

*Review*

## **Theoretical and Methodological Approaches to Understanding Human Migration Patterns and their Utility in Forensic Human Identification Cases**

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**Abstract:** Human migration patterns are of interest to scientists representing many fields. Theories have been posited to explain modern human evolutionary expansion, the diversity of human culture, and the motivational factors underlying an individual or group decision to migrate. Although the research question and subsequent approach may vary between disciplines, one thread is ubiquitous throughout most migration studies: why do humans migrate and what is the result of such an event? While the determination of individual attributes such as age, sex, and ancestry is often integral to migration studies, the positive identification of human remains is usually irrelevant. However, the positive identification of a deceased is paramount to a forensic investigation in which human remains have been recovered and must be identified. What role, if any, might the study of human movement patterns play in the interpretation of evidence associated with unidentified human remains? Due to increasing global mobility in the world's populations, it is not inconceivable that an individual might die far away from his or her home. If positive identification cannot immediately be made, investigators may consider various theories as to how or why a deceased ended up in a particular geographic location. While scientific evidence influences the direction of forensic investigations, qualitative evaluation can be an important component of evidence interpretation. This review explores several modern human migration theories and the methodologies utilized to identify evidence of human migratory movement before addressing the practical application of migration theory to forensic cases requiring the identification of human remains.

**Keywords:** human migration; forensic human identification; DNA; stable isotope

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## 1. Introduction

Studies of human migration have traditionally focused on the evolutionary expansion of modern humans as they populated first the African continent and subsequently spread into Europe, Asia, and, more recently, Australia and the Americas. Diffusion theorists have investigated migration as a mechanism for maintaining cultural continuity and the development of markedly diverse human cultures. More recently, a considerable emphasis has also been placed on the causes and impact of current individual and familial migration events within the last 50 to 60 years. Tracing individual movement patterns is important from a historical, economic, and social perspective. However, it is also an important consideration in the case of forensic human identification. While the identity of a decedent often is known or suspected at or around the time of death, in many cases identification of human remains cannot be facilitated without the application of technological methods (e.g., DNA profiling) or comparisons with missing persons reports. If geographic origins or recent residence cannot be determined, then it will be difficult to obtain medical and/or dental records that may be used for identification. The increasing degree of international travel and intra- and intercontinental relocation makes it more likely that the residence of an unidentified individual will not immediately be known, thus precluding DNA comparisons with suspected relatives and rendering missing persons reports useless.

The following is a cursory review of various theoretical approaches to the study of modern human migration, and includes an examination of several of the methods, intuitive and deductive, employed in the detection of human movement patterns before considering the tactical utility of the aforementioned concepts in determining forensic human identification.

## 2. Theoretical Approaches

Why do human migration studies matter? The answer to this question frequently depends on who is asking the question. For example, the anthropologist studies migration to explain biological changes and the transmission of cultural and linguistic traits at the populational level [1], whereas historians analyze cycles of continuity and change to understand migration processes and their implications, and also to correct misinterpretations [2]. Geneticists study human dispersal patterns to determine and explain genetic variation between populations [3]. Epidemiologists may examine particular migratory patterns to determine if health-related changes in a population are attributable to some extent to genetic predispositions evident in the source population [1]; social policy makers are interested in the potential policy implications of migratory behavior. The following briefly explores the theoretical underpinnings of modern human movement patterns, including diasporic migration.

### 2.1. Modern Theories of Human Movement Patterns

Studies of human migration have been dominated by researchers in three areas: anthropology, sociology, and history [2]. While the anthropological approach to migration has culled data from numerous subdisciplines (e.g., archaeology, ethnology, cultural anthropology) into theoretical frameworks based on climatology, genetics, and cultural systems such as marriage and kin, these models have tended to focus on early, non-literate societies [2]. The sociological approach to analyzing

contemporary migration patterns has generated a considerable number of economic, demographic, social, and policy-oriented theoretical models, most of which overlap to some extent. These theories address the main concerns of the scientist: who is migrating, why are they migrating, where are they going, and what are the repercussions of the move [4]? Numerous models, many of which are based on economic principles, have been developed to address internal migration and international migration patterns. Several of the more prominent theories are discussed below.

