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Differential diagnosis in archaeology

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ABSTRACT

Diagnosing archaeological bone specimens can be likened to practices used in medical and veterinary medical health care. Increasing the rigor of archaeological diagnosis can be supported by a systematic approach derived from health care settings. The process of information synthesis and diagnosis can be viewed as being very similar among these disciplines.

A first diagnostic step is developing an Initial Information Set (sometimes called an Initial Database in health care environments) from descriptive data about the archaeological specimen or the patient, accompanied by recording environmental and ecological observations. The second diagnostic step is to develop an Expanded Information Set that includes structured physical examination, constructing a problem list, and considering potential differential diagnoses for each recorded problem. Subsequently, a Diagnostics Information Set consists of outcomes of carefully selected diagnostic testing, and a Diagnostic Assessment is developed from an orderly mental synthesis of information across Information Sets.

Critical aspects of a structured and orderly process are preparing inclusive differential diagnoses, thorough mental synthesis across Information Sets, and recognizing that a short list of the most plausible diagnostic alternatives may represent the furthest possible extent of the evaluation for many archaeological bone specimens.

1. Introduction

There is a recognized need for increased rigor in archaeological diagnosis, just as there is a continuous charge to improve diagnostic processes in health care and in most areas of bioscience research (Freyschmidt, 2003; de Gray, 2007; Klaus, 2015). A large disease-specific literature exists on this subject, across health care and research disciplines. Yet, it is distressing that diagnostic reports in paleopathology, and particularly in animal paleopathology, continue to follow patterns that were established based on incomplete diagnostic methodology in prior publications.

This writing describes an approach to animal and human archaeological bone specimens, for classifying observations into a format that will facilitate orderly and more complete differential diagnosis.

Diagnosis in health sciences refers to identifying a condition or an illness, or establishing its underlying cause(s) (Webster's Encyclopedic Dictionary, 1989). The process through which archaeological scientists, clinicians, and biomedical researchers might conduct a specimen or patient evaluation involves first developing several Information Sets. Following, differential diagnosis is the process of mental synthesis across those Information Sets. Potential causes of recognized problems are considered subjectively and objectively in an orderly fashion, as are diagnostic tests, leading to either a definitive diagnosis or a brief list of the most plausible alternative diagnoses.

The similarities between the medical and veterinary medical diagnostic systems and the process of diagnosing archaeological specimens suggest that an Information Set approach and thought process for differential diagnosis in health care can be organized to support increased rigor in the study of archaeological specimens.

2. How does differential diagnosis work in the clinical setting?

2.1. *Initial Information Set – Signalment, Initial Evaluation, Environment*

2.1.1. *Signalment*

The Initial Information Set originates with *Signalment* information (Table 1), such as species, sex, age, and size. Additional descriptors often are species-specific, such as race and ethnicity among humans, or subspecies, strain or breed, coat color, and

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reproductive status, among domestic animals. *Signalment* features, while seemingly obvious, provide important direction for the subsequent differential diagnosis thought process by defining a field of vision without being limiting.

2.1.2. Initial Evaluation

The *Initial Evaluation* is the second portion of the Initial Information Set, first including the *health history* (Table 1). Recording of objective metrics such as weight, height, overall size, blood pressure, temperature, pulse rate, and respiratory rate, constitutes the first part of the *presenting status* (Table 1). Several additional important *presenting status* traits are more subjective, including character of pulse and respiration, state of hydration, evidence of pain, and state of alertness (Table 1). The patient's current *symptoms* are the last component of the *Initial Evaluation.* After all of the information is acquired, the provider mentally relates the *Initial Evaluation* to the *Signalment*. The resulting collection of observations thus begins to form the basis for subsequent components of the diagnostic thought process, and actions on the patient's behalf.

2.1.3. Environment

Since many diseases have cyclic characteristics, the Initial Information Set also includes a third component, the *Environment* (Table 1). Factors such as *season* and *weather* exert physiological stress, even when patients are confined indoors. *Intra- and inter-species contacts* are important not only in terms of aggression and other social interactions, but also because of potential disease transmission (e.g. zoonoses). Aspects of *culture* (*social norms*) may influence health and disease and must be considered, as should effects of *housing* and *daily activity*, such as type of work performed (Table 1).

