CHAPTER 1

The theoretical and scientific foundations of forensic anthropology

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1.1 Introduction

Despite its acceptance as a section in the American Academy of Forensic Sciences over 45 years ago (Thompson, 1982; Ubelaker, 2009), forensic anthropology has continued to be plagued by questions of scientific validity and rigor (Nordby, 2002). The legitimacy of forensic anthropology as a science and as a stand-alone discipline has been challenged repeatedly due to its perceived lack of a "grounding body of theory" (Adovasio, 2012). Viewed as a laboratory-based applied subfield of biological anthropology, it has been characterized as emphasizing methodology over theory, with a narrow focus on reconstructing the biological profile and establishing human identification (Adovasio, 2012).

The authors of this volume aim to show that this view of forensic anthropology is not only antiquated but also inadequate and inaccurate. This volume is an outgrowth of a symposium entitled "Application of Theory to Forensic Anthropology," presented at the 67th annual meeting of the American Academy of Forensic Sciences in 2015, and all of the presenters in this symposium are also chapter authors. As will be seen in the following chapters, forensic anthropology, a discipline that examines various aspects of the physical environment and material remains contained in that environment that are of legal significance, is firmly grounded in well-established scientific, logical theory. The goal of this chapter (and volume) is to explicate the theoretical bases for various specialized fields of inquiry in forensic anthropology and, through this process, define the basic elements of forensic anthropology theories, their interrelationships, and their relation to the logical reasoning process of the legal system in which they interact. The ultimate focus of the volume is to illustrate how these theoretical

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approaches form the scientific foundation for the discipline and shape the data collected and results obtained in forensic anthropological research.

1.2 A selective history of theory in forensic anthropology

Theories are explanations—answers to "why?" questions (Howard, 1993:7; Johnson, 1999:2; Hage, 2007:124–127; Boyd and Boyd, 2011). Scientific theories are explanations of observable, quantifiable phenomena (Salmon, 1982:158). They allow the construction of models to better understand dynamic events and their physical material consequences. As Johnson (1999:7) notes, "Facts are important, but without theory they remain utterly silent." Scientific theories are, importantly, amenable to testing by means of quantification and analysis of new observations.

Because of its strong applied nature, as noted earlier, it may be asked why scientific theories are important for forensic anthropology. As will be seen in the following chapters, theories provide a basis for generating and testing new hypotheses regarding forensic events and the evaluation of their likelihood and probability. They influence and direct every aspect of forensic anthropology, from field search and recovery to laboratory analysis to the courtroom. Clearly stating one's theoretical focus and methodology can reduce bias and mitigate unfounded, unsubstantiated statements in legal reports and testimony. Theory consequently strengthens arguments for plausibility, reliability, and relevance of data introduced in the courtroom—without it, forensic anthropologists risk having their credibility as expert witnesses dismissed and admissibility of their scientific evidence denied.

In order to fully understand the theoretical underpinnings of forensic anthropology, it is important to briefly review theoretical developments within its parent discipline, anthropology. Anthropologists have attempted to explain all aspects of what it means to be human; their theories have accommodated humans as biocultural creatures—dependent on behavior and social interactions as much as their biology for their ultimate adaptability and survivability. Any discussion of theory development in forensic anthropology must consider these broader historical influences.

Anthropology began as a recognized discipline in the mid-late nineteenth century, with the writings of Lewis Henry Morgan, Sir Edward Tylor, Herbert Spencer, and Karl Marx (McGee and Warms, 2012), who all expressed, in one form or another, an evolutionary view of human cultural development. These early writers felt that human cultures had evolved over time from primitive to more complex forms, adapting to their environments with new technologies and new forms of social organization.

This early cultural evolutionary view, although discredited due to its simplistic and inherently racist connotations, dovetailed nicely with the contemporaneous theoretical proposal of biological evolution by means of natural selection from Charles Darwin (1859). These evolutionary theories all considered adaptation,

reproductive success and consequent population growth, and a progression of change over time as important elements in any explanation of humans' current social and biological condition.

As the subfield of cultural anthropology developed in the twentieth century, its focus on human social and behavioral characteristics fluctuated between the later evolutionists' (e.g., Julian Steward, Leslie White) materialist perspective and that of the idealists. Materialists emphasized the roles of technology, modes of production and trade, and adaptation to the environment, while idealists (mentalists) focused on psychological, linguistic, and mental developments and their resultant influence on perceptions of reality as major theories explaining human behavior.

