Chapter 3
A Perspective on Zooarchaeology

For the last two centuries, bones, teeth, and shells have been accepted as evidence for chronology, ancient environment, and human activities. Faunal remains are credible evidence of past circumstances because they possess properties that have not changed over long spans of time. Zooarchaeological writings often have discussed such properties of animal bodies as *uniformitarian* ones (Binford 1981:234; Bonnichsen and Will 1980; Gifford-Gonzalez 1991; Lyman 1994). While the term "*uniformitarian*" has been called into question by some zooarchaeologists (e.g. Wolverton and Lyman 2000), as will be discussed in this chapter, whatever term one prefers, studying the present to understand the past is central to zooarchaeology, and this depends upon assuming that some *temporally invariant properties of animal bodies* exist. Zooarchaeological research today many times involves experiments or other contemporary observations of modification of faunal remains, intended to serve as analogues for archaeofaunal evidence. However, working with analogues has been a controversial area in archaeology, and an orientation to zooarchaeology should include a review of such matters.

3.1 Uniformitarian Approaches

The term *uniformitarian* entered geological discourse in the 1830s, when it was used in a review of Charles Lyell's *Principles of Geology* (Whewell 1832) to describe the approach taken in the multiple volumes of Lyell's work. Lyell, who was an adherent of the so-called gradualist view of earth history and trained as a lawyer, built upon the work of earlier generations of geologists, including James Hutton (e.g. Hutton and Playfair 1785) to "make a case" against the competing "catastrophist school of earth historians (Porter 1976). Catastrophists contended that repeated and unique calamitous events on a scale unknown in our present-day world produced the observed discontinuities of faunas in successive geological deposits. According to this scenario, each such catastrophe ended a major epoch of life on

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earth, produced the differences between ancient and modern faunas (Hooykaas 1970; Simpson 1963). In *Principles of Geology* (1830), Lyell argued that all geological and, by extension, paleontological, deposits could be explained by invoking the operation of processes observable in the contemporary world, rather than by citing catastrophic events exceptional to it. Lyell's approach rested on the assumption that geological processes had remained constant in their action and effects over the entire span of the earth's history. Paleontologist George Gaylord Simpson (1902–1984) called this position *methodological uniformitarianism* (Simpson 1970).

Prior to publication of Darwin's and Wallace's theory of organic evolution, Lyell also postulated that life forms did not alter significantly over earth history, a position Simpson labeled this *substantive uniformitarianism*, noting that this did not withstand the impacts of Darwin and Wallace's model for the organic evolution of species by natural selection (Darwin 1859; Wallace 1859). In the 1860s, convinced that the latter could account for the appearance of new species, Lyell abandoned his second position regarding the static nature of organisms. Lyell's methodological uniformitarian approach remains a cornerstone of the historical sciences, including geology and paleontology.

3.1.1 "Uniformitarian" vs. "Immanent"

For those who have read Wolverton and Lyman (2000) on the use of analogy in archaeology, it may be useful to point out some similarities and differences in how they and I approach terminology, which in part stem from the respective bodies of literature upon which we have drawn. At the outset, I stress that we are in agreement on the problems with analogies that can arise when properties that are outcomes of unique historic trajectories are confused with those produced by causal processes that operate uniformly over time and space. Wolverton and Lyman rely strongly on other work by paleontologist and philosopher of science George Gaylord Simpson, notably "Historical Science" (Simpson 1963), also citing a number of works by philosopher of archaeology Alison Wylie (1985, 1989), as well as key works in the argument over analogy in archaeology that occurred in the 1980s. In my own writings on the same topic (Gifford 1981; Gifford-Gonzalez 1991), I have drawn not only on Simpson's and Wylie's writings but also on the philosophical literature on analogy, some which will be cited in this chapter, as well as the work of evolutionary biologist Ernst Mayr (e.g. 1982). In writing my 1981 review article, I also cited works on the role of contemporary observations in paleoecology, as this field had emerged since the 1960s, which also will be cited in this chapter.

One key terminological difference is Wolverton and Lyman's rejection of the term "uniformitarian," preferring instead Simpson's (1963:24–25) term, "immanent," for,

> The unchanging properties of matter and energy [chemistry, mechanics, physics] and the likewise unchanging processes and principles arising therefrom are immanent in the mate-

> rial universe. They are nonhistorical, even though they occur and act in the course of history.

In Simpson's description, these contrast with contingent or "configurational" outcomes of such immanent processes within specific and unique historical trajectories. Wolverton and Lyman (2000:234) state, "configurations are the unique expression of particular combinations of immanent processes in operation in more or less unique sequences at particular intensities on particular phenomena." Paraphrasing Simpson, they note that erosion is an immanent process but the form of any specific geomorphological feature shaped by erosion is a unique configuration of processes and outcomes.

I incline against using "immanent," to describe such properties for two reasons. First, this term has a long history in philosophy and theology, meaning not only "inherent" but also, in philosophy, a solely mental action, and, in theology, literally "in-dwelling," as it has been used since the seventeenth century. Though "uniformitarian" carries nearly two centuries of baggage, at least that baggage can be unpacked solely within the historical sciences – as with Simpson's (1970) distinction between Lyell's substantive uniformitarianism, which has been discarded, and methodological uniformitarianism, which Simpson stipulated enables our study of planetary processes.

