebral column can be selected. The latter is preferable when more than one region of the vertebral column is affected. All anomalies present can be selected using the check boxes, and a discussion of the vertebral column as a whole is then entered into the description field. If the vertebral column is incomplete, individual vertebrae or regions should be selected to avoid confusion on the availability of elements for scoring. While Barnes (1994) and others have suggested that precondylar tubercles and paracondylar tubercles/processes on the occipital are a manifestation of developmental shifting, in Osteoware they are scored on the Size/Shape/Bone-Specific Abnormality data entry screen under the occipital bone (see Figures 2.2 and 2.21) to maintain the overall organization of scoring congenital abnormalities by skeletal element(s).

Vertebral Border Shifting
Border shifting refers to those anomalies associated with a change in placement of the transition point between vertebral types. On the data entry screen, all border shifts are listed regionally. However, they are described here based on the conceptual framework of cranial versus caudal shifting to facilitate interpretation of the pattern presented by an individual skeleton. Border shifting is most frequently reported at the lumbar/sacral transition, although Anderson (1996) suggests this may be, at least in part, an artifact of more easily visible changes associated with this boundary. More subtle changes at other boundaries, such as the presence of costo-vertebral facets on C7 when the cervical ribs are not recovered, are more easily overlooked. If one part of the vertebral column is affected, the other elements should be carefully inspected because shifts at multiple transition points do occur (Anderson 1996). While these shifts are often in the same direction, cases of cranial and caudal shifting in one individual have been reported (Barnes, 1994; Anderson, 1996; London et al., 2005).
CRANIAL SHIFTS: In a cranial border shift, the transition from one vertebral type to another occurs one segment higher than normal. For example, if the transition from cervical to thoracic is shifted cranially, the C7 will resemble a T1 and a cervical rib may be present. Similarly, a T12 may have lumbar features, or L5 can become part of the sacrum. In the case of occipitalization of C1, the atlas becomes partially incorporated into the occipital. While supernumerary vertebra are rare, because they are most often lumbar and the lumbar/sacral border is also the most commonly reported site of shifting, an L6 sacralization is listed as a separate choice on the menu. Shifting can be incomplete, so a vertebra may have some normal and some anomalous features for its positional identity.

Examples of cranial shifts are shown in Figures 8.2-8.4, and the complete list of cranial shifts scored in Osteoware is given below:

- Occipitalization of C1
- Thoracization of C7 and Cervical Ribs
- Lumbarization of T12
- Sacralization of L5 or L6

CAUDAL SHIFTS: With a caudal border shift, the transition from one vertebral type to another occurs one segment lower than normal. For example, if the transition from thoracic to lumbar is shifted caudally, L1 will have features indicative of a thoracic vertebra such as ribs or flat superior articular facets. Similarly, T1 can display cervical features or S1 may partially or completely separate from the sacrum and display lumbar features.
Examples of caudal shifting are shown in Figures 8.5-8.6, and the complete list of caudal shifts in Osteoware is given below:

- Paracondylar process (C1 facet)
- Cervicalization of T1
- Thoracization of L1 and Lumbar Ribs
- Lumbarization of S1
- Sacralization of caudal vertebrae

Note that the paracondylar process is only scored for the first cervical vertebra when there is a clear articulating facet on the transverse process of C1. The process itself is scored as an occipital Bone-Specific abnormality (Chapter 2).

**SCORING CRANIAL VS. CAUDAL SHIFTING:** It can be difficult to score shifting as cranial or caudal if the vertebral column is incomplete. For example, if the number of vertebrae in each segment were not known, the transitional vertebrae in Figure 8.6 might represent a sacralization of L5. However, in this case, L1 to L5 were present. While this could also be interpreted as a supernumerary lumbar vertebra and L6 sacralization, border shifting is more common and preferentially scored (see discussion of supernumerary vertebrae). When the vertebral column is less complete, more ambiguity results. Cranial shifting is more common (Barnes, 1994; Anderson, 1996), but in ambiguous cases both the cranial and caudal shift should be selected. This will allow searching of the database for cases of cranial or caudal shifts at a particular border and for cases where both cranial and caudal shifts were selected (ambiguous). A justification for the scoring should be given in the description.
Vertebral Anomalies Not Related to Developmental Shifting

UNUNITED COMPONENTS: The category of "Ununited components" can be applied to clefts in the neural arch (Figure 8.7), incompletely fused or unfused parts of the bones (such as the neural arch to the centrum), or other rare non-union anomalies such as non-fusion of the odontoid process (Figure 8.10). Note that cleft sacra are an exception because they are scored on the Vertebral Pathologies data entry screen on a continuum of severity for posterior sacral disraphism, including spina bifida (Chapter 7).