Close *housing* quarters in humans and animals can create emotional and physiological stress and facilitate transmission of infectious diseases, requiring that *cleanliness* in such environments must be managed aggressively and daily. Finally, *nutrition* plays a critical role in health, especially among young children and the elderly; the same is true for similar age groups of many mammals (Table 1).

2.2. Expanded Information Set – Physical Examination, Problem List, Differential Diagnosis

2.2.1. Physical Examination

The first component of the Expanded Information Set, *Physical Examination*, should be done directly by the health provider, using what is termed a "body systems approach" (Table 2). This approach is a thorough and orderly assessment of each of the patient's body systems: integumentary, muscular, skeletal, circulatory, respiratory, digestive, urinary, endocrine, reproductive, central and autonomic nervous, hematologic, immune, and special senses (vision, hearing, taste, smell) (Ham, 1959). All information is recorded and listed according to the body system into which observations are categorized (Tables 1 & 2).

A very important aspect of *Physical Examination* is that the provider must recognize and understand aspects and ranges of **normality**. Often, ranges of normal for any given body metric or function differ by species, breed or strain, age, sex, general state of health, and environmental influences. But, in all instances, abnormal cannot be recognized and described if the full range of normal is not understood. The provider must become accustomed to conducting the *Physical Examination* in the same way at every occasion, to insure that no major or minor observation is overlooked. It is critically important that all observations will be recorded at the time that they are made.

2.2.2. Problem List

The second component of the Expanded Information Set, the *Problem List,* is created by reviewing all previously-recorded abnormal data, regardless of evident relationship to presenting *symptoms* (Table 1). From the *Problem List*, the examiner begins to consider which body systems (or combinations thereof) could be affected, to explain each observation. The purpose of considering possible explanations for observations to this point is to establish all alternatives, following with intellectually-processed rule-outs, and then diagnostic tests as appropriate to further accept or reject causal hypotheses. The examiner must not overlook the fact that multiple disorders that cause similar *symptoms* may exist simultaneously.

2.2.3. Differential Diagnosis

Differential Diagnoses are the third component of the Expanded Information Set (Table 1). These are considered for **each** major and minor problem. Recognized problems are approached in *Differential Diagnosis* in the orderly manner that has characterized the components of *Signalment*, *Initial Evaluation*, *Environment*, *Physical Examination*, and *Problem List*. From these information sets, the Expanded Information Set is completed by compiling, reviewing, and mentally synthesizing the sum of the observations for each feature of the *Problem List,* to create the *Differential Diagnosis* list.

Creating an inclusive *Differential Diagnosis* is a significant challenge, often requiring considerable literature review. The mental process is an exercise in looking at each observation set in light of the others, while remaining conscious that plausible diagnoses are those that best align the components of the Initial and Expanded Information Sets.

2.2.4. The "DAMNIT" scheme

The "DAMNIT" pathophysiology format (Table 3) may be used to facilitate this mental synthesis within and across body systems. This format can and should be modified as required by varying clinical circumstances that require disease- or system-specificity (Saunders Comprehensive Medical Dictionary, 2007, modified for this manuscript). However, the DAMNIT format rarely is comprehensive and should be considered only as an information-processing guideline. It does not substitute for provider expertise, experience, and research effort (Saunders Comprehensive Medical Dictionary, 2007, modified for this manuscript). Many clinicians also use various subject-specific algorithms to support this process. In all events, information synthesis using a body systems format is preferred for final refinement of *Differential Diagnosis* (Table 2).

At this point of a clinical investigation, the examiner who has followed an orderly and sequential evaluation format usually will have a good grasp of the presenting patient and circumstances, and will be prepared to list most likely diagnoses and proceed to confirmatory (or rule-out) diagnostic studies.