Second, and perhaps more importantly, Simpson's 1963 discussion, referred *only* to physicochemical processes as having immanence, or operating in a law-like fashion. His article, and the conference volume in which it appeared (Albritton 1963), came at a time of ferment within the non-archaeological historical sciences, in which paleontologists were debating the limits of uniformitarian assumptions and the possibilities of formulating law-like principles for their field, anticipating by some 20 years similar debates in archaeology. Much of Simpson's 1963 essay is devoted to an insightful consideration of the concept of "scientific law" in the nonhistorical sciences and how this has structured the course of expectations in geology and paleontology. Simpson (1963:29) discusses the complications that arise for the historical sciences when they seek to emulate the nonhistorical physical sciences in discovering laws. He argues that this is "mistaken in principle," because,

> Historical events, whether in the history of the earth, the history of life, or recorded human history, are determined by the immanent characteristics of the universe acting on and within particular configurations, and never by either the immanent or the configurational alone.

Wolverton and Lyman (2000:234) state "…the processes that result in biological evolution—genetic transmission, mutation, drift, differential reproduction, survival, and selection—involve immanent properties and processes," and (2000:236) "Immanent analogies involve using laws that apply in all times and places to understand a configuration of unknown creation." DNA and RNA themselves are composed of molecules and hence governed by chemical processes that may be universal in Simpson's sense. However, from my point of view, Wolverton and Lyman's second statement would exclude all the processes cited in the former, since, if we strictly adhere to the Simpsonian dichotomy, the life processes on our planet may not be the only template for life in the universe.

One could dismiss this observation as an interesting but irrelevant quibble, but it's quite relevant to the dichotomy Wolverton and Lyman seek to develop, and to the serious issues with which those of us using analogy must grapple. DNA might not the only possible chemically based form of information transmission in living matter in the universe, but even if it may not be universally "true" off-planet, can those of us who work here on earth assume it worked the same during a specific span of earth history? That is, could we proceed on the working assumption that DNA operated more of less similarly over the span of, say, hominin evolutionary time? For this span of earth history, can we assume it has been as uniform in operation as are radioactive isotopes? Likewise, vertebrates evolved and they did not exist "at all times." Does this mean that they lack any inherent properties might hold true, when and where they did and do exist? If this were not the case, why would we do bone modification experiments to understand more of traces on ancient specimens? How can paleontologists believe themselves to be justified in diagnosing tooth marks on the 90 million year old shell of an ammonite invertebrate, and even in suggesting the dinosaur species that created them (Gale et al. 2017)?

The thinking of another philosopher of biological science, Ernst Mayr (1904–2005), provides a slightly different perspective from Simpson's on uniformity of process and, by extension, on reasoning by analogy. I owe a great debt to Kent Flannery for directing my attention to Mayr's writings in his final chapter of *Guilá Naquitz*, (Flannery 1986), in which he referred to Mayr's approach to scientific explanation. Flannery noted that Mayr's approach made more sense to him for studying the shift toward cultivation than did the reductionist approaches modeled on the physicochemical sciences, which had hitherto been held up as ideals of scientific explanation in archaeology. Like Simpson, Mayr acknowledged that biological and ecological systems must be viewed differently than physicochemical systems (e.g. Mayr 1982). Like Simpson as well, Mayr asserted that biologists do themselves a disservice if they conclude that their inability to reduce ecosystem function to simple, determinative statements reflects theoretical inadequacy. He called for acknowledgement that that different concepts and forms of explanation are necessary for biological and ecological systems. Mayr asserted that biological systems can be studied systematically, as did Simpson, but he differed in that he believed predictive statements about the outcomes of processes operating in them can be made, but that these are often *probabilistic* in their operation. Such processes would not be immanent in the way Simpson defined that term in 1963.

In discussing a methodology for studying biological systems, Mayr (1982:63–67) stressed the concept of *emergence*, which in his usage he tied to the notion that organisms and ecosystems commonly have a hierarchical organization. Emergent properties of a complex system, whether it is an organism or an ecosystem, cannot be accounted for by invoking explanations based on properties of any lower-level component. Moreover, such complex systems may exhibit behavior and organize themselves in ways that are not predictable based upon the sum of their parts. The philosophy and study of emergence in physical and biological systems is a field unto itself, and the reader may find entry point to that literature in Corning (2002).

The rather simple example of water has been used to convey the idea of multiple levels of integration and "behavior" involved in emergence. Water is composed of molecules, each typically comprising two hydrogen ions and a single oxygen ion, though variations (isotopes) exist. The behavior of water at this level is best studied by theory that treats it as a chemical compound, taking into account its constituent ions, variations in the structure and behavior of hydrogen and oxygen isotopes in the molecule. However, when water molecules exist together in gaseous, liquid, or solid states, such basic chemical concepts may not adequately account for their behavior. One must instead use physical theories of phase change to understand how, when, and why water molecules become a solid, a liquid, and a gas. When small units of liquid water such as raindrops combine into more massive bodies, predicting how they will behave another area of physical theory. Water moving downhill may move in harmonic waves and so forth. To account for its behavior of water in such aggregates and contexts, one turns to fluid dynamics, rather than relying only on bodies of theory that worked well at lower levels of integration. We know from everyday life that even sophisticated, satellite-based observations of water phase states can only give us estimated types, times of arrival and chances of precipitation.