This theoretical dichotomy was also expressed in archaeology in the second half of the twentieth century. Prior to this, archaeology was initially focused on recovering material remains from impressive ancient sites and civilizations. Theoretical orientation was largely inductive and was primarily focused on descriptive culture history—dating artifacts, sites, and civilizations and organizing them into a chronology. In America and Britain, this approach began to change in the 1960s and 1970s, with the advent of the "New Archaeology."

Theory was at the heart of this revolution. Lewis Binford (1977, 1983), Michael Schiffer (1976), and many others championed this "New Archaeology," which explicitly recognized the hidden theoretical basis of archaeology and the building of theory through actualistic (middle-range) studies. These researchers sought to establish a firmer foundation for archaeological theory, with the goal of developing scientifically-based broad foundational laws, models, and explanations of human behaviors.

An important publication within archaeology during this time with implications for forensic anthropological theory was Michael Schiffer's (1988) "The Structure of Archaeological Theory," which described "three great realms" (Schiffer, 1988:464) of archaeological theory applicable to the study of human behavior—social, reconstruction, and methodological. Within these categories, he also described the presence of three levels of theory—high, middle-range, and low. Schiffer's high-level theories were broad and comprehensive, while middle-range theories served to link these high-level theories to empirical generalizations (low-level theories). An example of high-level social theory would be diffusion theory, as espoused by many anthropologists in the early twentieth century. Independent inventions spread from their centers of origin over a period of time, and this explained culture change and adoption of new traits (Harris, 1968:380–383). Perhaps more obvious is the role of reconstruction theory (often considered "middle-range"), which attempts to link the static archaeological (or forensic) record to the dynamic forces that produced it. Here, theory is clearly more applied, focusing on the development of observation-based explanations and improved inferences about events of significance. Schiffer's (1988) discussion of lithic use-wear analysis and its application toward reconstructing stone tool use in the past serves as a good archaeological example. Microscopic use-wear analysis helps to identify the raw materials

processed by lithic tools by comparing the edge wear on archaeological specimens to the wear on experimentally produced stone tools used on known, specific raw materials (Vaughan, 1985). Finally, Schiffer (1988) originally defined methodological theory as a separate "realm" in his hierarchical model. Within this category, he included what he called recovery theory (e.g., protocols for conducting an archaeological survey or excavating a burial) and analytic theory (methods of analysis); these were considered to be low-level because they are "… more empirical in content…" (Schiffer, 1988:462).

This acknowledgement of a theoretical foundation based on actualistic and experimental studies became a major aspect of archaeological research, leading to the recognition of archaeology as a science (at least as it was practiced by many archaeologists). The "positivist" science-oriented materialist view of the past became a hallmark of archaeology and related disciplines during this time. However, beginning in the late twentieth century, this positivist (Giddens, 1974; Comte, 1975; Mill, 2009) or (to use an archaeological term) processualist view of science as an objective, unbiased method of study that explains natural phenomena through the careful analysis of material physical objects began to be criticized (Robson, 2002; Wylie, 2002). Post-processualist archaeological theorists emphasized a focus on uncovering the mental attributes of past peoples and meanings they assigned to artifacts and features. It was also recognized by postpositive, post-processual critics that scientists' own biases and theoretical orientations can influence and color the results of their research. Although sometimes viewed as antiscience, it can be argued that this postpositive approach offers a sobering and perhaps more realistic perspective regarding research by consciously recognizing the biases that may influence scientists. By actively recognizing and controlling these biases, scientists may make more progress toward the positivist goal of objectivity (see Chapters 2, 3, and 5 of this volume for a more thorough discussion of how cognitive bias affects forensic anthropology research).

In the midst of twentieth-century theory development in other areas of anthropology, forensic anthropology was in its infancy. Although considered by many to be a "subdiscipline" of biological anthropology, it can trace its roots to the fields of medicine and anatomy in the nineteenth century, as some practitioners in these fields began to apply anatomical knowledge to the task of human identification (Ubelaker, 2009; Tersigni-Tarrant and Shirley, 2013). In this clinical context, the importance of theory was not recognized or emphasized. Although still predominantly housed within anthropology departments (at least in the United States), this close relationship of forensic anthropology with clinical medicine continues to the present, with many forensic anthropologists currently employed in university or medical school anatomy departments or medical examiner's offices (Bethard, 2017). Early twentieth-century practitioners of forensic anthropology were primarily anatomists or physical anthropologists who engaged only in "laboratory-based and episodic involvement in forensic cases" (Dirkmaat and Cabo, 2012:6). This also has, perhaps, contributed to the perception of a

dearth of theory in forensic anthropology today, where its practice is often seen as providing a technical service to medical examiners, coroners, and law enforcement when decomposed or skeletal remains of a decedent are present.