### 2.1.1. Internal Migration Theory

Most of the historical classic models of migration revolve around the economic forces affecting an individual's decision on where to establish residency [5]. Generally, migration followed a path from areas in which wages were low and labor was in demand to areas in which income and opportunities exceeded the originating area. Ravenstein (1885 [6]) conducted the first systematic study of human migration and subsequently established economic motivation as the backbone of the entire concept. Lewis (1982 [7]) deemed the tenets of Ravenstein's study the "laws" of migration: migration is generally followed by a countermigratory event; most individuals migrate short distances; migrants relocating longer distances typically choose larger cities as their destination; preferential migration is evident in females and individuals (cf., sex differential [8]); migration exhibits directionality (*i.e.*, rural residents migrate more frequently than do their urban counterparts); young adults are more likely than families to make international moves. Despite the fact that Ravenstein's conclusions were based on observations of Western societies and thus skewed by the significant influence of industrialization on primarily short distance migration [5,9], his work identified important aspects of internal or regional migration and laid the groundwork for future theoretical models (e.g., [10]).

Central to many models of migration are two groups of causal factors affecting one's decision to migrate: push and pull factors [10]. Push factors are relative to the home country or region, while pull factors are associated with the potential destination. Typical push factors include but are not limited to: lack of jobs or few opportunities; adverse environmental conditions (e.g., famine, natural disasters); poor infrastructure, including inadequate medical care; lack of political or religious freedom. Some pull factors enticing migrants into other areas are increased job opportunities; better living conditions; freedom of speech; improved infrastructure and security. This partial list of causal factors applies not only to internal migration but international moves as well.

Recent studies of internal migration have categorized the migrant and motivating factors in terms of human capital, producers, and consumers [11]. Many economists who study migration employ a micro-level approach based on a labor-flow model, which essentially assumes a migrant will choose the destination offering the highest income in order to maximize his or her utility. Sjaastad (1962 [12]) first made the connection between migration and investment in human capital with a reductive model that identifies a migrant's ability to earn income as human capital and considers the act of migration an investment in one's own capital. In other words, the decision to relocate is solely influenced by the upfront costs and potential uncertainties associated with migration weighed against actual or perceived benefits (*i.e.*, income potential). Notably, Sjaastad's (1962 [12]) model assumes that migration "costs" are synonymous with distance traveled, and that greater distances unequivocally result in more

uncertainty regardless of beneficial kinship and migrant networks that may be of assistance to the migrant [13,14].

The problem with the above economic internal migration model and closely related international migration models (e.g., Borjas 1987, 1991 [15,16]) is that they often assume that all variables reach ideal proportions (e.g., Sjaastad's model assumes 100% probability of the migrant securing employment in the destination) and remain constant between conditions in the migrant's home and potential locations destination (e.g., uneven distribution of amenities in both locations). Further, they fail to account for the multitude of non-economic causal factors (e.g., social and natural forces). Empirical data suggests that income maximization is not the sole deciding factor in the decision to migrate (e.g., [17]). Additional modeling flaws include the inability to account for multiple migrations, household migration decisions, uncertainty resulting from insufficient labor market information on a destination, remitting portions of one's income to family remaining in the home location, and how an individual's place in their life cycle affects if, when, and how many times they migrate [18].

Theoretical shortcomings in human capital-investment models gave rise to equilibrium models of migration. These models acknowledge the diachronic nature of a continuum of income, prices, supply, demand, amenities, and utility functions [11] while preserving the importance of the migrant's role as consumer. Consumption varies significantly within and between countries, especially developing vs. developed; amenities contributing to a higher quality of life (e.g., many of the causal factors identified in Lee's 1962 push/pull model) are strong motivators. Thus, equilibrium models are particularly suited to international migration studies. Household production migration models follow the same concept as the equilibrium or consumption models, although they identify the household as the migratory unit and consider variables relating to household production, consumption, and risk (see [19–21]), simultaneously removing from the equation all individual influence or preference.

### 2.1.2. International Migration Theory

Borjas (1987, 1991 [15,16]) presented a two-stage international model designed to address the wide variation evident between workers and the associated conditions in source and destination countries. Instead of assuming all variables are held constant and at ideal levels, his model acknowledges the range of personal (*i.e.*, worker) and economic (e.g., wage differential) characteristics evident in both countries. The first stage of Borjas' (1987 [15]) model is based on several dichotomous assumptions that predict: (1) a directly proportionate relationship between migration rate and the destination country's mean income rate, (2) an inversely proportionate relationship between migration rate and source country's mean income rate, (3) a migration rate inversely proportionate to the relative costs of migration, and (4) less-skilled workers are more likely to migrate when skill transferability between the source and destination countries is low/unlikely. The second stage of the Borjas (1991 [16]) model builds upon its fundamental assumptions by incorporating predictions concerning the relationship between migration rate and mean level of education in the source country (e.g., notable disparities in mean education level within a source country result in smaller numbers of individuals migrating abroad). While the Borjas model has been used for years, others have expanded upon it as more current issues affecting immigration (e.g., explicit immigration restrictions) have become apparent [22,23].