Biologists and ecologists face the challenge of identifying and applying the appropriate theory and method to study each level of emergence and integration: that of cell components and their chemical operations, of organ systems, of organisms, and of organisms interacting together in plant and animal communities. Nonetheless, ecosystems have do have regular relationships between constituent processes and outcomes, for example, that between the amount of precipitation and standing biomass (Ogutu and Dublin 2002). Many of the components in these regularities are variable over space and time. Therefore, they are not well suited to the simple, cause-effect descriptions that work so well at molecular level.

For those of us in historical sciences such as paleontology and archaeology, the question is whether and how this approach, rather than the immanent-configurational distinction, is the best way to consider how analogical inference works in our inquiries, which, as Simpson stated, are not amenable to the "all times, all places" generalizations of the physical sciences. If this is the case, then "explanation" depends upon the level of integration at which one is working, and reasoning by analogy becomes more complicated at levels where processes operate probabilistically. The next sections of this chapter explore why this is so, and why actually making some forward progress, despite the lack of "all times, all places" generalizations on which to base all our inferences, might be possible.

To sum up this rather long detour, I agree with Wolverton and Lyman that archaeologists, who are a kind of historical scientists, must handle reasoning by analogy very carefully. I also agree with them that different kinds of analogies exist that vary in their strength of relationship to causal processes, and therefore have different limits on the plausibility of inferences drawn using them. I will continue to use "uniformitarian," or "inherent" rather than "immanent," for the reasons outlined above, which I hope will become even clearer through the balance of this chapter. I also will use the term *actualism* as do paleoecologists, who, like archaeologists, find it informative to make contemporary observations to elucidate the patterning in evidence from the past. How we parse out what can be known through such observations and what cannot is the subject of the balance of this chapter. Finally, I will introduce some distinctions used by philosophers of analogy that I have found useful in sorting out stronger from weaker analogies to zooarchaeology (Gifford-Gonzalez 1991), as has Wylie in her writings on analogy in archaeology in general (1982, 1985). In this process, I also draw upon some of Lyman's salient earlier writings (e.g. Lyman 1987).

3.1.2 Actualism

A methodologically uniformitarian approach offers the historical sciences a practical research strategy for learning more about the past, using modern analogues. Lyell argued that, if earth processes have remained constant, one could understand the origins and nature of deposits by studying processes that are forming analogous deposits in the present day. In historical sciences, and more recently in archaeology, studying present-day analogues to learn more about preserved evidence from the past has been called *actualism* (Binford 1981; Gifford 1981; Herm 1972; Hooykaas 1970; Lawrence 1971). The word may puzzle English speakers, since in English, "actually" means, "in fact." However, in contemporary German and Romance languages, the cognate means, "of the present," or "contemporary." Actualism, brought into English from its prior use German paleontology, thus refers to *studying contemporary processes and their products to assign meaning to evidence from the past*.

3.2 Reasoning by Analogy

It is useful to explore the relation of uniformitarian assumptions, actualism, and reasoning by analogy specifically in relation to the study of archaeofaunas. Animal remains are reliable indicators of past processes and contexts *only* if one takes a uniformitarian perspective. When we infer a mammal's age-at-death from an unfused epiphysis of an archaeological specimen, we assume that the same growth processes that produce such features in the present did so in the past. We interpret a carnivore tooth mark on a fossil bone by assuming that it was produced in the unobservable past in the same way as ones we can observe created today.

Through the 1960s and 1970s, archaeology saw many debates over reasoning by analogy. Some early processual archaeologists claimed that archaeology could and should move beyond analogical reasoning to inference by deduction, based on law-like generalizations (Binford 1967; Freeman 1968). Richard Gould (1978; Gould and Watson 1982) reasserted that we could "escape" from using analogies by relying on "laws," statements of invariable causal relationships in nature, derived from ecology, biology, and geology. Alison Wylie (1982, 1985), an archaeologist and philosopher of science, responded that application of law-like generalizations in explanations relies on the assumption that the processes and relationships stipulated in the law were the same in the remote past as observed in the present. This is, she argues, a special and complex form of analogical reasoning relying upon complex, uniformitarian relationships. Today, most archaeologists accept that both our methods of inference, and even how we know what we know, usually rest on analogies (Binford 1981, 1987; Hodder 1982).

One can sum up a perspective on the use of analogy in archaeology in three statements: analogy is inevitable; analogy can be abused; analogy can be refined by actualistic research. The next sections examine each statement more closely, with an emphasis on avoiding the pitfalls.

3.2.1 Analogy Is Inevitable

Working with archaeofaunal samples, we use analogy pervasively, from naming the osteological element and identifying the species from which it came to inferring details of ancient environment or ecological interactions. For example, when encountering a fossilized bone identical to a right femur of a modern deer, most researchers will automatically call the fossil a deer femur. The fossil specimen is named based upon its resemblance to modern femora, via a complex, virtually instantaneous, assessment of its relevant physical characteristics. In fact, the specimen may differ from modern deer femora in some traits, such as in its weight, color, and chemical composition, but researchers probably will decide these are not relevant to identifying the bone and the species, based upon another set of assumptions that these traits reflect postmortem taphonomic processes, while their primary concern is with its earlier, life context. So, in naming the bone they make an analogy with modern deer femora, based on relevant *criteria of similarity*.