A review of all research articles, case studies, and technical notes ($n=644$) with significant forensic anthropology content or relevance from the *Journal of Forensic Sciences* (*JFS*) from 1995 to 2014 recorded thematic content, theoretical foundation, methodological approach, and research focus across this 20-year period (Boyd and Boyd, 2015). A recent expansion of this study also includes *JFS* articles from 2015 to November, 2017 (n=182). Identification of decedents through their biological profile and antemortem conditions (e.g., facial reconstruction), relying on evolutionary principles of human variation, still comprises the majority of published research. However, papers on perimortem (trauma) and postmortem (taphonomic) processes have become more prominent since 2010, and, in the last 3 years (2015–2017), there has been a notable increase in articles relating to trauma, taphonomy, and recovery methods. The frequencies of these topics are greater than the frequency of articles on any specific aspect of the biological profile. The great majority of researchers employ the scientific method, relying on macro- or microevolutionary theory (including natural selection); however, the exact nature of their theoretical foundation is rarely discussed, and explicit statements regarding hypotheses being tested are inconsistent and often absent. Although often not explicitly discussed in the publications, interpretive theories linking theoretical concepts to observed phenomena (e.g., principles of physics to explanations of blunt force trauma fracture propagation) and methodological theory discussions on archaeological search and recovery or new laboratory analysis techniques are primarily correlated with the previously noted research on perimortem and postmortem processes.

In sum, although it is clear that a firm theoretical (and, scientific) foundation underlies the majority of forensic anthropology research, this theoretical basis has not been explicitly recognized, developed, or communicated. Evolutionary theory (as per Darwin) and its explanatory power for interpreting human skeletal variation are still at the heart of much of what forensic anthropologists study, but modern forensic anthropology research has significantly expanded this foundation, particularly through its interdisciplinary engagement with aspects of physics, engineering, biology, chemistry, geology, anatomy, and other sciences. Eclectic borrowing of theoretical ideas from these and other disciplines serves to strengthen our theoretical base and scientific framework.

1.3 A modern perspective on forensic anthropology theory

It is apparent from the aforementioned discussion that forensic anthropology has not historically had a distinctive, unifying theory of its own and when theoretical approaches are borrowed from other disciplines, they are not overtly recognized.

In response to this conundrum, in 2011, Boyd and Boyd incorporated many elements of the Schiffer (1988) model into an exploration of forensic anthropology theory, and they applied his hierarchy of high-level, middle-range, and low-level theoretical concepts to forensic anthropological research. They also illustrated the relevance of several theoretical models derived from archaeology (e.g., agency theory, nonlinear systems theory) to interpretation of the more recent (forensic) past and emphasized the importance of the case study in initial theory building and hypothesis testing.

Ultimately, these aspects of hierarchical theory building have as their goal improving our inferences about the past—whether recent or distant. Forensic anthropology is, therefore, analogous to other historical sciences that rely on current observations to build theoretical interpretations of prior events. This is one reason Schiffer's (1988) model of archaeological theory was considered a good starting point for building forensic anthropological theory.

While a general application of the Schiffer model in forensic anthropology has been instructive as a heuristic device for clarifying and organizing theoretical approaches (Boyd and Boyd, 2011), as with all models, particularly hierarchical ones, it can be overly simplistic and obfuscate the actual process of theory building, particularly in developing sciences (see Salmon, 1982:178). We therefore recommend a more modern and realistic interpretation of forensic anthropological theory—one that, as we will see, is not hierarchical or static but based on three dynamic interacting *forms* of theory: foundational, interpretive, and methodological.

Foundational theories are those that are general, broad, and overarching and ground the discipline in a solid scientific framework. Since, ultimately, forensic anthropology focuses on once-living, sexually reproducing biological organisms, the most basic theory that grounds the discipline, as noted earlier, is Darwinian biological evolution by means of natural selection (Darwin, 1859; Mayr, 2001; Quammen, 2006). This theoretical base allows us to address several issues of relevance to forensic anthropologists, including human and nonhuman anatomical similarities and differences, human variation, sexual dimorphism, and ontogeny. These are all important concepts enabling the estimation of the biological profile and establishing personal identification from the remains of a decedent—traditionally the major goals of forensic anthropological practice. Although foundational theories like these are well established, they can be strengthened or modified with new interpretations or methods—the traditional phyletic gradualism model of evolution by means of natural selection was modified by the concept of punctuated equilibrium, for example (Elderidge and Gould, 1972). In forensic anthropology, evolutionary theory has been reflected in recent studies of secular trends and intergroup variation in aspects of the biological profile—notably stature—that stress the need for population-specific standards and the revision of standards based on nineteenth- to early twentieth-century skeletal collections (Meadows and Jantz, 1995; Jantz *et al.*, 2008; Spradley *et al.*, 2008; Wilson *et al.*, 2010; Gocha *et al.*, 2013). An understanding of biological evolutionary theory, therefore, forms the ultimate grounding for forensic anthropological analysis and interpretation.