The internal and international immigration models discussed above are explicit, in that they generally assume that the migration decision and the act itself is synchronic and irreversible; none of the models account for the variability involved in temporary migration, multiple migrations, or involuntary migration [11]. Despite the focus on permanent immigration, historically immigrants have returned to their original homelands after spending a period of time in their destination countries (e.g., the post World War I large net outflow of immigrants from the U.S.). Reasons for these return migrations vary. For example, an improved quality of life in the source country may become possible, the support system offered by family relationships in the migrant's native region may become a primary motivating factor, or the destination country has implemented immigration policies making it impossible for the migrant to remain there past a certain date. Further, an immigrant may choose to return to the source country after coming to the conclusion that the decision to migrate was based on inaccurate knowledge of the destination country or simply an error in judgment [11].

The increasing globalization of world markets over the past decade has had a tremendous impact on immigration; temporary immigration rates have increased markedly [11]. It is now common for multinational companies to move personnel between various international locations. Most countries issue visas without expiration dates to relocated multinationals and their family members. Temporary immigration also results from country-specific immigration policies. Generally, high-income destination countries make it easier to obtain work permits or temporary resident visas than permanent resident visas. The issuance of such temporary immigration documents is not new; numerous countries have developed work programs designed to offer immigrants temporary resident status in exchange for a specified—or unspecified—labor period. For example, the large number of Americans drafted into service during World War II prompted the U.S. government to offer Mexican immigrants temporary work visas in exchange for performing mostly farm-related labor duties (*i.e.*, Bracero Program). Similarly, some western European countries (e.g., West Germany, France) exhibiting labor shortages in the 1960's instituted guest worker programs in which immigrants from areas such as southern Europe and South Africa were able to relocate temporarily to the destination countries. Many migrants wishing to become permanent residents participated in these guest worker programs to gain entry, remaining in the countries until they were eventually granted permanent status. More recently, this trend has been observed in the Persian Gulf states (e.g., Dubai), which have hired temporary workers from densely populated countries such as Pakistan and India. However, the destination countries have imposed restrictions on the temporary visas to ensure foreign-born workers do not remain in their country permanently [11].

Temporary immigration models are very similar to conventional models with notable exceptions. Dustmann (2001 [24]) assumes higher wages overseas, but speculates that consumption (e.g., amenities) is preferentially associated with the source country. As long as the immigrant maintains close ties to the native country, immigration rates are lower and the length of stay is decidedly temporary. If conditions in the source country deteriorate while simultaneously improving in the destination country, immigration rates increase and the stay abroad is extended. While empirical data supports Dustmann's (2001 [24]) predictions, the model is flawed in its failure to accommodate discrete variables such as significant family events, loss of employment, or changes in immigration policies [11]. Mexican immigrants to the U.S. consistently list source country population density and a persistently weak

economy as primary causal factors for emigration [25], yet their established networks in the destination country often eclipse income and prices as the primary determinants of duration [26].

Individuals leaving their home countries as a result of intolerable conditions (e.g., political, social, environmental) or those who are forcibly removed are considered involuntary immigrants. These individuals are often referred to as asylum seekers or refugees; their immigration concerns are not factored into any of the above explicit or implicit models [11]. Over the past 20 years relevant immigration issues have arisen. During the 1990's Europe experienced an influx of refugees a result of war and ethnic cleansing in the Balkans; currently Africa and the Middle East are exhibiting high rates of emigration. Because it is conceivable that most refugees will improve their conditions by immigrating, most of the theoretical work in this area concerns the enslaved migrant [11].

Between 1500 and the late 19th century approximately 11 million Africans were enslaved and transported to the Western Hemisphere by slave traders from various European countries (see [27–29]). "Human trafficking" is the current term most commonly applied to forced immigration of this type [11]. The basic labor-flow model of immigration may be most applicable to analyses of immigration characterized as slavery or human trafficking since it fundamentally concerns the shifting of labor resources from one country to another. Of course, in this model the enslaved individual has no ownership over his or her own human capital; all costs and returns are borne and received by the slave owners. Thus, the trafficking of humans can be quite profitable for the source country or "owner" provided the gains outweigh the costs; this was the case for some of the source countries (e.g., Holland, Portugal, England) exporting slaves during the Atlantic slave trade [emphasis added]. Essentially, provided all other variables are held constant, forced international immigration (*i.e.*, slavery) is more likely to occur if the costs of enslavement and international transport are relatively inexpensive, slave labor in the destination country generates a profit for the owner (*i.e.*, income gained substantially surpasses maintenance costs), and slave labor is less expensive than alternative forms of labor [11].