2.3. Diagnostics Information Set

2.3.1. Medical tests

Medical testing is constructed to confirm or reject from the list of hypothesized differential diagnoses (Mark, 2005) (Table 1). If medical testing is done haphazardly, the result can be overlooking correct diagnoses because the proper confirmatory tests were not selected or because the hypothesized cause was incorrect and overemphasized. Within each category of medical test procedures are various choices, depending on target criteria for retaining or eliminating causal alternatives from the *Differential Diagnosis* (Tables 1 & 2). Clearly, the thought process for test selections must be orderly and deliberate.

2.4. Diagnostic Assessment

Once diagnostic tests are planned and completed based on alternative possibilities from the *Differential Diagnosis*, the provider should be in a position to establish either a definitive final diagnosis or a narrowed list of possible diagnoses, to be followed by more advanced tests (Mark, 2005) or consultation with a specialist. Diagnostic Assessment completes a process that is based on recognizing problems and potential causes of those problems, refining this list progressively to the shortest number of factually supportable diagnoses. The two most significant challenges are (a) building an accurate and complete problem list, and (b) building sufficiently inclusive differential diagnoses for each problem.

3. How does differential diagnosis work in archaeology?

3.1. Overview

The importance, and the difficulty, of understanding the thought process that is critical to health care decision making should not be underestimated (Mark, 2005). A thorough and orderly approach is a foundation of a proper diagnostic process for archaeological specimens as well as living subjects. Furthermore, the impact of the huge volume of information available to modern health care diagnosticians (Mark, 2005) touches all other life sciences, including paleopathology. Thus, one might consider how to define a similarly thorough and orderly approach to diagnosis in archaeological science.

3.2. Initial Information Set – Specimen, Initial Evaluation, Ecology

3.2.1. Specimen

In archaeology, a *Specimen* can be described in a fashion similar to *Signalment* data that describe the clinical patient. *Signalment* features that are relevant to the *Specimen* include species and taxonomy; size and metrics; sex; racial type; maturity (juvenile or adult); and general appearance. Defining breed or "breed type" (animals) can be challenging when viewing an archaeological specimen, but size often is a useful and informative descriptor that is accessible. For modern domestic dogs, size can predict likelihood of certain pathologies or can suggest anticipated non-stochastic longevity (Sutter et al., 2007). Clearly, not all desired information is available universally, but the same is true in health care circumstances. *Specimen* characterizations thus contribute to an Initial Information Set in parallel with that defined for health care applications, in a way that provides the field of vision for further evaluation (Table 1).

3.2.2. Initial Evaluation

In archaeology, no medical history, current patient status, or current symptoms are available to acquire the second component of the Initial Information Set, the *Initial Evaluation*. However, an *Initial Evaluation* can be derived from observations of the nature of the burial site; geological age (time since death); the conditions of excavation of the remains; whether remains are partial or complete, intact or damaged post-burial; bone surface appearance and state of preservation; and taphonomical description (Table 1). Just as *Initial Evaluation* in the clinical arena describes the immediate status of a presenting patient, these features of the paleopathology Initial Information Set outline important "presenting" characteristics of the archaeological specimen, providing a context for subsequent diagnostic steps.

3.2.3. Ecology

The third component of the paleopathology Initial Information Set, and the equivalent of the *Environment* in the clinical arena, might be described as *Ecology*. Original climate; season of death; cultural context; archaeological site context (immediate surroundings such as housing; all species that are present; non-burial, individual burial, group burial, or cemetery) can provide diagnostic clues as do *Environment* circumstances for the clinical patient (Table 1).