Interpretive theories build research-generated and validated explanations that can be used to interpret specific events and underlie the forensic anthropological analyses of antemortem, perimortem, and postmortem processes. The classic application of interpretive theory is found in taphonomic research, which has long been recognized as a major area of interest in forensic anthropology because of its importance in determining the postmortem interval (PMI) (Lyman, 1994; Haglund and Sorg, 1997, 2002; Pokines and Symes, 2014). This form of interpretive theory defines how recovered remains may have been altered by natural forces or human behavior and permits the more accurate differentiation of peri- and postmortem events. A focus in taphonomic research is on the behavioral effects of various agents on the body and the forensic scene and their interpretation. These agents can range in scale and influence, from the blowflies initially infesting a corpse and the animals dismembering it, to the activities of field investigators documenting the forensic scene, to the medical examiners and forensic anthropologists conducting their laboratory analysis and interpretation (Boyd and Boyd, 2011). Schiffer and Skibo's (1997) concept of a "behavioral chain," with interactions between various agents and material remains all along the trajectory of transformation and recovery, is quite an applicable model for the creation of a forensic scene. All of the agents involved and their activities affect the final interpretation of the scene and its structure. Awareness of the potential biases introduced by these agents (including forensic anthropologists) in all contexts is a very important product of interpretive taphonomic research and theory building.

The empirical basis for interpretive theory is also important in the study of the effects of trauma on the human skeleton. For example, research documenting the process and timing of bone fracture repair for different age groups through macroscopic, microscopic, and radiographic observations is important in identifying prior injuries and can also be used to investigate claims of abuse, especially in children or the elderly. Theoretical models defining violent behavior, its timeline, and its consequences can then be developed (Walker *et al.*, 1997; Love *et al.*, 2011; D. Boyd, Chapter 9, this volume). Experimental and case studies involving perimortem blunt force, sharp force, and gunshot trauma (Symes *et al.*, 2002; Passalacqua and Fenton, 2012; Berryman *et al.*, 2013; Powell *et al.*, 2013; Love *et al.*, 2015) also exemplify interpretive research by providing a rigorous database for the recognition and interpretation of these events in actual cases.

Methodological theory includes recovery theory, analytical theory, and statistical theory. Methodological theory is just that—it provides the reasons behind *why* we use a certain protocol for the collection and analysis of relevant data. Methodological theory tests and develops valid methods and procedures for conducting both field recovery and laboratory research (see Chapters 8, 11, 12, and 14 for examples). Detailed procedures have been developed for the accurate recovery of both surface and buried human remains (Rhine, 1998; Dupras *et al.*, 2012; Hunter *et al.*, 2013; Groen *et al.*, 2015) to ensure that maximum contextual integrity is preserved and documented. The rationale for following certain procedures is based on robust

inductive experiential and experimental data derived from thousands of prior case studies in a variety of environments. Without robust methodological theory and its application, a forensic scene and the data recovered from it can be permanently compromised.

Once the material items and human remains from a forensic scene are removed to the laboratory, analytical and statistical methodological theory become prominent. Why are certain procedures used for processing human remains? What statistical methods and measurements are most appropriate for the analysis of human remains? The answer to the "why?" theory question is, therefore, that certain procedures work best and are standards that other forensic anthropologists are following (or should follow). Methodological theory forms the basis for many forensic anthropology articles published in the *JFS*, in that these studies are often testing prior analytical methods or proposing new ones. Of course, following the optimum analytical protocols strengthens our inferences about prior events. Appropriate methodology guides the observation and collection of data and influences the interpretation (explanation) of *any* past event. As such, methodological theory should be considered the basic tool from which *all* theories are built.

These three forms of theory are critical for the process of theory building in forensic anthropology and serve to strengthen the scientific framework of the discipline. However, their relationship with each other is not necessarily linear or hierarchical. They come together in a flexible, interactive process that is dependent upon logical reasoning, described as follows.