## 2.2. Diasporas

While the term 'diaspora' is perhaps most familiar in relation to the Jewish and Trans Atlantic slave trade experiences [30], and has been studied with equal frequency in the two aforementioned contexts (e.g., [31–33]), the term is generally associated with coerced dispersal from one's homeland. Communities developing as a result of diasporic migration are characterized by what is typically an involuntary dispersal from the home community, yet these communities maintain a constant link, spiritual or otherwise, with the original homeland [30]. Involuntary immigration may result either from direct persecution or more indirect economic and/or political pressures [11].

Theoretical models developed to explain Imperial and trade diasporas are concerned primarily with the accompanying expressions of change exhibited within the original and host communities [34]. Diasporas can be differentiated from migration based on numerous characteristics identified by Cohen (2008 [35]), not all of which are applicable to each diaspora event. Generally, however, diasporas can be distinguished based on the following: dispersal, forced or voluntary, from one's homeland into at least two foreign regions; expansion from a homeland for purposes of work, trade, or other pursuits; a collective spiritual connection to the homeland, frequently involving myth-like properties; a strong group ethnic consciousness; difficulty assimilating into the host community; shared empathy and

responsibility between the members of various diasporic settlements; the frequent coordination of a collective return movement to the homeland despite general satisfaction with the current way of life. While the term has perhaps been most applied to the Jewish and African experiences, Brubaker (2005 [36]) and others (e.g., [37,38]) have noted the term's expansion to include the Armenian and Greek diasporas and, more recently, long distance nationalists (e.g., Irish, Kurds), labor migrants, and the New Orleans and U.S. Gulf Coast residents who were evacuated or displaced as a result of Hurricane Katrina.

Many cultural studies of diaspora groups focused primarily on the retention and transmission of cultural traits within migrant communities (e.g., [31–33,39]). The same cultural focus was noted in early archaeological studies on African diasporas, which comprised the bulk of these initial diaspora studies [40]; Webster (2010 [41]) provides a thorough review of the African diaspora, an event in which over 10 million Africans were enslaved and transported by force to the Western Hemisphere during the 400 year-long Atlantic slave trade [11]. Recent diaspora work has placed more of a bioarchaeological emphasis on health status and lifestyle of the immigrants (see [42]).

The introduction of trade and colonial diaspora research has brought to the forefront the unique attributes of these corresponding communities. Cohen (2008 [35], p. 83) has described trade diasporas as a collection of "spatially dispersed" groups that are interconnected yet distinct from their homeland and the current communities in which they live. Archaeological investigations of Chinese trade diaspora communities appear to support Cohen's claim; studies conducted by Voss (2005 [43]) and Diehl *et al.* (1998 [44]) simultaneously demonstrated cultural continuity and affiliation with the homeland and few attempts at assimilation into the host community. Colonial diasporas concern the migratory experiences of colonizers, and have largely been ignored by archaeologists [34]. Cohen (2008 [35], p. 69) has coined the term "Imperial diaspora" to describe the British Empire and other colonial expansions as groups marked by a strong ethnic identity and consistent deference to the homeland's social and political institutions.

### 3. Evidence of Migration

Numerous approaches designed to detect evidence of migration in the archaeological record have been developed. These techniques yield findings which can be loosely classified as either indirect (*i.e.*, primarily inferential) or direct (*i.e.*, quantifiable). Most of the following methods have been primarily, if not entirely, applied to prehistoric human migration studies. Nonetheless, they illustrate the type of evidence that may be present in a forensic context and the quandary posed by subjective interpretation of evidentiary material during the course of a medico-legal investigation.

#### 3.1. Archaeological and Bioarchaeological Evidence

Archaeologists have numerous implements in their tool kits with which to detect evidence of human migration: fossils representative of humans at various points during their evolutionary continuum have been recovered; material culture has been used to distinguish groups; burial ritual evidence yields insight into the mortuary practices—and social structure—of the parent community; skeletal remains can be cultural indicators. Since the above methods require speculation based on sometimes incomplete specimens, interpretations may be biased by subjective analyses. Consider, for example,

the dilemma arising from the conflicting fossil hominid evidence supporting each of the theories explaining the initial expansion of anatomically modern humans. Strict proponents of the three models all claim, based on their determinations of "evidence", that their respective theory best explains incredibly complex migration patterns occurring within an extremely broad spatial context [45] [emphasis added].