Most paleontologists or archaeologists will take inferences by analogy considerably further. Although they did not find any other deer bones, they accept that the fossil femur once existed in a skeleton. They also infer that the ancient femur was linked to specifiable muscles, tendons, and ligaments, the quadruceps femoris and not the biceps brachii, for example, with specific locomotor functions. They even will accept that the ancient deer was a browser, with the ruminant digestive system characteristic of the species. They might go even further, inferring that the ancient deer was an adult when it died, because the epiphyses at either end of the bone were fully fused. If pushed, they would probably also accept that the bone and the entire deer's body grew from a fertilized ovum, with cells diversifying into specialized bone tissues. Given an adequate modern comparative set of male and female deer femora, they might even infer that the fossil bone probably came from a male.

By this time they will have inferred a great deal about the anatomy, physiology, embryology, feeding, and reproductive potential of an animal we have never seen, all based on one specimen. This is what philosophers call *ampliative inference*. The researchers have in fact mobilized a very complex web of analogies to infer the prehistoric existence of physical traits and behaviors that they have not actually seen. Yet, no one would believe there is much fantastic or weak about these inferences. These broad inferences are all based on this object's similarity to other objects documented in the contemporary world, and from the fact that, in the known world, objects resembling a deer femur do not come into existence and function in ways other than this.

3.2.2 Analogy Can Be Abused

However, it is possible to make less secure inferences about the ancient deer. For example, one might say that this male deer had been very reproductively successful, or that he had indigestion when he died. Intuitively, most of us would feel less secure about these inferences, because we cannot see clear linkages between the femur and these inferences – one can conceive of too many possible exceptions. This gut-level feeling tells us something about what makes a strong analogy.

Secure analogical inferences, such as those about the functional anatomy and embryological development of the deer femur, are based on clear functional links between key features of the bone and wider linkages of its contemporary counterparts. These in turn are based upon inherent properties of organisms, traits and functions that result from interaction of genetic coding with environmental context. Moreover, in the background to these linkages is the knowledge that there are no documented cases in which femora came into the world in the absence of those specified biological contexts and histories. Thus, embryological development and functional anatomy of femora are "necessary and sufficient" causes of their existence. They are the "source side" for the phenomenon we examine (Wylie 1989).

This more warranted, functionally based type of analogy has been called *relational analogy*. These rest upon stipulated functional relationships, such as structure or causation, among the phenomena described (Wylie 1985; Hesse 1966; Copi 1982). They are considered to be stronger forms of analogy than those based solely on resemblances of form, or *formal analogies*. The latter are akin to what Simpson (Simpson 1963) called "configurational" properties, outcomes of historical processes that bear some resemblance to one another but lack specifiable structural or causal relationships. Drawing upon Simpson's discussion, Wolverton and Lyman (2000) called these "configurational analogies."

For some early processualists (e.g. Ascher 1961; Binford 1967; Freeman 1968), a key motivation for seeking an alternative to analogical reasoning was their dislike of questionable practices involved in archaeologists' use of "ethnographic analogy". Egregious cases attributed processual traits to a past society based upon that society's formal resemblances to an ethnographically documented group among whom those traits exist. For example, Ancestral Pueblo people living in the Four Corners region of the American Southwest are clearly related to modern Pueblo Indians, sharing architectural and ceramic traits. Some archaeologists uncritically attributed ethnographically documented Pueblo social and ideological perspectives and practices to ancestral Puebloans, without considering the effects of four

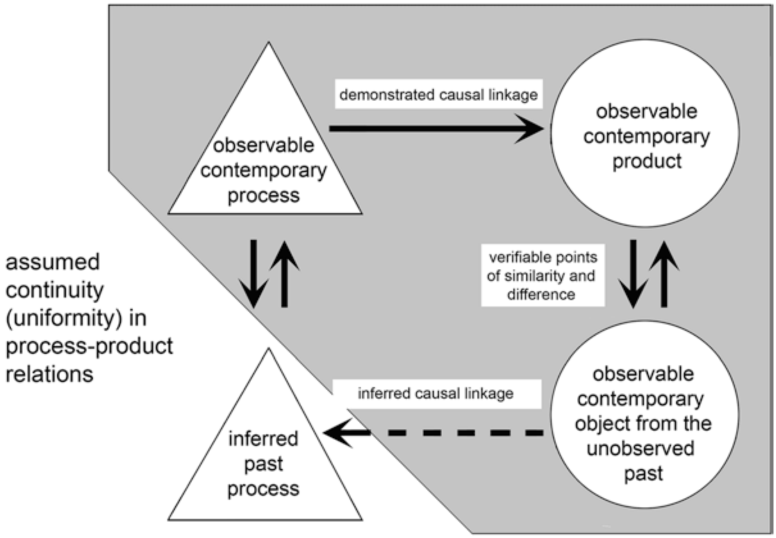

Fig. 3.1 A model of analogical reasoning in historical science. Shaded area indicates the zone of contemporary observations. The "inferred similarity" on the left may also be viewed as one or more uniformitarian assumptions. (Redrawn by author from Gifford-Gonzalez (1991:222, Fig. 3.2), used with permission of Elsevier)