1.3.1 Three forms of logical reasoning

In the late nineteenth century, the American philosopher and logician Charles Sanders Peirce defined three categories of reasoning—deduction, induction, and abduction (1965:99). He briefly defined their distinctiveness: "Deduction proves that something must be; Induction shows that something is actually operative; Abduction merely suggests that something may be" (Peirce, 1965:106; Walton, 2004, emphasis in original).

Deduction can be more specifically envisioned as an inference for which if the premises are true, then the conclusion must also be true (Walton, 2001). Deductive statements are non-defeasible (irrefutable) facts. For example, humans, as bipedal creatures, have a uniquely shaped innominate (relatively compact, with a wide, curved ilium) compared with terrestrial quadrupeds. *If* an innominate with the attributes described earlier is recovered from a forensic scene, *then* deductively it *must* be from a bipedal animal (i.e., a human).

Inductive inferences are based on probability. These are the statements produced as a result of experimentation on and statistical analysis of a data set. So, for example, adult stature estimates can be obtained (for a specific sex) by calculation using linear regression. The result is a statistical forensic mean *estimate* of the living stature of the person, with an associated range, indicating that the *true* biological stature is within that range (probably). Discriminant functions for sex and ancestry

estimation in ForDisc will produce estimates with probabilities assessing the accuracy of their determination (Ousley and Jantz, 2005).

In both deductive and inductive reasoning, the logical process proceeds from premises to conclusions (if the innominate has these characteristics, then it must be human; if we use the long bone measurements of individuals of known stature, we can then derive a formula for predicting stature of unknown individuals). Both forms of logic are, of course, components of the classic hypothetico-deductive method of reasoning and investigation in science (Leblanc, 1973; Gibbon, 1984:12–13; Komar and Buikstra, 2008), wherein a hypothetical if-then (deductive) statement is tested by experimentation with new evidence (induction) and either supported or rejected as a result.

But how are those hypotheses created in the first place? Peirce (1965), Magnani (2001), Walton (2001, 2004), and many other logicians (e.g., Shelley, 1996; Gabbay and Woods, 2005) see the source of these hypotheses as abduction. Unlike deduction and induction, abductive reasoning "starts from the known facts and probes *backward* into the reasons or explanations for those facts" (Walton, 2001:145; emphasis ours). Peirce (1965:325) describes abduction in this way: "when we find some very curious circumstance, which would be explained by the supposition that it was a case of a certain rule, and thereupon adopt that supposition." This statement illustrates the *first* meaning or form of abduction: discovery and the creative process of generating a plausible hypothesis. The *second* meaning of abduction is evaluative and is referred to as inference to the best explanation (Lipton, 1991; Magnani, 2001:19; Taroni *et al.*, 2006:27). This second meaning is the one most commonly applied to abduction (Walton, 2001). However, both meanings can be considered part of a logical process: a "surprising" or "curious" object or event is discovered, and initial hypotheses are generated to explain it. Then, based on available evidence and the knowledge base of the observer, the best of these hypotheses is selected as the most likely explanation. This can be envisioned as the initiating stage of the hypothetico-deductive analytical process described earlier.

Abductively-selected best explanations or arguments are both presumptive and plausible, compared with their rejected competitors. Presumptive arguments are based on the specific context that one is trying to understand. Using contextual data (e.g., the location and position of a body at a forensic scene), several presumptive hypothetical explanations can be made and evaluated, leading to the recognition of the most plausible (or reasonable, based on available information). Then "…we infer that the best *potential* [plausible] explanation is an *actual* explanation" (Lipton, 1991:60). For example, at our hypothetical forensic scene in a somewhat isolated rural area, there is the body of an individual with severe blunt force trauma to the chest and face lying 20 m from a car that has left the road and crashed into a tree. The car door on the driver's side is open and there are blood stains leading from the car along the ground surface to the body. The most plausible explanation, given the contextual evidence, is that the body and the crashed

car are related and that the injured driver of the car expired after leaving the vehicle to seek help. The lack of any contradictory evidence (gunshot trauma, evidence for another occupant of the car) for intentional injury of the deceased by another party strengthens this abductive explanation.

As shown in the aforementioned example, the evaluation and determination of the best explanation is a dialectical process—each abductive hypothesis needs to be evaluated in a dialogue with other competing hypotheses (Walton, 2001). The hypothesis that best explains the available evidence or facts is, as Lipton (1991) noted earlier, selected as the actual explanation. It should be emphasized, however, that abductive explanations *are* defeasible (falsifiable), unlike deductive explanations. They are *tentative* assessments of the truth. New evidence or facts can lead to the rejection of a prior "best" explanation. As an example, note the several cases of exoneration of individuals by DNA evidence who were previously judged "guilty" (Berger, 2006). So, one might think of abductive reasoning as a somewhat open-ended process, contingent on current knowledge.