When written records are unavailable for consultation and comparison, archaeologists often must rely on stylistic variation in material culture to distinguish between groups, based on the assumption that groups of people subscribing to particular cultural norms will leave behind traces of their unique identity [46]. However, differentiating between ethnic groups using material culture is not always unambiguous [47,48]. For example, Andrushko *et al.* (2009 [49]) acknowledged the crucial role of migration in the development of Andean social customs. Various Andean ethnic groups have been successfully distinguished based on ceramic style, yet these stylistic variations can be due to regional, temporal, or status-based differences (see [49]). Further, some symbols of identity (e.g., some Andean apparel items) never make it into the archaeological record [50]. Another complication is the dynamic nature of ethnic identity, which may not always be evident in the material assemblages left behind [51–53]. Indirect representations of identity also fail to discriminate between the internalized nature of identity and the external labels affixed by others [54,55].

The material culture of Africans enslaved in the Americas has been studied for several decades [41]. Slave-made ceramics, motifs, and architectural elements have been exemplified as strategies by which slaves and their descendants maintained and adapted their cultural traditions. While critics of this work have characterized the artifacts as lacking in specificity (see [56]), the more thorough studies have incorporated ethnographic evidence in their analysis of New World material culture believed to represent West African practices (e.g., burial position [57]). Fennell's (2007 [58]) analysis of the use of 'core' symbols within diasporic cultures combines anthropological theory with archaeological data to describe group identities.

Burial rituals and treatments are known to vary among individuals and to exhibit change over time ([59], p. 41). Historical trends in mortuary patterns have been characterized in terms of social and political contexts [60,61]. The structure and complexity of a society can be inferred from the burial treatment afforded to its citizens; the more complex a society, the more variability is evident in its mortuary rituals [62]. Binford (1971 [62]) and Saxe (1971 [63]) arrived at similar conclusions based solely on ethnographic data. O'Shea's (1984 [64]) analysis of prehistoric mortuary variability incorporates archaeological data and statistical analysis and arrives at similar conclusions that can realistically be applied to archaeological settings: mortuary populations tend to reflect the demographic and physiological characteristics of their living populations ([64], p. 34).

While mortuary archaeology has uncovered material evidence of mortuary practices, it may also provide information on aspects completely unrelated to manner of death or mortuary treatment (*i.e.*, preparation of the deceased) [65]. These clues can be present in the form of grave goods which may be authenticated, thus constituting direct evidence; other clues are more implicit and subject to interpretation (e.g., what does it *mean* to find a particular artifact associated with a particular burial?) [65]. Pearce (2010 [66]) was critical of using mortuary analysis - and epigraphic evidence—as the basis for making inferences regarding human migration. Based on his analysis of several examples from various Late Roman cemeteries, the identification of specific origins at the individual or

community level was implausible based on the significant variation in cultural elements present in the burials. While the problems appear to be mostly empirical (e.g., insufficient data on burial practices within a region, small sample sizes), speculation is also a problem; to what degree of probability can one identify group boundaries from artifacts, and thus infer migration has occurred?

Although mortuary analysis does not necessarily include a thorough examination of skeletal material (e.g., determine evidence of pathology or other geographically pertinent identifying characteristics), geolocational information may be obtained from the remains. Craniofacial robusticity and dental complexity and traits (e.g., incisor shoveling, three-rooted mandibular molars) are known to exhibit populational and temporal variation (see [67], p. 311).

Bioarchaeological analyses have been incorporated into mortuary archaeology, thus facilitating the formation of biocultural interpretations of skeletal and associated burial treatment data [68,69]. While the physical characteristics of human skeletal remains can function as indicators of ancestry, health, occupation, and lifestyle, caution must be employed when offering interpretations of skeletal material. For example, mortuary and bioarchaeological analyses of structured ancient burials may yield a trove of information suggestive of populational demographics, but what knowledge or evidence indicative of migration can we glean from the analysis of the single modern burial of a homicide victim? Depending on the degree of trauma evident in the remains and/or taphonomic influences, the evidence may tell us more about the individual(s) responsible for the burial than the identity of the deceased. And what sweeping generalizations can be inferred from the remains of one individual, particularly considering the extent to which international relocation is observed within all populations? While subjectivity is inherent in the above approaches, standardization of methods and logical evaluations based on multiple lines of hard evidence are paramount in order to posit feasible interpretations that are inclusive of associated material culture.

### *3.2. Biomolecular and Biogeochemical Evidence*

#### *3.2.1. DNA*

The concept of DNA profiling as a method of positive identification emerged in 1985 when Alex Jeffreys discovered significant individual variation between individuals in particular regions of DNA [70–72]. While early use of the DNA technique was applied primarily to questions of paternity [71], its utility in problems of human identification became unmistakable when DNA analysis positively identified skeletal remains as those of Josef Mengele [73].