centuries of colonization and resistance. Cordell and Plog (1979) challenged unwarranted assumptions of ethnographic similarity between ancient and recent Pueblo dwellers. Reconstructions of early hominin adaptations displayed parallel, problematic uses of ethnographic analogy. Isaac (1971) initially interpreted small clusters of stone tools and animal bones in Plio-Pleistocene deposits as "home base" camps like those of modern foragers. From this, Isaac inferred that similar socioeconomic relations, including food sharing and division of labor by gender, existed one-and-a-half million years ago. Binford (1981), Hill (1984), and others criticized such inferences as unwarranted, given the lack of functional links between the spatial patterning and such behavioral characteristics.

3.2.3 Actualistic Research Can Refine Analogy

One can explore functional and causal relationships necessary for relational analogies only in present-day situations. Only in the present can researchers observe an archaeological object and explore possible functional links between a process that we suspect may have produced such an object and its actual material products, a cause and its effects (Binford 1983: 98–100). By establishing causal linkages, one can return to archaeological materials with a sense that the analogies used to interpret them are secure. The basic relationships in using modern analogues are outlined in Fig. 3.1. Based upon certain assumptions intrinsic to our discipline, we

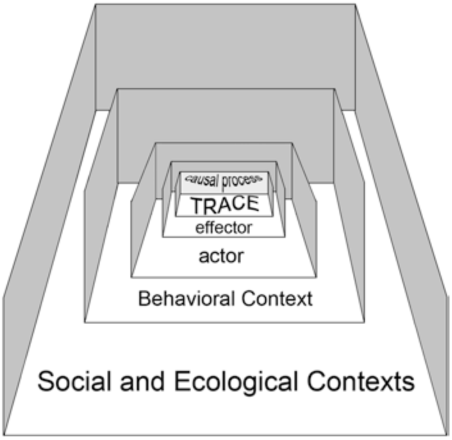

Fig. 3.2 A model of different levels of inference in zooarchaeology. (Redrawn by author from Gifford-Gonzalez (1991:229, Fig. 2), used with permission of Elsevier)

accept an object as a remnant of a past time. If some trait of this archaeological object is not completely understandable, based on our knowledge of the contemporary world, we select a modern analogue. Through comparison, we verify that the two objects are similar in aspects that we believe are relevant to our inquiry (criteria of similarity), at the same time noting traits that differ between the two (Copi 1982; Wylie 1985). Based again on our knowledge of the present-day world, under controlled circumstances, we establish which among a range of processes that might create the trait we are seeking to elucidate. We may discover that other processes than we originally imagined actually created the feature. With our new understanding of the contemporary cause of the feature, and based on the resemblance of the experimental evidence to the archaeological evidence, we infer that a similar process produced the archaeological feature in the past.

Inferring the cause of the prehistoric feature requires that we assume that similar processes have produced similar traces over long stretches of time. The practice of investigating potentially uniformitarian processes and their products by observation of modern-day analogues is actualism. At the most basic level of assigning meaning to zooarchaeological materials, we believe our inferences to be warranted, given observed relationships between dynamic causes and their static effects.

3.3 Actualistic Research in Zooarchaeology

Zooarchaeologists and paleontologists have done actualistic research on animal remains with increasing frequency over the last 30 years, reflecting their widespread recognition of the productive research relationship of analogical reasoning, uniformitarian assumptions, and actualism. This research includes *experimental archaeology* and, when humans are among the actors modifying faunal remains and creating evidence (the modifications), the study will probably be called *ethnoarchaeology*. Studies of modifications to animal remains by other actors in natural settings might be termed *landscape taphonomy*. I would include prudent use of historically and ethnographically documented *causal* relationships as relevant to establishing relational analogies, for the same reasons as discussed by Wolverton and Lyman (2000), serving as the main basis for setting up a relational analogy. However, all this rests upon having excluded all other possible causes for the effect or effects seen, and therein lies Wolverton and Lyman's objection to using essentially contingent, or configurational patterning based upon a few cases as if they were truly uniformitarian. This is especially problematic in levels of systemic integration where causal processes may operate probabilistically. Actualistic research in zooarchaeology has produced great gains in understanding bone surface modifications. Part IV of this book shows that actualistic research on bone collectors and bone modifiers has specified causal processes for many formerly ambiguous modifications, such as cut marks, tooth marks, weathering, and spiral fractures. Part V will explore how actualistic research has elucidated causes of bone element preservation or destruction of various found in prehistoric bone assemblages. However, this section also demonstrates that behavioral inferences from element frequency patterning may be problematic precisely because only human selectivity, rather than intrinsic properties of elements themselves, was assumed to be the causal process behind the patterns.