1.3.2 Theory building in forensic anthropology: Linking logic and theory

Science is a process that utilizes these three forms of reasoning to develop and test hypotheses and to consequently build theory. The relationship between these three types of logical reasoning and theory building is reiterative and dynamic—logical reasoning and theory building are clearly nonlinear processes. Figure 1.1 illustrates the interactive nature of these three forms of theory and reasoning that are linked together and provide necessary feedback for each other in the process of theory building. As shown in the figure, foundational theory provides the basis for abductively developing a hypothesis (a tentative interpretation) to explain initial observed data. Deductive if-then statements, which delineate expectations that may be confirmed by testing, are generated, and the observed data, along with new information, are inductively collected and tested using methodological theory. This testing may support the hypothesis, thus establishing an interpretive theory for the observations in question, or the hypothesis may be rejected, leading to a new cycle of hypothesis generation, deduction, and inductive data collection and testing. While deduction and induction are applied to address specific research problems in forensic anthropology, much of the reasoning process used—especially regarding specific cases and their interpretation—is abductive in nature, postulating and deriving prior causes for currently perceived effects, based on the best available evidence. Successful hypothesis testing may eventually enhance or strengthen foundational theory.

In a comparable example, Magnani (2001:23) describes the theory building process as it relates to medical diagnoses: "…*selective abduction* is the making of a preliminary guess that introduces a set of plausible diagnostic hypotheses, followed by deduction to explore their consequences, and by induction to test them…."He therefore feels that the inference to the best explanation model

actually describes the whole scientific "abduction—deduction—induction cycle" (Magnani, 2001:25; also see Gabbay and Woods, 2005:79) at all levels. Abductive reasoning is clearly a predominant form of reasoning in all historical sciences (Fogelin, 2007). By definition, geologists, paleontologists, archaeologists, and forensic anthropologists observe present-day objects or contexts of interest and seek to develop plausible explanations about the past historical processes (premises) that led to their present form.

As shown in Figure 1.1, methodological theory generates the empirical data that ultimately form the basis for broader, more general foundational theory. How did Darwin *see* natural selection? By following the traditional scientific method (i.e., using inductive methodological theory) and carefully collecting specimens and recording observations on his *Beagle* voyage and, afterward, documenting the results of selective animal breeding around his rural Down House home in England (Quammen, 2006). From these data, he deduced the theory of natural selection.

In taphonomic research, how do we build interpretive theory regarding the postmortem effects of carnivore (Haglund, 1997a; Colard, *et al.*, 2015), rodent (Haglund, 1997b), and vulture (Reeves, 2009) activity on human remains? We abductively infer explanations based on initial observations, develop testable hypotheses, and then inductively through our established research design (methodology) collect empirical data to evaluate those hypotheses.

It is clear then that abductive, deductive, and inductive logic are all operative within and provide an important link between methodological, interpretive, and

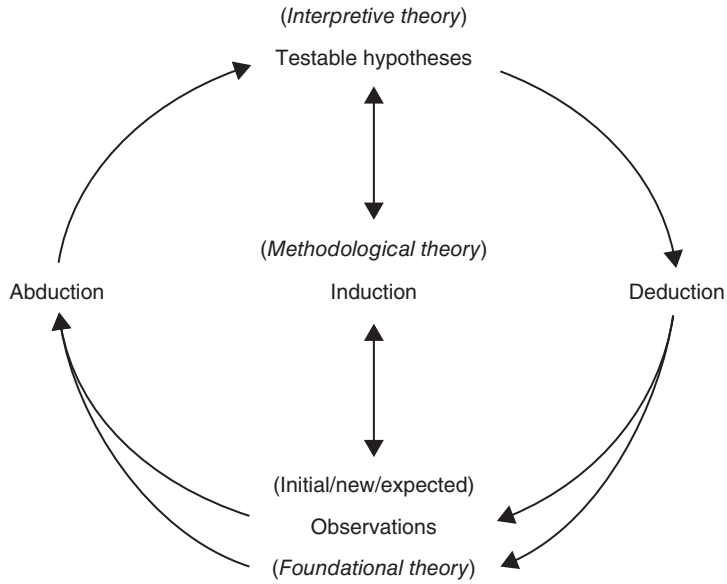

Figure 1.1 The interrelationships between forms of theory and logic in scientific research and theory building. Source: adapted from Magnani, 2001.