Several types of DNA profiling have been used in human migration studies. Nuclear DNA (nuDNA) and mitochondrial DNA (mtDNA) are both accessible in a cell, but different genetic information is available from each type of DNA [74,75]. Nuclear DNA represents the combined parental genetic material (*i.e.*, one copy of nuDNA inherited from each parent), whereas the non-recombinant nature of mtDNA means it is maternally inherited and, theoretically, is traceable back to a single female ancestral type [5]. Similarly, the non-recombinant properties of Y chromosome DNA means it is passed from a male to his male offspring, and thus has been of interest in genetic studies due to its potential to trace paternal lineage [3].

The extraordinary differential in number of copies per cell between nuDNA and mtDNA (2 and more than 1000, respectively) contributes to the unique identifying capabilities of each: nuDNA allows the positive identification of an individual while mtDNA confirms familial relationships. Due to the significantly higher number of mtDNA copies per cell, the analysis of mtDNA is a viable option in cases where STR analysis of biological samples is impractical (e.g., severely decomposed or skeletonized remains) (e.g., [76]) or nuDNA simply cannot be recovered [77–80]. The likelihood that a mtDNA profile can be generated under these circumstances makes it an especially useful technique when applied to historical investigations (e.g., Romanov children [81]) and modern forensic cases (e.g., the “Adam” case [82]); mtDNA can be compared to any maternal relative if no immediate relative is available for identification of the body or a nuDNA comparison [79,80].

Mitochondrial DNA and Y chromosome DNA studies have been useful in proposing explanations for the major human migration events. Forster (2004 [83]) examined recent mtDNA studies in conjunction with archaeological and climatological data, concluding that paleoclimate played a major role in the chronology of prehistoric migrations and demographic expansions. Schurr (2004 [84]) has described major geographic trends in the distribution of mtDNA variation in the Americas. The mtDNA lineages present in Native American populations can be attributed to five founding groups (see [84]), all of which are differentially distributed at the continental level; it is probable that the distribution reflects original settlement patterns and regional interpopulational variation. Most of the Y chromosome genetic variation observed in Native American populations appears to be linked with similar distribution patterns present in Siberian populations, suggesting two different population histories within the New World (*i.e.*, a secondary expansion of ancient Asian populations) (e.g., [85,86]). Conversely, previous analyses of Neandertal mtDNA sequences suggested that Neandertals and modern humans did not interbreed. However, the recent sequencing of an entire composite Neandertal genome from three individuals presents clear evidence of gene flow between Neandertals and modern humans [87].

Until recently mtDNA and Y chromosome DNA were the two preferred genetic markers for studying human history [3]. However, these two types of DNA are necessarily sex-biased and therefore cannot account for most of the human genetic variation factor of demographic reconstructions [3]; mtDNA and Y chromosome DNA are just two tiny components of what is otherwise an enormous human genome. Nevertheless, both types of DNA analysis are useful in determining individual human identity provided biological evidence from potential relatives is available for comparison, or haplotype databases are sufficiently large enough to account for significant variation in haplotype frequencies within a particular population [79]. While positive identification is facilitated only by nuclear DNA, ancestral haplotype markers are linked to geographic provenance, and can correlate with life history evidence (e.g., isotope markers from permanent teeth) to provide a general identity profile.

### 3.2.2. Stable Isotope Profiling

Hydrogen, oxygen, carbon, and nitrogen are biologically important chemical elements that vary in their isotopic forms [88]. Variation in the stable isotope composition of various biological material occurs with comparative predictability such that inferences regarding diet reconstruction from  $\delta^{13}\text{C}$  and

$\delta^{15}\text{N}$  values [89–91] and the natal origin of unidentified human remains may be formulated [88]. Hydrogen ( $\delta^2\text{H}$  or  $\delta\text{D}$ ) and oxygen ( $\delta^{18}\text{O}$ ) isotope abundance values are indicators of climatic change [92] while  $\delta^2\text{H}$  and  $\delta^{18}\text{O}$  values of animal and human tissue are linked to food and water intake [93–98].  $^{18}\text{O}/^{16}\text{O}$  and  $^2\text{H}/^1\text{H}$  isotope ratio analyses are germane to migration studies because their distribution in meteoric precipitation, which is consumed by humans in the form of drinking water and water contained in fruit and vegetables, varies geographically—and predictably—depending on climatic variables [99]. Similarly, the  $^{87}\text{Sr}$  composition in nutritional resources is dependent upon an area's geological characteristics, and thus can be useful as a geolocational indicator of the geographic origins associated with human skeletal remains [100–102], provided the impact of global food consumption on measured strontium ratios (*i.e.*, "the supermarket effect") is negligible [103].