3.3. Expanded Information Set – Physical Examination, Problem List, Differential Diagnosis

3.3.1. Physical Examination

After careful assessment of the Initial Information Set, and exercising caution not to pre-conclude at this point, the next step is to develop an Expanded Information Set. The latter begins with information obtained by thorough and orderly *Physical Examination* of the specimen (Table 1). For example, the author always examines a given bone, such as a humerus, in the same manner and progression. The *general appearance* is noted, and successive humeral evaluation points include the proximal articular surface and articular margins, medial aspect, lateral aspect, and intertubercular groove. Tendon and ligament courses and attachment points are considered. The bone shaft follows, looking for evidence of trauma, abnormalities of curvature or muscle attachments, subjective bone strength, supratrochlear foramen, and unusual markings or color. Finally, the distal bone is evaluated from cranial, caudal, medial, and lateral aspects; the articular surface and articular margins are examined, as well as tendon and ligament courses and attachment points. All available remains should be evaluated by a similar orderly and repeatable process. Each specific observation also should be placed in a context of full-skeleton distribution.

3.3.2. Problem List

The examiner then considers whether known disorders of the various body systems could cause or contribute to the identified abnormalities. This thought process is reiterated over all of the body systems (Table 2), for each item on the problem list. For this reason, the *Problem List* (Table 1) must reflect all observations, however minor or seemingly unrelated to the presenting appearance. As in the clinical setting, the "DAMNIT" format (Table 3) or various specific algorithms may be useful in guiding the thought process, but the more thorough body systems approach (Table 2) is preferred for finalizing the *Differential Diagnosis* list.

Clearly, most information that would be available during life cannot be obtained from an archaeological specimen. However, approaching the archaeological specimen using a consistent and thorough method allows the examiner to self-inquire whether detectable deviations from normal bone might have a cause or contribution from soft tissue disorders or physiological derangements. For example, the examiner who recognizes hypertrophic osteopathy (HO) must understand that HO is an occasional consequence of many and different thoracic diseases, but also has been identified in association with a number of diseases of the genital and urinary systems. HO seems to occur more frequently in humans and dogs, among Mammalia. Thus, considering potential causes of HO in individual instances involves review of many potential differential diagnoses and influences (Lawler et al., 2015).

3.3.3. Differential Diagnosis

Another now-obvious question relates to information-sourcing in body systems disease literature, for potential components of a Differential Diagnosis list. Table 4 lists several general textbook reference works that are preferred by the author, although internet search engines can be helpful also. Often, it is useful to review potential Differential Diagnoses in more than one text, since clinical and pathology treatises are directed differently. Furthermore, food-producing domestic animals, working animals, companion or

human-associated carnivores, and wild animals, tend to have different disease spectra, albeit with potential commonalities as well.

3.4. *Diagnostics Information Set*

The Diagnostics Information Set for the archaeological specimen can involve various components. However, the underlying basis remains unchanged. Diagnostic testing (Table 1) is intended to confirm or reject causal hypotheses. For archaeological specimens, diagnostic tests might include imaging (photography, radiology (Freyschmidt, 2003; Schreiner et al., 2004), computed tomography (Friedman et al., 2012), electron microscopy (Olsen, 1988); histology and photomicrography (Skedros et al., 2011, 2014); mineralogy; bacteriological (especially molecular methods) and parasitological examinations (Reinard, 1992); and at times, genomic studies (Wilbur et al., 2009) (Table 1).

Diagnostic testing should not be a prospecting expedition, but should be considered carefully with respect to information desired. For example, radiography is most easily obtained, while computed tomography tends to be more clarifying. When practical and available, histological description will give valuable information about structural modification and often can support a degree of clarification that surpasses that yielded by imaging. Ultimately, planning for diagnostic studies must respect the synthesis process and be directed toward confirming or ruling out differential diagnostic possibilities.

3.5. *Diagnostic Assessment*

Diagnostic Assessment, as in the clinical setting, completes the observational, intellectual, and technological evaluation of a specimen, reflecting initial observations that are consistent with pathological change. In terms of paleopathology assessment, refining this list progressively to the shortest number of factually supportable diagnoses often represents the furthest extension of the process that is reasonable.

In many instances, it is far preferable to report a diagnostic refinement that concludes with a short list of *Differential Diagnoses* that are plausible, based on the synthesis of information from the Initial and Expanded Information Set components, and Diagnostics Information Set applications. Paleopathology literature contains many examples of overextending investigative outcomes to a single diagnosis (as does medical literature). Resulting errors tend to persist in subsequent literature, and may represent significant long-term barriers to scientific progress.