foundational theory. However, the interaction of all these forms of theory and logical reasoning is not reflected in a simple, linear model, but involves a great deal of feedback and information from a variety of sources. Thus, theoretical development is a "messy" and complex process, even in the sciences, and involves subjective insights gained through experience and observation, as well as rigorous, structured experimental testing. As Salmon (1982:173) states:

> Theories are usually developed in a very unsystematic manner. Scientists employ a variety of "methods," approaches, and techniques. Comparative studies, observations of "dynamics," extrapolation from other theories in related areas, pursuit of hunches—these and a host of other means not easily fitted within any rigorous "logic of discovery" are used.

In sum, theories should be envisioned as dynamic, vibrant explanatory statements, subject to expansion and revision at *all* levels and types, given new data.

1.4 Forensic anthropology theory and modern practice

Although not often recognized, aspects of logical reasoning and theory building that form the scientific basis of our discipline are prominent in forensic anthropology. The chapters in this volume exemplify this.

Contributions from positivism, processualism, and post-processual theoretical approaches are explored, as they are related to forensic anthropology, in Chapters 2–4 of this volume. Chapters 2 and 3 by Winburn and Warren *et al.* consider problems of bias and objectivity in forensic anthropological research and practice—something that affects all scientific endeavors. Allysha Winburn (Chapter 2) discusses the influence of both subjectivity and objectivity in the practice of forensic anthropology, noting the importance of recognizing sources of error. Purely objective, unbiased interpretations are not possible. Instead, she emphasizes the need for a more "mitigated objectivity" that realistically and critically evaluates the limitations and capabilities of forensic anthropology research.

Mike Warren, Amanda Friend, and Michala Stock (Chapter 3) address the problem of cognitive bias in forensic anthropological practice and the need to recognize the contextual and interpretive factors that create this bias. They suggest methods (such as established laboratory policies and procedures) that can help alleviate this problem or, at least, recognize its effects on forensic interpretation.

Soren Blau (Chapter 4) provides an international perspective on theory development in forensic anthropology and stresses the need for better communication between forensic practitioners and academics in this endeavor. She emphasizes the importance of ethical considerations when working internationally and sensitivity to other cultures' views regarding their dead. She focuses on the applied aspects of forensic anthropology and the important development of a sound "theory of practice."

As discussed earlier, a traditional focus in forensic anthropology has been estimating biological profile and establishing personal identification. Chapters 5 and 6 address the theoretical basis for the analysis and interpretation of major aspects of the biological profile—ancestry and age. Chapter 5, by Stephen Ousley, Richard Jantz, and Joseph Hefner, notes the biases in both past and current anthropological conceptions of ancestry (or "race"). They show that many current genetic analyses, which address covariation among multiple traits, do "indicate strong geographical patterning" and regional variation between populations. Designations of social race are indeed corroborated by multivariate morphological and genetic analyses.

Natalie Langley and Beatrix Dudzik (Chapter 6) delve into the history and theory behind the estimation of age from the skeleton, emphasizing the importance of the environment as well as genes in phenotypic development. They therefore stress the need to develop "population-specific standards" for age estimation using modern samples rather than ignoring secular change and continuing to rely on nineteenth- and early twentieth-century skeletal collections.

Additional methodological applications to forensic anthropological identification questions are exemplified by Chapters 7 and 8. Christian Crowder, Deborrah Pinto, Janna Andronowski, and Victoria Dominguez discuss the historical development of theories regarding bone biology in Chapter 7, specifically focusing on the process of bone growth and remodeling in response to mechanical loading. Histological analyses used to estimate age at death and differentiate human from nonhuman bone are described as examples of the application of all levels of theory to the understanding of bone development and its reaction to stress.

In Chapter 8, Lesley Chesson, Brett Tipple, James Ehleringer, Todd Park, and Eric Bartelink describe the use of stable isotope analysis to create "isoscapes," which can delineate the geographical/environmental source of human remains and the movements of decedents over time and across space. This method can play a useful role in the identification of unknown individuals by placing them in their antemortem contexts.

The scientific foundation for interpretations of antemortem, perimortem, and postmortem processes is explored in Chapters 9–13. Trauma analysis and interpretation is an increasingly important aspect of forensic anthropology and includes both antemortem and perimortem processes. In Chapter 9, Donna Boyd reviews the anatomical basis for fracture repair and its applications for evaluating forensic non-accidental pediatric and elderly deaths. She documents the significant variation in bone healing processes and rates, which are dependent on a number of intrinsic and extrinsic factors, and stresses the need for anatomically-informed, microscopically-based documentation of time since injury (TSI) estimates. A new model for TSI estimation, based on an archival bone fracture database, is presented.