Ericson's (1985 [104]) seminal work was the first to illustrate the potential utility of strontium isotope ratios in investigating childhood and marital residence patterns. Subsequent stable isotope studies investigating human origins began to proliferate in the early 1990's. Much work investigating the effectiveness of strontium isotopes in determining geographical origins and migration patterns has been conducted on European prehistory samples (e.g., [105–108]), those from the American Southwest [109,110], South America (e.g., [49]) and diaspora communities (e.g., [111,112]). For example, Price *et al.* (1994 [105]) have noted significant variation in  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios from two archaeological sites believed to belong to the Bell Beaker period, an era distinguished by the seemingly random geographical distribution of characteristic material culture. While results from this study and another [106] are suggestive of variation in residence patterns within the Bell Beaker period, questions regarding the extent of relocation and frequency of movement are likely to remain unanswered without supporting ethnographic data and analysis of tissues representative of a person's lifetime. Similarly, preferential sampling procedures may yield inaccurate  $^{87}\text{Sr}/^{86}\text{Sr}$  values and inflate evidence of immigration [110].

Since  $\delta^{18}\text{O}$  values in drinking water are subject to alteration by climatic variables, the analysis of both  $^{18}\text{O}$  and  $^{87}\text{Sr}$  isotope data can allow the placement of further constraints on the geographic origins of individuals [108]. More recent work examining isotopic signatures as indicators of geographic origin and immigration patterns has studied  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios in conjunction with  $^{18}\text{O}/^{16}\text{O}$  ratios to increase the robustness of the data and resulting inferences (e.g., the Americas [113–115]; early medieval [107,108]; African diaspora [111]; Imperial Rome [112]).

Origin and migration studies utilizing stable oxygen isotope techniques emerged in the early 1990's with Schwarcz *et al.*'s (1991 [113]) demonstration that human skeletal remains recovered in Canada were actually those of U.S. military personnel. Studies analyzing human skeletal material from several Mexican Teotihuacan archaeological sites have employed  $^{18}\text{O}/^{16}\text{O}$  ratio analysis of human tooth enamel samples from living and archaeological samples to establish baseline isotopic data and confirm isotopically distinct populations [114–117]. Similar work by Prowse *et al.* (2004, 2005, 2007, 2010 [69,118–120]) has demonstrated the utility of oxygen isotope analysis in reconstructing the paleodiets and migration patterns of individuals interred in a Roman cemetery; childhood immigration from areas outside of Rome, possibly including North Africa has been strongly supported. More recently, Bell *et al.*'s (2009 [121]) multi-isotopic analysis of skeletal remains recovered from the *Mary Rose*, a 16<sup>th</sup> century sunken British warship, has suggested that a significant number of the ship's crew may have been non-natives. Particularly, the  $^{18}\text{O}/^{16}\text{O}$  isotope ratio data imply that these individuals

may have originated from lower latitudinal regions in which English was not spoken. Bell *et al.*'s findings lend support to the theory that a language disparity between the crew members and ship captain resulted in a critical navigational error, which ultimately led to the sinking of the *Mary Rose*.

Due to the significant correlations between oxygen and hydrogen isotopes and climate variables, these two isotopic systems are frequently analyzed together to strengthen the resulting data. However, few of the growing number of geographic origins and migration studies employing  $^{18}\text{O}$  isotope analysis have included  $^2\text{H}$  analysis, presumably due to hydrogen exchangeability issues associated with extracting and measuring the  $^2\text{H}$  composition of various biological materials [122–124]. Following the seminal work of Cormie *et al.* (1994 [125]), most of the work involving the hydrogen isotopic analysis of collagen extracted from bone and teeth has been performed on animal samples to establish bone collagen as a proxy for climate variables such as humidity and precipitation (e.g., [126]). However, the number of studies focusing on the  $^2\text{H}$  analysis of hair and fingernails is steadily increasing. These biological materials are suitable for making inferences regarding the last several months of an individual's life, so isotopic data obtained from keratin is more useful in determining recent movements or recent residence as opposed to birth place and childhood migration patterns; strands of hair may be measured along their entire length to assess the isotopic ratios incorporated at weekly or monthly intervals [96,127,128].

#### 4. Discussion and Conclusions

While climate variability over the past two million years is presumed to have influenced human migration patterns (see [45]), it seems doubtful at this juncture that global climate change is having a similar impact on modern migration patterns. What is clear is that people migrate for many different reasons. Undoubtedly many if not most people choose relocation as a means of improving their financial situations. While this assumption is accommodated by the complex economic migration models (e.g., labor-flow), Lee's (1966 [10]) push/pull causal factors may have more practical value in forensic contexts since the factors are clearly defined and correlate with amenities important to many individuals (e.g., social programs, climate). Similarly, recent research trends in migration studies of modern societies have focused on more contemporary themes (e.g., the effect of globalization on migration patterns) [2,129].