At its best, landscape taphonomy assesses the systematic processes underlying the fate of animal remains in their postmortem contexts, when not only biological agents but also weather and geological processes affect the condition and, ultimately, survival of organic remains. Bones, shells, and other remains play a role in ecosystems, as food, shelter, and otherwise useful items to various organisms. Greater knowledge of structural and functional relations of animal remains as elements in ecosystems is beginning to elucidate the pre-depositional fate of bones. One example of this is discussed in detail in Chap. 21, when a variety of processes have been seen to exert differentially destructive effects on various skeletal elements. Elements with high surface area to volume ratios are more vulnerable to weathering, trampling fragmentation, and some forms of microbial attack.

3.4 Levels of Analogical Inference in Zooarchaeology

Actualistic research may help us infer that a groove on a bone surface was made by a carnivore tooth, and even, from its size, geographic, and temporal context, that it was probably a hyena's tooth, but what does the presence of the tooth mark testify to the behavioral, social, or ecological *context* in which the mark was made? Did the hyena scavenge the bone it gnawed from another carnivore's kill or did it hunt its prey cooperatively with other hyenas, as some are known to do? These questions all pertain to behavior and ecology, and simply identifying the tooth mark does not answer them, even though one can assume that the animal lived in such contexts.

3.4.1 Causal Process, Effector, Actor, Behavioral, Social, and Ecological Contexts

This section presents several distinctions based upon Mayr's (1982) approach to hierarchically organized systems that will prove useful in later chapters on bone modifications. These also serve to introduce a product-focused approach to zooarchaeological analysis. Figure 3.2 presents a visual model for a nested set of causal relationships. Innermost is the actual *trace* that is present to study as empirical evidence. This is the product of a *causal process*. In the example discussed above, the causal process was a hyena's tooth pressing down on and moving across the surface of a skeletal element, causing the surface to give way a bit and producing a groove. One can call the hyena tooth the *effector*, the actual physical cause of the modification. Beyond this is the *actor* that creates the trace though the causal process, in this case, the hyena that did the gnawing.

Encompassing the causal process, product in the form of a trace, and the actor is the *context* in which the actor produced the evidence. The most immediate is the *behavioral context* in which the trace was produced; in the case of the hyena tooth mark, this could be "scavenging" or "predation," Beyond this are the *social and ecological contexts*, referring to the web of social (pack-living, living in a pair, solitary) and ecosystem relations in which the actor lived and acted.

Establishing a strong relational analogy that implicates a causal process, an effector, and an actor is relatively straightforward. This requires excluding other possible causes. For example, based again upon the aggregate findings of actualistic research, many vertebrate taphonomists don't think one can make infer the species of a bone gnawer from tooth marks (Fernández-Jalvo and Andrews 2016) and recommend using a more conservative and defensible inference of actor such as "large carnivore," rather than stipulating this was made by a hyena.

The real challenge comes if one hopes to use hyena tooth marks to infer whether the animal was hunting or scavenging when it gnawed the bone it had acquired. In terms of the "necessary and sufficient" idiom, neither such activity is a necessary cause of the mark. At the scales of organization described in behavioral, social, and ecological contexts, relational analogies – so valuable for the power they bring to analogical inference – are rare. Given that ecosystems and even living organisms are complex, emergent levels of biological organization, Mayr (1982) argued that one cannot account for their functioning by pursuing reductive explanations such as are common in physical and chemical sciences, and which worked so well in the example given for trace/process/effector levels. Outcomes of processes are more likely to vary and are best described by probabilistic, likelihood statements, rather than those of the "if a, then b" variety. Analogical reasoning is not impossible in these contexts, but it is much more complex, and it probably has different standards for evaluating its soundness. This presents inferential problems to zooarchaeological researchers who, as much as they are delighted to recognize tooth scores or cut marks, really want to learn more about the behavioral, social, and ecological circumstances of human ancestors. There is nothing inherent in the immediate causal relations that allow us to infer behavioral context. To paraphrase the old joke about a rural New Englander giving directions, we "can't get there from here," at least not in the way that we did with the trace-effector-actor example. The question is how *do* we get there from here, if at all?

It would be an error to conclude that one should – or could – avoid using analogies taken from modern ecology or even ethnography because of such variability and complex determinacy. It is hard to imagine how one could say much about prehistoric materials without using analogies, whether naming objects, describing their function, or defining their contexts. Wylie (1989) lays out a discerning discussion of this use of "suppressed analogy."

3.5 Using Analogy at Higher Levels of Systemic Integration

Given the complexities outlined above, prudent use of analogy involves at least three methodological tactics. The first is simply to evaluate whether specific analogies are relational or formal, thus clarifying the strength of the inferences possible. This evaluation could involve investigating systematic, functional links between classes of archaeological evidence and their causes and associated actors *in the present*. Granted, this boils down to what Wolverton and Lyman (2000) remind us are empirical generalizations, and we should never assume they have the same strength as relational – Wylie's (1989) "source side" – analogies.

In determining the causal actor or actors responsible for specific patterns in our data, it is nearly impossible to use any one line of evidence that has shown itself to be ambiguous in relation to which actor that produced it. A second tactic is to not rely on any one type of data to make a causal inference, but rather to use multiple, independent lines of evidence. Such an approach was termed *"forensic"* by Lyman (1987), emphasizing parallels to investigations in which multiple lines of evidence, each independent of the other, are brought to bear on determining the agent behind an event. The more lines of evidence point to the same causal process, effector, and actor, the more likely it is that these were responsible for the outcomes being investigated. This approach to dealing with ambiguous causal agency or circumstances has sometimes been called "contextual analysis," or described as applying independent uniformitarian "frames of reference" Binford (1987; 2001).