Following along the child abuse theme, Chapter 10 by Jennifer Love and Miriam Soto Martinez describes the theoretical basis for differentiating between accidental and non-accidental trauma in children. They emphasize the importance of using

the pediatric skeletal examination (PSE) methodology to more accurately analyze remains from suspected child abuse decedents. Knowledge of bone biomechanics, an understanding of the stages of motor skill development in growing children, and the identification of specific fracture types and their frequencies all are important sources of information for building an inductive model to evaluate possible child abuse cases.

Chapter 11, by Hugh Berryman, John Berryman, and Tiffany Saul, addresses bone trauma analysis through the perspective of material science and engineering. They propose a fracture assessment triad model for the analysis of bone fractures, consisting of documentation of fracture behavior (resulting from tension and stress), an understanding of the intrinsic characteristics of bone, and an evaluation of extrinsic factors (such as the direction and duration of the force causing the fracture). When two of these factors are known, the third can be logically inferred, given the known mechanical and physical properties affecting fracture.

John Williams and Ronald Davis (Chapter 12) apply Locard's theory regarding the transfer of evidence to GIS mapping of the different striation patterns on the cut surfaces of sawed bones. They show that GIS can assist in the interpretations of fine scale cuts on individual bones and that this method can be used to identify different classes of saws from kerf wall striations.

Daniel Wescott defines the interpretive theory behind taphonomic research and its use in PMI estimation in Chapter 13. Identifying taphonomic causes and their effects is a complex process, and he makes a strong case for the importance of cross-disciplinary collaboration in research and methodology to enhance this analysis. Because we are anthropologists with an ability to interact with different cultures, people, and settings, forensic anthropology should lead this collaborative effort.

The last section of the volume addresses connections between forensic anthropology and other disciplines and addresses the importance of theory in a legal context. In Chapter 14, Clifford Boyd and William Baden address the relationship between theoretical development and organization in archaeology and forensic anthropology with specific applications to the postmortem process of decay. Agency and nonlinear systems theory provide the basis for computer modeling of decay rates from 30 forensic cases to develop a model for PMI estimation. Nonlinear modeling is shown to accurately and realistically depict the decay process.

John Schweikart and Cheryl Johnston in Chapter 15 discuss influences of methodological theory derived from archaeology and also geophysics on forensic anthropology. They note that "backflow" from these influences has led to the development of forensic archaeology and forensic anthropologists well versed in the archaeological methods of search, recovery, and documentation. In addition, many forensic anthropologists are now trained and experienced in the use of geophysical remote sensing methods and their interpretation in forensic contexts.

Forensic anthropology, as an applied science, operates within a legal setting, and in Chapter 16, Donna and Clifford Boyd address the importance of theory in this context. Law and science differ in their views of truth, proof, and timeline. However,

some commonalities between the two include their use of abductive logic and dialogue as well as statistically-based assessments of probability in the evaluation of data (evidence). It is shown that acceptance of forensic anthropologists as expert witnesses and admissibility of their evidence and testimony ultimately depends upon a sound theoretical and scientific basis for everything (methods and analyses) that they do. Mechanisms to develop an understanding between law and science through education and discourse between these entities are proposed.

Chapter 17 (Epilogue) summarizes some of the most important points of the volume, particularly as they relate to the identification of past and current theoretical approaches and their applications in forensic anthropology casework and research. Suggestions for meaningful future research and theory development, particularly in interpretive and methodological areas, are also discussed.

1.5 Final comments

As a largely applied enterprise, forensic anthropology has had its theoretical and scientific basis unrecognized for decades. However, whether implicit or explicit, theory guides all data collection and interpretation in the sciences. As section members within the American Academy of Forensic Sciences and as participants in legal proceedings, the need for forensic anthropologists to address the scientific *why* questions about the methods and analyses they use in their research and practice is clearly fundamental.

The chapters in this volume document the varied theoretical bases for specialized areas of study in forensic anthropology and the multiple forms of theory that they represent. However, the editors stress that this volume should not be considered the end point in any discussion of theory and its application to the field. Instead, it is hoped that the authors' presentations will engender future richer theoretical discussions and critical evaluations of theory and science in forensic anthropology—discussions that will only strengthen the discipline as a whole.

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