SUPERNUMERARY VERTEBRAE: Using Barnes' (1994) interpretation of vertebral anomalies, supernumerary elements in the vertebral column are rarely found, and most cases of variation in the number of each vertebral type are developmentally related to border shifting. The modal number of vertebral elements in humans is 7:12:5:5:4, although 7:12:5:5:5 is nearly as common (Pilbeam, 2004). While caudal elements are an exception to the general rule of consistency in the number of vertebrae, they are less likely to be preserved and more likely to be overlooked or lost during excavation or curation of archaeological remains. In cases of any doubt, the elements should be interpreted as border shifting. Thus, when the only vertebrae recovered are thirteen thoracic elements, it should be scored as a border shift and not as a supernumerary thoracic element. Preference for scoring border shifting extends to complete remains when the total number falls within the common modal range of 33 or 34 vertebrae. For example, if the number of vertebrae is 7:12:6:5:4, this should be interpreted as two border shifts with lumbarization of S1 and sacralization of the first.

Figure 8.7 Cleft T11-L1 is scored as ununited components. a) posterior view; b) superior view. Although this is a subadult, neural arch fusion should have taken place in this 11 to 13 year old (photos by C. Wilczak).
caudal vertebrae (Figure 8.6). While this protocol will likely underestimate the prevalence of supernumerary vertebrae, it does allow for consistency in scoring anomalies.

CONGENITAL BLOCK VERTEBRAE:
During embryonic development, segmented somites undergo reorganization and portions of the somitic tissue form sclerotome blocks that encase the notocord. It is the sclerotome blocks that ultimately develop into the vertebrae, but they first undergo a resegmentation where each block splits into two and the caudal half fuses with the cranial half of the block below (Usher and Christensen, 2000; Pilbeam, 2004). Congenital block vertebrae can form through failures in this resegmentation.

Although any part of the vertebrae can display congenital fusion, most commonly, the centra are completely fused with complete or partial fusion of the neural arch (Barnes, 1994). The case presented in Figure 8.8 illustrates one variant in expression of block vertebrae with partial fusion of the centra and complete fusion of the neural arches. Congenital fusions need to be distinguished from fusion caused by other disease processes, which are not scored on the Vertebral Anomalies data entry screen. Osteophytes with fusion of spicules, and syndesmophytes (ligament) fusions related to DISH and spondyloarthropathies are both scored on the Vertebrae data entry page. Posterior joint ankylosis due to arthritis is scored under Arthritis and fusion as a complication of fracture is scored under Trauma.

WEDGED (Congenital or Idiopathic Only): Congenitally wedged vertebrae result from a relatively slower ossification in one half of the vertebral body. The wedge may be directed anteriorly or posteriorly (Figure 8.9). Wedging
due to compression fracture or other non-congenital pathology should be scored on the Vertebrae data entry screen.

**OTHER VERTEBRAL FUSIONS:** Anomalous fusions that do not represent block vertebrae are scored separately. Although rare, they are sometimes encountered as seen in the odontoid process fusion shown in Figure 8.10. In this case, C2 is also scored as an ununited component.

**OTHER VERTEBRAL ANOMALIES:** Less common variants in vertebral morphology are scored using the *Other vertebral anomalies* check box. Some can arise due to failure of notochord regression, such as hemivertebrae and butterfly vertebra (Figure 8.11), while others are hypoplastic developmental defects such as the absence of a cervical pedicle (Barnes, 1994; Brasili et al., 2002; Mays, 2007). Users of Osteoware should be familiar with the Vertebrae data entry screen as some variants (e.g., congenitally cleft sacra) are scored on that data entry screen for reasons explained in Chapter 7, and they should not be mistakenly entered as *Other vertebral anomaly.* A complete discussion of the anomalies should be given in the description field. Using standard names for specific anomalies will facilitate later searches of a database and we recommend Barnes (1994) as the priority reference source.
Chapter 9: Arthritis
by J. Christopher Dudar

Arthritis is among the most frequently encountered pathological conditions in archaeologically recovered human remains (Weiss and Jurmain, 2007). It is a poorly understood disease process of the articular surfaces that can involve: 1) loss of articular surface cartilage; 2) exposure of subchondral bone; 3) remodeling producing cysts, focal nodules, and surface osteophytes; and 4) eburnation polish due to bone-on-bone contact, with or without grooving.

Arthritis can be subdivided into:

- Osteoarthritis, primarily characterized by abnormal bone formation such as marginal lipping and surface osteophytes.
- Erosive arthropathies, involving inflammation and extensive subchondral destruction, e.g., rheumatoid, septic, and juvenile chronic arthritis.

Even the distinctions within this most basic subdivision can be deceptive, as advanced stage osteoarthritis may manifest considerable erosion, while erosive arthropathies may themselves be compounded by bone formation. Most forms of arthritis display similar alterations of the joint surface; therefore, diagnostic reliability is relatively low.