Often no single line of evidence unambiguously identifies an actor or context of production, but, if the preponderance of independent lines of evidence points to a given actor or context, we feel more strongly warranted in specifying it as the most likely possibility. The courtroom standard of "beyond a reasonable doubt" may thus not be a realistic standard for zooarchaeologists, but something close to such a criterion, based on the concatenation of "circumstantial evidence," may be achieved.

The key requirement for independent lines of evidence is that they may not be produced by the same process. For example, two morphologically distinct marks of carnivore teeth on a bone, pits and scores, are not independent evidence for the action of carnivores because both are produced virtually simultaneously by gnawing

(Chap. 12). By contrast, the presence of many gnawed bones and no human artifacts in a small cave more strongly suggests the activities of a carnivore. Two independent lines of evidence, the gnaw marks and the physical context, both point to the same agency or context production. Chapter 17 presents some cases of such reasoning.

The third tactic entails a longer game: doing more systematic work on constructing plausible, analogy-based arguments about the complex, higher-level systems that Fig. 3.2 calls "context." Zooarchaeologists are already doing this when they make arguments based on multiple and independent lines of evidence, such as frequencies of cut marks, osteological element frequencies, relative species composition of samples, and so forth, as will be outlined in Part V.

3.6 "Signatures" and Equifinality

Through actualistic research, zooarchaeologists have defined distinctive traces, to use the terminology of Fig. 3.2, or what are sometimes called "signatures," made by a specific actor. However, actualistic research has also shown that different causes can sometimes produce very similar final effects, requiring further research to distinguish.

The case of so-called pseudo-cut marks, or trampling marks (Chap. 13) is one such example. In the early 1980s, Shipman and her coworkers (1981; Shipman and Rose 1983) used SEM to describe multiple morphological criteria of stone tool cut marks, demonstrating that these differed from the marks of carnivore teeth. A few years later, paleontologists described similar marks on fossils from epochs predating the existence of hominins (Behrensmeyer et al. 1986; Fiorillo 1989). They also experimentally demonstrated that these "pseudo-cut marks" could be created on bones trampled by hoofed animals against a substrate with angular particles. In this case, the *causal process* and *the effector* that produced pseudo-cut marks and stone tool cut marks is the same: a sharp, angular edge of a stone dragging over a relatively fresh bone surface. However, the *actors* differed. Therefore, the inferences from the traces about effectors and actors were ambiguous.

Lyman (1987) described such cases as problems of *equifinality* ("same end" or same final outcome). Alan Rogers (2000) has pointed out that biologist and cyberneticist von Bertalanffy's (1968, 1949) original definition of equifinality refers to outcomes that are identical and can never be distinguished. Rogers makes the case that some outcomes called "equifinal" in the zooarchaeological literature are not really equifinal in Bertalanffy's sense. We will return to Rogers' important methodological point several times in this book, especially in Part V. For the present, it is sufficient to explore how zooarchaeologists deal with the very real problem of sorting out actors when effectors and causal processes are virtually identical.

The case of cut marks and pseudo-cut marks sheds light on ways of coping with the dilemma of equifinality. Rogers (2000), suggests that one should first ask whether this is a problem in the primary data (some quality of the materials that one can physically examine) or in secondary data (an issue with the derived statistical characterizations of the materials). The pseudo-cut mark example shows that it is possible to have similar primary evidence produced by different actors. In the case of pseudo-cut marks, researchers brought together several new, independent lines of evidence to better identify the most likely actor. To address this, investigators undertook a new round of research to distinguish these two traces *on the basis of other criteria than the traces themselves*. This included the substrate type: does the matrix in which the bones were found contain angular materials that could have caused pseudo-cuts when the bones were trampled? Researchers also assessed placement of the marks on the bone: are the marks in anatomically "logical" zones for butchery, or more or less randomly located on convex surfaces, where they would be in contact with angular stones if trampled? Multiple lines of evidence, each involving relational analogies based in immanent properties of the materials, work together to reduce ambiguities in any single line of evidence.

3.7 A Product-Focused Approach

This book takes a *product-focused approach* to analysis of archaeofaunal specimens (Gifford-Gonzalez 1991) that concentrates on specimens as the end-products of complex chains of events during life and after death. This includes both the various stages of the biostratinomic realm and the subsequent, *diagenetic* realm of physicochemical transformation (see Part IV). It is a truism that paleontological and archaeological faunal assemblages have complex histories, during which many processes may act upon them. Some such processes leave traces of their operation, some do not, and some may obscure or remove the marks of others. For example, the surface of a bone lying out in open air cracks and exfoliates, removing shallow cut marks made on its original outer layer.

This sequential process of postmortem modification has been called the "taphonomic overprint" (Lawrence 1968). Earlier taphonomic writings often emphasized the progressive losses of information about life context through various postmortem processes acting on organic remains (Lawrence 1968; Meadow 1980; Clark and Kietzke 1967). This point of view is correct, as it describes the progressive, postmortem divergence of animal remains from their original contexts as constituents in living organisms. However, the "overprint" perspective suggests a chimerical goal for taphonomic and zooarchaeological analysis: that of "unbiasing" an archaeofaunal sample back to its original context in a living system.