There are problems, however, with applying any migration theory to forensic investigations in which the identity of a deceased is unknown. It is this author's opinion that it is highly unlikely an initial assumption regarding identification would be based on migration theory. If identification documents are not present on the decedent, then other clues on the body (e.g., unique body modification) or those in the near vicinity giving some indication of identification are likely to be sought. If an item believed to be associated with the body is recovered, then perhaps the significance of the item can facilitate theories regarding the person's recent whereabouts.

In such cases where identity may be suspected but not verifiable, pinpointing an individual's geographic origins and possible residence just prior to death may contribute to definitive forensic identification. Perhaps a distinctive material item associated with the body can be traced back to the individual (e.g., hotel key card) or an activity in which he or she was a participant (e.g., ticket stub from a sporting event). Clothing can indirectly suggest an individual's origins; a body clad in winter

apparel and recovered in a tropical climate might indicate that the individual was a very recent visitor to the area. If there are no material clues associated with the remains, then perhaps fingerprints may be retrieved and checked against a computerized database. While fingerprints are no longer considered irrefutable proof of identity in the United States (*i.e.*, *U.S. v. Llera Plaza et al* 2002), they remain a valuable tool for law enforcement in the U.S., and are considered a valid form of identification by other countries (see [130]). DNA may also be sampled from the individual and results checked against a database (e.g., CODIS) or compared to a relative's sample if the remains are believed to be those of a missing person for whom a report has been made and the relative is available for comparison. Notably, DNA analysis of unidentified human remains is conducted primarily to establish a linkage between the deceased and an alleged perpetrator of the crime [75]. While DNA analysis can be performed on skeletonized remains, there are situations in which this method is not feasible and alternate techniques must be considered. Physical characteristics such as age, sex, ancestry, and stature may be ascertained from the remains and compiled into a forensic anthropological profile, which can then be compared against a missing persons report(s).

It is clear that some of the methods used to study migration in ancient populations are inherently flawed due to their subjective nature. For example, one of the problems in interpreting identity from material culture is the responsive nature of ethnic identity and the inadequacy of static assemblages in identifying past groups and their movements [51–53]. While a forensic investigator examining items found with a body has the advantage of evaluating the materials in a current context, he or she still must inject meaning into the objects if their significance is not immediately known.

Stable isotope profiling can provide investigators with data suggestive of geographic origins and recent residence. Notably, isotope studies, particularly multi-elemental studies, have led to the identification of severely mutilated bodies recovered many miles away from their homeland [101,131]; corroborative DNA evidence in conjunction with isotopic data can further narrow law enforcement efforts to establish identification. Stable isotope data acquired during a homicide investigation in the UK prevented the imprudent search of thousands of immigrant records for a fingerprint match [131]. Consequently, DNA cross-matching analysis facilitated the identification of the victim (a Kenyan immigrant who unlawfully applied for asylum by claiming Somalian origins) and the apprehension and conviction of his killers. If regional origins can be identified, then the chances of identification are greatly improved and the incorporation of migration theory into the investigation is more feasible. However, there are cases in which stable isotope analysis and DNA evidence are insufficient to establish a positive identification (e.g., [82,132]). For example, stable isotope profiling of a child's torso recovered in London, England, revealed that the boy had most likely originated from West Africa; these findings supported haplotype data obtained from DNA evidence (*i.e.*, mtDNA and Y chromosome analysis) [82]. Despite multiple lines of evidence suggesting the child may have been a victim of human trafficking and subsequent ritual murder, the remains were not identified until years later when the child's former caretaker came forward with information concerning the case.

Much speculation surrounds the historical and current migratory events mentioned previously, yet little if any attention has been placed on the significance of migration as it relates to forensic investigations. For example, the applicability of diaspora characteristics to contemporary human movement patterns makes this type of migration event pertinent to forensic contexts. It is clear that significant diversity is evident among diaspora communities [133] and interactions between diasporas

and homelands and host communities are complex [30]; no longer can these groups of individuals be characterized simply by forced dispersal and victimization. More attention to migration behavior associated with involuntary relocation and temporary migration patterns would provide a more comprehensive understanding of these events as they have occurred in the past and as they evolve in contemporary societies. Further, closer scrutiny of the relationship between human migration patterns and the perception of such by law enforcement agencies handling forensic cases in which potential immigrants—documented or undocumented—are involved is advisable.

In conclusion, while most of the human migration theories used by researchers studying past populations are helpful in positing theories of group identification, they are of more limited value to the forensic investigator. The modern context of forensic casework necessitates a holistic approach in which identification of the decedent is paramount to the investigation.

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