Due to the multifactorial etiology of arthritis and the complexity of the disease process, there is poor overall agreement on its clinical definition and some of the joint changes scored as osteoarthritis by skeletal biologists may not be related to significant dysfunction in life. This has spawned a more conservative perspective among some physical anthropologists who may employ only advanced arthritic alterations in skeletal diagnosis, like subchondral erosion and eburnation, or even recommend scoring of eburnation as the only diagnostic indicator of osteoarthritis (Jurmain, 1999; Weiss and Jurmain, 2007).

However, Ortner (2003:545) has remarked that, “Despite the challenges of accurate diagnosis and the problems inherent in obtaining reliable data on the prevalence in archaeological skeletal remains, . . . osteoarthritis is an important dimension of paleopathology that deserves careful analysis and interpretation.” Thus scoring in Osteoware includes barely discernible manifestations of all articular and periarticular alterations in order to capture potentially meaningful data. Scoring of each change separately allows for flexibility in the final interpretations until the issue of diagnosis is further clarified. For purposes of convenience, “arthritis” and “arthritic” will be used in reference to all alterations to joint surfaces scored in this module.

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1 All photographs by the author
**Arthritis Data Entry**

From the Bone drop-down menu on the Side / Aspect / Section data entry screen, choose a skeletal element or a joint (and the respective bones involved) from the joint drop-down list. In many instances, selecting a joint is preferable when arthritic changes are similar over all joint surfaces. When arthritic changes are widespread, the user may choose entire appendages or even Skeleton, Total, although a loss in data detail will likely result. In all cases involving selection of multiple joint surfaces, the codes for arthritic changes and any comments entered will be copied in the database under each individual bone.

Because arthritis is a progressive disease, all indications of abnormal articular surface morphology should be recorded to document possible early stages of arthritis that may shed light on the etiology of the disease (Figure 9.1). All observations of arthritic changes should be made using visual aids, such as raking light and low magnification (5-10x).

**ARTHРИTIS AFFECTING THE VERTEBRAL COLUMN:** The Arthritis data entry page does not cover some conditions specific to the spine, such as vertebral end plate porosity or vertebral body osteophytosis, which are recorded on the Vertebrae data entry screen. However, alterations of the diarthrodial spinal joints should be recorded in the Arthritis data entry screen.
Surface Porosity: Degree

An articular surface should be observed using visual aids such as low magnification (5-10x) and a raking light source for manifestations of subchondral porosity. Expression of porosity from least to most severe is recorded by selecting all the degrees that apply to the joint surface under observation. To score the first two categories, at least ten pores in the size range should be clustered in an area one centimeter square or less.

BARELY DISCERNIBLE POROSITY: Scoring in this category implies that visual aids are required to confirm the presence of porosity (Figure 9.2a).

CLEARLY PRESENT POROSITY: Clear presence indicates that individual pores are easily visible without visual aids. Pore size can range from pinpoint to pores > 0.5 mm (Figure 9.2b).

COALESCED SURFACE POROSITY: Coalescence is recognized when the walls/divisions between adjacent pores are obliterated, forming ‘figure-eight’ or ‘peanut-shaped’ pores. The coalescence of one pair of adjacent pores is sufficient for Coalesced Surface Porosity to be a correct choice (Figure 9.2b and 9.3).

Figure 9.2 Porosity on the posterior aspect of the right femoral condyles. a) barely discernible to clearly present; c) large, clearly present pores (with erosion). At least two cases of coalesced pores are also present.

Figure 9.3 Coalesced porosity as seen in the ‘figure-eight’ or other irregularly shaped pores. There is a white substance (possibly adipocere) embedded in pores towards the bottom of the image, and barely discernible eburnation polish to the upper left of the image center.
Marginal Lipping

The perimeter of an articular surface should be observed using visual aids such as low magnification (5-10x) and a raking light source for manifestations of marginal lipping. The range of expression of marginal lipping from least to most severe is selected from the check boxes. Select all boxes that apply for the articular surface or joint under observation.

BARELY DISCERNIBLE: Scores in this category imply that visual aids are required to confirm the presence of the incipient lipping. Barely discernible lipping is usually less than 1 mm in height (Figure 9.4a).

ROUNDED RIDGE LIPPING: The lipping presents a rounded profile in cross section, is easily palpated, and easily observed without visual aids. It is usually greater than 1 mm in height (Figure 9.4b).

SHARP RIDGE SOMETIMES WITH CURLED SPICULES: Scoring in this category only requires that the lipping be sharp in cross section and greater than 1 mm in height. Irregularity of the lipping sometimes includes bony spicules that are curled or uncurled (Fig 9.4c).