A final note is appropriate with respect to cause(s) of death. Archaeological diagnosis of a serious disease is not an obligate indicator that the illness represented by the observations caused death. In fact, definitive diagnosis of death causality often is quite difficult, even in the postmortem room, with an intact, recently deceased human or animal subject, and with supportive Information Sets that have been described herein. Thus, assigning a specific cause of death in the archaeological specimen should be done only when the evidence is so compelling that it would be medically impossible to conclude otherwise. This practice will prevent cluttering literature with persisting incomplete or incorrect conclusions.

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Table 1
Health Care and Paleopathology Information Sets.

Health Care (human, animal)	Paleopathology
Initial Information Set	**Initial Information Set**
Signalment	Specimen
species, subspecies	species, taxonomy
breed, strain or race, ethnicity	size and metrics
sex, size	sex
coat color (animal)	racial type
reproductive status	adult or juvenile
	general appearance
Initial Evaluation	Initial Evaluation
health history	burial circumstances
presenting status (objective, subjective)	geological age (time since death)
symptoms	excavation circumstances
	skeleton complete or incomplete
	state of preservation
	taphonomic observations
Environment	Ecology
season, weather	original climate
inter-, intra-specific contacts	season of death
culture or social factors	cultural context
housing, daily activity	archaeological site context (housing, other species present)
cleanliness, nutrition	
Expanded Information Set	**Expanded Information Set**
Physical examination	Physical examination
body systems notes	all observations, skeletal distributions
Problem list	Problem list
major, minor	all observations
Differential diagnoses	Differential diagnoses
body systems format	body systems format
damnit format	damnit format
Diagnostics Information Set	**Diagnostics Information Set**
Clinical chemistry & hematology	
Imaging (radiology, computed tomography, μCT)	Imaging (radiology, computed tomography, μCT)
Histology	Electron microscopy
Mineralogy	Histology
Biochemistry (genomics, immunology)	Mineralogy
Electron microscopy	
Microbiology	Microbiology
live studies (screening, specified)	histology
	molecular
Parasitology	Biochemistry (genomics)
	Parasitology
Diagnostic Assessments	**Diagnostic Assessments**
Refined differentials list	Refined differentials list
Definitive diagnosis (by problem list)	Definitive diagnosis (by problem list)

Table 2
Body Systems in Diagnostic Orientation.

Body Systems*
Integumentary
Muscular
Skeletal
Circulatory
Respiratory
Digestive
Urinary
Endocrine
Reproductive
Nervous
Hematologic
Immune
Sensory

* Ham AW. Histology, 6th Ed. Lippincott, 1959.

Table 3
Modified DAMNIT format for archaeological differential diagnosis.

D	Developmental genetic *in utero* or post-birth non-genetic *in utero* or post-birth Degenerative aging-related disease-related organ failure dementia
A	Anomaly inherited, congenital, acquired Autoimmune inherited, induced
M	Metabolic disorders (organ knowledge critical) intrinsic (from within) extrinsic (from without)
N	Nutrition excess, deficiency, imbalance Neoplasm benign (single, multiple) malignant (focal, metastatic)
I	Inflammation heat, swelling, redness, pain, cellular infiltrates) Infection focal, multifocal, systemic virus, bacteria, fungus, prion? Immune humoral, cell-mediated Iatrogenic (caused by health care provider) Idiopathic (cause unknown)
T	Toxic acute chronic Trauma acute chronic

Table 4
Useful General Text References for Medical Differential Diagnosis.

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Gibbons, WJ (ed). 1966. Clinical Diagnosis of Diseases of Large Animals. Philadelphia, Lea & Febiger, 1966 – Veterinary
Ham AW. Histology, Philadelphia, Lippincott, Multiple editions – Species non-specific
Kasper DL, Braunwald E, Fauci AS., Hauser SL, Longo DL, Jameson JL (eds). Harrison's Principles of Internal Medicine. New York, McGraw-Hill Publishing, Multiple editions – Human
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