Lyman (1994) and I (Gifford 1981; Gifford-Gonzalez 1991) have argued that this is not a realistic aim. Rather than viewing taphonomic analysis as "stripping away the overprint" from biological remains, it is more productive to focus on taphonomic effects as evidence *added* to specimens by postmortem processes. In fact, taphonomic evidence is a form of *trace fossil*, testifying to the action of other organisms and non-biological processes on organic remains. Referring to the effects of diagenetic processes on stable isotopes in bone, geochemist Andrew Sillen

(1989:228) put it this way, “Diagenesis suffers from a bad name; we tend to see it as the mist on the window rather than part of the view.” In fact, these altered materials are all we have to deal with in our analyses, so we need to follow tactics suited for learning what their preserved evidence can tell us.

A starts from the viewpoint that each specimen has an individual , some of which can be discerned from its form, composition, and modifications. These include attributes are functionally related to the specimen’s ontogenetic development and the role it played during life, while others were produced by the processes that acted upon it after death. Analysis therefore always begins with recording data from individual specimens. However, just as there is no typical archaeological site, there is no typical bone. To understand the dominant processes that created a bone assemblage, data from individual specimens must be read as an *aggregate pattern*.

Patterning in data from a faunal assemblage is thus the cumulative reflection of redundant incidents of human behavior or the action of other processes that produced certain repeated effects on faunal remains. The dominant patterns of modification should reflect at least some of the most common processes affecting animal remains as the assemblage formed. Methodologically, zooarchaeologists’ task is to understand those processes that created patterning in the data. Like other historical scientists, zooarchaeologists must also consider the possibility that some processes affecting archaeofaunal samples left few or no distinctive traces.

3.8 Types of Evidence in Zooarchaeology

Zooarchaeologists may handle bones one by one, but they almost immediately begin to derive data from them to look for the aggregate patterns of data noted above. Two basic categories of information are used in zooarchaeological analysis, upon which nearly all other abstractions of data and inferences are built.

3.8.1 Primary Versus Secondary Data

Reitz and Wing (2008) and Clason before them (1972) defined *primary data* versus *secondary data*. Primary data can be physically inspected on actual specimens and include species, age, and sex identification, presence or absence of elements and portions of elements, and modifications. Secondary data are types of information abstracted from a faunal assemblage in aggregate, such as relative frequencies of species, age structure, patterns of butchery, and so forth.

Reitz and Wing (2008) argue that primary data are more amenable to replication by another researcher and subject to “less interpretive latitude” than are secondary data. At least in the abstract, this should not be the case if secondary data manipulations are clearly enough described so as to be replicated by other researchers.

The distinction between primary and secondary data may be useful to maintain as we look at debates about the meaning of patterning in aggregate data, and debates over equifinality in archaeofaunal data, as will be discussed in Part V.

3.8.2 Element Frequencies and Surface Modifications

Nearly all the data discussed in this book can be classed as one of two other types: *bone surface modifications* and *element frequencies*. Bone surface modifications (Fisher 1995) include cuts, chops, burning, other effects of humans, claw and tooth marks and other effects of biological agents, or weathering and other geological or mechanical forces. Researchers cited in this book refer to these as the "traces" or "signatures" of various agents. Recognizing these, as well as pathologically derived markings, depends on knowledge of the modal appearance of unmodified bones. Our ability to recognize and derive useful information from such modifications has expanded tremendously since the 1970s, and much of this book will be devoted to summarizing what is known about the causes of various bone modifications, as well as unresolved problems in making plausible inferences from them.

Element frequencies are counts of specimens of skeletal elements relative to one another in a faunal sample. Statements such as, "Caribou were the most common species in the assemblage," or "Aardvarks are rare in Late Stone Age sites," are based on element frequency data. In addition to species abundances, reconstructed age-at-death profiles of animals in a sample and inferences about hunting, herd management, or seasonality drawn from them depend upon counts and reckoning the relative frequencies of age-diagnostic bones and teeth. Studies of size variation of species over time, often linked to climatic fluctuations or intensities of cropping in species of indeterminate growth (e.g. Klein 1986; Broughton 1997), depend upon totals of identified elements with metrical attributes. Studying butchery and selective body segment transport by humans, be they hunter-gatherers or market-economy butchers, also depends on frequencies of elements from different body segments. These are likewise the data on which assessing the amount of in-place destruction of more delicate bones is based. Thus, taxonomic abundance, age and sex structure, and body part representation are all different permutations of basic element frequency data.

To sum up, zooarchaeologists have only begun to address the relation of aggregate patterns of evidence to analogues in the present, and, as will be seen in Part V, the level of controversy over conclusions about behavioral, social, and ecological contexts reflects this less constrained area of inference. Fundamentally, zooarchaeologists are seeking to use such data as *proxies* for unobservable behavior or its contexts. However, other sciences such as plant and animal ecology work with aggregate data and address similarly complex relationships, many of which are not directly observable. They therefore might provide zooarchaeologists with models for doing this kind of work, as will be discussed in Part V.

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