INITIAL AND FULL JOINT FUSION: Initial fusion requires some evidence of incipient anklyosis around or across a joint space. Fusion involves partial or complete immobility at the affected joint (Figure 9.5). When taphonomic damage has occurred, it may be difficult to discern the boundary between the last two choices. Ortner (2003) maintains that joint fusion (ankylosis) does not occur in osteoarthritis alone but results from complications due to trauma, septic arthritis, or other arthropathies.

Figure 9.4 a) barely discernible lipping of the distal humerus; b) rounded-ridge lipping on the anterior aspect of the medial condyle of the tibia, note the clearly present porosity and surface osteophyte along the intercondylar eminence; c) sharp ridge with curled marginal lipping on the distal femur.
Surface Osteophytes

Surface osteophytes are any discrete bony adhesions to the otherwise smooth joint surface. An articular surface should be observed using visual aids such as low magnification (5 -10x) and a raking light source for evidence of surface osteophytes. The range of expression from least to most severe is selected from the check boxes. Select all that apply for the articular surface or joint under observation.

BARELY DISCERNIBLE OSTEOPHYTES:
Scores in this category imply that visual aids are required to confirm the presence of an incipient osteophyte, which is usually less than 1 mm above the surrounding articular surface (Figure 9.6a).

CLEARLY PRESENT OSTEOPHYTES: An osteophyte is clearly present when it is easily palpated and observable without visual aids. They are usually greater than 1 mm in height (Figure 9.6b).

Figure 9.5 Humerus and ulna fused at the elbow. Note the articulating radius remained capable of pronation/supination despite advanced marginal lipping.

Figure 9.6 a) barely discernible surface osteophytes (red arrow) on the distal humerus, note the area of clearly present porosity and erosion on the capitulum (black arrow); b) clearly present surface osteophytes of the distal femur.
**Erosion**

Erosion is defined as a loss of subchondral bone that alters the joint surface profile and is accompanied by other arthritic manifestations. An articular surface should be observed using visual aids such as magnification (5-10x) and a raking light source. The range of expression of erosion from least to most severe is selected from the check boxes. Select all that apply for the articular surface or joint under observation.

**BARELY DISCERNIBLE EROSION:** Scores in this category imply that visual aids are required to confirm the presence of the incipient erosion (Figure 9.7). It usually extends less than 2 mm below the surrounding unaffected articular surface.

**CLEARLY PRESENT EROSION:** Erosion is clearly present when it is easily palpated and observable without visible aids (Figure 9.8). The erosion extends more than 2 mm below the unaffected articular surface.
Eburnation
Eburnation is caused by the loss of articular cartilage and bone-on-bone contact that produces a polished surface with a smooth, ‘ivory-like’ appearance. The articular surface is observed under low magnification (5-10x) and a reflecting light source. The range of expression is recorded from least to most severe by selecting all check boxes that apply for the articular surface under observation.

BARELY DISCERNIBLE EBURNATION:
This selection implies that visual aids are required to confirm the presence of incipient eburnation. This is best seen by the slight reflection of a light source off polished areas of the articular surface, which are usually less than 3 to 4 mm in diameter.

POLISH ONLY: Eburnation is easily observed with reflected light (Figure 9.9).

POLISH WITH GROOVES: Eburnation is easily observed with reflected light, and also displays discernible wear marks, or grooving, along the axis of motion of the joint (Figure 9.10). These grooves can be observed with or without visual aids such as magnification and a raking light source.
Extent of Surface or Margin Affected

Each of the five articular surface alterations (Porosity, Marginal Lipping, Surface Osteophytes, Erosion, and Eburnation) are also scored for the proportion or extent of the joint surface or circumference affected. The scoring is a simple estimate of the fraction affected: less than a third (<1/3); one-third to two-thirds (1/3 to 2/3); or greater than two-thirds affected (>2/3).

The “total” surface or margin used in this estimate depends on the initial entry of bones or joints. If individual bones were selected, then either the proximal or distal articular surface of that bone serves as the estimate of “total” surface. If a joint was selected, then all articulating joint surfaces should be utilized in the estimate.

Erosive arthritis

The necrosis of the joint synovium in erosive arthritis results from an intense inflammatory response, potentially leading to complete destruction of joint cartilage, exposure of subchondral bone, focal areas of cortical erosion and reactive sclerosis, peripheral osteoporosis, possible joint deformity, and fibrous or even bony ankylosis/fusion of the joint elements (Figure 9.11). Many of these joint surface alterations are scored in the Arthritis data entry screen. However, some erosive arthritic changes may be scored under other categories when appropriate, such as Bone Loss for cystic subchondral pitting.

While the Arthritis screen does not provide a data entry point for the etiological origin of the conditions scored, only the resulting manifestations, the user is encouraged to enter all observations that could lead to a differential diagnosis in the description field.
Literature Cited


